Changes in Literacy Skills as Cohorts Age

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As our societies transform into knowledge societies, skills are playing an ever-increasing role in life. Despite recent efforts to consistently measure adult skills across countries, a challenge remains to understand how skills evolve over time and what the main drivers behind these changes are. By applying demographic methods to estimate the development of skills over the life course, this paper presents the reconstruction of empirical adult literacy test results along cohort lines by age, sex, and educational attainment for 44 countries for the period 1970–2015. Results suggest significant heterogeneity in the pattern of changes in literacy skills with age, reflecting the differential exposure to cognitive stimulation over the life course and suggesting that the development of skills in a country is also the consequence of a changing composition of its population. Gender, however, was found to have hardly any effect on how literacy skills evolve between the ages of 15 and 65. On the aggregate level, findings reveal considerable differences between countries—regarding both the level of skills and their development over time. Overall, it was found that massive educational expansions happening globally in the recent past only partly resulted in a corresponding rise in skills.

Introduction

Over the last decades, policymakers have been focusing primarily on universalizing access to education. With the average educational attainment increasing for younger cohorts around the globe, however, attention is now shifting toward how successfully people can acquire skills during and beyond school, and why populations in some countries are learning more than others. As an example, while Goal 2 of the Millennium Development Goals (MDGs) in 2000 proposed to "achieve universal primary education," Goal 4 of the successional 2015 Sustainable Development Goals (SDGs) aimed to "ensure inclusive and equitable quality education and promote lifelong

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learning opportunities for all." In addition, economists, demographers, and sociologists have recognized not only the intrinsic value of skills, but also provided evidence of their social and economic benefits (Becker 1994; Crespo Cuaresma, Lutz, and Sanderson 2014; Gupta 1990; Lutz 2013; Mincer 1974; Muttarak and Lutz 2014; Schultz 1961).

This new policy focus also calls for monitoring the level of skills in a population. Qualitative measures of human capital, that is, measures of skills, began evolving in the 1960s, when the International Association for the Evaluation of Educational Achievement (IEA) pioneered development of international student assessments. Consistent data for comparing the educational achievement of different school systems over time, however, have only been available since the late 1990s and early 2000s, when surveys such as "Trends in Mathematics and Science Study" (TIMSS), "Progress in International Reading Literacy Study" (PIRLS) (both coordinated by IEA), or the "Programme for International Student Assessment" (PISA, coordinated by the Organisation for Economic Co-operation and Development [OECD]) started to collect data on a regular basis for a large number of countries around the globe. These tests, however, focus exclusively on the school-age population, which proves problematic for various reasons when aiming to measure the skills of a population. First, school tests naturally exclude large parts of the population—not only those who already finished school, but also those who never attended school in the first place or did not continue education until the age of 15, when international assessments usually take place—thus potentially resulting in some kind of selection bias. Second, school assessments do not provide information about changes in skills over the life course (or beyond the age when formal education is usually attained). Therefore, using student assessments, it is not possible to account for increases of skills over the life course (e.g., lifelong learning), or for potential depreciation of skills with age. Finally, the prevalence of skills in an adult population at a given time reflects a rather complex interplay of several factors, in particular age and cohort effects. Therefore, when school participation rates or the length of schooling change over time—as recently happened in virtually all countries—there is a little value from using test scores of 15-year-olds currently in school to make inferences about the cognitive skills of today's working-age population.

Only recently there have also been initiatives to test the skills of adults on an international level. The Educational Testing Service (ETS; in partnership with a number of agencies and international organizations including the OECD) collected large-scale data on adult skills that are comparable between countries via the "International Adult Literacy Survey" (IALS) between 1994 and 1998 and the "International Adult Literacy and Life Skills Survey" (ALL) between 2003 and 2008 for a limited number of countries. In addition, between 2011 and 2017, the OECD implemented the "Programme for the International Assessment of Adult Competencies" (PIAAC), where skills of numeracy, literacy, and problem-solving in technology-rich environments of adults aged between 16 and 65 were tested in a total of 37 countries—at present, the most important international large-scale assessment of adult skills. For developing countries, the World Bank has developed a similar test, named the "Skills Toward Employment and Productivity Survey" (STEP) that includes a literacy test link with items that are linked to the literacy scale used in PIAAC.

Despite these recent efforts to consistently measure adult skills, a major challenge remains to track changes in skills over time. To better understand skills-related effects on economic growth, sustainable development, or demographic changes, we not only need to understand how skills differ between populations, but also how skills have evolved over time within the same population and what the main drivers are behind these changes. At present, however, there are not enough longitudinal data available to understand the complex interplay of age, cohort, and period effects—all potentially impacting skills development over the life course. This is the gap this research intends to fill. By applying demographic methods to estimate the changes in literacy skills as cohorts age, I reconstruct adult literacy test results for 44 countries back to 1970.

In this paper, I exclusively focus on literacy skills—mostly because of the availability of high-quality cross-country data (which is larger for literacy than for any other skill domain), but also because they play a central role in human well-being. Without adequate literacy skills, individuals cannot meaningfully participate in society and engage in political discourse (Barrett and Riddell 2019). Moreover, studies have shown that literacy skills also have a strong impact on economic well-being: those with greater literacy enjoy better employment opportunities and receive higher earnings (Green and Riddell 2013; Hanushek et al. 2015). Finally, literacy skills have been shown to be closely correlated with other skill domains (see Figure A1 in the Appendix in the Supporting Information), thus also providing a good proxy for the overall skill level in the population.

It is important to mention that, by using large-scale adult literacy skills assessment data, this paper rests on the implicit assumption that literacy ability reflects a universal set of cognitive characteristics that can be reliably assessed through paper and pencil tests. This is a strong assumption and although it is not the topic of this paper, it is worth referring to the broad body of literature questioning the premises, constructs, and outcomes of literacy and other skills assessments (see, e.g., Hamilton and Barton 2000; Sticht 2001; or St. Clair 2012 for a summary of the arguments). Here, I only want to acknowledge that literacy as measured in large-scale surveys is a particular construct, namely, the ability to retrieve certain types of information from certain types of texts and diagrams, that can be measured in a test situation. It certainly does not represent a complete measure of human capital or literacy abilities as it excludes some important parts that make up an individual's complex multilayered set of literacy practices, such as critical evaluation of texts, creative writing, or social literacy practices. Nevertheless, I argue that as long as we are aware of these limitations, assessment surveys as used in this paper can be a high-quality source of data for researchers, educators, and policymakers, revealing detailed information on measurable skills and competencies of adults around the world.

The remainder of this paper is structured as follows. In "Effects on skills over the life course" section, a short literature review is provided on skill gain and skill loss over the life span, as well as the main factors impacting these changes. "Data sources" section presents the data sources used in this paper, followed by "Methodology" section explaining in detail the methodology. After presenting the results in "Results and discussion" section, I conclude and discuss potential limitations in "Conclusion" section.

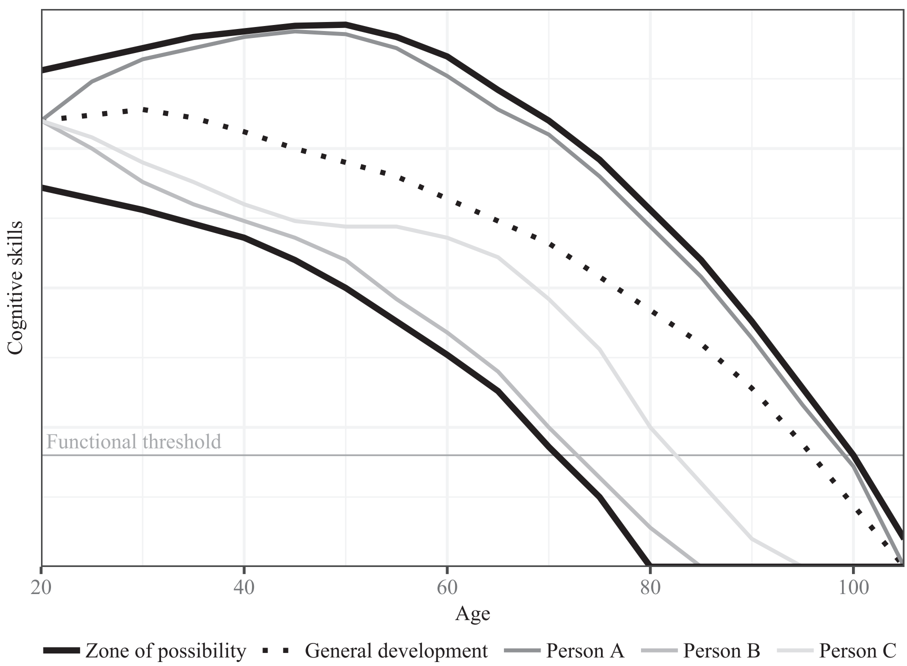
Effects on skills over the life course

Three main effects that impact the changes of skills over the life course, that is, age, cohort, and period effects, have been identified in the literature. In the following, each of these effects and their impact on skill gain and skill loss over the life span will be discussed in a little more detail.

"Age effects," that is, the mere impacts of growing older, have been identified as key drivers of skills change over the life course. Several studies have found a tendency for cognitive skills to rise in the early years and then eventually decline as adults age (Hertzog et al. 2008; Desjardins and Warnke 2012; Skirbekk, Loichinger, and Weber 2012; Green and Riddell 2013; Barrett and Riddell 2016; Paccagnella 2016a). However, aging and skills do not have a straightforward relationship, with many individual, contextual, and social factors influencing its development. Nevertheless, there are attempts in the literature to define a "normal age effect" related to skill development. Hertzog et al. (2008), for example, suggest that skill decline for an individual under "typical" circumstances can begin as early as age 20 and continue into old age, accelerating particularly after the age of 50. However, especially for young adults, individual trajectories may vary considerably, depending on biological, behavioral, environmental, and social influences. Figure 1 depicts a zone of possible cognitive development across adult life, which is delineated by optimal and suboptimal boundaries. This zone of possibility suggests that growing old eventually constrains cognitive functioning, but not all individuals need to follow the general trend. Depending on a variety of factors, including education or practice factors (e.g., practices at work that require cognitive application), individuals' trajectories may vary within this zone, as exemplified by the very different trajectories for persons A, B, and C.

