Macroeconomic Growth and Lifelong Learning

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MACROECONOMIC GROWTH AND LIFELONG LEARNING

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EXECUTIVE SUMMARY

It is essentially undisputed that the human capital of a nation accumulated through schooling and lifelong learning is crucially important to the economy's innovative capacity and ability to compete in the globalized world of the 21st century. A substantial body of research has shown that human capital has positive effects not only on individuals' success in the labor market, but also on their general well-being. However, the empirical literature relies almost exclusively on school attainment measures of human capital, such as years of schooling. Due to differences in the quality of schooling over time and across countries, these measures might be poor approximations of effective human capital. Moreover, measures of educational attainment just reflect an individual's human capital at the end of formal schooling, which may not be good indicators of effective human capital when individuals need to constantly adapt their skills to structural and technological change throughout their entire working life.

PIAAC, a new international adult skill survey developed under the patronage of the OECD, offers novel insights on the role of cognitive skills in modern knowledge-based economies. Research based on these data shows that higher cognitive skills – measured across numeracy, literacy, and ICT (information and communication technology) domains – are systematically related to higher employment probabilities. Moreover, better cognitive skills are also associated with higher wages in all countries participating in PIAAC, with economically meaningful effect sizes. Among prime-age workers (35-54 years old), going up one out of five competency levels in numeracy skills is associated with increased hourly wages averaging some 18 percent across countries. But perhaps the most striking finding from the international analysis is the substantial heterogeneity in returns to skills across countries. Estimated returns to skills in the countries with the highest returns (the United States, Ireland, and Germany) are roughly twice as large as in the countries with the lowest returns (Sweden, the Czech Republic, and Norway). Intriguingly, returns to skills are systematically lower in countries with higher union density, stricter employment protection, and larger public-sector shares.

This new research adds to previous evidence showing that cognitive skills are closely linked to economic growth. An increase in educational achievement by 50 PISA points translates into 1 percentage point higher growth rates in the long run. Importantly, what matters for growth is the skills that people have actually learned, not how long people stayed at school. This evidence strongly calls for a focus on educational outcomes, not just attainment.

Given that human capital is a leading determinant of employment, earnings, and economic growth in modern knowledge-based economies such as the European Union, it is all the more worrying that many European countries show a rather poor performance in the recent PIAAC test when compared with the top-performing countries. This signals a dire need for reforms if the European Union wants to prosper in the future.

Regarding human capital accumulated at school, a number of rigorous studies show that a good governance framework of the school system and effective teachers are important for achieving high levels of skills among students. However, continuing structural and technological change of the economies clearly asks for skill adaptations and a process of lifelong learning after school. This puts the focus on policies that ensure that skills are effectively retained and used. Furthermore, skills also accumulate by regularly practicing them. This learning-by-doing seems to develop skills at a faster rate when there is substantial novelty and challenge in the scope of everyday activities undertaken by employees. An economy which has its production composed of intellectually complex activities also appears to grow faster. In fact, more than half of the real per capita income growth in the United States over the period 1980-2010 resulted from an increased complexity of jobs, while just about one-third came from growth in average years of schooling.

Our knowledge is more limited on the best role that governments can play in the area of lifelong learning. To find out the best ways to nurture the skills of adults, more research is needed to evaluate the outcomes and effectiveness of different adult education and training programs. It is also of paramount importance to continue the efforts to measure adult skills consistently within and across countries, to be able to investigate how achievement develops over longer time periods. The skill trends revealed by such repeated adult skill surveys would allow for a judgement of whether any reforms implemented by a country helped to improve people's achievement levels.

1. INTRODUCTION

Human capital analysis starts with the assumption that human capital is in large part acquired through schooling and lifelong learning. While these activities are costly, they should also entail future benefits, or some sort of return (for instance, in terms of higher wages). Following the seminal contributions of Theodore W. Schultz, Gary S. Becker, and Jacob Mincer, literally hundreds of studies have investigated the individual returns to human capital on the labor market. At the same time, another literature has developed that assesses the role of human capital for economic growth at the macroeconomic level.

At the individual level, human capital can be regarded as skills that make workers more productive in performing their work tasks and as the knowledge and competencies that enable people to generate and adopt new ideas that spur innovation and technological progress. This productivity-enhancing effect of human capital increases a person's wage or allows her to escape unemployment and find a job in the first place. At the macroeconomic level, human capital can spur economic growth by increasing aggregate productivity and by facilitating the creation and diffusion of new technologies. Beyond these economic benefits, developing human capital also offers nonproduction benefits such as increased work satisfaction, improved health decisions, reduced crime, improved citizenship, and better parenting.

In general, human capital accumulation is considered to occur mainly through formal education and lifelong learning. While most of the public debate focuses on education as the most powerful instrument related to developing human capital, it has also been emphasized that lifelong learning is a key area for human capital investments.[1] Still, while numerous studies have tried to determine who pays for training, who receives it, and how training can influence wages and other productivity-related outcomes, the empirical evidence on the effects of training is still scarce.

Another key challenge for the work on the role of human capital in modern economies concerns its measurement. Both at the micro and the macro level, the empirical literature relies almost exclusively on available quantity-based measures of human capital investment such as educational attainment, which is typically measured by years of schooling. While such measures are certainly related to human capital and, in fact, have been shown to be economically relevant, they nevertheless might be poor approximations of effective human capital.

For example, the quality of schooling might change over time and might vary across countries (Hanushek and Zhang, 2009). Approximating an individual's stock of human capital with years of schooling is especially problematic for cross-country comparisons.

[1] Nobel Prize Laureate Robert E. Lucas (2009), for instance, has recently emphasized that the productivity growth of the industrialized economies is largely attributable to the continuous exchange of ideas.

Such comparisons implicitly assume that the contribution of each school year to human capital accumulation is independent of the quality of the education system. In the words of Hanushek and Woessmann (2008, page 629): *"[A] year of schooling in Papua New Guinea is assumed to create the same increase in productive human capital as a year of schooling in Japan."* This can certainly be questioned. Moreover, years of schooling reflect only a person's human capital at the end of formal education, neglecting the knowledge and skills that are acquired during working life.

Thus, the correct measurement of human capital is a key concern in many human capital analyses, particularly in the empirical investigation of the impact of human capital on economic growth. In this literature, the schooling data from Barro and Lee (1993, 2001, 2010) have been the primary source for measures of human capital. In a recent contribution, Hanushek and Woessmann (2008) include measures of average cognitive skills in a country, obtained from the mathematics and science scores of various international student achievement tests, in a standard growth regression framework. When cognitive skills are included, the estimated relationship between years of schooling and growth approaches zero and becomes insignificant. They conclude that "school attainment has no independent effect over and above its impact on cognitive skills" (see Hanushek and Woessmann, 2008, page 639).[2] However, these measures of *students'* cognitive skills may still be incomplete approximations of a nation's effective human capital.

Until fairly recently, almost all of the international evidence on the cognitive skills of the adult population came from the International Adult Literacy Survey (IALS), which was conducted in the mid-1990s.[3] However, skill measures from two decades ago may no longer be good indicators of the situation in economies that have undergone substantial technological change (Autor, Levy, and Murnane, 2003; Goldin and Katz, 2008; Acemoglu and Autor, 2011). Only recently, a new large-scale assessment of the skills of the adult population was conducted, the Programme for the International Assessment of Adult Competencies (PIAAC). Compared to IALS, PIAAC has greater country coverage, considerably larger sample sizes, and skill tests that cover a wider variety of competencies. Moreover, to investigate the role of complex problem solving (CPS) skills in modern knowledge-based economies, the project "Lifelong Learning, Innovation, Growth & Human Capital Tracks in Europe" (LLLight'in'Europe)[4] collected data from more than 950 workers across 13 countries.[5]

The purpose of this report is twofold. First, it provides evidence for the crucial role of human capital for individual and social prosperity. Second, it sheds light on the sources of cognitive skills, mainly focusing on schooling and lifelong learning.

[2] See also Hanushek and Kimko (2000) and Hanushek and Woessmann (2008, 2015).

[3] Hanushek and Woessmann (2011) provide a detailed review of the economic studies using IALS data.

[4] See http://www.lllightineurope.com/home/ for details.

[5] The findings on CPS skills can be found in Policy Briefs P4 ("Complex problem solving: a promising candidate for facilitating the acquisition of job skills"), P6 ("Income returns to complex problem solving skills are strongly significant"), P7 ("Income growth is related to complexity"), and E4 ("Enterprises are greatly important for lifelong learning activities"). See also See also Ederer et al. (2015) for a detailed assessment of the wage returns to CPS skills.

The report contains both, a detailed review of the existing literature and original research conducted within the scope of LLLight'in'Europe project using the PIAAC data. The report thus focuses on the situation of advanced economies with a particular focus on the EU Member States.

The report starts with the theoretical background of why human capital – developed through schooling and lifelong learning – is expected to affect economic prosperity from a micro and macro perspective. Sections 3 and 4 present the empirical evidence on the role of human capital for macroeconomic growth, employment, and individual earnings, respectively. Section 5 focuses on the sources of human capital accumulation, specifically looking at schooling, vocational and general education, on-the-job training, and learning-by-doing.

2. THEORY: WHY HUMAN CAPITAL AFFECTS PROSPERITY

In his *Principles of Economics* (1890), Alfred Marshall wrote that the *"most valuable of all capital is that invested in human beings."* However, insights from his early analyses of investment in human capital, as well as work on the topic by Adam Smith and Milton Friedman, were almost entirely ignored in early discussions of productivity and economic growth. Even as late as the 1950s, economists generally assumed that the quality of labor input was exogenously given and not augmentable. This assumption was seriously challenged, however, when T. W. Schultz, Gary S. Becker, and Jacob Mincer began to investigate the implications of human capital investment for economic growth and related economic questions.

Modern human capital analysis starts with the assumption that human capacities are in large part acquired via informal and formal education at home and at school, through training, and through training. These activities are costly: they involve both direct expenses and foregone earnings or consumption. However, these activities also promise benefits, such as improved earnings and employment opportunities, along with non-monetary gains, such as an increased health consciousness and improved citizenship. The key idea is that individuals decide on their education, training, and other knowledge acquisition by weighing the benefits and costs. Because benefits derived from these activities accrue mainly in the future, the cost involved in acquiring learned capacities can be viewed as an investment.

The notion that activities which enhance human capacities can be regarded as an investment is the backbone of contemporary theory on human capital, but the general idea itself can be traced back to the *"Dawn of Economics."* For example, in his *Wealth of Nations* (1776), Adam Smith wrote: *"The improved dexterity of a workman may be considered in the same light as a machine or instrument or trade which facilitates and abridges labour, and which, though it costs a certain expence, repays that expence with a profit."* The fundamental practical advantage of understanding human capital accumulation as an investment is that the standard tools of economic analysis can be applied to analyzing its determinants and consequences.

Modern human capital research mainly focuses on two complementary aspects. One is reflected in the work of Jacob Mincer, Gary S. Becker, and others, who developed the general theory of human capital and centered their attention on the study of the relationship between human capital and labor income. The other aspect is reflected in the work of Schultz, Denison, and Griliches, who use the theory of human capital to analyze productivity and economic growth. Today, it is undisputed that human capital is a crucial explanatory factor in the fields of labor economics, productivity analysis, development economics, and economic growth. However, research on the returns to human capital accumulation has expanded into many other areas and human capital has been shown to affect many other outcomes, including non-monetary ones.

2.1 Human Capital and Individual Productivity

Classical human capital theory regards human capital as a means of production, into which additional investment is costly, but can yield additional output. Thus, if human capital accumulation is viewed as an investment, rather than as consumption, there should, almost by definition, be some sort of return on it. This testable implication of human capital theory had a great impact on research in labor economics. The past 40 years have witnessed a vast number of studies focused on quantifying the benefits of expenditures that can influence the future labor market productivity of an individual. These expenditures can take many forms: migration, health care investments, search for employment, family formation. However, formal education and training receive by far the most attention in the literature. Similarly, even though human capital investments may be made for both pecuniary and non-pecuniary reasons, the majority of studies in labor economics focuses on estimating the effects on future earnings. Initially, the economic literature's focus on earnings drew heavy criticism from other disciplines as being too narrow and detracting from other education benefits. However, increasing evidence on the effects of education made it obvious that any contribution of more education to higher earnings and better jobs only added to other, non-monetary benefits.

