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Working paper

Changes in literacy skills as cohorts age: a demographic reconstruction of adult literacy test results

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Abstract

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 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 age of 15 and 65. On the aggregate level, findings reveal considerable differences between countries – both regarding 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.

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1. 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, the attention is now shifting towards 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) targeted in 2000 to "achieve universal primary education", Goal 4 of the successional 2015 Sustainable Development Goals (SDGs) envisaged to "ensure inclusive and equitable quality education and promote life-long 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, i.e. measures of skills, have been first evolving in the 1960s, when the International Association for the Evaluation of Educational Achievement (IEA) pioneered in developing international student assessments. Consistent data for comparing the educational achievement of different school systems over time are, however, only 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 Students 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 at measuring 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 inform on changes in skills over the life course (also beyond the age when formal education is usually attained). Therefore, by using student assessments, it is neither possible to account for increases of skills over the life course (e.g. life-long learning), nor for potential depreciation of skills with age. Finally, the prevalence of adult skills in a 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 it recently happened in virtually all countries – there is a little value from using test scores of 15-year-olds currently in school to infer about 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 which 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, 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, World Bank has developed a similar test, named the 'Skills toward Employment and Productivity Survey' (STEP) which 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. In order 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 are the main drivers 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 the skills development over the life course. This is the gap this research is aiming 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.

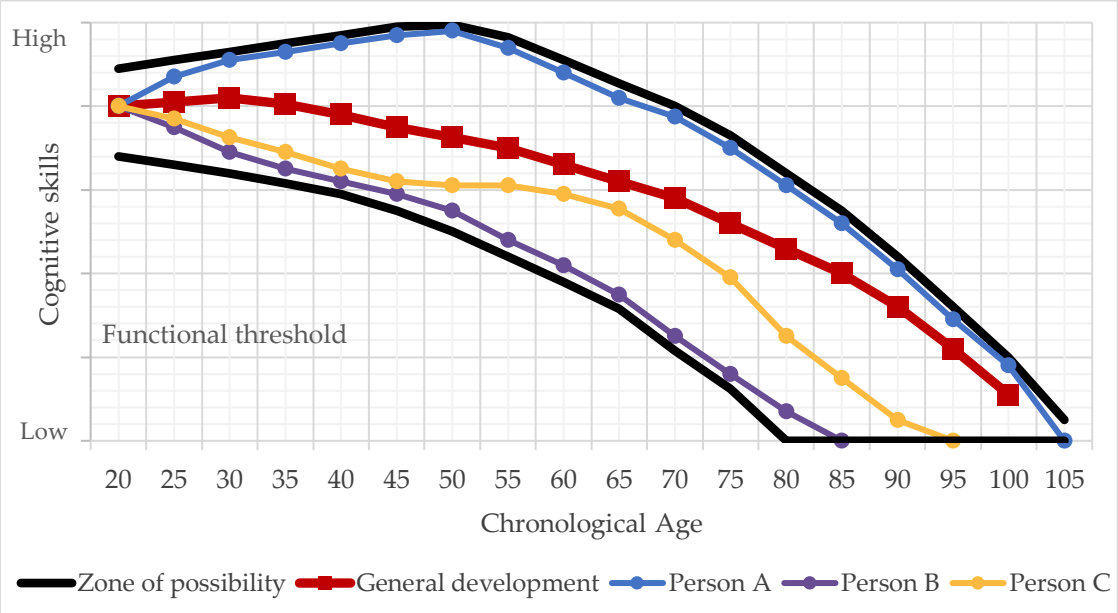
The remainder of this paper is structured as follows. In Section 2, a short literature review on skill gain and skill loss over the lifespan as well as the main factors impacting these changes is provided. Section 3 presents the data sources used in this paper, followed by Section 4 explaining in detail the methodology. After presenting the results in Section 5, I conclude and discuss potential limitations in Section 6.

2. Effects on skills over the life course

Three main effects that impact the changes of skills over the life course: 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, i.e. 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 et al., 2012; Green and Riddell 2013; Barrett and Riddell 2016; Paccagnella 2016). However, ageing and skills is not a straightforward relationship, with many individual, contextual, and social factors influencing the 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.

Figure 1. Zone of possible cognitive development across adult life.



Source: Adapted from Desjardins and Warnke 2012.

Similarly, Desjardins & Warnke (2012) highlight that until about the age of 18 to 20, cognitive skills of all kinds are expected to increase, but thereafter, development patterns are expected to diverge. For some people and type of skills, this would mean a decline already in early adulthood, while others may experience a continuous rise of skills, followed by a stagnation, and eventually a decline. Factors found to influence skill gain and skill loss over the lifespan 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 & 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 & 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 & 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, i.e. whether a skill loss is due to contextual conditions between the measurement points or due to skill decline because of ageing. The scarcity of data further hampers the undertaking of country-specific age-period-cohort analyses on a global scale. Surveys measuring adult skills have been traditionally 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.

3. Data sources

As mentioned in the introduction, international large-scale adult literacy skills assessments have only emerged recently. Following the pioneering work of national adult literacy assessments undertaken in the United States and Canada in the early 1990s, the 'International Adult Literacy Survey', 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 been previously covered in IALS, the 'Adult Literacy and Lifeskills Survey' (ALL) was administered in 11 countries between 2003 and 2008. Finally, the OECD's 'Programme for the International Assessment of Adult Competencies' (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 21st 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. Thanks to the continuity in survey methodology and the usage of trend items which were asked in all three surveys, it is possible to analyze trends over time in countries which 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 'Skills toward Employment and Productivity Survey' (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.

3.1. Programme for the International Assessment of Adult Competencies (PIAAC), Adult Literacy and Lifeskills Survey (ALL), and International Adult Literacy Survey (IALS)

The 'Programme for the International Assessment of Adult Competencies' (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 21st century: literacy, numeracy, and problem solving in technology-rich environments.

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

- They should be preconditions for successful integration 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 socio-economic background.
- They need to be highly transferable, i.e. being relevant to multiple social fields and work situations.
- They should be 'learnable' and, therefore, subject to the influence of policy makers (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 by combining the Item Response Theory 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 ten 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 Survey of Adult Skills Technical Report (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 socio-economic 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 to 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 USA conducted the survey for the second time. In each participating country, a nationally representative sample of around 5,000 respondents were selected. It is planned to repeat the survey every ten 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 **International Adult Literacy Survey (IALS)** and the **Adult Literacy and Lifeskills Survey (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. Items from IALS and ALL were also included in PIAAC, allowing data from these previous surveys to be linked to trend data from participating countries in PIAAC, which was also made use of in the current paper. Table 1 provides an overview about which PIAAC countries have also participated in IALS and/or ALL.

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

Country	IALS			ALL		PIAAC		
	1994	1996	1998	2003	2006-07	2011-12	2014	2017
Australia		✓			✓	✓		
Belgium		✓				✓		
Canada	✓			✓		✓		
Chile			✓				✓	
Czechia			✓			✓		
Denmark			✓			✓		
Finland			✓			✓		
Germany	✓					✓		
Hungary			✓					✓
Ireland	✓					✓		
Italy			✓	✓		✓		
Netherlands	✓				✓	✓		
New Zealand		✓					✓	
Norway				✓		✓		
Poland	✓					✓		
Slovenia			✓				✓	
Sweden	✓					✓		
UK		✓				✓		
USA	✓			✓		✓		

Source: Author's elaboration.