Similarly, Desjardins and Warnke (2012) highlight that until about the age of 18–20, cognitive skills of all kinds are expected to increase, but

FIGURE 1 Zone of possible cognitive development across adult life



SOURCE: Adapted from Desjardins and Warnke (2012).

thereafter, development patterns are expected to diverge. For some people and types of skills, this would mean a decline already in early adulthood, while others may experience a continuous rise of skills, followed by stagnation, and eventually a decline. Factors found to influence skill gain and skill loss over the life span and over time include education and training, behavioral and practice factors, as well as social factors. An extensive literature overview of the evidence on the factors causing skill gain and skill loss can be found in Desjardins and Warnke (2012).

In addition to pure age effects, "cohort effects" may also influence the development of skills over time (Flisi et al. 2019). Cohorts, as interpreted in this context, can be defined as a group of individuals who are characterized by some shared temporal experience or common life experience, such as year of birth, or year of exposure to a phenomenon (Desjardins and Warnke 2012). Given the specific age–period combination, cohort effects are always generation-specific. An important example of a cohort effect on skills is the nature and quality of schooling: a change to compulsory schooling laws, for instance, affects only a particular age cohort, while those who are older than a certain age cutoff are not impacted by the structural change. Similarly, the quality of education may not be constant across all age cohorts, but rather might have steadily improved or declined over time.

Finally, "period effects" can also play an important role, when assessing skills over time (Desjardins and Warnke 2012). Similar to cohort effects they are related to a specific event or phenomenon, however, with one distinctive feature: period effects impact everyone at the time of assessment, regardless of age or generation. Examples for such occasion-specific influences include economic conditions or the occurrence of a war or famine at the time of the study. Assessing the skills of the same population at a later time may thus lead to a very different performance. In practice, however, it is not always easy to identify the underlying reasons for observed changes, that is, whether a skill loss is a result of the contextual conditions between the measurement points, or the result of skill decline because of aging. The scarcity of data further hampers the undertaking of country-specific, age–period–cohort analyses on a global scale. Surveys measuring adult skills have traditionally been cross-sectional, hence only reflecting combinations of age, cohort, and period effects. Only recently, internationally comparable large-scale assessments of the same population at different points of time became available, allowing for a separation of these effects and a better understanding of skill development across generations.

The following sections will present these data sources and explain in more detail the methodology used to disentangle the above-mentioned effects.

Data sources

As mentioned in the introduction, large-scale, international adult literacy skills assessments have only recently emerged. Following the pioneering work of national adult literacy assessments undertaken in the United States and Canada in the early 1990s, the "IALS," developed by Statistics Canada and ETS in collaboration with participating national governments, was the first survey of this kind with 22 countries participating between 1994 and 1998. As a successor to IALS and with the goal of measuring a broader range of adult skills than had previously been covered in IALS, the "ALL" was administered in 11 countries between 2003 and 2008. Finally, the OECD's "PIAAC" was designed to assess the current state of the skills of individuals and nations in the new information age. It builds upon earlier conceptions of literacy from IALS and ALL to facilitate an appropriate assessment of the broad range of literacy skills required for the twenty-first century.

Given the lack of panel data on adult skills, particularly on an international level, all three above-mentioned surveys are used in this paper in order to track changes in skills over time. Due to the continuity in survey methodology and the usage of trend items that were asked in all three surveys, it is possible to analyze trends over time in countries that participated in at least two of these surveys. In addition, and to increase coverage among developing countries for the base-year estimates, I rely on the "STEP" data, a survey coordinated by the World Bank, which is also designed to allow for linkages with the PIAAC survey. In the following, all data sources are explained in greater detail.

Programme for the International Assessment of Adult Competencies, Adult Literacy and Life Skills Survey, and International Adult Literacy Survey

PIAAC provides the main data source for this research. It is a program of assessment and analysis of adult skills coordinated by the OECD. The major survey conducted as part of PIAAC is the Survey of Adult Skills, which assesses proficiency of adults (aged 16–65) in three information-processing skills considered essential for successful participation in the information-rich economies and societies of the twenty-first century: literacy, numeracy, and problem-solving in technology-rich environments.

PIAAC aims to assess how well people are able to access, understand, analyze, and use text-based information as well as representations of various types (e.g., pictures, graphic representations, mathematical notations, etc.). In addition, all competencies measured in PIAAC aim to fulfil the following requirements:

- They should be preconditions for successful integration into and participation in the labor market, in education and training, as well as in social and civic life.
- They should be relevant to all adults, regardless of cultural or socioeconomic background.
- They need to be highly transferable, that is, relevant to multiple social fields and work situations.
- They should be "learnable" and, therefore, subject to the influence of policymakers (OECD 2016a).

The PIAAC survey design is based on a latent regression item response model, with proficiency scores scaled between 0 and 500. To increase the accuracy of the cognitive measurement, PIAAC uses plausible values (PVs), which are multiple imputations, drawn from *a posteriori* distribution. This is done by combining the Item Response Theory (IRT) scaling of the cognitive items with a latent regression model using information from the background questionnaire in a population model. For each survey participant, a set of 10 PVs for all proficiency domains was estimated to replicate a probable score distribution that summarizes how well each respondent answered a small subset of the assessment items, and how well other respondents from a similar background performed on the rest of the assessment item pool. Further details on the statistical test design of PIAAC can be found in the "Technical Report of the Survey of Adult Skills" (OECD 2016b). In addition to the module on the direct assessment of skills, PIAAC also includes a detailed background questionnaire that collects information about demographic and socioeconomic characteristics, use of skills in daily life, and characteristics of working life.

In total, 37 countries have participated in PIAAC so far. The first round of the survey collected data from around 166,000 adults aged 16–65 in 24 countries or regions in 2011 and 2012. In 2014, the second round of the survey was conducted, with data collection in nine additional countries. Finally, in 2017–2018, five new countries participated in the survey and the United States conducted the survey for the second time. In each participating country, a nationally representative sample of around 5,000 respondents were selected. The survey's plan is to repeat the survey every 10 years, with preparations for the second wave of data collection currently in process.

PIAAC builds on knowledge and experiences gained from previous international adult assessments: the IALS and the ALL. Both data sources are also used within this paper, which allows me to analyze literacy outcomes at different points of time. IALS was conducted between 1994 and 1998 as the first-ever, large-scale, international comparative assessment designed to identify adult literacy skills in 22 countries and regions. A few years later, ALL measured the literacy and numeracy skills of a nationally representative sample of 16- to 65-year olds in 11 participating countries/territories. Table 1 provides an overview of which PIAAC countries have also participated in IALS and/or ALL.

Literacy definitions in OECD adult skills surveys. As mentioned in the introduction, analyses throughout this paper focus exclusively on literacy skills, as these are tested in all of the three previously described surveys as well as in the World Bank's STEP Skills Measurement Program (see "Programme for the International Assessment of Adult Competencies, Adult Literacy and Life Skills Survey, and International Adult Literacy Survey" section). Literacy skills are considered a core requirement for developing higher order skills as well as for positive economic and social outcomes. As shown by previous studies, literacy is also closely linked to positive outcomes at work, to social participation, and to lifelong learning (OECD 2013). The following section describes how literacy is defined and conceptualized in each of the three surveys.

PIAAC literacy definition. In PIAAC, literacy is defined as the "ability to understand, evaluate, use and engage with written texts to participate in society, achieve one's goals, and develop one's knowledge and potential" (OECD 2013, 4). The literacy assessment in PIAAC encompasses a wide range of skills, such as vocabulary, language proficiency, and comprehension, combined with the ability to apply these in circumstances that arise in everyday life. To get a better understanding of how literacy is conceptualized

TABLE 1 PIAAC countries that have also participated in IALS and/or ALL by year and assessment

	IALS			ALL		PIAAC		
Country	**1994**	**1996**	**1998**	**2003**	**2006–2007**	**2011–2012**	**2014**	**2017**
Australia		√			√	√		
Belgium		√				√		
Canada	√			√		√		
Chile			√				√	
Czech Republic			√			√		
Denmark			√			√		
Finland			√			√		
Germany	√					√		
Hungary			√					√
Ireland	√					√		
Italy			√	√		√		
The Netherlands	√				√	√		
New Zealand		√					√	
Norway				√		√		
Poland	√					√		
Slovenia			√				√	
Sweden	√					√		
UK		√				√		
USA	√			√		√		

SOURCE: Author's elaboration.

in PIAAC, two examples of literacy items are referred to in the Appendix in the Supporting Information.

The PIAAC literacy assessment is further complemented by a test of "reading components" skills to provide more detailed information about adults with poor literacy skills. It focuses on the basic set of decoding skills that enable individuals to extract meaning from written texts: knowledge of vocabulary, ability to process meaning at the level of the sentence, and fluency in reading passages of text (OECD 2016a). As "reading components" is a new domain, not available in IALS and ALL, results are not included in the analyses of this paper.

IALS literacy definition. Quite similar to PIAAC, the 1994 IALS definition of literacy refers to "the ability to understand and employ printed information in daily activities, at home, at work and in the community, to achieve one's goals and to develop one's knowledge and potential" (OECD 2000, x). IALS measured three domains of literacy: (1) prose literacy, defined as the knowledge and skills needed to understand and use information from texts including editorials, news stories, poems, and fiction; (2) document literacy, defined as the knowledge and skills required to locate and use information contained in various formats, including job applications, payroll forms, transportation schedules, maps, tables, and graphics; and (3) quantitative literacy, defined as the knowledge and skills required to apply arithmetic operations to numbers embedded in printed materials (National Center for Education Statistics 2018). For reasons of comparability, only results from (1) prose literacy and (2) document literacy were used in this paper.