The analysis of the value of formal education – in particular schooling – follows the original work by Mincer (1970, 1974). The famous Mincerian wage regression aims at discovering the relationship between market wages, education, and experience. In its simplest form, the Mincerian wage regression can be written as:

$$\ln(y_i) = \beta_0 + \gamma S_i + \beta_1 E_i + \beta_2 E_i^2 + \beta_3 G_i + \varepsilon_i,$$

where y_i is the hourly wage of individual *i, S* is the quantity of schooling, *E* is years of actual labor-market experience (the inclusion of a quadratic term captures that the tenure-earnings relationship may be non-linear), *G* is a gender indicator, and ε is a stochastic error. The focus of attention is γ, the earnings gradient associated with years of schooling.[6]

[6] Under specific assumptions, this wage effect of a year of schooling can be interpreted as the rate of return to education in the sense of an investment return that can be compared to the rates of return of alternative investments; see Chiswick (1998) and Heckman, Lochner, and Todd (2006).

To date, there is already a huge amount of evidence on the returns to schooling. Hundreds of papers have been published estimating the return to education investment around the world. Several more recent papers review the available evidence or conduct meta-analyses (Psacharopoulos, 1994; Card, 1999; Harmon, Oosterbeek, and Walker, 2003; Psacharopoulos and Patrinos, 2004; Heckman, Stixrud, and Urzua, 2006). The evidence clearly documents that more schooling is associated with higher individual earnings.

However, the estimated rate of return to schooling varies significantly between studies. For example, returns to schooling appear to be higher in low-income countries, for women, and for lower levels of schooling (Psacharopoulos and Patrinos, 2004). It is thus difficult to quantify the value of schooling in general, but the average estimated rate of return is probably around 10 percent. At least, this is the figure that most labor economists would give when asked to provide a rough estimate of the average return to schooling. A rate of return of 10 percent implies that an additional year of schooling is associated with a 10 percent increase in earnings.

Estimates of the return to schooling also vary significantly depending on the assumptions made and the estimation technique employed. In fact, in the last two decades, academic debate has largely focused on the question of whether simple estimates provide credible measures of the causal effect of schooling. The key challenge when estimating causal effects of schooling is the problem of selection based on unobservable characteristics. For example, if more able individuals are also more likely to obtain additional schooling, the estimated return to schooling could be biased upward because more able individuals would presumably also earn more even in the absence of additional investment in schooling.

Thus, since the 1990s, there have been several contributions to the literature on the returns to schooling that focus explicitly on such issues of endogeneity (e.g., Angrist and Krueger, 1991; Harmon and Walker, 1995; Ashenfelter and Rouse, 1998; Oreopoulos, 2006). These studies either attempt to difference out the impact of unobservable confounding factors in a panel framework, or apply more sophisticated estimation strategies that exploit exogenous variation in schooling investment to estimate the causal effect of schooling. The results of these studies show that the rate of return is affected by employing such alternative estimation approaches. Frequently, employing more demanding estimation techniques even leads to larger estimates of the returns to education (e.g., Oreopoulos, 2006). The overall conclusion of earlier studies estimating simple Mincerian wage equations, however, is confirmed: education has a strong causal impact on earnings.

Individual financial returns to schooling, however, are only a part of the overall benefit of education. Several studies show that schooling affects many aspects of individuals' lives, both inside and outside the labor market. Non-monetary returns to education can take many forms. Evidence suggests that there are even non-pecuniary returns to schooling in the labor market.Such non-pecuniary labor market benefits may include higher fringe benefits, higher job satisfaction, and lower unemployment probabilities (Oreopoulos and Salvanes, 2011).

An overwhelming amount of evidence documents non-pecuniary returns outside the labor market. For example, Wagstaff (1993) shows that schooling improves health while simultaneously reducing the number of physician visits. In particular, individuals with more schooling react more quickly and more effectively to new information on health (Kenkel, 1991; Glied and Lleras-Muney, 2008). Education matters also in a competitive marriage market (Becker, 1973; Chiappori, Iyigun, and Weiss, 2009) and affects family formation (Rockwell, 1976; Chadwick and Solon, 2002). Moreover, education affects fertility (Black, Devereux, and Salvanes, 2005, 2010), teenage pregnancies (Black, Devereux, and Salvanes, 2008), divorce rates (Oreopoulos and Salvanes, 2011), and parenting (Kalil, Ryan, and Corey, 2010). Education also appears to affect preferences, risky behavior, crime, and trust (Lee and McCrary, 2005; Oreopoulos and Salvanes, 2011).

Finally, the social returns to investment in education may even exceed the private returns due to externalities and spillovers. For example, positive effects of education on crime, health, fertility, and improved citizen participation may not only affect the utility of the individual who invested in his or her own human capital, but also the utility of others in the economy.

Indeed, recent evidence supports the existence of externalities of education in relation to reduced crime (Lochner and Moretti, 2004), improved health of children (Currie and Moretti, 2003), and improved civic participation (Dee, 2004; Milligan, Moretti, and Oreopoulos, 2004). Moreover, there may be direct production spillovers: individuals may benefit from having better educated co-workers. However, the empirical evidence on direct production spillovers is ambiguous and not completely positive in nature (Acemoglu and Angrist, 2001; Moretti, 2004; Ciccone and Peri, 2006). For example, social returns might actually drop below private returns when taking into account the social cost of subsidized education (Psacharopoulos and Patrinos, 2004) or education may act as a signaling device, rather than actually enhancing an individual's productivity. However, the overall evidence suggests that social returns are higher than private returns (Lange and Topel, 2006).

2.2 Human Capital and Macroeconomic Development

Given the evidence on individual returns to human capital accumulation, it seems logical that human capital would also matter for the macroeconomic performance of the economy as a whole. In fact, the advent of human capital theory in the 1950s led researchers to attempt a better understanding of the roles that education and training play in determining a country's growth prospects. However, from a theoretical point of view, it took some time before the role of human capital investment was well integrated in theories of economic growth.

Early neoclassical growth models did not consider education as an input to production. These early theoretical attempts to understand economic growth are based on models characterized by a neoclassical production function with diminishing returns to capital inputs. This functional form, however, implies that in the absence of continuing improvements in technology per capita growth will cease. This modeling deficiency was initially patched over by assuming that technological progress occurred in an exogenous manner (Solow, 1956). It was not until the late 1980s and 1990s that neoclassical growth models were modified to explain technological progress within the system. Human capital accumulation plays a key role in these models as a main determinant of technological progress and, thus, long-term economic growth.

The idea that human capital could generate long-term sustained growth was one of the critical features of the "new growth" literature initiated by Romer (1986) and Lucas (1988). The initial wave of these growth models did not really provide a theory of technological change, but posited that spillovers of knowledge between producers and external effects from human capital helped avoid the tendency for diminishing returns to the accumulation of capital. For example, in order to capture the critical role investment in human capital plays in economic growth, Lucas (1988) combined the theory of human capital and Solow's model of economic growth to show the consequences of technological change for economic growth, and established a model emphasizing human capital accumulation through schooling and learning-by-doing, as well as emphasizing physical capital accumulation and technological change. In Lucas's model, the individual's "human capital" was the embodiment of Schultz's and Becker's human capital concept, Solow's technology change, and Romer's knowledge accumulation through learning-by-doing.

The more elaborate incorporation of R&D theories in the growth framework (Romer, 1990; Aghion and Howitt, 1992, 1998) further advanced the theoretical understanding of long-term economic growth. These models also highlight the role of education in generating and diffusing new technologies. Ultimately, an economy's rate of growth depends on technological progress, or improvements in the technology that transforms factors of production into output. Such improvements in total factor productivity emerge from innovation of products and processes. In so-called endogenous growth models, innovation arises from intentional investments in research and development. This process is fundamentally guided by the underlying invention of people, which flows from the knowledge and skills of the population. Here, education plays the crucial role of increasing the innovative capacity of the economy by producing a continuing stream of new ideas and technologies. By inventing and marketing these new ideas and new technologies, highly educated people give rise to sustained growth dynamics in these models. Relatedly, in technological diffusion models, the rate at which economies can absorb the technological developments that happen outside depends again on the knowledge and skills of its population.[7] Theoretically, the macroeconomic (social) returns to education may be higher or lower than the individual (private) returns discussed above.

[7] See the contributions by Nelson and Phelps (1966), Welch (1970), and Benhabib and Spiegel (2005)

On the one hand, the macro returns may exceed the individual returns if there are positive externalities. For example, in the spirit of the innovation effects emphasized in endogenous growth models, high-skilled inventors may produce innovations that also raise the productivity of other workers and ultimately of whole economies without all these benefits accruing to the innovator.[8] On the other hand, the social returns to education may also be lower than the private returns if part of the private returns comes in the form of unproductive signaling or screening.[9] Individuals may get more education simply to signal high ability to the labor market, so that educational institutions simply act as devices to select more able students as opposed to providing them with new knowledge and skills. However, the available evidence surveyed below strongly speaks towards an interpretation that the micro returns to education are by no means limited to private payoffs.

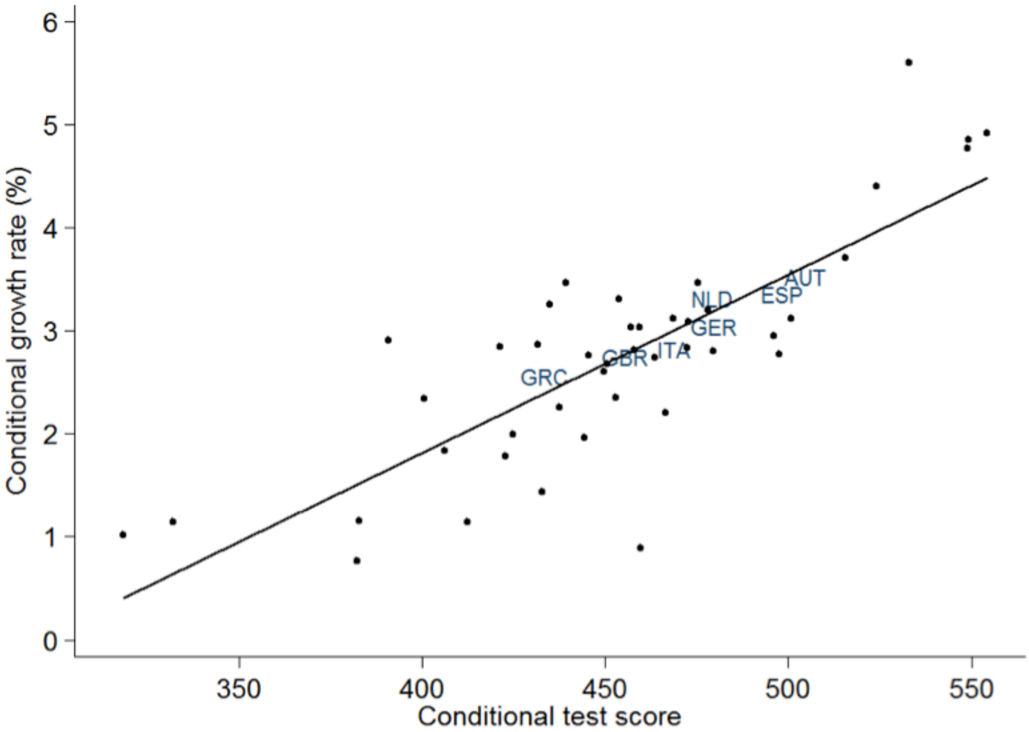
3. HUMAN CAPITAL AND ECONOMIC GROWTH

Over the recent past, empirical research has shown that education is indeed one – if not the most – important determinant of economic growth in the long run (i.e., of long-term growth trends beyond business-cycle fluctuations and temporary crises). The standard empirical approach to investigating effects of human capital on economic growth is to estimate cross-country growth regressions. These growth regression models relate countries' average annual growth in gross domestic product (GDP) per capita over several decades to measures of human capital and a set of other variables that affect economic growth.