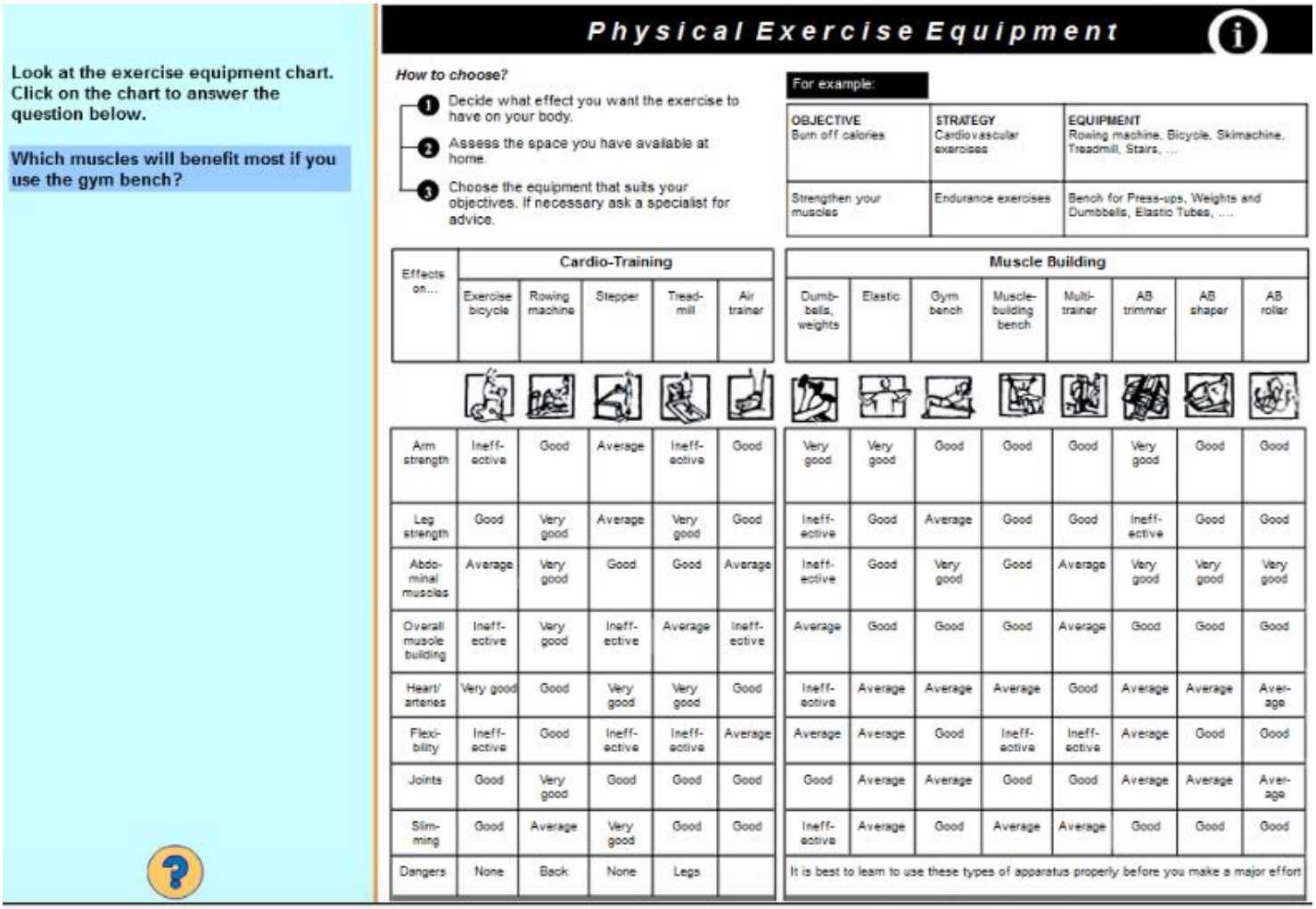
Analyses throughout this paper exclusively focus on literacy skills[1], as these are tested in all of the three previously mentioned surveys as well as in the World Bank's STEP Skills Measurement Program (see Section 3.2). In PIAAC, literacy is defined as the "ability to understand, evaluate, use and engage with written texts to participate in society, achieve one's goals, and develop one's knowledge and potential" (OECD, 2013, p. 4). Literacy skills are considered as 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 literacy assessment in PIAAC encompasses a wide range of skills, including decoding of written words and sentences, comprehension interpretation as well as the evaluation of complex text. It does not, however, involve the production of text, i.e. writing. In order to get a better understanding of how literacy is conceptualized in PIAAC, two examples of literacy items are presented below. Both use print-based stimuli and are presented in the form delivered by the computer-based version of the assessment. The first one (Preschool rules, Figure 2) represents an item of average difficulty that requires respondents to locate

[1] Sensitivity analyses have revealed that literacy skills are highly correlated with other skill domains (e.g. numeracy or problem-solving skills). Consequently, literacy skills can serve as a proxy for the overall skill level in a (sub-)population.

information in a text, whereas the second one (Physical Exercise Equipment, Figure 3) represents a relatively easy literacy item, focusing on the integration and interpretation of text.

Figure 2. PIAAC literacy sample item 2: Physical Exercise Equipment.



Look at the exercise equipment chart. Click on the chart to answer the question below.

Which muscles will benefit most if you use the gym bench?

Physical Exercise Equipment

How to choose?

1. Decide what effect you want the exercise to have on your body.
2. Assess the space you have available at home.
3. Choose the equipment that suits your objectives. If necessary ask a specialist for advice.

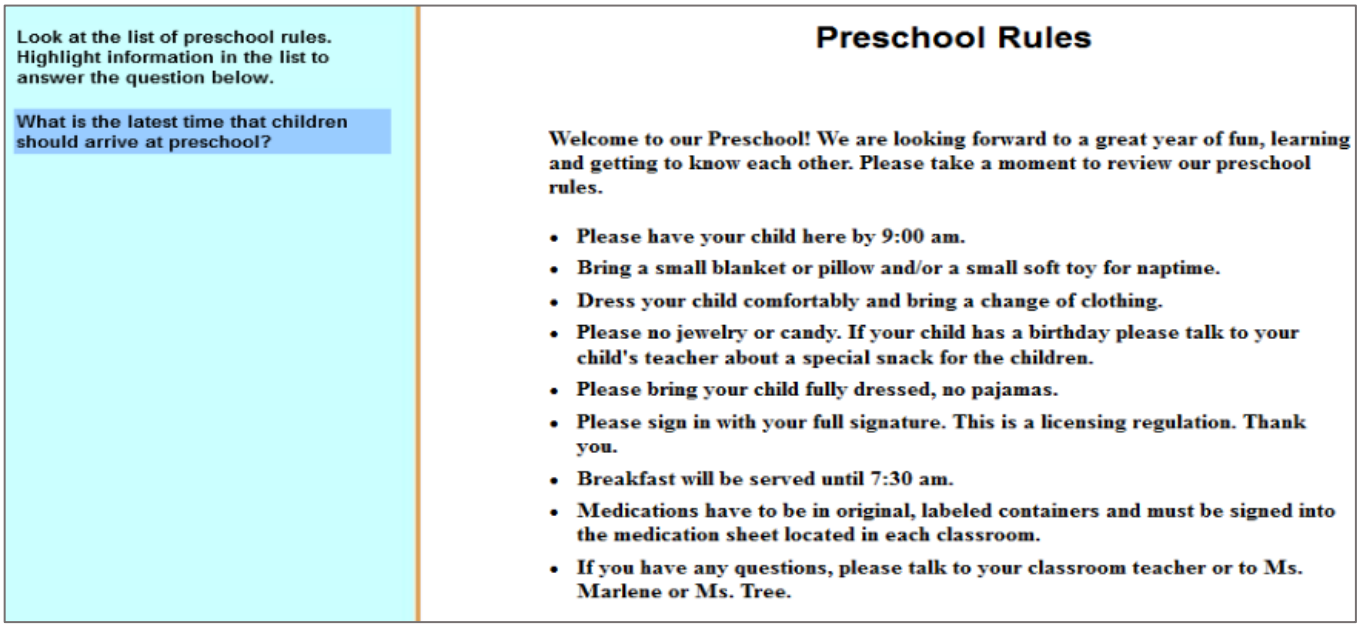
For example:

OBJECTIVE	STRATEGY	EQUIPMENT
Burn off calories	Cardiovascular exercises	Rowing machine, Bicycle, Skimachine, Treadmill, Stairs, ...
Strengthen your muscles	Endurance exercises	Bench for Press-ups, Weights and Dumbbells, Elastic Tubes, ...