ALL literacy definition. Finally, literacy in ALL was defined as "using printed and written information to function in society, to achieve one's goals, and to develop one's knowledge and potential," drawing attention to the fact that literacy is not seen "as a set of isolated skills associated with reading and writing, but more importantly as the application of those skills for specific purposes in specific contexts." Rather, it is meant to "capture the full scope of situations in which literacy plays a role in the lives of adults, from private to public, from school to work, to lifelong learning and active citizenship" (Murray, Clermont, and Binkley 2005, 95). As in IALS, literacy skills in ALL were again assessed separately for prose and document literacy. Examples of literacy items included in both IALS and ALL are referred to in the Appendix in the Supporting Information.

Although these definitions are quite similar, direct comparability of the constructs measured and the content of the instruments used to assess literacy skills is crucial when using data from different surveys to analyze skills over time; hence, all issues related to comparability between IALS, ALL, and PIAAC will be discussed in the next section.

Comparability between IALS, ALL, and PIAAC. As shown by the definitions above, there is, by design, considerable overlap between the definition of literacy skills in IALS, ALL, and PIAAC: the conceptualization of the cognitive processes used in gaining meaning from text, the definition of the contexts in which reading takes place, and the factors affecting the difficulty of test items are similar among all three surveys. Furthermore, PIAAC is linked to IALS and ALL through a number of common test items: 29 of the 52 literacy items included in the computer-based version of the literacy assessment were linking items (i.e., they had been used in the assessment of literacy in IALS and/or ALL); in the paper-based versions, 18 of the 24 items administered were linking items. Despite these similarities, however, PIAAC conceived literacy more broadly than IALS and ALL, encompassing the domains of prose and document literacy, which were assessed separately in IALS and ALL. To overcome these differences, results for prose and document literacy from IALS and ALL have been combined and re-estimated by Statistics Canada to make them comparable to PIAAC (Paccagnella 2016b). Within my analyses, I am therefore exclusively using these rescaled data.

Another major difference between PIAAC and IALS and ALL is related to the mode of delivery: whereas PIAAC was designed as a computer-based assessment (with a pencil-and-paper option for respondents without sufficient computer skills), both IALS and ALL were exclusively pencil- and paper-based surveys. This difference in the delivery mode could potentially affect the comparability of results. However, results of a field test, where a proportion of respondents were randomly assigned to either the computer-based or paper-based version of the assessment, identified no significant mode effects, suggesting that the mode of delivery does not affect comparability of results (OECD 2019).

Finally, the extent to which comparisons can be made between the surveys depends not only on the psychometric assessments, but also on the definitions of relevant subpopulations (e.g., educational attainment) that are derived from the background questions. To ensure consistency, derived trend variables were created in order to facilitate comparisons between assessments. These trend variables were used in my analyses for defining any subpopulations (Paccagnella 2016b).

In summary, PIAAC literacy results can be directly compared to literacy results from the previous OECD, IALS, and ALL surveys, as confirmed by the following statement in the OECD Reader's Companion that accompanies the report "Skills Matter: Additional Results from the Survey of Adult Skills": "[…] [T]he Survey of Adult Skills was designed to be linked psychometrically with IALS and ALL in the domain of literacy […]. Analysis of data from the field trial and from the main data collection confirmed that results from IALS, ALL, and the Survey of Adult Skills could be placed on the same scale in literacy [...]."(OECD 2019, 81). Nevertheless, caution is always advised when using nonpanel data to estimate trends over time.

Skills toward Employment and Productivity Survey

The "STEP" was developed by the World Bank in order to better understand the interplay between skills, on the one hand, and employability and productivity, on the other hand. The STEP program developed survey instruments tailored to collect data on skills in low- and middle-income country contexts. Three broad types of skills are measured within STEP: cognitive skills, defined as the "ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought" (as derived from Neisser et al. 1996, 77); socioeconomic skills (such as social, emotional, personality, behavioral, and attitudinal skills); and job-relevant skills (task-related skills, e.g., computer use). Data were collected between 2012 and 2017 in Albania, Armenia, Azerbaijan, Bolivia, Bosnia and Herzegovina, Colombia, Georgia, Ghana, Kenya, Kosovo, Lao PDR, Macedonia, Serbia, Sri Lanka, Ukraine, Vietnam, and the Yunnan Province in China. Each sample consisted of around 3,000 individuals and was representative of the urban adult population between the ages of 16 and 65 (World Bank 2014).

The measurement of cognitive skills, which is used in this paper, includes a direct assessment of reading literacy designed to identify respondents' levels of competence at accessing, identifying, integrating, interpreting, and evaluating information. A primary goal for the design of the STEP literacy assessment was to be able to link it to the PIAAC Survey of Adult Skills. Therefore, the STEP literacy test is capitalized on the same item pool as PIAAC, allowing for results to be reported on a common scale with common descriptions for interpreting the proficiency levels of the scale. This makes the two assessments directly comparable to each other. As in PIAAC, the STEP design is based on matrix sampling, where each respondent is administered a subset of items from a larger pool, resulting in different groups of respondents answering different sets of items. By using IRT, the distribution of the performance in a population or subpopulation can be described through estimating the relationships between proficiency and background variables, while at the same time reducing the response burden for each individual (Educational Testing Services 2014).

The STEP literacy assessment was administered in a total of 12 countries. However, only eight of them, namely, Armenia, Bolivia, Colombia, Georgia, Ghana, Kenya, Ukraine, and Vietnam, have implemented the full cognitive assessment including both the paper-based literacy assessment as in PIAAC and a short reading test. The remaining countries conducted only the core reading test, consisting of eight short items which thus were not relatable to PIAAC literacy scores. For this reason, only data from the above-mentioned eight countries are included in the analyses used throughout this paper. Given that items selected for these countries are derived from the literacy framework of PIAAC, PIAAC sample items referred to in the Appendix in the Supporting Information also apply to the STEP literacy assessment.

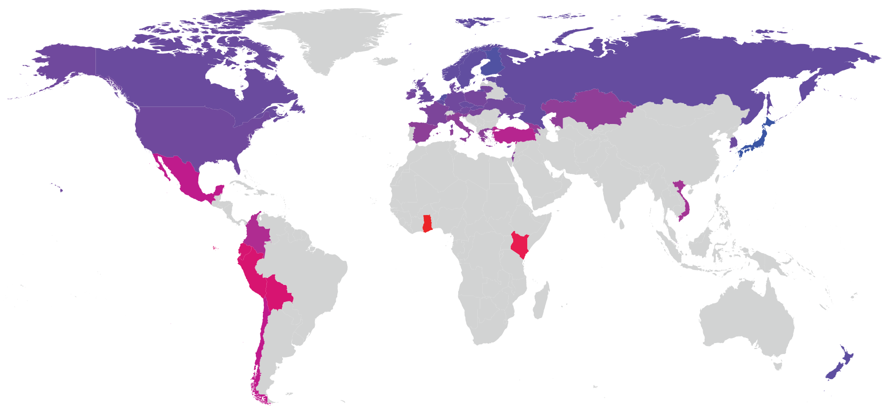
As mentioned previously, the target population in the STEP Skills Measurement Program is limited to urban adults. Therefore, STEP results for the eight countries included in the analysis were further adjusted to be representative for the entire country. Urban–rural corrections in literacy skills were derived from the Demographic and Health Survey (DHS),[1] with the ratio between DHS literacy results of the total population and those of the urban population serving as the correction factor. For three countries (Bolivia, Ghana, and Kenya), country-specific DHS information was used; for five countries (Armenia, Colombia, Georgia, Ukraine, and Vietnam), where no tested literacy data from DHS are available, corrections are based on regional averages.[2]

It is important to mention that although STEP and PIAAC use similar psychometric methods to estimate the literacy proficiency of participating adults (i.e., a common scale on which literacy proficiency is evaluated), there are still considerable differences, giving reason to treat any direct comparisons of results with caution. First and as already mentioned, the target population in STEP is limited to adults living in urban areas, while PIAAC is representative of all adults living in a country. Furthermore, this requires additional adjustments to the STEP data, making STEP results automatically more error-prone. Second, STEP uses—similar to IALS and ALL—only paper-based instruments, while the PIAAC assessment was designed to be primarily administered on a computer. However, and as mentioned in "Comparability between IALS, ALL, and PIAAC" section, differences in the delivery mode were shown to not significantly affect the comparability of results. Finally—and arguably most importantly—differences in the underlying distribution of proficiency of the population may impact the comparability, particularly when a large proportion of the population performs at the very bottom of the proficiency distribution—as is the case in some of the STEP countries. This will be discussed in more detail in the following section.

Both STEP and PIAAC survey designs are based on a latent regression item response model, built on the assumption that the “true” and unobservable proficiency of respondents lies in a unidimensional continuum and can be estimated on the basis of observed proxies such as the answers to a test. These answers are most informative when the test contains items with a difficulty level appropriate to the respondents. Consequently, an assessment might not perform equally well across heterogeneous populations with different levels of proficiency. Moreover, in both PIAAC and STEP, the assessment begins with a short module including eight easy items (the “core assessment”) with the aim of identifying respondents with low proficiency who would have little chance of successfully completing most items included in the assessment. To pass the core and move on to the full assessment, respondents must give a correct answer to at least three items in STEP and four items in PIAAC.[3] The share of adults failing the core is generally higher in lower income countries—which are overrepresented in STEP. A larger share of populations failing the core is, however, also associated with a larger share of people whose literacy proficiency estimates rely on little information about their actual performance, and much more on their background characteristics and the design of the underlying statistical model—ultimately resulting in a larger amount of error (Keslair and Paccagnella 2020).