If measured by the skills actually learned – particularly, the performance of the population on achievement tests in math and science – the education of its population is very closely linked to a nation's long-run growth rate. This is depicted in Figure 1, which plots countries' average annual rate of growth of real GDP per capita in 1960-2009 against the educational achievement scores of their populations (both after taking out effects of the initial level of economic development).[10] It is directly visible that there is a very close relationship between the two, with countries that do well on the achievement tests systematically having higher long-run growth rates than countries with poor educational achievement. In fact, such a simple model can account for about three quarters of the total cross-country variation in economic growth over the past half century. Moreover, the figure suggests a very strong effect: For every half standard deviation in test scores – equivalent to 50 points on the PISA scale – a country's long-run growth rate is 1 percentage point higher.

[8] At our current state of knowledge, the empirical bearing of the size of such externalities is open to debate, with the existing empirical literature being inconclusive; see, e.g., Acemoglu and Angrist (2000), Moretti (2004), Ciccone and Peri (2006), Iranzo and Peri (2009), as well as the literature on nonproduction benefits in the form of reduced crime, good citizenship, and better parenting referred to above.
[9] See, e.g., Spence (1973), Stiglitz (1975), Weiss (1995), Riley (2001), and Arcidiacono, Bayer, and Hizmo (2010)
[10] See Hanushek and Woessmann (2008, 2012a, 2015) for details on the effect of educational achievement on economic growth.

Figure 1: Educational achievement and economic growth rates



Added-variable plot of a regression of the average annual rate of growth (in percent) of real GDP per capita in 1960-2009 on average test scores on international student achievement tests, initial average years of schooling, and initial level of real GDP per capita (mean of unconditional variables added to each axis). "Conditional" refers to variation in growth rates and test scores, respectively, purged for variation in these other variables. Selected EU countries highlighted for expositional purposes.

Sources: Woessmann (2014), Hanushek and Woessmann (2015).

In this analysis, education is crucially measured as actual achievement, namely the average test scores on all international student achievement tests in math and science performed between 1964 and 2003. When the education of the population is instead measured by its average years of education, the association with economic growth is much weaker, and the model accounts for only one quarter of the cross-country variation in long-run growth (rather than three quarters with achievement). In fact, once differences in achievement are taken into account, there is no separate relation whatsoever between years of education and economic growth. This means that the quantity of education matters for growth only insofar as it in fact leads to better knowledge and skills of the population. It is what people know and can do that matters for economic growth, not how long it took them to reach that achievement. This evidence strongly calls for a focus on educational outcomes, not just attainment.

Several rigorous analyses, detailed in Hanushek and Woessmann (2012a, 2015), indicate that the achievement-growth picture indeed depicts a causal effect of better educational achievement on economic growth.

Among others, the effect is even larger if early achievement is separated out from subsequent growth by relating achievement on the tests performed through the mid-1980s to economic growth since the mid-1980s. This rules out that the association reflects simple reverse causation from growth to achievement, a concern that is anyways dampened by the ubiquitous result that higher education spending is not systematically related to better outcomes across countries. The concern that the association may capture additional unobserved factors such as economic institutions, the structure of the economy, or particular cultures that relate to both achievement and growth is mitigated by several additional detailed analyses.

A first analysis restricts the achievement variation to only that part that stems from observed differences in school systems such as exam systems, decentralization, or private competition. A second analysis shows that immigrants from countries with higher educational achievement reap substantial earnings returns on the same U.S. labor market, but only if they were indeed schooled in their home country, not if they were schooled in the United States. A third analysis disregards any level differences across countries and shows that countries that have improved their test scores over time have witnessed systematic upward trends in their economic growth rates. A fourth analysis takes the parameters of how education affects economic outcomes from well-identified microeconometric estimates to show that differences in education can account for substantial parts of the cross-country variation in levels of economic development. Finally, an analysis that relies solely on variation within countries and within industries shows that countries with a more skilled population experienced faster growth in skill-intensive industries (Ciccone and Papaioannou, 2009). Together, these analyses suggest that the educational achievement of the population indeed has a strong positive effect on a nation's economic growth.

A vast literature investigates the role of education in economic growth further, employing different measures of education and different methods such as growth regressions, growth accounting, and development accounting. Several pieces of additional work underscore the importance of measured skills for long-run growth.[11] An extensive empirical growth literature has focused on quantitative measures of schooling.[12]

[11]The research started with the seminal contribution by Hanushek and Kimko (2000). Additional contributions include, among others, Barro (2001), Woessmann (2003), Bosworth and Collins (2003), and Kaarsen (2014). See Hanushek and Woessmann (2011) for a review.

[12]Important contributions include, among others, Barro (1991, 1997), Mankiw, Romer, and Weil (1992), Bils and Klenow (2000), Bosworth and Collins (2003), de la Fuente and Doménech (2006), Vandenbussche, Aghion, and Meghir (2006), Cohen and Soto (2007), Aghion et al. (2009), and Barro and Lee (2013). For extensive reviews of the literature, see, e.g., Topel (1999), Temple (2001), Krueger and Lindahl (2001), Sianesi and Van Reenen (2003), and Pritchett (2006). See Delgado, Henderson, and Parmeter (2014) for a list of recent research.

In general, this literature has tended to find a positive association between quantitative schooling measures and economic growth. In fact, an encompassing robustness analysis has found primary schooling to be the most robust substantial influence factor on long-run growth among a long list of analyzed factors.[13] Still, the evidence presented above indicates that actual acquired skills play a dominant role when considered in cross-country growth regressions. A recent study has focused on the regional level and found that years of schooling are of paramount importance for differences in regional development across more than 1,500 subnational regions in 110 countries (Gennaioli et al., 2013). Another important line of research turns the focus from rates of growth to levels of development and analyses to what extent education can account for cross-country differences in the level of development.[14] Again, education plays a very important role once measured by actual achievement. Recently, research has also uncovered a great influence of education in historical economic development, showing the strong empirical relevance of education and literacy for catch-up during the Industrial Revolution and for Jewish and Protestant economic history.[15]

Another stream of literature focuses on the question of whether it is the level of human capital or, instead, changes in the level of human capital that is more important for economic growth. Early studies, such as Benhabib and Spiegel (1994), find a positive effect for educational levels, but not for changes in education. Other studies, such as Gemmell (1996), Topel (1999), and Krueger and Lindahl (2001), find that both, levels of schooling and changes in years of schooling may show a positive association with growth. Measurement error in the education data, which affects results based on changes in variables even more than results based on their levels, is likely a reason for these mixed findings (Krueger and Lindahl, 2001). More recent studies focus on data-quality issues and attempt to correct the estimated growth effects for measurement error (see Fuente and Doménech, 2001, 2006; Cohen and Soto, 2007). These studies find evidence of a positive association between changes in education and economic growth.

4. HUMAN CAPITAL AND INDIVIDUAL LABOR-MARKET OUTCOMES

This section presents the economic effects of human capital on employment and individual earnings, where human capital is measured by acquired skills from the recent PIAAC survey of adult skills. Contrary to other available measures of human capital, most notably years of schooling and test scores from student achievement tests (e.g., PISA, TIMSS), cognitive skills tested in PIAAC also include skills developed through lifelong learning activities during adulthood, such as on-the-job training.

[13] See the analysis of 67 explanatory variables in growth regressions on a sample of 88 countries by Sala-i-Martin, Doppelhofer, and Miller (2004), where primary schooling comes out as the most robust variable after an East Asian dummy.

[14] See, among others, Hendricks (2002), Woessmann (2003), Caselli (2005), Hsieh and Klenow (2010), Hanushek and Woessmann (2012b, 2015), Schoellman (2012), and Caselli and Ciccone (2013).

[15] See, in particular, Becker, Hornung, and Woessmann (2011), Botticini and Eckstein (2007), and Becker and Woessmann (2009).

Using the PIAAC data, we will show that wage returns to skills vary widely across countries, and we will provide some stylized facts about what accounts for these cross-country differences.

4.1 The PIAAC Data

PIAAC (Programme for the International Assessment of Adult Competencies) was developed by the OECD and the data were collected between August 2011 and March 2012.[16] PIAAC provides internationally comparable data about skills of the adult populations in 24 countries,[17] 23 of which are used in the analysis in Hanushek et al. (2015):[18] Australia, Austria, Belgium (albeit just Flanders), Canada, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Japan, Korea, the Netherlands, Norway, Poland, the Slovak Republic, Spain, Sweden, the United Kingdom (specifically England and Northern Ireland), and the United States. In each country, at least 5,000 adults participated in the PIAAC assessment, providing considerably larger samples than in the International Adult Literacy Survey (IALS), the predecessor of PIAAC.

PIAAC was designed to measure key cognitive and workplace skills needed for individuals to advance in their jobs and participate in society. In each participating country, a representative sample of adults between 16 and 65 years of age was interviewed at home in the language of their country of residence. The standard survey mode was to answer questions on a computer, but for respondents without computer experience there was also the option of a pencil-and-paper interview.[19] The survey included an assessment of cognitive skills in three domains: literacy, numeracy, and problem solving in technology-rich environments.[20] 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 (2013), refer to key information-processing competencies and are defined as

1. Literacy: ability to understand, evaluate, use and engage with written texts to participate in society, to achieve one's goals, and to develop one's knowledge and potential;

[16] Exceptions are Canada (November 2011 to June 2012) and France (September to November 2012).
[17] Nine additional countries plan to implement PIAAC in the period 2012-2016: Chile, Greece, Indonesia, Israel, Lithuania, New Zealand, Singapore, Slovenia, and Turkey.
[18] The authors do not use data for the Russian Federation in their analysis. According to the OECD (2013), data for the Russian Federation are preliminary, may still be subject to change, and are not representative of the entire Russian population because they do not include the population of the Moscow municipal area.
[19] On average across countries, 77.5 percent of assessment participants took the computer-based assessment and 22.5 percent took the paper-based assessment. A field test suggested no impact of assessment mode (OECD, 2013).
[20] Participation in the problem-solving domain was optional; Cyprus, France, Italy, and Spain did not participate in this domain.

2. Numeracy: ability to access, use, interpret, and communicate mathematical information and ideas in order to engage in and manage the mathematical demands of a range of situations in adult life;

3. Problem solving in technology-rich environments: ability to use digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks. This skill domain thus captures a person's skills to master information and communication technology (ICT) (see also OECD, 2015).

PIAAC measures each of the three skill domains on a 500-point scale. All three scales are intended to measure different dimensions of a respondent's skill set, although a person who performs well in literacy usually tends to have a relatively higher numeracy score, too. IALS, the predecessor of PIAAC, suffered from pairwise correlations of individual skill domains that exceeded 0.9, making it virtually impossible to distinguish between different skills. The score domains in PIAAC are less strongly correlated with an individual-level correlation between numeracy and literacy (problem-solving) of 0.87 (0.73).

Before the skill assessment, all participants responded to a background questionnaire that gathered information about labor-market status, earnings, education, experience, and demographic characteristics of the respondents. The measure of experience refers to actual work experience and was collected as the number of years where at least six months were spent in paid work.