Effects on...	Cardio-Training					Muscle Building							
	Exercise bicycle	Rowing machine	Stepper	Tread-mill	Air trainer	Dumb-bells, weights	Elastic	Gym bench	Muscle-building bench	Multi-trainer	AB trimmer	AB shaper	AB roller
Arm strength	Ineff-ective	Good	Average	Ineff-ective	Good	Very good	Very good	Good	Good	Good	Very good	Good	Good
Leg strength	Good	Very good	Average	Very good	Good	Ineff-ective	Good	Average	Good	Good	Ineff-ective	Good	Good
Abdo-minal muscles	Average	Very good	Good	Good	Average	Ineff-ective	Good	Very good	Good	Average	Very good	Very good	Very good
Overall muscle building	Ineff-ective	Very good	Ineff-ective	Average	Ineff-ective	Average	Good	Good	Good	Average	Good	Good	Good
Heart/ arteries	Very good	Good	Very good	Very good	Good	Ineff-ective	Average	Average	Average	Good	Average	Average	Aver-age
Flexi-bility	Ineff-ective	Good	Ineff-ective	Ineff-ective	Average	Average	Average	Good	Ineff-ective	Ineff-ective	Average	Good	Good
Joints	Good	Very good	Good	Good	Good	Good	Average	Average	Good	Good	Average	Average	Aver-age
Slim-ming	Good	Average	Very good	Good	Good	Ineff-ective	Average	Good	Average	Average	Good	Good	Good
Dangers	None	Back	None	Legs		It is best to learn to use these types of apparatus properly before you make a major effort							

Source: OECD 2012.

Figure 3. PIAAC literacy sample item 1: Preschoool Rules.



Source: OECD 2012.

In addition to literacy items similar to those presented above, 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).

3.2. Skills towards Employment and Productivity Survey (STEP)

The 'Skills toward Employment and Productivity Survey' (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), p.77); socio-economic 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 & Herzegovina, Colombia, Georgia, Ghana, Kenya, Kosovo, Lao PDR, Macedonia, Serbia, Sri Lanka, Ukraine, Vietnam, and the Yunnan Province in China. Each sample consists of around 3,000 individuals and is representative of the urban adult population between the ages of 16 and 65 (World Bank, 2014).

The measurement of cognitive skills, which is used within this paper, includes a direct assessment of reading literacy designed to identify respondent's 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, thus allowing for results to be reported on a common scale with common descriptions for interpreting the proficiency levels of the scale – making the two assessment 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 Item Response Theory (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 reading core test, consisting of 8 short items and thus 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, sample items presented in Section 3.1 (Figure 2 and 3) also apply to the STEP literacy assessment.

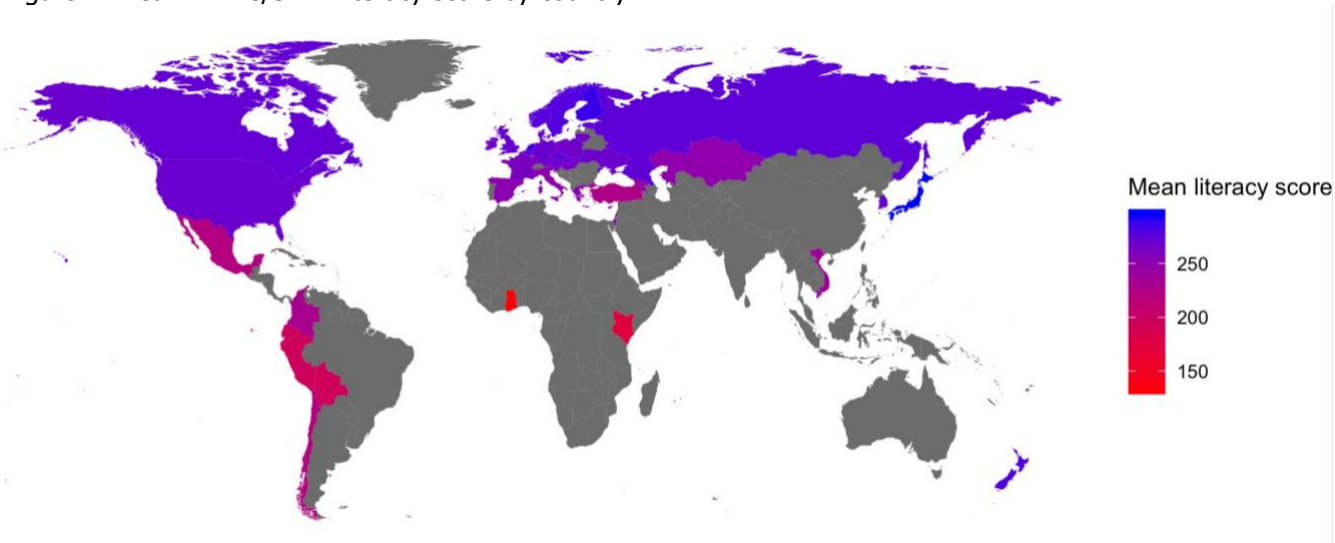
As mentioned previously, the target population in the STEP Skills Measurement Program is limited to urban adults. Therefore, STEP results for the eight countries included in the analysis were further adjusted to be representative for the entire country. Urban-rural corrections in literacy skills were derived from the Demographic Health Survey (DHS)[2], with the ratio between DHS literacy results of the total population and DHS literacy results 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[3].

[2] 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 of a cue card aloud in their preferred language. Further information about DHS can be found in Croft et al. (2018) and Rutstein and Rojas (2006).

[3] Regions are defined based on the United Nations' geographic regions (United Nations Statistics Divsion, 2021).

To provide an overview about data availability and mean performance on literacy, Figure 4 shows the mean literacy score by country for the population aged 15-64 for the 44 countries[4] 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.

Figure 4. Mean PIAAC/STEP literacy score by country



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

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

4. 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, Netherlands, New Zealand, Norway, Poland, Slovenia, Sweden, Switzerland, United Kingdom, and the United States.

The empirical analyses are based on a pooled dataset of IALS, ALL and PIAAC, from which I built cohorts[5] 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 5-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 e.g. 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[6] (see Figure A1).

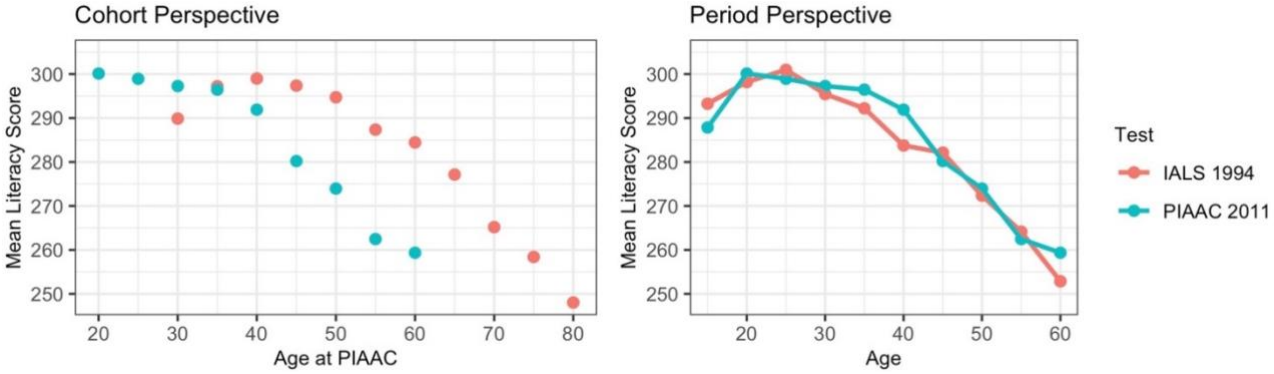
In line with literature findings, the empirical cohort analysis results suggest indeed that deterioration in the level of skills is happening because of age effects, with the beginning and extent of the decrease strongly depending on educational attainment. Figure 5 exemplifies this, showing two countries, a) Netherlands and b) Chile. On the left panel, cohorts are represented vertically, i.e. the x-axis represents the age at PIAAC, while participants in IALS are accordingly younger (e.g. x=40 represents an age cohort which aged 23-27 years old in IALS 1994 and 40-44 years old in PIIAC 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 have considerably declined 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.

[5] 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.