Having said that, and being aware of the limitations of the STEP survey and their impact on comparability with the results of the OECD adult skills surveys, I still decided to include STEP data as base-year data for the reconstruction of the eight low- and middle-income countries that have implemented the full STEP literacy assessment.[4] On the one hand, this is to increase geographic coverage and extend my analyses (and conclusions drawn from them) to a wider spectrum of countries—not just looking at rich OECD countries. On the other hand, previous studies have shown that the basic patterns observed in the analysis of multiple rounds of PIAAC data are confirmed in STEP (Keslair and Paccagnella 2020),

FIGURE 2 Mean PIAAC/STEP literacy score by country



SOURCE: Author's elaboration based on PIAAC and STEP data.

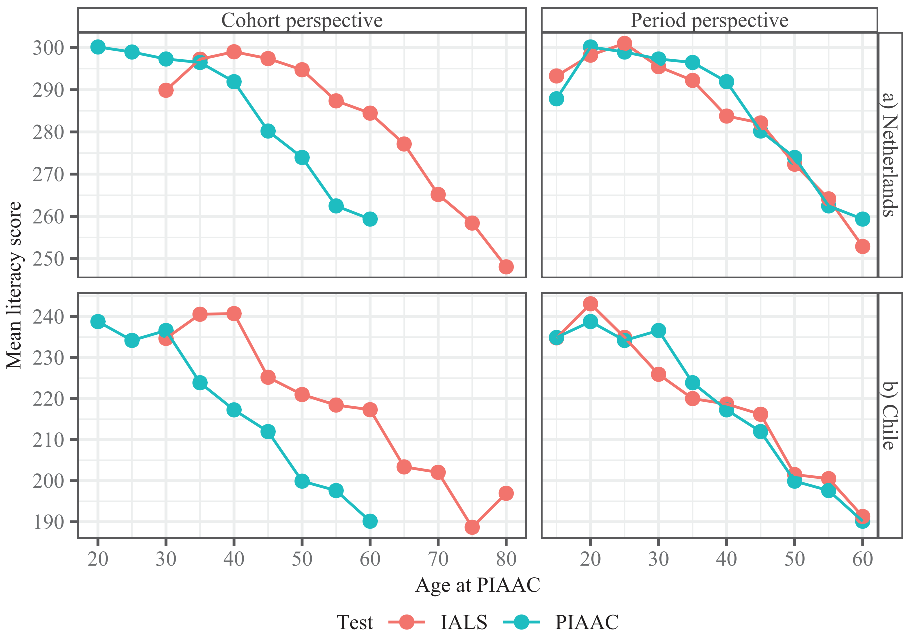
suggesting that—given the matched psychometric methods—results are still largely comparable. Nevertheless, it is important to be transparent about all the data issues involved so that readers can interpret the results with adequate caution.

To provide an overview about data availability and mean performance on literacy, Figure 2 shows the mean literacy score by country for the population aged 15–65 for the 44 countries[5] that participated in PIAAC or STEP. As depicted on the map, there is a considerable North–South divide, suggesting that the average level of skills is much lower in the Global South than in the Global North. Ghana, Kenya, and Peru are bringing up the rear, with scores considerably less than 200. On the other hand, Japan, Finland, and the Netherlands are leading the ranking, performing significantly better than the OECD average.

Methodology

For the reconstruction of adult literacy test results, the first step involves the identification of the extent of changes in skills with age and over time. For this purpose, data from three international, large-scale assessments were used: (1) the 1994–1998 IALS, (2) the 2003–2008 ALL, and (3) the 1st cycle PIAAC (2011–2017). This is possible because trend items from IALS and ALL were included in PIAAC, allowing data from previous surveys to be linked to trend data from participating countries in PIAAC. As highlighted in Table 1, countries for which tested adult literacy data are available for at least two points in time include Belgium, Canada, Chile, Czech Republic, Denmark, Finland, Germany, Hungary, Ireland, Italy, the Netherlands, New Zealand,

FIGURE 3 Changes in literacy skills over time from a cohort and period perspective, the Netherlands and Chile



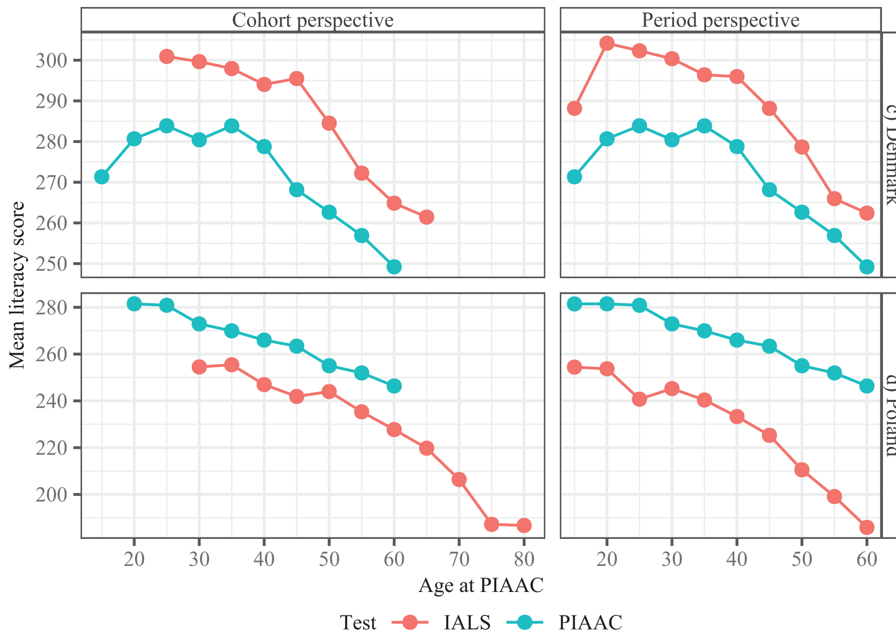
SOURCE: Author's elaboration based on IALS and PIAAC data.

Norway, Poland, Slovenia, Sweden, Switzerland, the United Kingdom, and the United States.

The empirical analyses are based on a pooled dataset from IALS, ALL, and PIAAC, from which I built cohorts[6] to investigate the skill development of different age groups over a period of roughly 20 years. Ideally and when available, I used single-year age groups, which were then aggregated to five-year age groups, depending on the year the surveys took place and the time lag between different surveys in each country. For example, in the United States surveys took place in 1996 (IALS), 2007 (ALL), and 2014 (PIAAC); hence, my analysis follows a cohort, which was, for example, 25–29 years old in IALS, 36–40 years old in ALL, and 43–47 years old in PIAAC. In this way, I was able to conduct country-specific cohort analyses for 17 countries[7] (see Figure A2 in the Appendix in the Supporting Information).

In line with literature findings, the empirical cohort analysis results indeed suggest that deterioration in the level of skills is happening because of age effects, with the beginning and extent of the decrease strongly depending on educational attainment. Figure 3 exemplifies this, showing two countries: the Netherlands and Chile. On the left panel, cohorts are represented vertically, that is, the x-axis represents the age at PIAAC, while participants in IALS are accordingly younger (e.g., x = 40 represents an age

FIGURE 4 Changes in literacy skills over time from a cohort and period perspective, Denmark and Poland

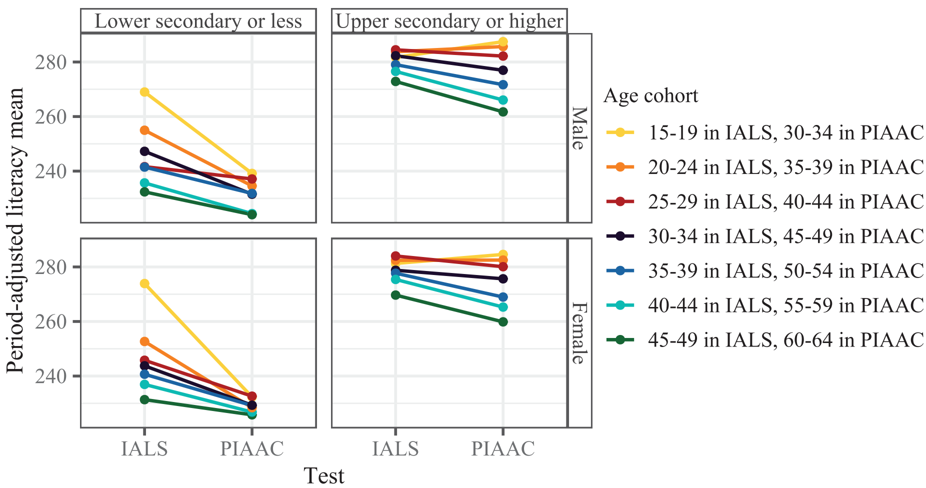


SOURCE: Author's elaboration based on IALS and PIAAC data.

cohort that was aged 23–27 years old in IALS 1994 and 40–44 years old in PIAAC 2011). On the right panel, test results are depicted from a period perspective, with the x-axis representing the age at the time of the test. In both countries, when looking from a cohort perspective, literacy skills declined considerably after age 20 for all but the youngest age groups, with stronger skill deterioration among older adults. In the Netherlands, where educational attainment is high, skills are still increasing until the age of about 35; in Chile, where educational attainment is lower, a minor skill gain is only observable until the age of 30. From a period perspective, however, mean literacy scores by age group are roughly identical between the two surveys, suggesting that no significant period effect occurred.

These results, however, were not found to be consistent among all countries. Figure 4 shows the changes in skills over time for two additional countries: Denmark and Poland, with Denmark experiencing significant skill loss, and Poland experiencing considerable skill gain between 1998 and 2011. In both countries, this development holds among all age groups, both from a cohort perspective and from a period perspective, suggesting that these countries were faced with period effects that had an impact on their overall level of skills.