4.2 Employment

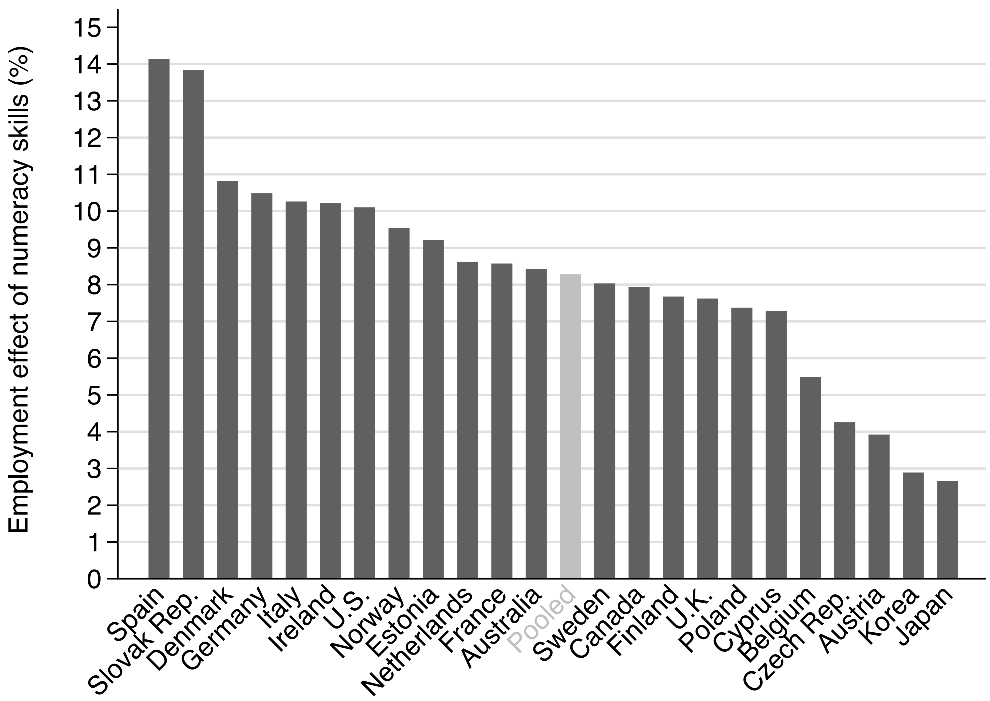
Using the PIAAC data, we first ask the question whether higher skills are related to a higher probability to be employed. In accordance with the International Labour Organization (ILO), employment in the PIAAC survey is defined as having paid work for at least one hour in the week before the survey. One reason why skills would affect employment is that individuals with higher earnings potential (due to higher skills) are more likely to choose to participate in the labor market. Another reason would be that low-skilled people are less likely to find a job on labor markets with effective minimum wages.

Figure 2 shows by how much the probability to be employed increases when numeracy skills increase by one standard deviation, which roughly corresponds to one out of five competency levels in PIAAC. Consistently across countries, better skills are significantly related to higher employment probabilities. In Germany, for instance, the employment probability increases by more than 10 percentage points for each competency level; the international average is 8 percentage points. The association between skills and employment probability is strongest for Spain and the Slovak Republic (14 percentage points), which is likely due to the high levels of unemployment in these countries.

These findings are the result of country-specific regression analyses in which a person's employment status (1: employed; 0: not employed) is regressed on the skill level, a quadratic polynomial in age, and gender. Thus, the estimates in Figure 2 account for any effect of age or gender on the probability to be employed. Moreover, as in the wage analysis below, the estimates pertain to prime-age workers aged 35-54 years.[21]

When measuring human capital as years of schooling instead of cognitive skills, we also observe a strong association between human capital and employment. Accounting for differences in the probability to be employed due to age and gender, each year of schooling increases the employment probability by an average of 3 percentage points across the PIAAC countries.

Figure 2: Cognitive skills and employment probability



Graph shows the average increase in the probability to be employed (either full time or part time) if numeracy skills increase by one standard deviation (within the respective country), accounting for gender and a quadratic polynomial in age. Dependent variable: employment indicator, taking the value of one if a person is employed (self-reported). Sample: all individuals aged 35-54 with self-reported employment status. Regressions are weighted using PIAAC sampling weights. Pooled specification includes country fixed effects and gives same weight to each country. All estimates are significant at the 1 percent level.

Source: Hanushek et al. (2015), own calculations.

[21] Results are qualitatively similar for workers aged 16-65 years.

Moreover, as detailed in Woessmann (2014), unemployment in modern labor markets is predominantly a phenomenon of the low-educated. On average across the EU-28 countries, unemployment among those with a low level of education is 17.9 percent, compared to 8.6 percent among those with a medium level of education and 5.9 percent among those with a high level of education.[22] In every single country, unemployment among the high educated is lower than among the medium educated, and unemployment among the medium educated is lower than among the low educated. In general, low-educated and medium-educated people make up the major share of European unemployment.

Of course, the result that human capital (measured either by educational attainment or by acquired skills) is significantly related to the employment probability does not imply that human capital has a causal effect on employment. For instance, people with a low preference to be active on the labor market may also be less likely to invest in their education. Thus, an unobserved factor – namely individual preference – affects a person's skill level as well as her employment probability, which cannot be accounted for in the regression. Moreover, skills may deteriorate if a person is not continuously employed, i.e., the direction of causation may go from (un-)employment to skills. However, while careful research on the relationship between education and unemployment is rather limited, available studies – mostly from the United States but also from Norway – suggest that education indeed likely has a causal effect on reducing unemployment and on increasing re-employment rates among those who are currently unemployed.[23]

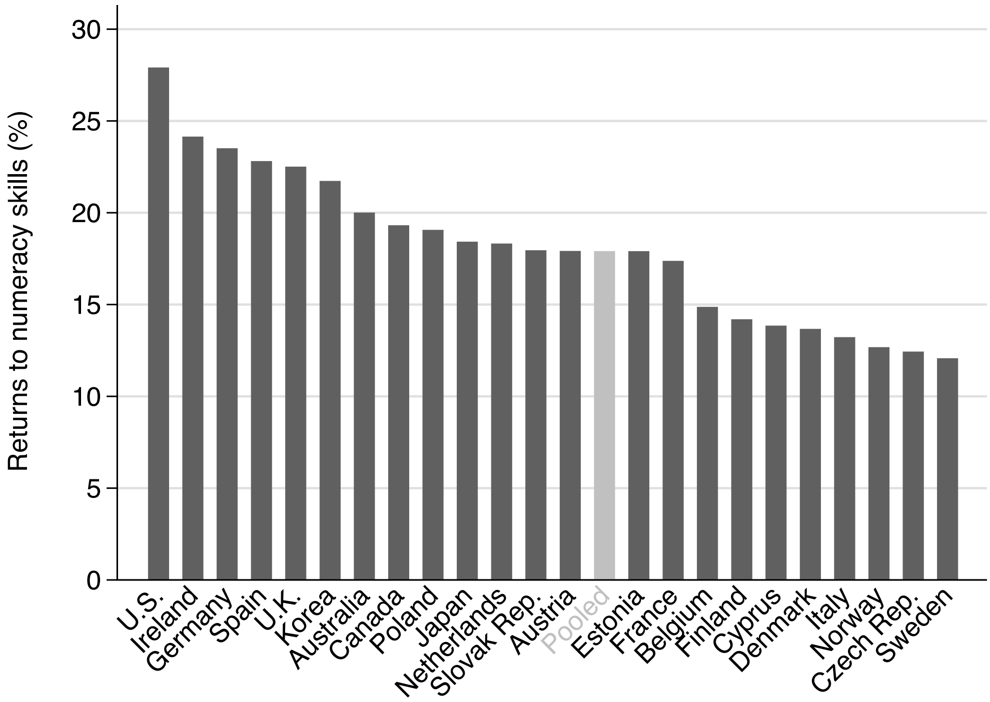
4.3 Wages

As argued above, to the extent that education increases individuals' productivity on the labor market, individuals with higher education should be able to earn accordingly higher wages. And indeed, the results shown in Figure 3 indicate that better skills are significantly related to higher wages. On average, going up one out of five competency levels in numeracy (roughly equivalent to one standard deviation) is associated with an average increase in hourly wages of 17.8 percent across the 23 countries surveyed in PIAAC. This figure refers to the prime-aged population (individuals aged 35-54), which makes it a good approximation for the returns in terms of entire lifetime earnings.[24] To obtain a homogeneous sample of workers with strong labor-force commitment, the estimations are based on a sample of survey respondents who work full-time.[25]

[22] The unemployment rates refer to the share of unemployed in the labor force. The three categories of educational attainment considered in each country are below upper secondary education (ISCED 0-2), at most upper secondary education (ISCED 3-4), and tertiary education (ISCED 5-8).
[23] See Li (2006), Riddell and Song (2011), and Oreopoulos and Salvanes (2011).
[24] For instance, Haider and Solon (2006) show that people with higher lifetime earnings have systematically steeper earnings growth. Thus, they suggest that current earnings are a good proxy for lifetime earnings only when observed between the mid-30s and late-40s. Furthermore, because skills are difficult to observe, it may take time for firms to learn about relevant differences among workers (Altonji and Pierret, 2001).
[25] Full-time employees are defined as those working at least 30 hours per week at the time of the survey.

But perhaps the clearest finding from Figure 3 is that the wage impact of skills varies significantly by country. Six of the countries indicate returns to skills that exceed 21 percent: the United States with almost 28 percent, Ireland and Germany with 24 percent, as well as Spain, the United Kingdom, and Korea. These high returns differ noticeably from those in another set of eight countries with returns to skills falling below 15 percent: Belgium, Cyprus, Czech Republic, Italy, and all the participating Nordic countries – Denmark, Finland, Norway, and Sweden. While a number of these countries do have significant income redistribution programs, it is important to remember that pre-tax and pre-transfer wages are being analyzed. Hence, different redistribution systems cannot account for the large differences in returns to skills across countries.

Figure 3: Cognitive skills and wages



Coefficient estimates on numeracy skills (standardized to standard deviation 1 within each country) in a regression of log gross hourly wage on numeracy, gender, and a quadratic polynomial in actual work experience. Sample: full-time employees aged 35-54. Regressions are weighted using PIAAC sampling weights. All estimates are significant at the 1 percent level.

Source: Hanushek et al. (2015).

While Figure 3 shows returns to numeracy skills, the data also reveal substantial returns to literacy and problem-solving skills. However, estimated returns tend to be largest for numeracy and literacy and smaller for problem-solving skills. Rich information provided in the PIAAC data reveals that the skill-earnings associations are highly robust to different earnings measures (e.g., monthly earnings and wages including bonus) and additional controls (e.g., parents' education and migration status). Differences in returns to skills across subsets of workers also present interesting patterns. Prime-age workers quite consistently show greater returns to skills than labor-market entrants. On average, women and men have identical returns in the sample of prime-age workers, while observed skills contribute somewhat less to wages for immigrants, part-time workers, and public-sector workers. However, also in these subgroups, better skills are also systematically associated with higher wages.

The findings from Figure 3 pertain to individuals who are already employed. However, we have shown above that skills also affect the probability to be employed in the first place. Hanushek et al. (2015) take the employment effects of skills into account by including the non-employed in the sample and assign them a very low wage (the authors use one percent of the median observed wage in a country). In line with the positive association of skills with employment probabilities, in such a model estimated returns to skills increase from the baseline estimate of 0.178 to 0.318.[26] These results suggest that by ignoring employment effects, the results in Figure 3 tend to underestimate the full returns to skills in the total population.

There is also abundant empirical literature that estimates the wage returns to differing levels of school attainment. [27] The easiest way to express this relationship is to estimate by which percentage earnings increase with each additional year of education. That is, each individual's educational attainment is simply expressed in terms of the years of education required to finish the respective degree. In this sense, the estimated earnings effect captures the average of the returns to a year of education at different (secondary and tertiary) levels of education.[28] Across the PIAAC countries, gross hourly wages increase by on average 7.5 percent with each additional year of education. Put differently, a five-year educational degree will be related to 38 percent higher earnings on average. This figure again refers to the prime-aged population working full-time. Just as in the returns-to-skills estimates, differences in earnings due to gender and work experience are accounted for in these estimates.

[26] Another way to take the employment participation decision into account is to estimate Heckman sample selection models. These models also yield returns to skills that are considerably higher than those presented in Figure 3.
[27] The large literature on the effects of educational attainment on individual earnings has been reviewed and interpreted by a variety of studies such as Psacharopoulos (1994), Card (1999), Harmon, Oosterbeek, and Walker (2003), Psacharopoulos and Patrinos (2004), and Heckman, Lochner, and Todd (2006). For a specific focus on EU Member States, see Harmon, Walker, and Westergaard-Nielsen (2001) and de la Fuente and Jimeno (2009).
[28] Of course, there may be differences between the returns to a year of compulsory schooling and to a year of education at the Master's level, and returns will depend on the specifics of each country and degree. But evidence showing that the return for each additional year of schooling in terms of a percentage increase in earnings appears remarkably stable across different education levels suggests that such a proceeding may provide a reasonable first glance of the overall return to education.