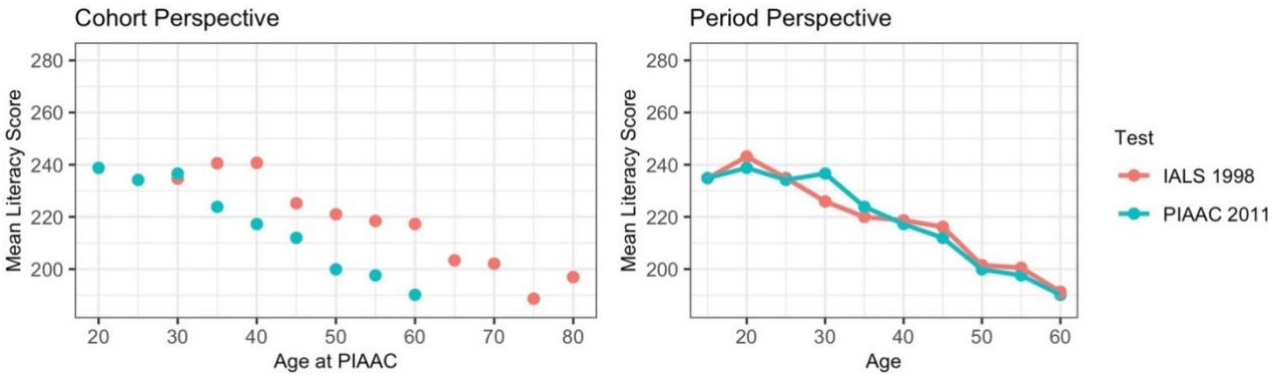
[6] From the 19 countries for which at least two literacy assessments are available, two had to be excluded from the analysis: Australia because microdata are not publicly available for this country; and Canada as age was only reported in 10-year age groups in the Canadian IALS and ALL microdata. Graphical results of the country-specific cohort analyses for the remaining 17 countries can be found in the Appendix.

Figure 5. Changes in literacy skills over time from a cohort and period perspective, Netherlands and Chile.

a) Netherlands



b) Chile

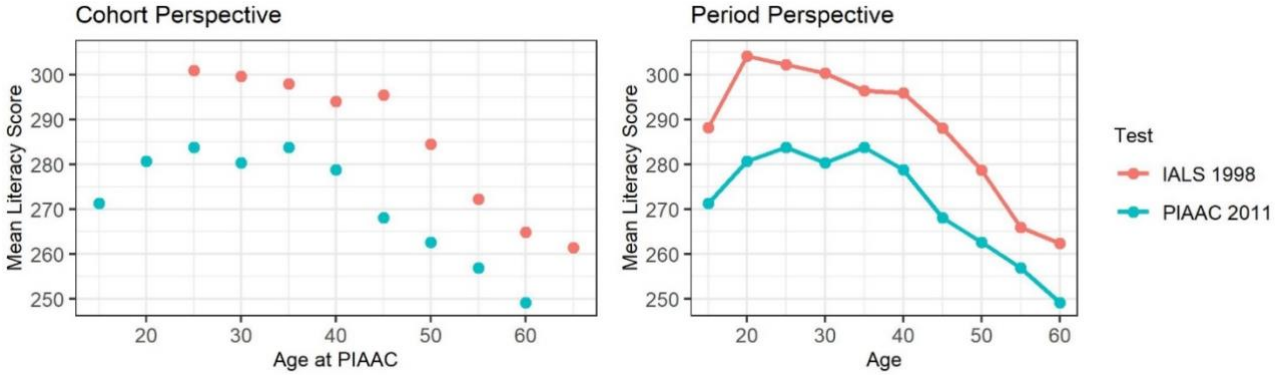


Source: Author's elaboration based on IALS and PIAAC data.

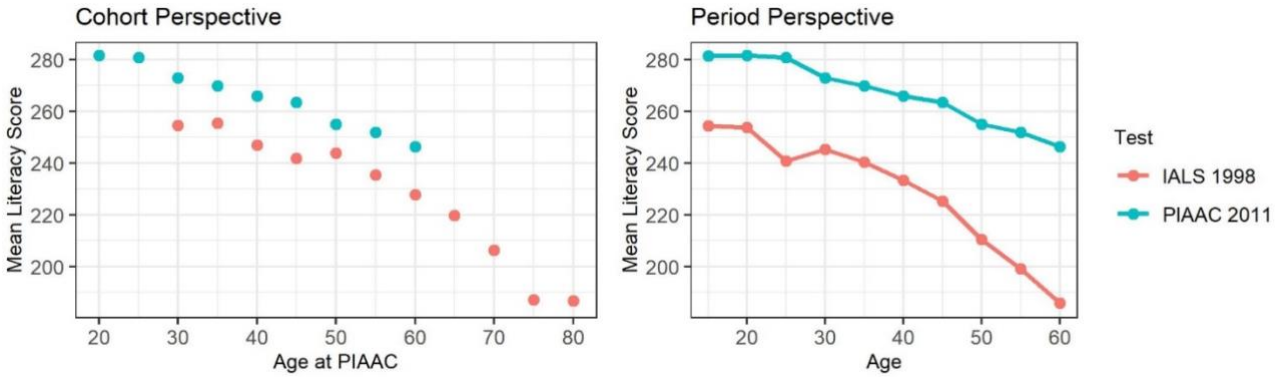
These results were, however, not found to be consistent between all countries. Figure 6 shows the changes in skills over time for two additional countries: c) Denmark and d) Poland, with c) experiencing significant skill loss, and d) experiencing considerable skill gain between 1998 and 2011. In both 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 6. Changes in literacy skills over time from a cohort and period perspective, Denmark and Poland.

c) Denmark



d) Poland



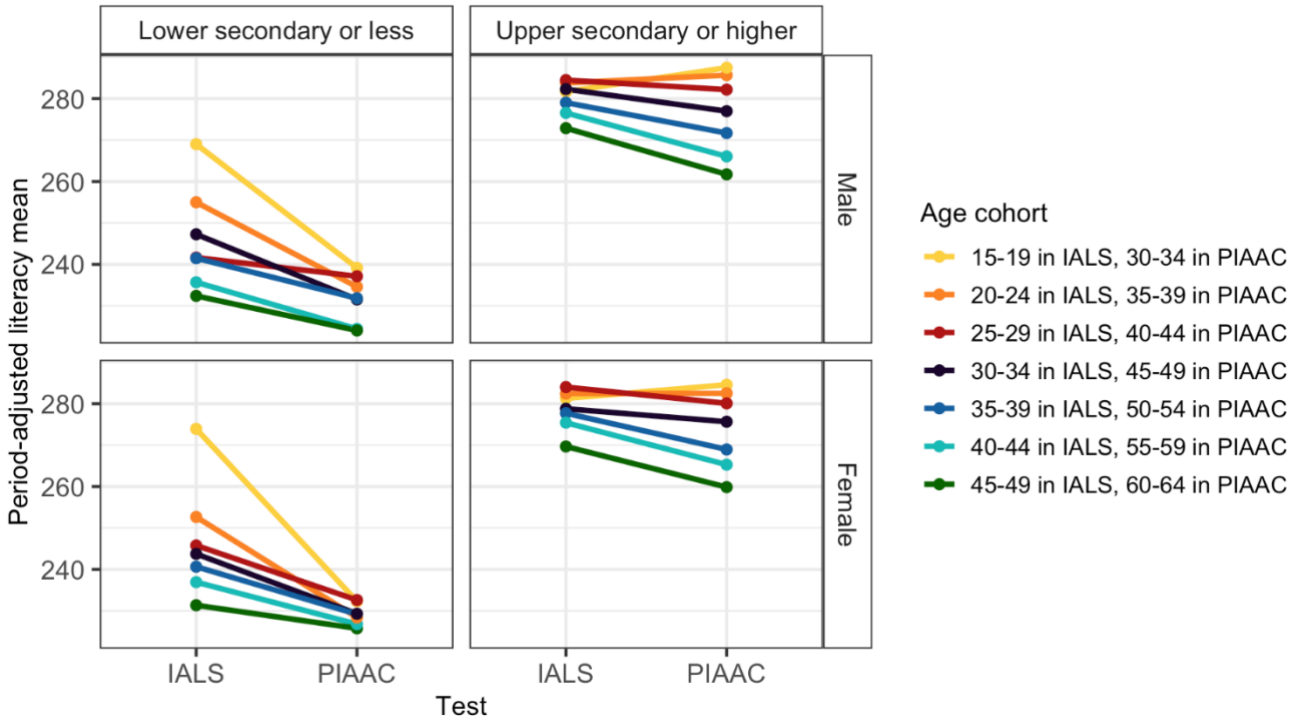
Source: Author's elaboration based on IALS and PIAAC data.

These findings certainly 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 6). 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[7]. 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 Figure 5 and 6). 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

[7] 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 be needed to be further reduced, or comparisons would be made between non-comparable (i.e. differently composed) populations, both potentially distorting the results.

as for potential gender differences. Figure 7 depicts the resulting standard age effect for different age cohorts which was used to reconstruct literacy test results until 1970. Sensitivity analyses of conducting the same kind of analysis for different countries separately confirmed that the age effect tends to be largely constant across different populations.