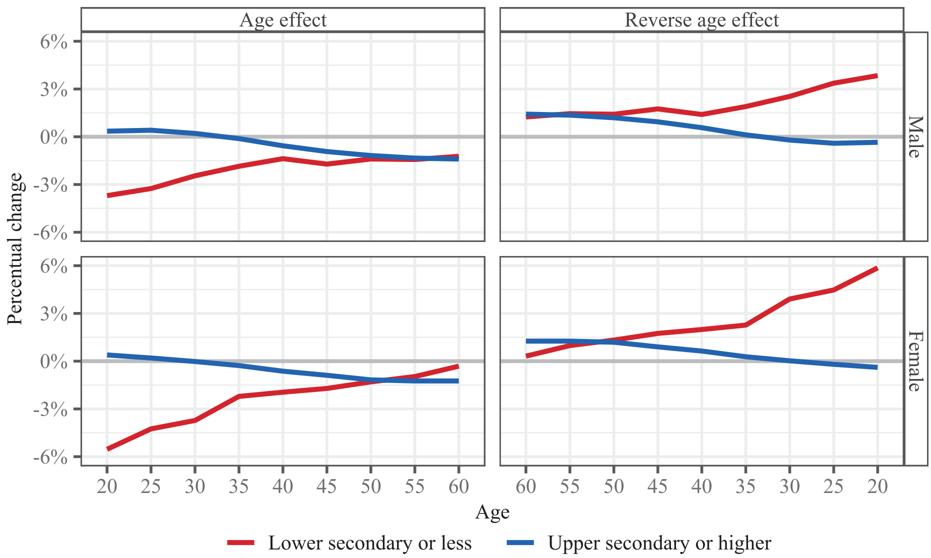
FIGURE 5 Estimated standard age effect, cohort perspective, IALS 1994–98 and PIAAC 2011–2017



SOURCE: Author's elaboration based on IALS and PIAAC data.

These findings give us important insights on cohort effects and shifts in the level of skills between generations for a specific time and country. At the same time, they prove that cohort effects can reveal very different trends for relatively similar countries (see Figure 4). Given the fact that, at present, there are not enough data available to expand these analyses to a global scale and for a longer period, additional assumptions for the reconstruction of adult literacy test results were made. First, a standard skill-age decay pattern was estimated by pooling all countries that participated in both IALS and PIAAC.[8,9] Since both IALS and PIAAC were conducted in different years for different countries, I applied the average duration of 15 years between the two tests to build age cohorts. Next, I adjusted for the mean score difference between IALS and PIAAC for each age group, respectively (as depicted in the period perspective of Figures 3 and 4). In this way, I was able to separate the pure age effect—which is assumed to be more stable across countries and time—from the more context-sensitive cohort and period effects. These calculations were done for two broad education categories ("lower secondary or less" and "upper secondary or higher"), and for women and men separately, to account for potential differences in skill loss/gain due to attainment of formal education as well as potential gender differences. Figure 5 depicts the resulting standard age effect for different age cohorts that were used to reconstruct literacy test results until 1970. Sensitivity analyses of conducting the same kind of analysis separately for different countries confirmed that the age effect tends to be largely constant across different populations (see Figure A3 in the Appendix in the Supporting Information).

FIGURE 6 Estimated percentage change in literacy skills due to age effect (reverse direction used for reconstruction)

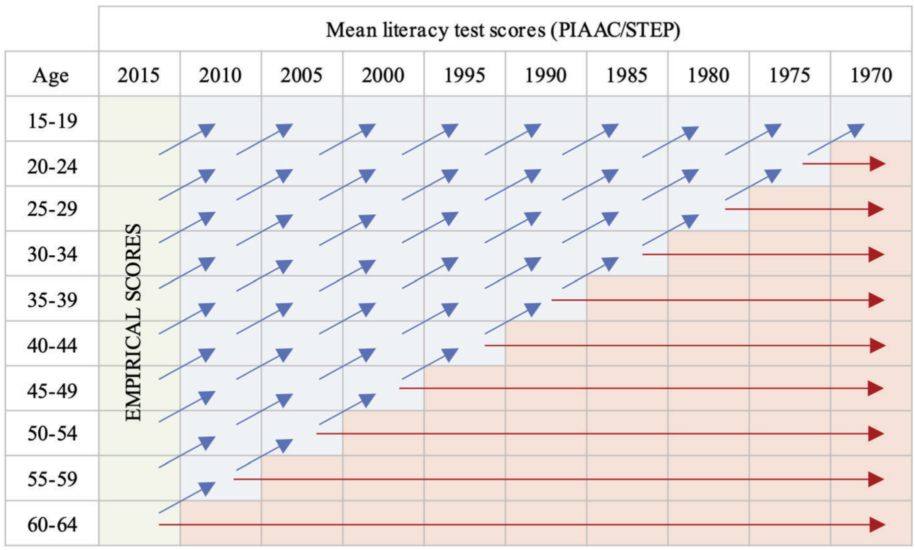


SOURCE: Author's elaboration.

As shown in Figure 5, the pattern implies that the skill loss due to age effects significantly differs for different age cohorts and by educational attainment. Those with lower education tend to lose the highest share of their skills rather soon after leaving school. This can be explained by the fact that less educated people frequently enter jobs in which they need fewer of the cognitive skills that are tested and thus do not practice some of those skills they learned in school.[10] In addition to that, parts of the PIAAC 30- to 34-year-old cohort (15- to 19-year olds in IALS) may have still been in education at time of IALS, thus potentially moving to the higher education group when participating in PIAAC. On the contrary, higher educated people are still able to moderately gain skills up to the age of 35. After that, skills remain largely constant until the age of approximately 45 when cognitive skills eventually start decreasing.

With regard to gender differences, variations are less observable. A closer look reveals, however, that the skills decline for lower educated women up to the age of 35 is a little bit steeper than for their male counterparts; similarly, the skill gain for higher educated women is slightly flatter compared to men. This may be explained by the fact that women are more likely to stay at home when they enter parenthood, thus facing lower cognitive demands than young fathers who tend to be continuously active on the labor market. For older age groups, gender differences in the development of skills due to age effects can hardly be identified.

FIGURE 7 Schematic depiction of demographic reconstruction of PIAAC/STEP literacy skills



SOURCE: Author's elaboration.

Based on these period-adjusted trends of cohorts over time, I further derived an age-, sex-, and education-specific skill growth function over the life course (presented in Figure 6), depicting the percentage change in literacy skills as cohorts age. This function is assumed to be constant for all countries and over time.

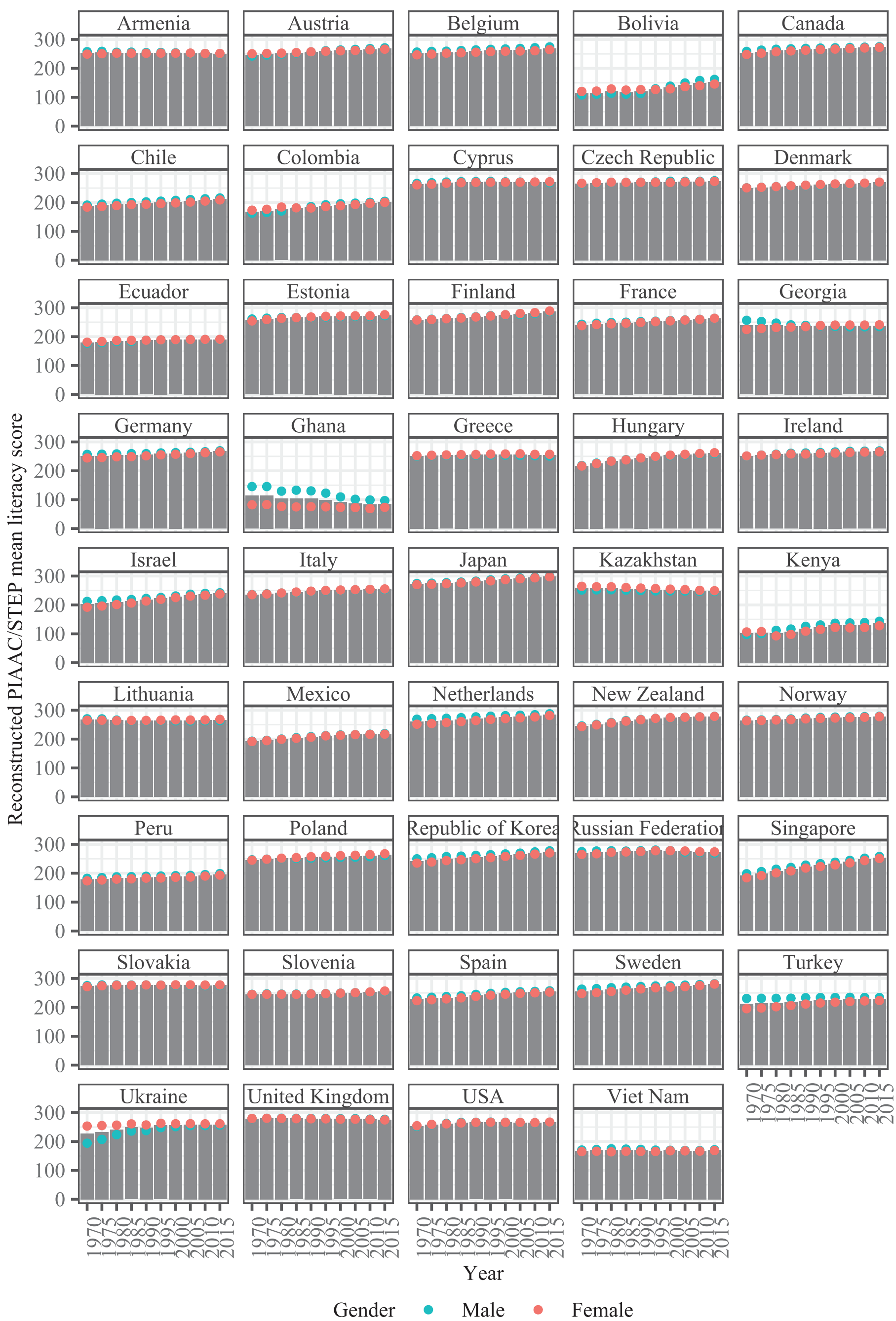
This estimated percentage change in skills is essential for the reconstruction of literacy test scores along cohort lines. The starting point for the reconstruction is provided by the empirical mean literacy scores of 2015 (coming from PIAAC and STEP results available for 44 countries), disaggregated by age, sex, and four educational-attainment categories: primary or less, lower secondary, upper secondary, and post-secondary education.[11] The reader should note, however, that empirical literacy scores serving as base-year data originate from any round of data collection in PIAAC cycle 1 (2011–2017) or STEP data collection between 2012 and 2016. As the interpolation of skills data in single-year intervals to obtain 2015 values is not possible because of the nonavailability of more than one data point over time for most countries, PIAAC and STEP literacy test results provide the unmodified basis for the 2015 base-year scores—despite small variations in time. Starting from these base-year data, for each age group literacy scores are reconstructed in five-year time steps by applying the percentage change in skills due to the reverse age effect (as depicted in Figure 6). Figure 7 shows a schematic depiction of how this reconstruction works. As an example, take the mean score of 60- to 64-year olds tested in 2015 (green area in Figure 7) that provides the basis for the estimated mean score of 55- to 59-year olds in 2010 (blue area in Figure 7), adjusted by the sex- and education-specific percentage change. For age groups for which I was not able to build cohorts for the whole or parts of the reconstruction period (e.g., 60- to 64-year olds in 2010 were too old to be tested in 2015, depicted as the red area in Figure 7), I assumed the age-, sex-, and education-specific scores to be constant over time. In this way and based on empirical literacy scores from PIAAC and STEP, I was able to obtain estimated mean scores by five-year age groups, sex, and four educational attainment categories[12] from 1970 to 2015 for 44 countries.[13]