Much research has gone into the question of whether such associations between education and earnings indeed depict a causal effect of education on earnings.[29] A prime concern has been that more able people may be more likely to get additional education and may independently receive higher earnings because of their higher ability. Methods to get around such biases have included the use of variation in education stemming from historical events like changes in compulsory schooling laws and in restrictions on child labor, variation in education stemming from differences in the distance to the nearest educational institution, and variation in education occurring between siblings and twins. The exact interpretation of these can sometimes be quite complicated and is often limited to specific subgroups of the population. But overall, this literature suggests that, while returns can clearly differ across subgroups, the causal effect of years of education may be at least as high as the associations depicted above.[30]

Unlike the efforts to identify the rate of return to school attainment, the literature on returns to skills stops short of providing convincing evidence that the observed variation in cognitive skills is truly exogenous. One noticeable exception is the study by Hanushek et al. (2015), who exploit plausibly exogenous variation in skills using changes in U.S. compulsory schooling laws over time at the state level. Falck, Heimisch, and Wiederhold (2015) further add to the discussion about causality in returns-to-skills estimations by using a source of exogenous variation in skills across countries. Specifically, they use the reach of the traditional voice telephony networks, which were a prerequisite for broadband infrastructure roll-out, to predict individuals' current ICT skills. The underlying idea is that ICT skills develop by learning-by-doing for which Internet availability is a precondition (see also Section 5.4 below). Both studies confirm the result from the returns to educational attainment literature that measured returns in more rigorous empirical analyses are at least as high as those obtained from naïve OLS estimations.

4.4 What Determines Cross-Country Differences in Returns to Skills?

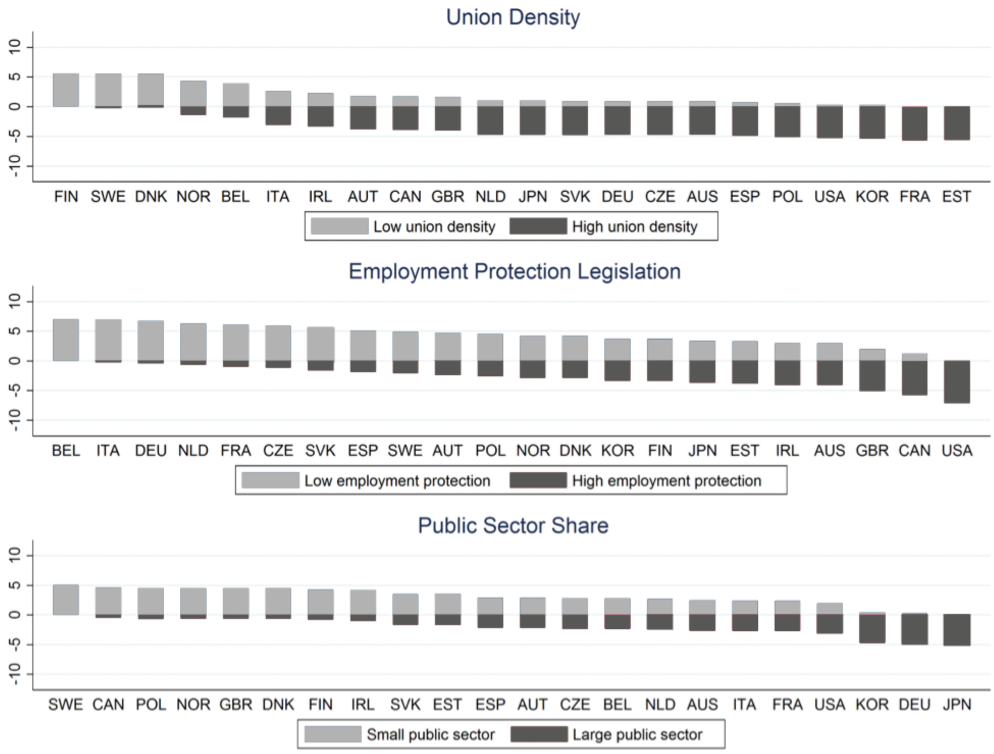
The results from the previous section show the crucial role of cognitive skills for wages. However, it is also apparent that returns to skills differ markedly across the 23 countries that participated in the PIAAC assessment. This raises the question whether there are features of country economies such as labor and product market regulations that are systematically related to differences in skill returns. Thus, Hanushek et al. (2015) establish a set of stylized facts about country characteristics that are systematically related to differences in the returns to skills across countries.

[29] See, in particular, Card (1999) and Heckman, Lochner, and Todd (2006) for reviews and Oreopoulos (2006) and Carneiro, Heckman, and Vytlacil (2011) for recent contributions.
[30] Recent evidence suggests, however, that estimates based on changes in compulsory schooling laws may in fact be smaller, after all; see Pischke and von Wachter (2008), Devereux and Hart (2010), Grenet (2013), and Stephens and Yang (2014).

The authors find that, intriguingly, returns to skills are systematically lower in countries with higher union density, stricter employment protection legislation, and larger public sectors. By contrast, product-market regulations and the existence of a minimum wage are not systematically related to differences in skill returns across countries. Skill returns also do not vary systematically with the level or distribution of skills in a country.

To document the size of the effects of these institutions, consider what would happen to the returns to skills in the pooled sample if all countries had the institution of the country with the lowest or highest value of this institution, respectively. These counterfactual simulations show that the return to skills in the pooled sample would range from 14 percent to 20 percent if all countries had the highest or the lowest observed value of union density, respectively; from 15 percent to 22 percent for employment protection legislation; and from 16 percent to 21 percent for the public-sector share. Figure 4 shows the counterfactual returns for each country individually (upper panel: union density; middle panel: employment protection; lower panel: public-sector share). For example, if employment protection would be as strict in the United States as it is in Belgium (the country with the highest protection), the simulations suggest that the return to skills in the United States would be 21 percent instead of the actual 28 percent (i.e., decrease by 7 percentage points). Conversely, if Germany had the low level of employment protection of the United States, its return to skill would be 30 percent instead of the actual 23.5 percent based on this simulation (i.e., increase by 6.5 percentage points).

Figure 4: Counterfactual simulation



The graph shows predicted returns to skills assuming counterfactual institutions. Returns are predicted for each country assuming the maximum (dark gray bar) and the minimum (light gray bar) level of the respective institution across all countries. Union Density: share of wage and salary earners who are trade union members. Employment Protection Legislation: composite indicator measuring strictness of employment protection for individual and collective dismissals. Public Sector Share: share of workers employed in the public sector. The country with the lowest (highest) value is Estonia (Finland) for union density; the United States (Belgium) for employment protection legislation; and Japan (Sweden) for public sector share.

Source: Hanushek et al. (2015), own calculations.

Given these results, the question emerges why returns to skills are systematically lower in countries with higher union density, stricter employment protection legislation, and larger public sectors. One likely explanation for this finding is that institutional structures that operate to reduce wage dispersion are likely to restrict the extent to which skills can be rewarded on the labor market. For example, in his classic study of unionism and wage dispersion, Freeman (1980) emphasized that union policy of standardizing rates reduced wage dispersion. Relatedly, in a model of union electoral competition, Frandsen (2012) derives an optimal union wage schedule that reduces the return to skill. Similarly, tighter employment protection legislation and larger public-sector shares may give rise to compressed pay schedules that put an upper bound on skill returns.

Moreover, in a world of continuing structural and technological change, lifelong learning assumes a crucial role in keeping people's skills adaptable.

Thus, another rationale for the above labor-market institutions to reduce returns to skills may be that these institutions influence the occurrence and content of lifelong-learning activities, preventing an individual's cognitive skills from remaining (or becoming) productive in the labor market. This possible explanation, however, has not yet received any attention in the literature. The PIAAC data would provide the opportunity to test this channel directly because they contain information on the occurrence and degree of lifelong learning activities (e.g., on-the-job training) measured consistently across countries. However, any research on the question whether labor-market institutions affect returns to skills through its impact on lifelong learning would have to address the problem of omitted variables, i.e., unobserved factors that simultaneously affect lifelong learning activities and labor-market institutions. For instance, a worsened economic situation in a country may lead to fewer training activities (because firms are lacking financial resources to finance training) and stricter employment protection (because unions want to prevent large-scale worker displacements).

5. SOURCES OF COGNITIVE SKILLS

Given the crucial importance of the knowledge and skills of the population for economic prosperity, the second part of the report provides a discussion how skills can be developed, which also entails cautious implications for policy-making.

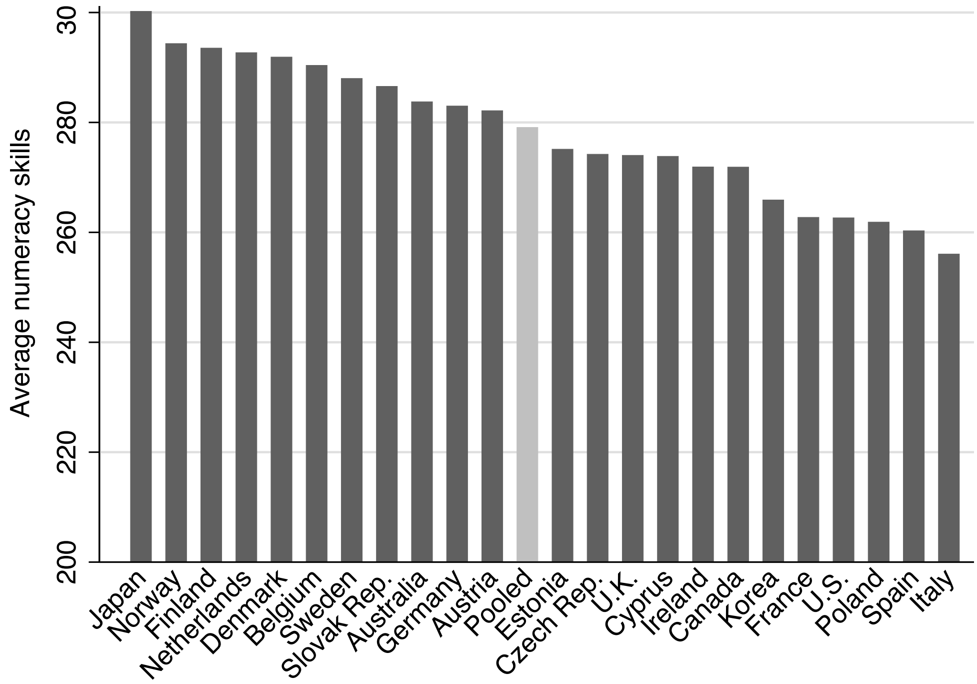
5.1 Cognitive Skills around the World

We begin by using the PIAAC survey to assess differences in cognitive skills across countries. Figure 5 shows the current levels of adult skills, measured as average PIAAC numeracy scores, for the samples of prime-aged, full-time employees in the 23 PIAAC countries.[31] We observe that respondents in Japan achieve the highest average numeracy score, and respondents in Italy the lowest, with a difference in average achievement between these two countries amounting to 89 percent of a standard deviation in test scores in the international sample.

Further, it is apparent that many EU countries perform close to the international average (279 PIAAC points). But even the EU top performers of Norway (294), Finland (294), and the Netherlands (293) fall short of the international top performer Japan (300). At a worrying level, Italy (256) and Spain (260) fall substantially short of the international performance and constitute the bottom in the international comparison. Interestingly, however, the United States (266) also belong to the worst-performing countries in the PIAAC numeracy assessment.

[31] We used the same sample to obtain the returns-to-skills estimates shown in Figure 3. Results are qualitatively similar when using all PIAAC respondents.

Figure 5: Numeracy skills of the adult population



PIAAC numeracy proficiency, 2011/12. Sample: full-time employees aged 35-54.

Source: Hanushek et al. (2015), own calculations.

These substantial performance differences signal the need for reform in a number of countries, especially in part of the European Union and in the U.S. Below, we review the existing literature regarding policies that may (or may not) foster the development of skills.