Figure 7. Estimated standard age effect, cohort perspective, IALS 1994-98 and PIAAC 2011-17[8].



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

As shown in the figure above, 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 had learned in school. In addition to that, parts of the PIAAC 30-34-years-old cohort (15-19 years old in IALS) may have been still 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.

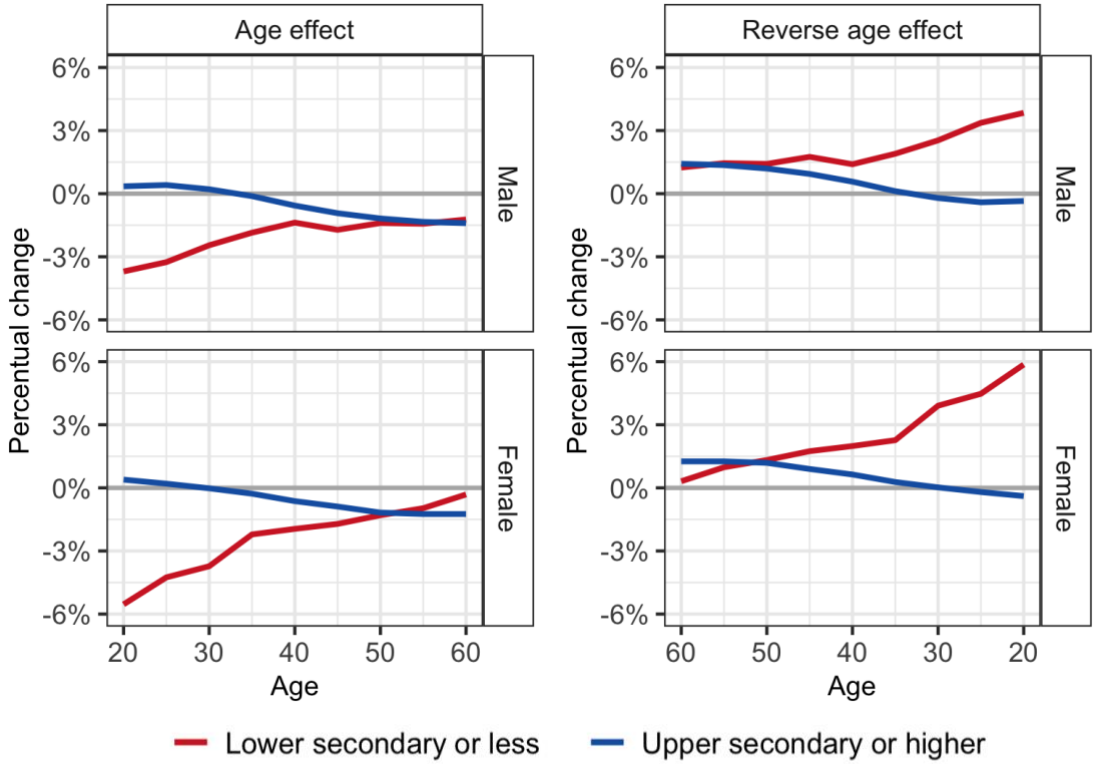
As regards gender differences, variations are less observable. A closer look reveals, however, that the skills decline for lower-educated women up to the age of 35 is a little bit steeper than for their male counterparts;

[8] The following 16 countries were merged to develop the standard age effect: Belgium, Canada, Chile, Czech Republic, Denmark, Finland, Germany, Hungary, Ireland, Italy, Netherlands, New Zealand, Norway, Poland, Slovenia, Sweden.

similarly, the skill gain for higher-educated women is slightly flatter as 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.

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 8), depicting the percentage change in literacy skills as cohorts age. This function is assumed to be constant for all countries and over time.

Figure 8. Estimated percentage change in literacy skills due to age effect (reverse direction used for reconstruction).



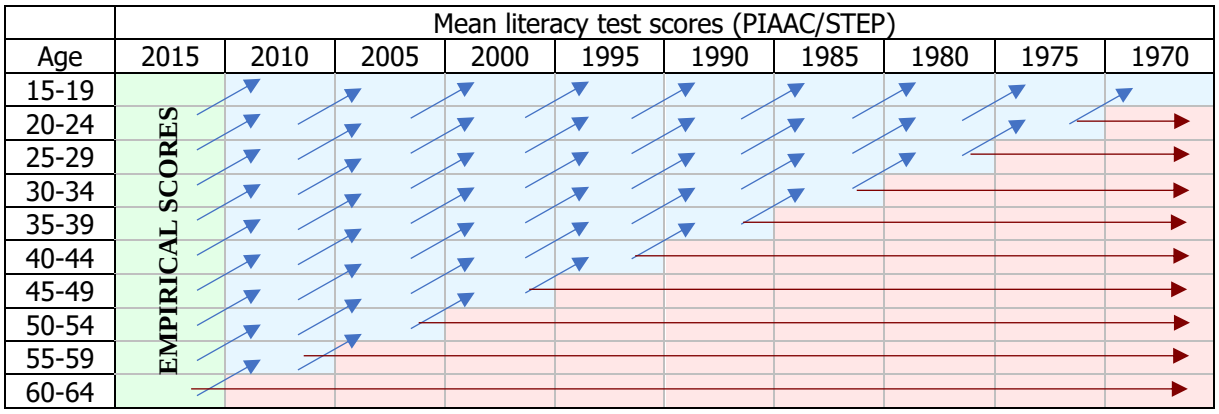
Source: Author's elaboration.

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[9]. The reader should note, however, that empirical literacy scores serving as base year data

[9] In order 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/web/packages/intsvy/intsvy.pdf.

originate from any round of data collection of PIAAC cycle 1 (2011-2017) or STEP data collection between 2012 and 2016. As interpolation of skills data in single-year intervals to obtain 2015 values is not possible due to the non-availability 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 5-year time steps by applying the percentage change in skills due to the reverse age effect (as depicted in Figure 8). Figure 9 shows a schematic depiction of how this reconstruction works. As an example, take the mean score of 60-64-year-olds tested in 2015 (green area in Figure 9) which provides the basis for the estimated mean score of 55-59-year-olds in 2010 (blue area in Figure 9), 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. 60-64-year-olds in 2010 were too old to be tested in 2015, depicted as red area in Figure 9), 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 5-year age groups, sex, and four educational attainment categories[10] from 1970-2015 for 44 countries.

Figure 9. Schematic depiction of demographic reconstruction of PIAAC/STEP literacy skills.



Source: Author's elaboration.

[10] 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.