Results and discussion

Based on the methodology described in "Methodology" section, literacy test scores by age, sex, and educational attainment were reconstructed for 44 countries back to 1970—in five-year steps and for the age groups 15–19 to 60–64. Figure 8 highlights the results by depicting the mean literacy scores by country and year for the working-age population aged 20–64, with the dots representing the gender-specific mean literacy scores.[14]

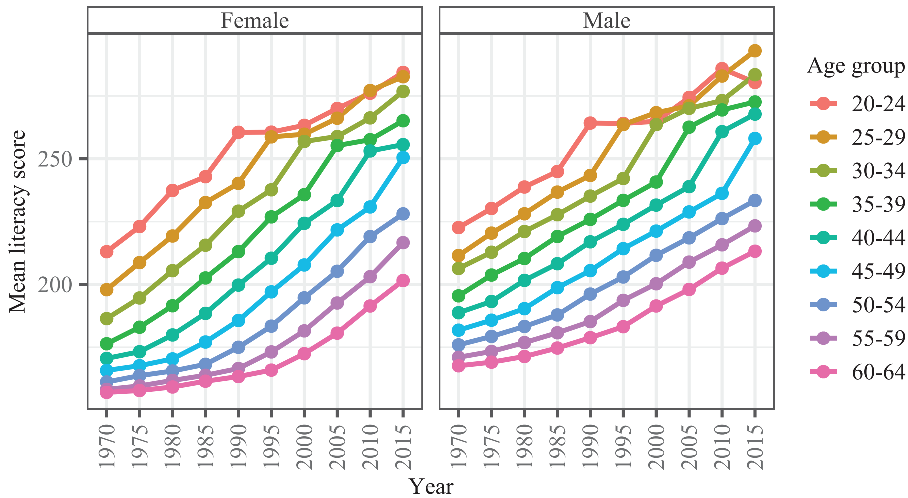
As can be seen on the figure, not only does the level of literacy skills vary greatly for different countries, the development over time shows different trends for different populations. Although in most countries, skills have remained roughly constant or even increased slightly over the last 45 years, there are a few exceptions where skill loss of the working-age population can be observed. In Ghana, for example, skills started declining in the early 1990s—despite significant educational expansion in recent years. This is consistent with previous findings of the existence of a quantity–quality trade-off, in which the quality of the education system is expected to decline when the education system expands, at least in the initial stage (Mare 1979, 1981; Raftery and Hout 1993; Shavit and Blossfeld 1993). This phenomenon partly results from a reduction in selection effects, that is, in more restricted education systems (before educational expansion happened) only the “strongest” students would have remained in the schooling (Spaull and Taylor 2015). In addition, educational expansion may also result in the potential inability of the education system to cope with the increase in the number of students, as well as insufficiency of school inputs and low government spending—particularly in low-income settings. However, highly developed countries are also not immune to these developments. The United Kingdom, for example, has also experienced a minor decline in literacy skills over the last decades—albeit at a much higher skill level. Overall, when comparing the results with the increase in the average duration of schooling for the same age group and period (Wittgenstein Centre for Demography and Global Human Capital 2018), the development of

FIGURE 8 Reconstructed mean literacy scores of adults aged 20–64 by country and gender, 1970–2015



SOURCE: Author's elaboration.

FIGURE 9 Reconstructed mean literacy scores by five-year age groups and gender, Singapore, 1970–2015



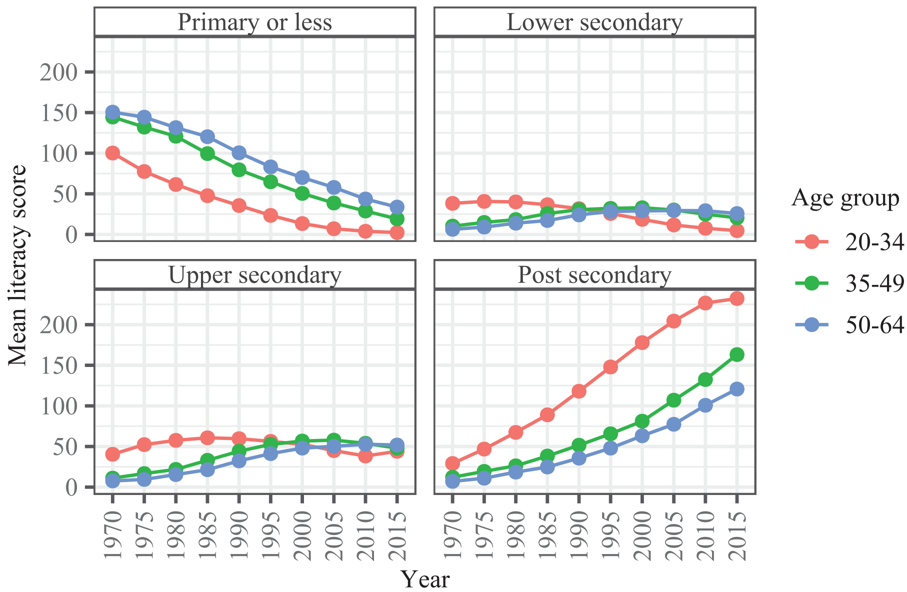
SOURCE: Author's elaboration.

skills can hardly keep up with the steep increase in mean years of schooling in any country.

When looking at gender differences, most countries do not show significant gender gaps in literacy skills among the working-age population. However, there are a few exceptions: in Ghana, Kenya, or Turkey, for example, men are still significantly higher skilled than women—even though the gap slowly decreases over time. This gender disparity is likely to result from girls being denied equal access to education. In other countries, most notably in Ukraine or Kazakhstan, the reconstruction reveals quite the opposite results: while women used to have considerably higher literacy skills than men, there are hardly any gender variations in more recent years. This phenomenon is a result of women in older age groups having performed considerably better than men in recent PIAAC/STEP surveys; given the small sample sizes in some of the country–age–sex–education groups, however, the reconstruction results need to be treated with caution. In addition, it is important to note that although literacy skills are generally strongly correlated with other skill domains, gender was shown to influence different kinds of skills in different directions (OECD 2013, 2016a).

As previously mentioned, the prevalence of adult skills in a population at a given time reflects a complex interplay of age and cohort effects, not discernible when looking only at the aggregated value, as changes in the level of skills in a country may be the consequence of a changing composition of the population (i.e., younger cohorts with a different educational attainment distribution slowly replacing older ones). Therefore, disaggregating skills by age, sex, and educational attainment can further help disentangle the different effects and their impact on a population's level of skills.

FIGURE 10 Reconstructed mean literacy scores by broad age groups and educational attainment, Singapore, 1970–2015

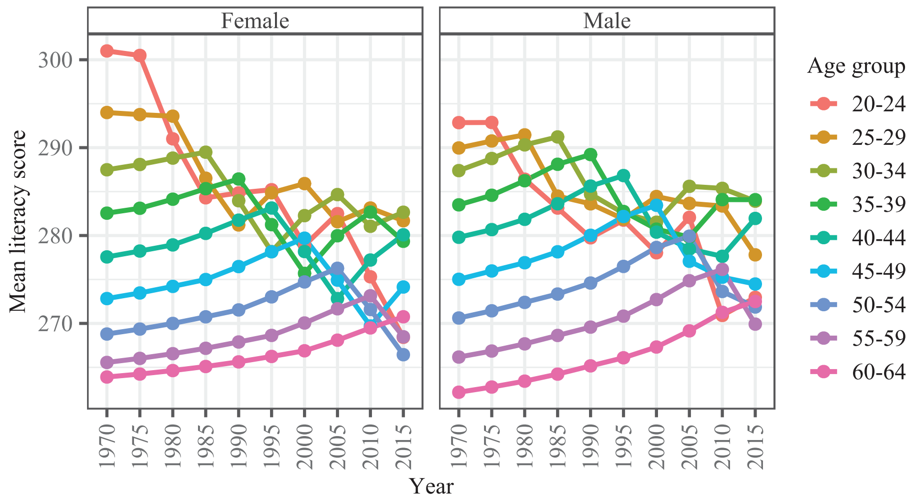


SOURCE: Author's elaboration.