5.2 Schooling

As considerable evidence suggests that most of the skill foundation is laid during youth, any policy aiming at the improvement of skills should have a particular focus on schools and high-quality early childhood education.[32]

Large numbers of studies investigate the determinants of student achievement within individual countries.[33] The clearest conclusion from this "educational production function" literature is that achievement reflects a combination of a wide variety of family background factors, school inputs, and institutional factors.

[32] See Blau and Currie (2006), Cunha et al. (2006), and Heckman (2008).
[33] See, for example, the reviews in Hanushek (2002) and Glewwe et al. (2013).

In contrast, specific conclusions about the impact of resources have been much more limited. There has, for example, been considerable research on overall educational expenditures and on resource inputs such as class size, but the existing research has not identified these as being strong drivers of international differences in achievement. In particular, there is no indication that those countries that spend more on education perform systematically different on international achievement tests from countries with lower spending levels.[34]

The lack of findings on resources has led to a different set of international studies that focuses on the effects of institutional features of the school systems. These include the degree of local decision making, the use of accountability systems, and direct rewards for personnel in the schools.[35]

The conclusion that a good governance framework of the school system is important for achieving high levels of skills is closely linked to research pointing to the central role of teachers and to the impact that differences in teacher effectiveness have on student outcomes.[36] The most convincing studies show that teacher impacts on student reading and math performance differ greatly and that there is huge variation in teacher value-added (Hanushek and Rivkin, 2012).[37] These individual country studies suggest that the consideration of common measures of teacher quality in existing international studies may be incorrect. The detailed within-country studies (going beyond just the value-added studies) have generally shown that the common measures of teacher differences – teacher education and teacher experience levels – are not consistently related to student achievement, raising questions about the reliance on these in international studies. In a closely related set of within-country and international studies, researchers have used measures of teacher salaries as proxies for teacher quality, implicitly assuming that higher-paid teachers have higher skills or are more motivated (e.g., Dolton and Marcenaro-Gutierrez, 2011).[38] However, the within-country evidence again indicates that teacher salaries are a weak measure of teacher quality (see the overview by Hanushek and Rivkin, 2006).

[34]See Hanushek (2006) for a review of the effects of school resources and the international evidence in Hanushek and Woessmann (2011).

[35]For example, positive impacts have been estimated for school autonomy (especially in developed countries; cf. Hanushek, Link, and Woessmann, 2013) and for increased competition reflected in the share of privately operated schools (West and Woessmann, 2010). See the range of institutional studies in Hanushek and Woessmann (2011).

[36]See the reviews in Hanushek and Rivkin (2010, 2012) and the recent work by Chetty, Friedman, and Rockoff (2014a, 2014b) that traces teacher effects into the labor market.

[37]For a sample of the research into teacher effectiveness, see Rockoff (2004), Rivkin, Hanushek, and Kain (2005), Kane, Rockoff, and Staiger (2008), Chetty, Friedman, and Rockoff (2014), and the summary in Hanushek and Rivkin (2010). As an indication of the magnitudes involved, Rivkin, Hanushek, and Kain (2005) estimate that the effect of a costly ten student reduction in class size is smaller than the benefit of moving the teacher quality distribution one standard deviation upwards.

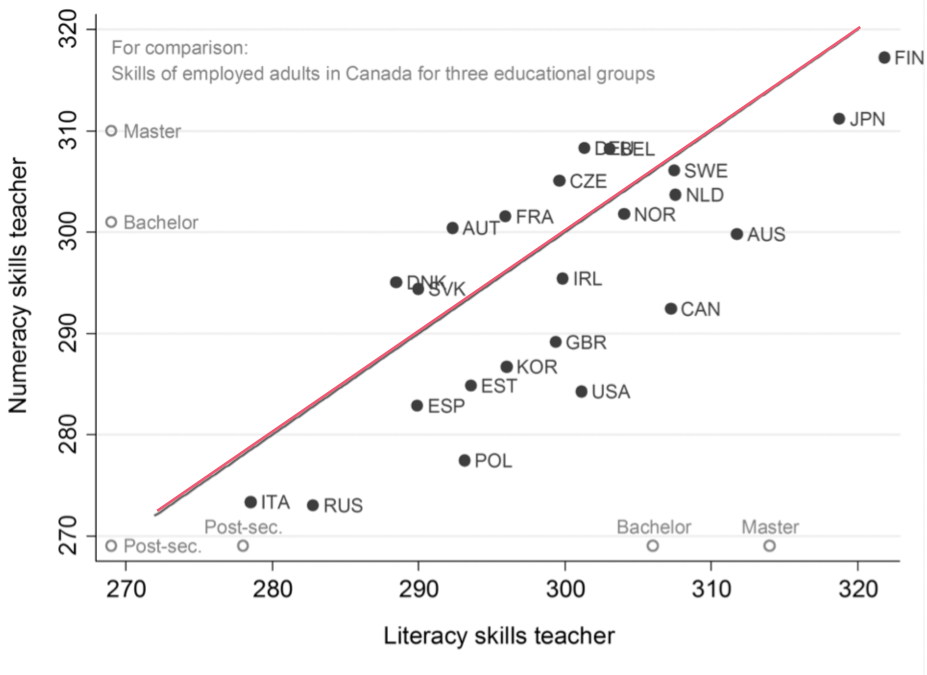
[38] For a review on teacher performance pay, see Leigh (2013). See also the international investigation of performance pay in Woessmann (2011).

While results are not entirely consistent across studies, perhaps the closest proxy of an underlying dimension of teacher quality is the cognitive skill of teachers as measured by scores on achievement tests (see Eide, Goldhaber, and Brewer, 2004; Hanushek and Rivkin, 2006). In a study for a developing country, Metzler and Woessmann (2012) show the relevance of teacher subject knowledge for student performance. Exploiting within-teacher within-student variation using data from 6th-grade students in Peru, they find a positive impact of teacher subject knowledge on student performance in math. Bietenbeck, Piopiunik, and Wiederhold (2015) also find a positive effect of teacher subject knowledge on student performance for a large set of countries in Sub-Saharan Africa.[39] In the context of developed countries, Hanushek, Piopiunik, and Wiederhold (2014) provide evidence that country-level measures of teacher skills in numeracy and literacy, obtained from the PIAAC survey, are an important determinant of international differences in student performance.

Hanushek, Piopiunik, and Wiederhold (2014) also show that teacher cognitive skills differ substantially across developed countries (Figure 6). Teachers in Finland and Japan perform best in both numeracy and literacy, while teachers in Italy and Russia perform worst in both domains. Teachers in the United States (284 points) perform worse than the average teacher in numeracy (295 points), but are slightly above the international mean in literacy. To provide an impression of the international variation in teacher cognitive skills, Figure 6 also arrays the median teacher math and literacy skills across countries against the skills of adults by educational group within Canada. The authors use Canada for this skill comparison because it provides by far the largest country sample in PIAAC. The literacy skills of the lowest-performing teachers (in Italy and Russia) are similar to the literacy skills of employed Canadian adults with only a vocational degree (278 points). Teachers in Canada, the Netherlands, Norway, and Sweden have similar skills than adults with a bachelor degree (306 points). The literacy skills of the best-performing teachers (in Japan and Finland) are even higher than the skills of Canadian adults with a master or doctoral degree (314 points). This comparison, which looks similar for numeracy skills, underscores the vast differences in teacher cognitive skills across developed countries. These differences in teacher cognitive skills reflect both where teachers are drawn from in each country's skill distribution and the overall level of cognitive skills in each country's population.

[39] See also Harbison and Hanushek (1992) for the impact of measured teacher math skills on achievement in rural Brazil.

Figure 6: Teacher cognitive skills in developed economies



The grey black indicate country-specific teacher skills in numeracy and literacy. The grey circles indicate the median cognitive skills for three educational groups of employed adults aged 25-65 years in Canada (the largest national sample in PIAAC). Post-sec. includes individuals with vocational education (post-secondary, non-tertiary) as highest degree; Bachelor includes individuals with bachelor degree; Master includes individuals with a master or doctoral degree.

Source: Hanushek, Piopiunik, and Wiederhold (2014).

There is much less research on the best way to ensure that universities foster the knowledge and skills needed to prosper. But it seems that a similar set of conclusions as is the case for schools – about the importance of accountability, autonomy, choice, and competition – is warranted when considering improvements in the European system of higher education.[40]

5.3 General vs. Vocational Education

A particular aspect about lifelong learning relates to the question whether the skills generated by the particular education type are specific to a particular occupation ("vocational") or more general in their applicability. Some countries, particularly in Europe, stress vocational education types which develop job-related skills to prepare students to work in specific occupations.

[40]See Aghion et al. (2010) for a discussion.

Other countries, most notably the United States, instead emphasize general education types which provide students with broad knowledge and basic skills in math and communication and serve as the foundation for further learning on the job.

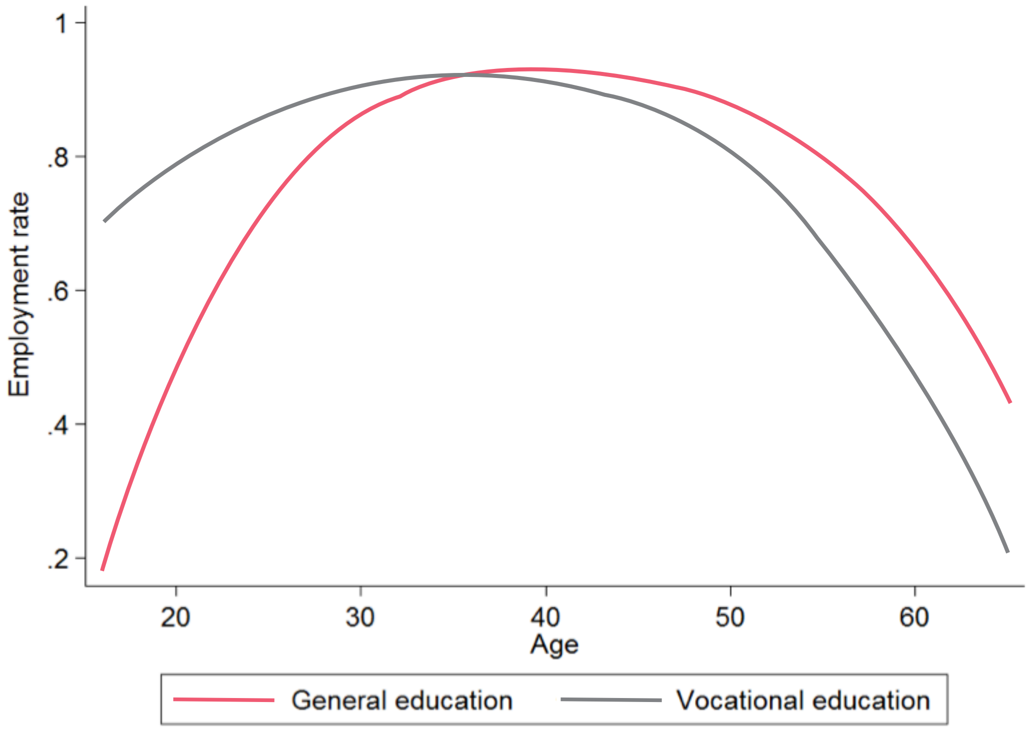
The advantage of vocational education programs is generally seen in that they help young people master the transition from school to work.[41] However, in an employment life-cycle perspective, economies are likely to change over time, and the lower adaptability of job-specific skills to technological and structural change may render these skills obsolete at a faster rate. In changing economies, workers at older ages may find it harder to stay employed or get re-employed if their acquired skills are focused on occupations for which there is not much demand anymore in the labor market. Although regular adult education and training may help update to more highly demanded skills, these workers may also find it harder to re-skill at a later stage because they are lacking some basic general skills that facilitate subsequent lifelong learning. The advantage of vocational programs at early age may thus come at the risk that at old age they face the disadvantage of reduced employment opportunities relative to workers who have undergone a more general education path and therefore can adjust better to changing technological working environments.