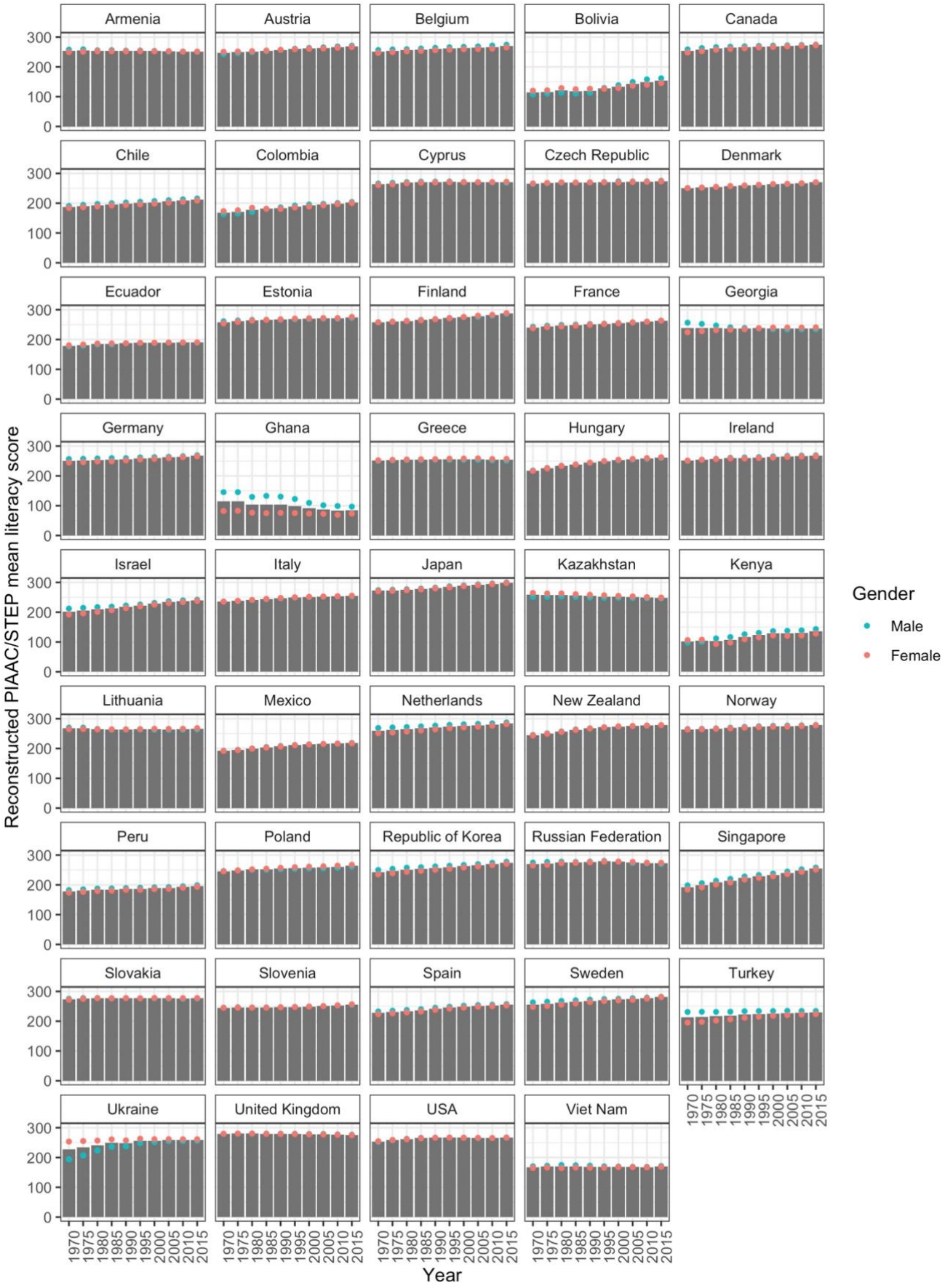
5. Results & Discussion

Based on the methodology described in Section 4, literacy test scores by age, sex, and educational attainment were reconstructed for 44 countries back to 1970 – in 5-year steps and for the age groups 15-19 to 60-64. Figure 10 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.[11] As can be seen on the figure, not only the level of literacy skills varies greatly for different countries, but also the development over time shows different trends for different populations. While 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 education system is expected to decline when the educational system expands, at least in the initial stage (Mare 1979; Mare 1981; Raftery and Hout 1993; Shavit and Blossfeld 1993). This phenomenon mostly results from the inability of the education system to cope with the increase in the number of students in the education system. In addition, the insufficiency of school inputs and low government spending in education in low-income settings may also affect educational achievement. However, also highly developed countries are not immune to these developments. 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 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 opposite results: while women used to have considerably higher literacy skills than men, there are hardly variations with gender in more recent years. This phenomenon is a result from 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 albeit literacy skills are generally strongly correlated with other skill domains, gender was shown to influence different kind of skills in different directions (OECD 2013, 2016a).

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

Figure 10. Reconstructed mean literacy scores of adults aged 20-64 by country, 1970-2015.

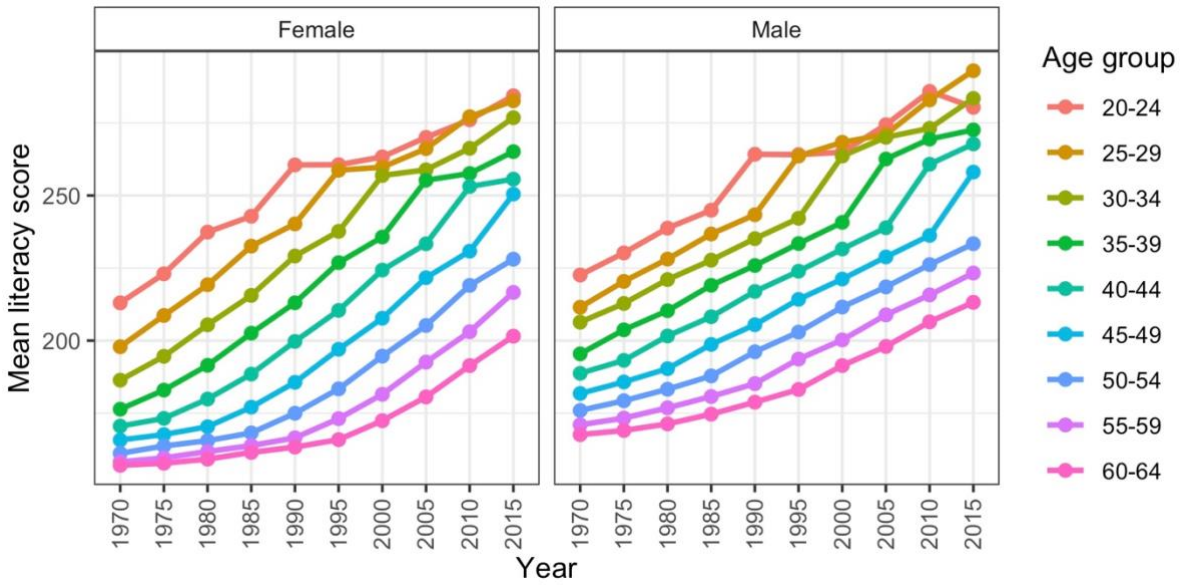


Source: Author's elaboration.

As mentioned previously, 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 different educational attainment distribution slowly replacing older ones). Therefore, disaggregating skills by age, sex, and educational attainment can further help disentangling the different effects and their impact on a population's level of skills.

Consider the case of Singapore, a country where the educational attainment distribution widely differs between age groups and gender: while in 2015 more than 80 percent of the population aged 25-29 in 2015 have some kind of post-secondary education, over a third of women aged 60-64 in Singapore have only primary education or never attended any schools. 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 literacy skills of highly educated young cohorts with poorly educated older ones. This is also reflected in Figure 11 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 partly results from the skill loss due to the age effect; on the other hand, this also reflects the continuously lower education of the elderly. Also, 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.

Figure 11. Reconstructed mean literacy scores by age groups and sex, Singapore, 1970-2015.

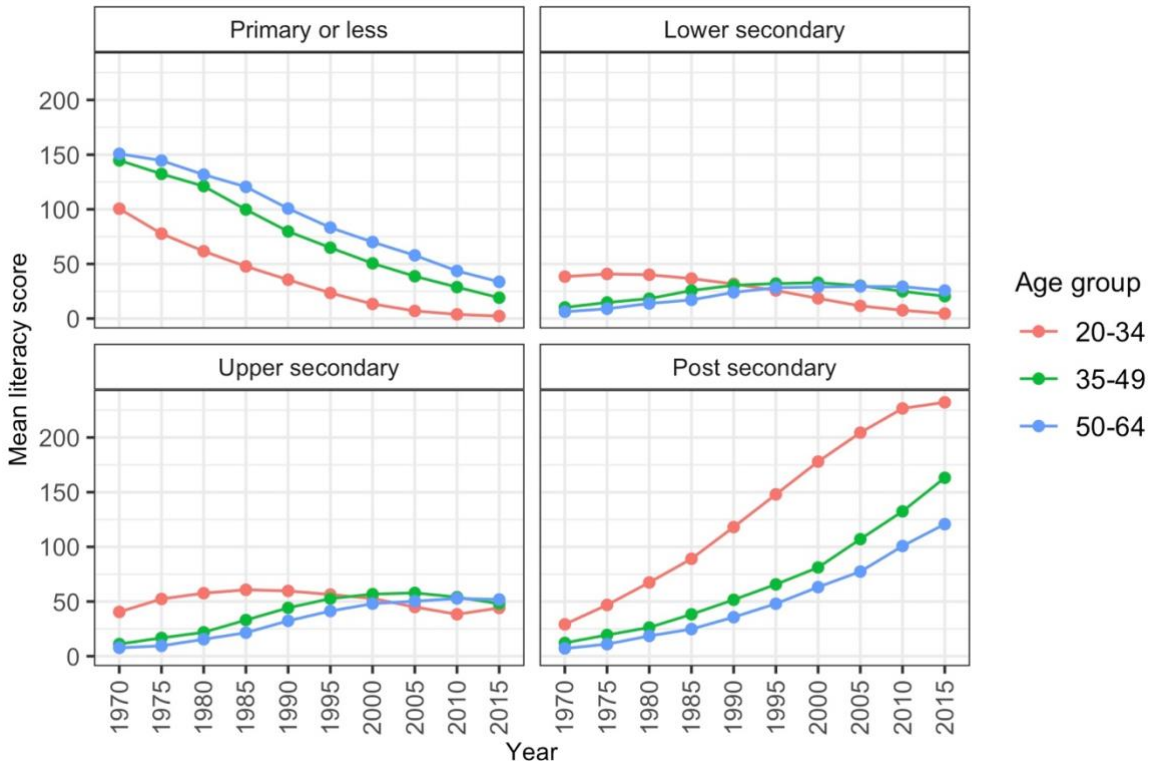


Source: Author's elaboration.