Consider the case of Singapore, a country where the educational attainment distribution differs widely between different age and gender groups: while in 2015 more than 80 percent of the population aged 25–29 in 2015 had some kind of post-secondary education, over one-third of women aged 60–64 in Singapore had only a primary education or never attended any school. This is a result of a cohort effect: the cohort of women aged 60–64 in 2015 were 5–9 years old in 1960—at that time, Singapore did not have universal primary education because it was still a poor developing country. Hence, under conditions of rapidly expanding school systems, skills-averaging over the entire adult population provide a poor measure as they combine the literacy skills of highly educated young cohorts with poorly educated older ones. This is also reflected in Figure 9 that shows Singapore's mean literacy score by age group and sex over time: during the whole period, older people have had consistently lower literacy skills. This results partly from the skill loss that comes with the age effect; on the other hand, this also reflects the continuously lower education of the elderly. Furthermore, while older age groups only recently experienced a skill gain, for younger cohorts, 1970–1990 marked the main period of skill gain—again reflecting the rapid educational expansion that started shortly before.

When further disaggregating the results by educational attainment, however, it becomes clear that skills in Singapore have been increasing only among those with higher education. Figure 10 shows the reconstructed

FIGURE 11 Reconstructed mean literacy scores by five-year age groups and sex, the United Kingdom, 1970–2015



SOURCE: Author's elaboration.

mean literacy score from 1970–2015, disaggregated by four educational attainment categories. While those with post-secondary education experienced rapid skill growth, the opposite holds true for those with only primary or no education: for these people, skills have continuously declined over the last decades, indicating again some kind of quantity–quality tradeoff. These effects seem to be even larger for younger age groups and suggest that the country's rise in skills (as depicted in Figure 8) is first and foremost driven by a growing group of highly educated individuals, rather than by a high-quality-education society at large. Although the number of Singaporeans with little or no education is rapidly decreasing, this of course raises questions about inequality and gives reason to suspect that the gap between high-performing and low-performing individuals will further increase in the future.

Quite contrasting but equally interesting results are presented in Figure 11, depicting—equivalent to Figure 9—the mean literacy score by age group and sex between 1970 and 2015, but this time for the United Kingdom. As can be seen on the graph, while older age groups have continuously experienced a skill increase corresponding to the ongoing educational expansion, younger age groups—despite country-wide lower secondary education—reveal a significant skill decline over the last decades. This is in line with recent international student assessments: PISA results, for example, show for the United Kingdom, relative to other countries, a decline in literacy, math, and science since 2000 (the first round of PISA) (Heath et al. 2013), with only the latest PISA tests again indicating a minor rise in international schooling rankings. However, once again it is important to note that these reconstruction results—in the absence of better data availability—rely solely on a standard education- and gender-specific age effect, which does not account for country-specific circumstances or events, such as education policies or reforms.

The examples of Singapore and the United Kingdom nicely illustrate the importance of disaggregating skills by subpopulations. Especially in societies where inequality is high or cohort effects took place that may have impacted the level of skills, mean values averaged over the whole population can be particularly biased. Results of this research, therefore, include reconstructed literacy scores disaggregated by age, sex, and educational attainment back to 1970 for all 44 countries.

Conclusion

As our societies transform into knowledge societies, sophisticated comprehension and advanced skills of all kinds become essential for successful integration and participation, not only in the labor market, but also in social and civic life. Despite this rising importance, consistent measures of adult skills across countries are still scarce and have evolved only recently. Even less is known about trends and developments of skills over time. The current paper, therefore, aimed to reconstruct literacy test results of the working-age population back to 1970 by applying the demographic method of cohort analysis. Based on empirical PIAAC and STEP results available for the base year, I was able to estimate literacy test scores by age, sex, and educational attainment for 44 countries in five-year steps between 1970 and 2015.

Reconstruction results reveal significant differences between countries for the period 1970–2015—both regarding the level of skills as well as their development over time. Although in most countries, skills have remained roughly constant or even increased slightly over the last 45 years, other populations have experienced minor skill loss. Overall, results suggest that the massive educational expansion that happened globally in the recent past only partly resulted in a similar rise in skills. Moreover, the level of skills vastly differs for different subpopulations, suggesting that the development of skills in a country is also the consequence of a changing composition of its population. While cohort effects, such as the nature and quality of schooling, usually impact the level of skills of the working-age population with a certain time lag, skill changes due to age effects tend to significantly differ with educational attainment and for different age cohorts. Gender, on the other hand, was found to have hardly any effect on how skills change over the life course.

Nevertheless, this study has potential limitations. Because of the limited data availability, assumptions had to be made in order to arrive at the results presented. First of all, the standard age pattern was assumed to be constant among all 44 countries and over time. Given that existing country-specific analyses have proven that cohort effects may reveal very different trends for relatively similar countries, this is indeed a strong assumption. Moreover, this standard age effect is based on a limited number of countries, most of which are high-income OECD countries. However, given the fact that, at present, there are not enough data available to expand these analyses to a global scale and a longer period, and by being transparent about underlying assumptions and shortcomings, I still believe that this work is an important first attempt to consistently reconstruct literacy skills over time. Finally, it is important to recall that this work only covers a very specific type of skills, namely, literacy skills as measured in large-scale assessment surveys. Despite studies having shown that these skills are closely correlated with other type of skills (Reiter et al. 2020), one should be cautious when transferring these results to all kinds of competencies. As more empirical information on tested adult skills become available, I hope to further improve and validate current results in future research.

Data availability statement

Results for all 44 countries, including reconstructed literacy scores disaggregated by age, sex, and educational attainment back to 1970, can be found in the following GitHub repository: https://github.com/clreiter/Adult-literacy-test-results-reconstruction.

Notes

The author wants to thank Anne Goujon, Wolfgang Lutz, Caner Özdemir, and Dilek Yildiz for their valuable inputs and comments.

1 The Demographic and Health Survey (DHS) is an international household survey program that, since 1984, has conducted more than 400 surveys in over 90 developing countries. Since 2000, the standard DHS questionnaire includes a short literacy test, where each respondent with low education is asked to read a sentence on a cue card aloud in their preferred language. Further information about the DHS can be found in Croft et al. (2018) and Rutstein and Rojas (2006).

2 Regions are defined based on the United Nations' geographic regions (United Nations Statistics Division 2021).

3 Reasons for introducing this screening mechanism are mostly practical: not passing the core assessment indicates that the skills of these individuals are so low that undertaking the full assessment would have generated little additional information and would only have been a frustrating and negative experience for the respondent.

4 STEP data were not used, however, to derive the estimated standard age effect as depicted in Figure 7. Therefore, STEP results do not have any impact on reconstruction results of countries participating in the PIAAC survey.

5 Australia was excluded from the analysis as PIAAC microdata are not publicly available for this country.

6 Ideally, I would be able to follow the same individuals over their life course. However, as no true panel data on adult skills exist, I made use of the fact that although we cannot observe the same people at different points in time, we are able to observe representative samples of the population at different points in time.

7 From the 19 countries for which at least two literacy assessments are available, two had to be excluded from the analysis: Australia because microdata are not publicly available for this country; and Canada as age

was only reported in 10-year age groups in the Canadian IALS and ALL microdata. Results of the country-specific cohort analyses for the remaining 17 countries can be found in graphs in the Appendix in the Supporting Information (see Figure A2 in the Appendix in the Supporting Information).

8 As the number of countries participating in ALL is much smaller than for IALS and PIAAC, ALL test results were excluded from the estimation of a standard age effect. To additionally integrate ALL results, either the country coverage would need to be further reduced, or comparisons would be made between noncomparable (i.e., differently composed) populations, both potentially distorting the results.

9 The following 17 countries were merged to develop the standard age effect: Belgium, Chile, Czech Republic, Denmark, Finland, Germany, Hungary, Ireland, Italy, the Netherlands, New Zealand, Norway, Poland, Slovenia, Sweden, the United Kingdom, and the United States.

10 It might be argued that it is not so much the higher use of skills among the better educated that leads to lower skill loss, but rather that those with more education had more and longer practice on standardized testing because of longer time spent in education. While this cannot be proved (all measurements of literacy used in this paper are derived from a standardized test situation), sensitivity analyses included in the Appendix in the Supporting Information (Figure A4 in the Appendix in the Supporting Information) suggest that the more rapid decline in assessment scores among lower educated populations might indeed be caused by a lack of use of cognitive skills. By plotting the self-declared use of reading skills (as included in the PIAAC background questionnaire) against age and education, it becomes clearly visible that use of literacy skills (both at work and at home) is significantly lower for less educated people. In addition, those with only lower secondary education or less tend to reduce their use of reading skills at home most strongly soon after leaving school.

11 To account for the complex sample design of PIAAC and STEP (i.e., replicate weights and plausible achievement values), the R package intsvy, which provides tools and analyses specifically designed to work with international assessment data, was used to calculate means. For further information on the intsvy package, please see https://CRAN.R-project.org/package=intsvy.

12 While the empirical scores of the base year are disaggregated by age, sex, and four levels of educational attainment, the estimated standard skill growth function over the life course is only defined for two education categories and by sex. This cruder disaggregation was found to be most consistent between countries. Given the different scores in the base year, reconstruction results still differ between four education categories.

13 To test the robustness of the reconstruction results, I have added a sensitivity analysis in the Appendix in the Supporting Information where I compared PISA mean reading scores (at age 15) with the (reconstructed) PIAAC mean literacy scores (at age 15–19) for all years and countries available (see Figure A5 in the Appendix in the Supporting Information). The resulting correlation coefficient is $r = 0.62$, which is reasonably high given the well-known differences between the two surveys (different scales, different constructs measured, different target population, etc.). In addition, the level of correlation was not found to systematically decrease if we go further back in time, suggesting that the correlation between the reconstruction results and PISA scores (in the respective year) is similar to the correlation between empirical PIAAC scores and PISA scores.

14 Mean scores by country were aggregated based on the population distribution by age, sex, and education in the respective years, retrieved from the Wittgenstein Centre Human Capital Data Explorer (Wittgenstein Centre for Demography and Global Human Capital 2018).

References

Barrett, Garry F., and W. Craig Riddell. 2016. “Ageing and Literacy Skills: Evidence from IALS, ALL and PIAAC.” SSRN Scholarly Paper ID 2803849, Social Science Research Network, Rochester, NY. https://papers.ssrn.com/abstract=2803849.