As shown in Figure 7, this trade-off between early advantages and later disadvantages of vocational programs in terms of employment is indeed visible in the data, in particular in countries that have strong apprenticeship programs (e.g., Denmark, Germany, and Switzerland).[42] At early ages, employment rates are higher for people who have obtained a vocational degree. However, this turns around at older ages, when people with a general education degree have substantially higher employment rates. It is important to be aware of this life-cycle pattern in assessing the relative merits of general and vocational education programs.

[41]Existing evidence on this mechanism is mixed, however; see Arum and Shavit (1995), Malamud and Pop-Eleches (2010), and the reviews and discussions in Ryan (2001), Müller (2009), Wolter and Ryan (2011), and Biavaschi et al. (2012).

[42]See Hanushek et al. (2014) for details. The restriction to (prime-age) males with their historically stable aggregate labor-force participation patterns aims to circumvent concerns in the comparison of younger and older workers about cohort-specific selection into work by females induced by their historically changing labor-force participation in many countries. Additional recent examples of labor-market analyses beyond the entry phase that are in line with this pattern include Cörvers et al. (2011), Weber (2014), and Golsteyn and Stenberg (2014)

Figure 7: Education type and life-cycle employment



Male employment rate by age and education type. Sample: "apprenticeship countries" (Denmark, Germany, and Switzerland). Smoothed scatterplots using locally weighted regressions, based on International Adult Literacy Survey (IALS) data.

Source: Hanushek et al. (2014).

This aspect of individual employability may also have implications for the economy as a whole. It has been argued that the propensity to use vocational rather than general education may be an underlying cause of growth-rate differentials between the United States and Europe. The argument is simply that vocational, occupation-based as opposed to general, concept-based education may lead to slower adoption of new technologies in times of rapid technological and structural change.[43]

5.4 Training

While much of the public debate focuses on schooling, skills can also be retained and improved later in life. In fact, in a world of continuing structural and technological change, it is of paramount importance that people update their skills and keep them adaptable for future changes in skill demand. One of the main drivers of this lifelong learning is, presumably, training.

[43] See Krueger and Kumar (2004a, 2004b). The pattern is also in line with the model by Gould, Moav, and Weinberg (2001) where technological progress leads to a higher depreciation of technology-specific skills as opposed to general skills.

As opposed to education, training occurs when a person is already part of the labor market. Work-related training[44] could for example increase human capital of the employees leading to higher worker productivity. Economic research has tried to determine the impact of training for the past decades, starting with the seminal contribution by Becker (1962) who views on-the-job training as a part of human capital investments that increases future earnings. Since then, numerous studies have tried to determine who pays for training, who receives it and how training can influence wages and other productivity-related outcomes.[45] Unfortunately, to date, there is no study that has directly looked at the effect of training on skills, so we assume in the following – in accordance with the human capital theory outlined above – that any positive wage impact of training also entails a positive impact on (productivity-enhancing) skills.

One major problem that studies investigating the role of training for wages have is the possible existence of omitted variables. For instance, individuals who are more able or talented than others may also be more productive and thus receive higher wages. The very same individuals might also choose to obtain longer training spells because learning something new is not as costly for them as for less talented workers. In this scenario personal ability, which cannot easily be measured and included in the regression, raises both wage and (the duration of) training. Therefore, naïve OLS estimates of the effect of training on wages likely overestimate the impact of training. A second reason for bias in OLS estimations is reverse causality. For instance, workers who recently got promoted typically receive a higher wage in their new position but might also receive more training to get prepared for new challenges. In this case the higher wage has an impact on individual training and the effect goes in the complete opposite direction.

A couple of studies have convincingly tackled these problems. Leuven and Oosterbeek (2008) and Goerlitz (2011) try to identify random reasons why individuals who wanted to participate in a training course did not do so (e.g., due to an unexpected illness). These workers are then used as a comparison group for those who actually received training. Neither of the two studies finds any significant effect of training on wages. Hence, the most convincing empirical research on the topic suggests that training itself does not lead to higher wages or, presumably, higher skills. However, further research on this topic is certainly warranted because, to date, only very few studies have provided a careful assessment of the wage impact of training.

[44] *The two most important types of work-related training are on-the-job training which takes place at the workplace during regular working hours and off-the-job training which an employee receives away from the workplace (see, for example, Lynch, 1992).*

[45] *For instance, Lynch (1992), Bartel (1992), Lechner (1999), Abadie et al. (2002), Gerfin (2004), Leuven and Oosterbeek (2008), and Goerlitz (2011).*

Moreover, no study has specifically looked at changes in cognitive skills as a result of participation in training activities.[46]

Furthermore, available evidence suggests that government subsidization of job-related training of the workforce is generally inefficient.[47] Similarly, evidence on the effectiveness of public-sector job training for the unemployed is rather disappointing (for a survey, see Heckman, LaLonde, and Smith, 1999). However, a meta-analysis of 199 active labor market policies suggests that government training programs, although ineffective in the short term, are associated with positive medium-term impacts (Card, Kluve, and Weber, 2010). Still, judging by the available evidence, government interventions tend to be more effective when instituted at younger ages.[48]

5.5 Learning-by-doing

Finally, another mechanism through which lifelong learning affects skills is learning-by-doing at the job. Everyday economic activities often have side effects, and one of them is that people get better at what they are doing. Studies of production performance provide evidence that labor productivity gradually improves with the volume of activity – the so called Wright's law in manufacturing. Two recent contributions assess the role of learning-by-doing in skill development and economic growth.

Learning-by-doing and ICT skills

Falck, Heimisch, and Wiederhold (2015) provide direct evidence on the existence of a learning-by-doing channel in the accumulation of ICT skills. They use the PIAAC survey, which is the first-ever study that assessed individuals' ICT skills in an internationally comparable fashion, to show that individuals acquire ICT skills by performing ICT-related tasks. This learning-by-doing is facilitated, or rendered possible at all, when access to the Internet is available. Thus, the authors exploit differences in the technologically determined probability of having Internet access countries. This variation stems from the extent of the pre-existing fixed-linevoice-telephony network, which is upgraded in most countries to provide fast Internet access by means of the so-called DSL technology.

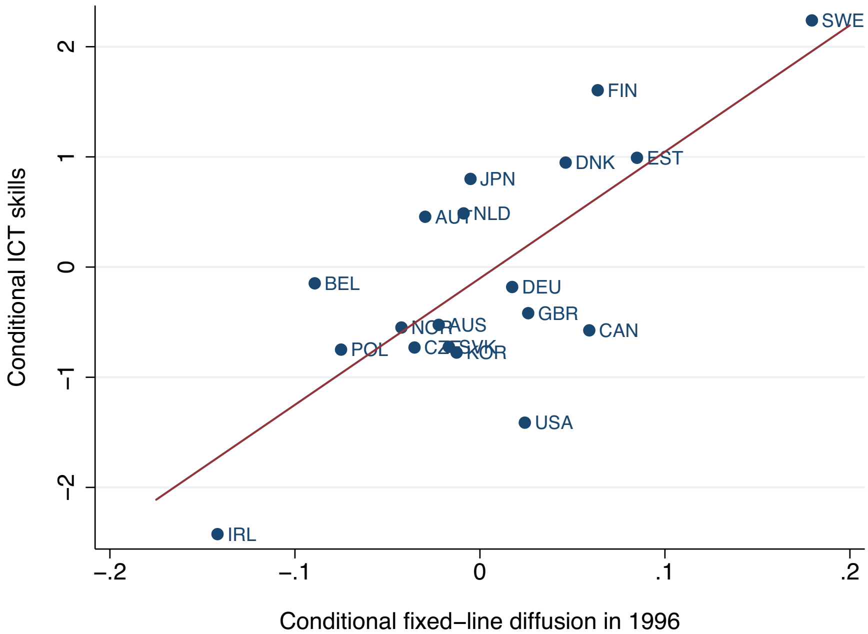
[46]Traditionally, formal education and training are sequential and separated in time, i.e., an individual first receives formal education in school, then receives job training and acquires work-related skills while performing the job. On-job schooling, however, provides adult workers with formal education while at work. Employees can keep their working positions and further their studies in school at the same time. Especially in China, who tended to have a severe lack of college-educated persons at the beginning of the economic reforms in 1978, on-the-job schooling is a widespread phenomenon. Based on data from the Chinese Household Income Project in the period 1995-2007, Li, Liu, and Ederer (2014) find that the wage returns to a college or a graduate degree earned while working are significantly lower than the returns on corresponding degrees earned via full-time studies.

[47] See Falch and Oosterbeek (2011) and Oosterbeek (2013).

[48]See Heckman (2006) and Cunha et al. (2006).

Figure 8 provides graphical evidence that individuals living in countries with a farther-reaching voice-telephony network in 1996 have higher ICT skills today. In terms of magnitude, the estimates suggest that increasing the voice-telephony penetration rate from 17 percent (Poland) and 68 percent (Sweden) is associated with an increase in ICT skills of about 49 PIAAC points (which corresponds to one out of five proficiency levels in PIAAC).

Figure 8: Past fixed-line diffusion and ICT skills



Added-variable plot of a regression of ICT skills (standardized to standard deviation 1 across countries) on fixed-line diffusion (in 1996), GDP per capita (in 1996), country-level wages of workers aged 50-60, quadratic polynomial in work experience, female indicator, and years of schooling. Except for fixed-line diffusion and GDP per capita, all variables are measured in 2011/12. "Conditional" refers to variation in ICT skills and fixed-line diffusion, respectively, purged for variation in these other variables. Sample: employees aged 20-49, no first-generation migrants.

Source: Falck, Heimisch, and Wiederhold (2015).

Falck, Heimisch, and Wiederhold (2015) also provide two placebo tests to solidify the evidence for the existence of a learning-by-doing channel in the accumulation of ICT skills. First, they show that pre-existing fixed-line diffusion is associated with no appreciable changes in numeracy and literacy skills, suggesting that the authors' empirical strategy isolates ICT skills (vis-à-vis generic skills or general ability). Second, the extent of a country's traditional voice telephony network is irrelevant in a sample of first-generation immigrants who are unlikely to have acquired ICT skills in the PIAAC test country.

Learning-by-doing, complexity, and economic growth

At the macroeconomic level, there exist "learning-by-doing" models (most notably, Arrow, 1962 and Lucas, 1988), in which productivity and the resulting economic growth is the serendipitous by-product of experience gained in the production of goods.

These models, implicitly or explicitly, assume that learning-by-doing yields productivity gains because the workers' knowledge and skills in producing the good accumulate with experience in production. While early macroeconomic models treat learning very simplistically as a result of increasing the volume of output, more recent models (e.g., Lucas, 2009) explicitly model learning as being the result of a continuous exchange of ideas. However, even in this new stream of literature it has been ignored that the complexity of tasks people perform at work may also matter for learning-by-doing. Learning-by-doing can be expected to develop skills at a faster rate when there is substantial novelty and challenge in the scope of everyday activities undertaken by employees. Thus, an economy which has its production composed of intellectually complex activities may have a better chance of developing highly skilled workforce in the longer run.

Patt (2015) tests the idea that complexity matters for learning-by-doing and, subsequently, economic growth.[49] He employs a standard growth accounting framework, which decomposes GDP per capita growth into a weighted sum of growth rates of inputs to the aggregate production relation:

$$Y = A * F(K, H),$$

where physical capital *K* and human capital *H* are the inputs, and *A* is the technology multiplier (typically interpreted as total factor productivity). By considering learning-by-doing, Patt (2015) recognizes that the stock of human capital, *H*, depends on both complexity of the tasks performed in production, *x*, and the age distribution of workers, characterized by the parameter λ:

$$H = H(x, \lambda).$$

Age matters because learning is a dynamic process, and changes in the age composition can result in changes in an economy's average human capital stock. Younger economies will have lower per capita income but faster growth, all other things being equal.

In general, any international analysis on the importance of learning-by-doing for growth is necessarily limited by lack of comparable data on occupational structures and performed tasks at work. Thus, Patt (2015) uses data at the U.S. state level from the Integrated Public Use Microdata Series (IPUMS) data of the Minnesota Population Center (Ruggles et al., 2010), which provides detailed occupational information. He combines data on the occupational composition of states from IPUMS with data on the task content of occupations, provided by the Occupational Information Network (O*NET).[50] Specifically, O*NET contains information on job requirements grouped in three distinct categories: abilities, skills, and generalized work activities.