However, when further disaggregating the results by educational attainment, it becomes clear that skills in Singapore have been only increasing among those with higher education. Figure 12 shows the reconstructed 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 trade-off. These effects seem to be even larger for younger age groups and suggest that the country's rise in skills (as depicted in Figure 10) is first and foremost driven by a growing group of highly-educated individuals, rather than by a high-quality education society at large. Albeit the number of Singaporeans with little or no education is rapidly decreasing, this raises of course questions about inequality and gives reason to suspect that the gap between high-performing and low-performing individuals will further increase in the future.

Figure 12. Reconstructed mean literacy scores by broad age groups and educational attainment, Singapore, 1970-2015.

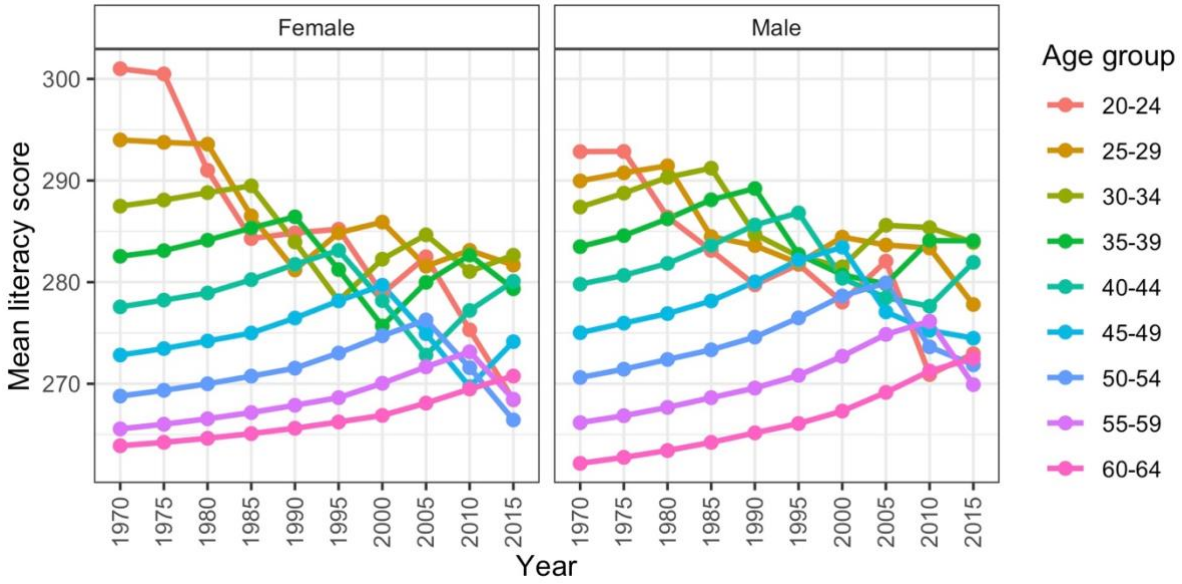


Source: Author's elaboration.

Quite contrasting but equally interesting results are presented in Figure 13, depicting – equivalent to Figure 11 – the mean literacy score by age group and sex between 1970 and 2015, but this time for the UK. 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 UK, 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 indicating again a minor rise in international school 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.

Figure 13. Reconstructed mean literacy scores by age groups and sex, UK, 1970-2015.



Source: Author's elaboration.

The examples of Singapore and the UK nicely illustrate the importance of disaggregating skills by sub-populations. 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, which can be found in the following GitHub repository: https://github.com/clreiter/Adult-literacy-test-results-reconstruction.

6. Conclusion

As our societies transform into knowledge societies, sophisticated comprehension and advanced skills of all kinds become essential for a 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 only evolved recently. Even less is known about trends and developments of skills over time. The current paper, therefore, aimed at reconstructing 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 5-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. While 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 likewise rise of skills. Moreover, the level of skills vastly differs for different sub-populations, 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. Due to 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 between 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.