——— 2019. “Ageing and Skills: The Case of Literacy Skills.” *European Journal of Education* 54 (1): 60–71. https://doi.org/10.1111/ejed.12324.

Becker, Gary S. 1994. *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education*, 3rd edition. Chicago, IL: University of Chicago Press. https://www.nber.org/books/beck94-1.

Crespo Cuaresma, Jesús, Wolfgang Lutz, and Warren Sanderson. 2014. “Is the Demographic Dividend an Education Dividend?” *Demography* 51 (1): 299–315. https://doi.org/10.1007/s13524-013-0245-x.

Croft, Trevor N., Aileen M. J. Marshall, Courtney C. K. Allen, Arnold, Fred, Assaf, Shireen, Balian, Sarah, Bekele, Yodit, Bizimana, Jean de Dieu, Burgert, Clara, Collison, Debbie, Fishel, Joy, Fleuret, Julia, Florey, Lia, Guzman, Jose Miguel, Head, Sara, Joseph, Richard, Kishor, Sunita, Linn, Annē, Lowell, Joanna, Mallick, Lindsay, Marchena, Claudia, Mutima, Fidele, Nybro, Erica, Parra, Lady Ortiz, Pullum, Tom, Purvis, Keith, Reed, Christian, Reinis, Kia, Rey, Luis Alejandro, Rojas, Guillermo, Semenov, Gulnara, Sow, Amadou, Staveteig, Sarah, Taylor, Cameron, Themme, Albert, Wang, Wenjuan, Way, Ann, Winter, Rebecca, Yu, Mianmian and Zweimueller, Sally. 2018. *Guide to DHS Statistics*. Rockville, MD: ICF. https://dhsprogram.com/Data/Guide-to-DHS-Statistics/index.cfm.

Desjardins, Richard, and Arne Jonas Warnke. 2012. “Ageing and Skills: A Review and Analysis of Skill Gain and Skill Loss Over the Lifespan and Over Time.” Working Paper 72, OECD Education Working Papers, Paris. https://doi.org/10.1787/5k9csvw87ckh-en.

Educational Testing Services. 2014. *A Guide to Understanding the Literacy Assessment of the STEP Skills Measurement Survey*. Washington, DC: Work Bank. https://microdata.worldbank.org/index.php/citations/9683.

Flisi, Sara, Valentina Goglio, Elena Claudia Meroni, and Esperanza Vera-Toscano. 2019. “Cohort Patterns in Adult Literacy Skills: How are New Generations Doing?” *Journal of Policy Modeling* 41 (1): 52–65. https://doi.org/10.1016/j.jpolmod.2018.10.002.

Green, David A., and W. Craig Riddell. 2013. “Ageing and Literacy Skills: Evidence from Canada, Norway and the United States.” *Labour Economics* 22 (June): 16–29. https://doi.org/10.1016/j.labeco.2012.08.011.

Gupta, Monica Das. 1990. “Death Clustering, Mothers’ Education and the Determinants Of Child Mortality in Rural Punjab, India.” *Population Studies* 44 (3): 489–505.

Hamilton, Mary, and David Barton. 2000. “The International Adult Literacy Survey: What does it Really Measure?” *International Review of Education /Internationale Zeitschrift Für Erziehungswissenschaft/Revue Internationale de l’Education* 46 (5): 377–89.

Hanushek, Eric A., Guido Schwerdt, Simon Wiederhold, and Ludger Woessmann. 2015. “Returns to Skills around the World: Evidence from PIAAC.” *European Economic Review* 73 (January): 103–130. https://doi.org/10.1016/j.euroecorev.2014.10.006.

Heath, Anthony, Alice Sullivan, Vikki Boliver, and Anna Zimdars. 2013. “Education under New Labour, 1997–2010.” *Oxford Review of Economic Policy* 29 (1): 227–247.

Hertzog, Christopher, Arthur F. Kramer, Robert S. Wilson, and Ulman Lindenberger. 2008. “Enrichment Effects on Adult Cognitive Development: Can the Functional Capacity of Older Adults be Preserved and Enhanced?” *Psychological Science in the Public Interest* 9 (1): 1–65. https://doi.org/10.1111/j.1539-6053.2009.01034.x.

Keslair, François, and Marco Paccagnella. 2020. *Assessing Adults’ Skills on a Global Scale: A Joint Analysis of Results from PIAAC and STEP*. Paris: OECD. https://doi.org/10.1787/ae2f95d5-en.

Lutz, Wolfgang. 2013. “Demographic Metabolism: A Predictive Theory of Socioeconomic Change.” *Population and Development Review* 38: 283–301.

Mare, Robert. 1979. “Social Background Composition and Educational Growth.” *Demography* 16 (1): 55–71.

——— 1981. "Change and Stability in Educational Stratification." *American Sociological Review* 46 (1): 72–87.

Mincer, Jacob A. 1974. *Schooling, Experience, and Earnings*. Cambridge, MA: NBER. https://www.nber.org/books/minc74-1.

Murray, T. Scott, Yvan Clermont, and Marilyn Binkley. 2005. *Measuring Adult Literacy and Life Skills: New Frameworks for Assessment*. Ottawa: Statistics Canada.

Muttarak, Raya, and Wolfgang Lutz. 2014. "Is Education a Key to Reducing Vulnerability to Natural Disasters and Hence Unavoidable Climate Change?" *Ecology and Society* 19 (1): 42–49.

National Center for Education Statistics. 2018. "What Does IALS Measure?" https://nces.ed.gov/surveys/ials/measure.asp.

Neisser, Ulric, Gwyneth Boodoo, Thomas J. Bouchard Jr., A. Wade Boykin, Nathan Brody, Stephen J. Ceci, Loehlin, John C., Perloff, Robert, Sternberg, Robert J. and Urbina, Susana. 1996. "Intelligence: Knowns and Unknowns." *American Psychologist* 51 (2): 77–101. https://doi.org/10.1037/0003-066X.51.2.77.

OECD. 2000. *Literacy in the Information Age: Final Report of the International Adult Literacy Survey*. Paris: OECD.

——— 2013. *Skilled for Life? Key Findings from the Survey of Adult Skills*. Paris: OECD Publishing.

——— 2016a. *Skills Matter: Further Results from the Survey of Adult Skills*. OECD Skills Studies. Paris: OECD Publishing. https://doi.org/10.1787/9789264258051-en.

——— 2016b. *Technical Report of the Survey of Adult Skills (PIAAC)*, 2nd edition. Paris: OECD. http://www.oecd.org/skills/piaac/PIAAC_Technical_Report_2nd_Edition_Full_Report.pdf.

——— 2019. *The Survey of Adult Skills: Reader's Companion*. OECD Skills Studies, 3rd edition. Paris: OECD.

Paccagnella, Marco. 2016a. "Age, Ageing and Skills." OECD Education Working Paper No. 132. Paris: OECD Publishing. https://www.oecd-ilibrary.org/content/paper/5jm0q1n38lvc-en.

——— 2016b. "Literacy and Numeracy Proficiency in IALS, ALL and PIAAC." OECD Education Working Paper No. 142. Paris: OECD Publishing. https://doi.org/10.1787/5jlpq7qglx5g-en.

Raftery, Adrian E., and Michael Hout. 1993. "Maximally Maintained Inequality: Expansion, Reform, and Opportunity in Irish Education, 1921-75." *Sociology of Education* 66 (1): 41–62.

Reiter, Claudia, Caner Özdemir, Dilek Yildiz, Anne Goujon, Raquel Guimaraes, and Wolfgang Lutz. 2020. "The Demography of Skills-Adjusted Human Capital." IIASA Working Paper WP-20-006 (May). Laxenburg: IIASA. http://pure.iiasa.ac.at/id/eprint/16477/.

Rutstein, Shea Oscar, and Guillermo Rojas. 2006. *Demographic and Health Surveys Methodology: Guide to DHS Statistics*. Calverton, MD: ORC Macro. http://migrationdataportal.org/resource/demographic-and-health-surveys-methodology-guide-dhs-statistics.

Schultz, Theodore W. 1961. "Investment in Human Capital." *The American Economic Review* 51 (1): 1–17.

Shavit, Yossi, and Hans-Peter Blossfeld. 1993. *Persistent Inequality: Changing Educational Attainment in Thirteen Countries*. Boulder, CO: Westview Press.

Skirbekk, Vegard, Elke Loichinger, and Daniela Weber. 2012. "Variation in Cognitive Functioning as a Refined Approach to Comparing Aging Across Countries." *Proceedings of the National Academy of Sciences* 109 (3): 770–774. https://doi.org/10.1073/pnas.1112173109.

Spaull, Nicholas, and Stephen Taylor. 2015. "Access to What? Creating a Composite Measure of Educational Quantity and Educational Quality for 11 African Countries." *Comparative Education Review* 59 (1): 133–165. https://doi.org/10.1086/679295.

St Clair, Ralf. 2012. "The Limits of Levels: Understanding the International Adult Literacy Surveys (IALS)." *International Review of Education /Internationale Zeitschrift Für Erziehungswissenschaft/Revue Internationale de l'Education* 58 (6): 759–776.

Sticht, Thomas G. 2001. "The International Literacy Survey: How Well Does It Represent the Literacy Abilities of Adults?" *Canadian Journal for the Study of Adult Education* 15 (2): 19–36.

United Nations Statistics Division. 2021. *Standard Country or Area Codes for Statistical Use (M49)*. New York: UNSD. https://unstats.un.org/unsd/methodology/m49/.

Wittgenstein Centre for Demography and Global Human Capital. 2018. "Wittgenstein Centre Data Explorer (Beta)." Vienna. http://www.wittgensteincentre.org/dataexplorer.

WorldBank. 2014. "STEP Skills Measurement Surveys: Innovative Tools for Assessing Skills." Social Protection and Labor Discussion Paper 1421. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/516741468178736065/STEP-skills-measurement-surveys-innovative-tools-for-assessing-skills.