[49] *See Nedelkoska, Patt, and Ederer (2015) for micro-level evidence on learning by problem-solving.*

[50] *Starting with the seminal contribution by Autor, Levy, and Murnane (2003), a rapidly expanding literature has used information on job tasks provided in O*NET and its predecessor Dictionary of Occupational Titles (DOT) to explore changes in occupational structure. Examples are Autor, Katz, and Kearney (2006, 2008), Goos and Manning (2007), Borghans, ter Weel, and Weinberg (2008), Autor and Dorn (2009, 2013), Peri and Sparber (2009), and Goos, Manning, and Salomons (2014). See Acemoglu and Autor (2011) for an overview.*

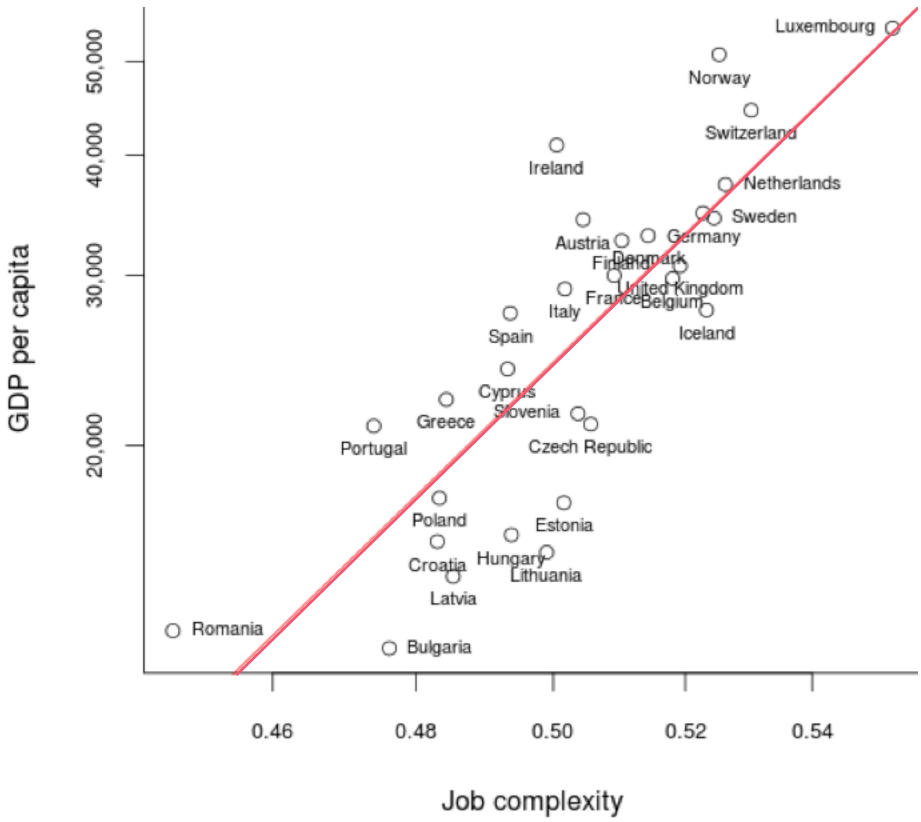
Employing a data reduction technique to take into account that different questions in O*NET often measure the same underlying factor, Patt (2015) derives a measure of occupational job complexity that is composed of intelligence ability, cognitive skill, managerial skill, and analytical and managerial work activities.

Patt's growth-accounting exercise suggests an important role of complexity for economic growth. He finds that more than half of the real per capita income growth in the United States over the period 1980-2010 resulted from an increased cognitive complexity of jobs, while just about one-third came from growth in average years of schooling.[51] Historically, the increase in complexity was fueled by the growth of such industries as health, finance, and professional services, which increased the demand for high complexity occupations and resulted in substantial income growth. Therefore, increases in the cognitive complexity of jobs going hand in hand with lifelong learning to master these new task requirements appears to have played a key role in the increase of the standards of living in the United States.

Similarly, complexity also appears to be important for the economic development in Europe. Figure 9 depicts the correlation between occupational job complexity and GDP per capita for a large set of European countries. As evidenced by the plot, countries with a higher level of complexity systematically have a higher per capita income than countries with low complexity; the correlation between both variables is 0.81.

[51] *Expansions in working hours contributed the remaining 20 percent to per capita income growth.*

Figure 9: Job complexity and economic development



*Correlation between country-level job complexity and GDP per capita. Job complexity is computed combining information on job requirements from O*NET with data on the occupational composition of countries from Eurostat's Labor Force Survey (LFS). Job complexity is measured in percentiles (ranging from 0 to 1). Data on GDP per capita, measured in million PPP US-$ (base year 2005) divided by population size, refer the 2011 and are obtained from Penn World Tables 8.0. Note that the y-axis is in logarithmic scale.*

Source: Patt (2015).

6. CONCLUSIONS

The idea that human capital is crucial for future prosperity is no longer controversial. Policymakers regularly emphasize the importance of schooling and lifelong learning to the economy's innovative capacity and ability to compete in the globalized world of the 21st century. In the words of President Barack Obama: *"Whether it's improving our health or harnessing clean energy, protecting our security or succeeding in the global economy, our future depends on reaffirming America's role as the world's engine of scientific discovery and technological innovation. And that leadership tomorrow depends on how we educate our students today."* [52]

Existing research investigating the effects of human capital accumulation supports this view. Human capital has been shown to have substantial positive impacts not only on individuals' success in the labor market, but also on their general well-being. Moreover, there is a great deal of evidence suggesting that aggregate human capital is a main driver of economic growth. However, the empirical literature is plagued by measurement issues and the available quantity-based measures of human capital investment, such as average years of schooling, may be poor proxies for actual productive human capital. Moreover, measures of educational attainment just reflect an individual's human capital at the end of formal schooling, which may not be good indicators of effective human capital when individuals need to constantly adapt their skills to structural and technological change.

Direct measures of cognitive skills can be used to complement and enhance quantity-based measures. Cognitive skills have been shown to be economically important and to have additional explanatory power compared to mere quantity-based measures. However, data that provides direct measures of cognitive skills, along with information on economic outcomes, are scarce. This is particularly true in the case of data sets that contain information on cognitive skills of adult populations, which are probably the most reliable proxies of effective human capital in economies that have undergone substantial structural and technological change.

The new PIAAC data are basically the only source of data that contains internationally comparable information on cognitive skills of the working-age population and economic outcomes for a large set of countries. Research based on these data shows that higher cognitive skills – measured across numeracy, literacy, and ICT domains – are systematically related to higher employment probabilities. Moreover, better cognitive skills are also associated with higher wages in all countries participating in PIAAC. The effect sizes of these returns to skills estimates are economically meaningful. Among prime-age workers, going up one out of five competency levels in numeracy skills is associated with increased hourly wages averaging some 18 percent across countries.

[52] Office of the Press Secretary, White House Office, "Remarks by the president on the "Educate to Innovate" Campaign and Science Teaching and Mentoring Awards," January 6, 2010.

But perhaps the most striking finding from the international analysis is the substantial heterogeneity in returns to skills across countries. Estimated returns to skills in the countries with the highest returns (the United States, Ireland, and Germany) are roughly twice as large as in the countries with the lowest returns (Sweden, the Czech Republic, and Norway). Intriguingly, returns to skills are systematically lower in countries with higher union density, stricter employment protection, and larger public-sector shares. However, positive returns to skills exist not only at the individual level, but also at the macroeconomic level. The skills of a country's population are very closely linked to that country's long-run growth rate. An increase in educational achievement by 50 PISA points translates into 1 percentage point higher growth rates in the long run. Importantly, what matters for growth is the skill level that people have actually achieved, not how long people stayed at school.

Given these high returns to skills both at the individual and the macroeconomic level, it is all the more worrying that many European countries show a rather poor performance in the recent PIAAC test when compared with the top-performing countries (e.g., Japan). Therefore, the second part of this Thematic Report summarizes previous research on how cognitive skills accumulate, providing insights to policy-makers in Europe and elsewhere which reforms may help to improve people's achievement levels.

Regarding skills learned at school, a number of rigorous studies show that a good governance framework of the school system and effective teachers are important for achieving high levels of skills among the students. However, continuing structural and technological change of the economies clearly asks for skill adaptations and a process of lifelong learning after school. This puts the focus on policies that ensure that skills are effectively retained and used. But skills also accumulate simply by regularly practicing them at home or at work. This learning-by-doing seems to develop skills at a faster rate when there is substantial novelty and challenge in the scope of everyday activities undertaken by employees. An economy which has its production composed of intellectually complex activities also appears to grow faster. In fact, more than half of the real per capita income growth in the United States over the period 1980-2010 resulted from an increased complexity of jobs, while just about one-third came from growth in average years of schooling. Also in Europe, job complexity and standard of living are positively related.

Still, the best way to nurture skills among adults remains unclear. One main lifelong-learning activity is on-the-job training provided by employers. A large number of empirical studies deal with the effects of on-the-job training on wages, which can be regarded as a proxy for skills. While the majority of studies find positive correlations between training and wages, the most compelling evidence suggests that these correlations cannot be interpreted as a causal effect of training. In fact, studies which exploit exogenous variation in training participation by considering individuals who cancelled their training course due to random reasons (e.g., illness) typically find no positive effects of training on wages and, presumably, skills. However, to date, there are only few rigorous studies in this field.

Our knowledge also remains limited about the best role that governments can play in the area of adult education and training. Available evidence suggests that government subsidization of job-related training of the workforce is generally inefficient. Public-sector job training programs seem to be associated with positive medium-term impacts, although in the short term they often appear ineffective. To find out the best ways for the government to support lifelong learning, more research is needed to evaluate the outcomes and effectiveness of different adult education and training programs.

The best recommendation might be to make sure to rigorously evaluate the outcomes and effectiveness of any adult education and training program in order to learn which policies might work to foster skills in the adult population. It is also important to continue the efforts to measure adult skills consistently within and across countries, allowing not only to observe current achievement levels, but also to analyze how achievement develops over longer time periods. The skill trends revealed by such repeated adult skill surveys would allow for a judgement of whether any reforms implemented by a country did have the desired effects on the country's overall achievement level.

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6. PROJECT IDENTITY

LLLight'in'Europe is an FP7 research project supported by the European Union, which has investigated the relevance and impact of lifelong learning and 21st century skills on innovation, productivity and employability. Against the background of increasingly complex tasks and jobs, understanding which skills impact individuals and organizations, and how such skills can be supported, has important policy implications. LLLight'in'Europe pioneered the use of an instrument to test complex problem solving skills of adults in their work environment. This allowed for the first time insights into the development of professional and learning paths of employed individuals and entrepreneurs and the role that problem solving skills play. Additionally, LLLight'in'Europe draws on a series of databases on adult competences from across the world to conduct rich analyses of skills and their impact.

These analyses were conducted in concert with different disciplines. Economists have been analyzing the impact of cognitive skills on wages and growth; sociologists have been investigating how public policies can support the development of such skills and lifelong learning; innovation researchers have been tracking the relationships between problem solving skills, lifelong learning and entrepreneurship at the organizational level;. educational scientists have investigated how successful enterprises support their workforce's competences; cognitive psychologists have researched on the development and implications of cognitive skills relevant for modern occupations and tasks; and an analysis from the perspective of business ethics has clarified the role and scope of employers' responsibility in fostering skills acquisition in their workforce. The team has carried out its research and analyses on the value of skills and lifelong learning in EU countries, USA, China, Latin America and Africa.

The result is a multi-disciplinary analysis of the process of adult learning and problem solving in its different nuances, and of the levers which can support the development of these skills for both those who are already in jobs, and for those who are (re)entering the labor market, as well as the development of effective HR strategies and public policy schemes to support them.

Coordinator	Zeppelin University
Project Director	Peer Ederer
EU Project Officer	Monica Menapace
EU Contribution	€ 2,695,000
EU Project #	290683
Project Duration	January 2012 – September 2015

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