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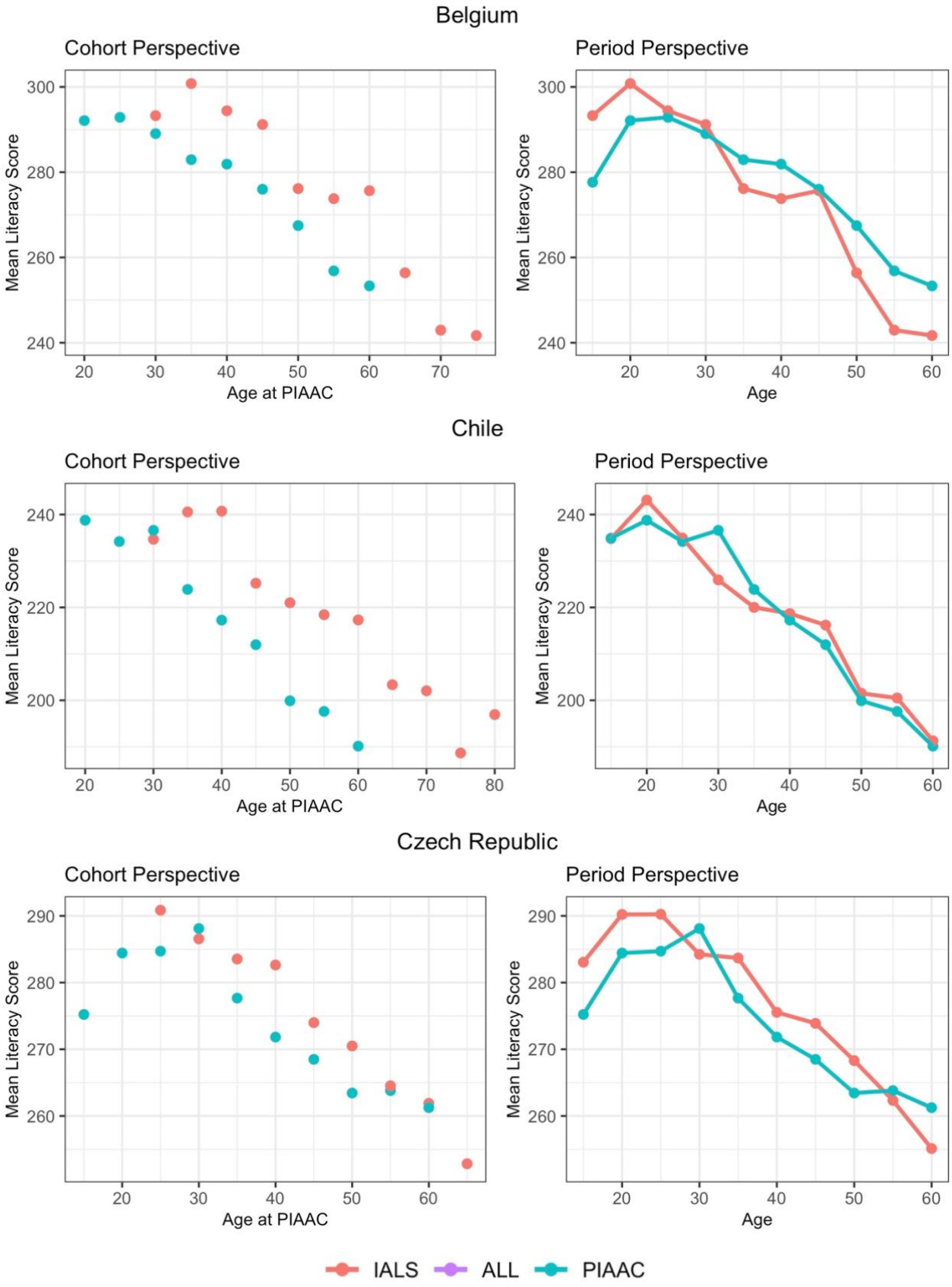
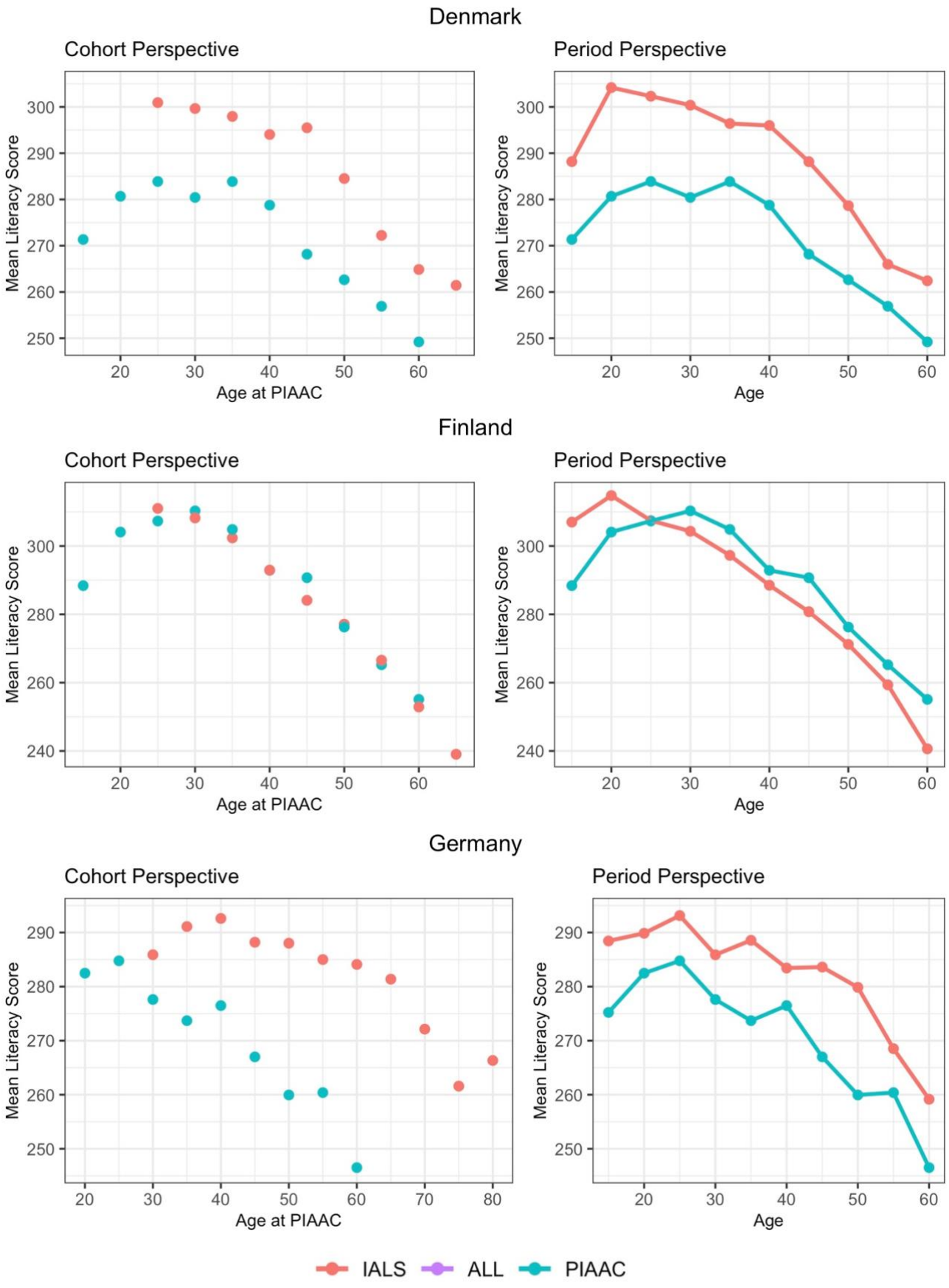
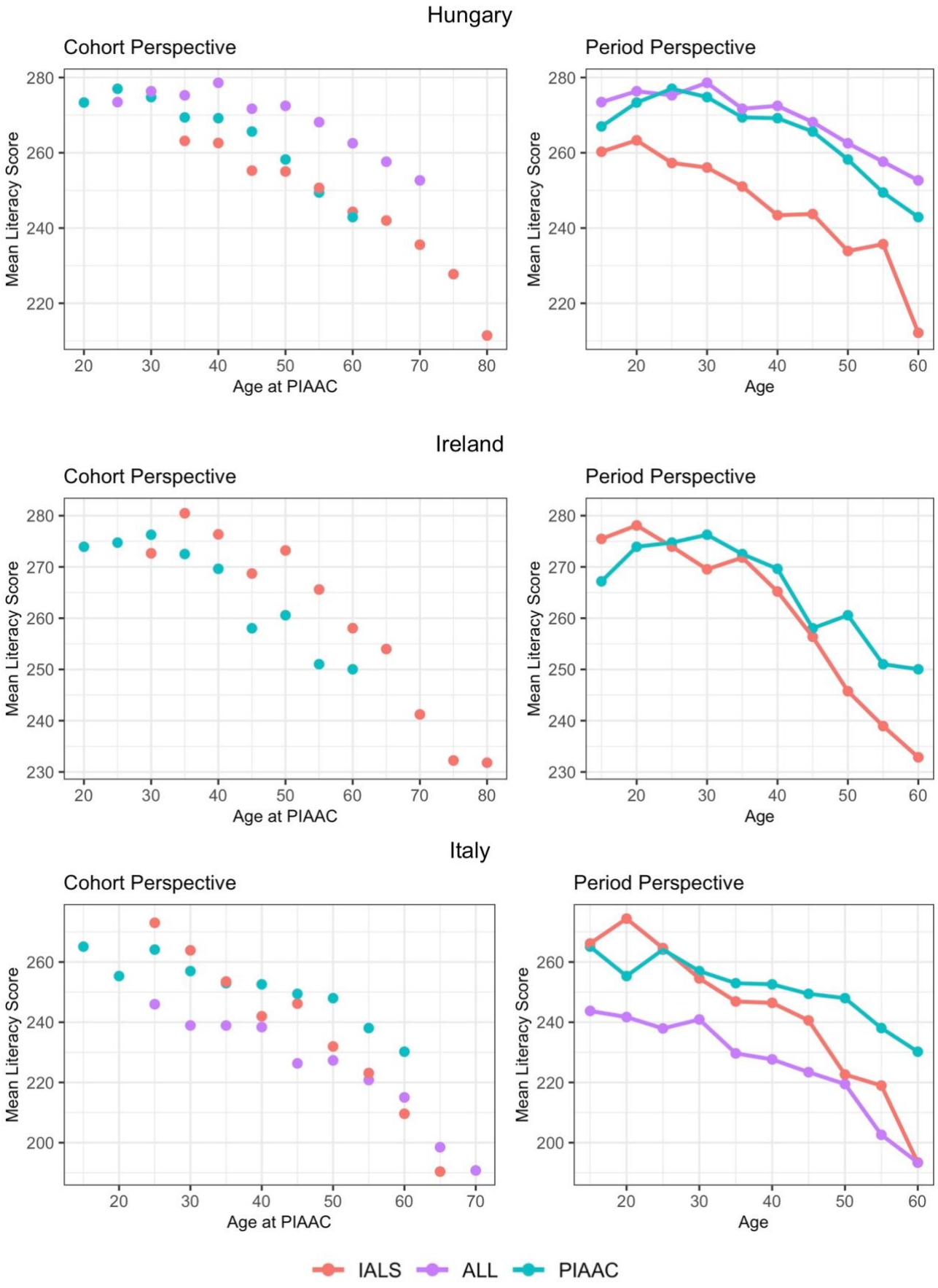
Appendix

Figure A1. Country-specific cohort analyses, IALS 1994-98, ALL 2004-08, PIAAC 2001-17.




Denmark
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
Finland
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
Germany
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
IALS
ALL
PIAAC


Hungary
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
Ireland
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
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Italy
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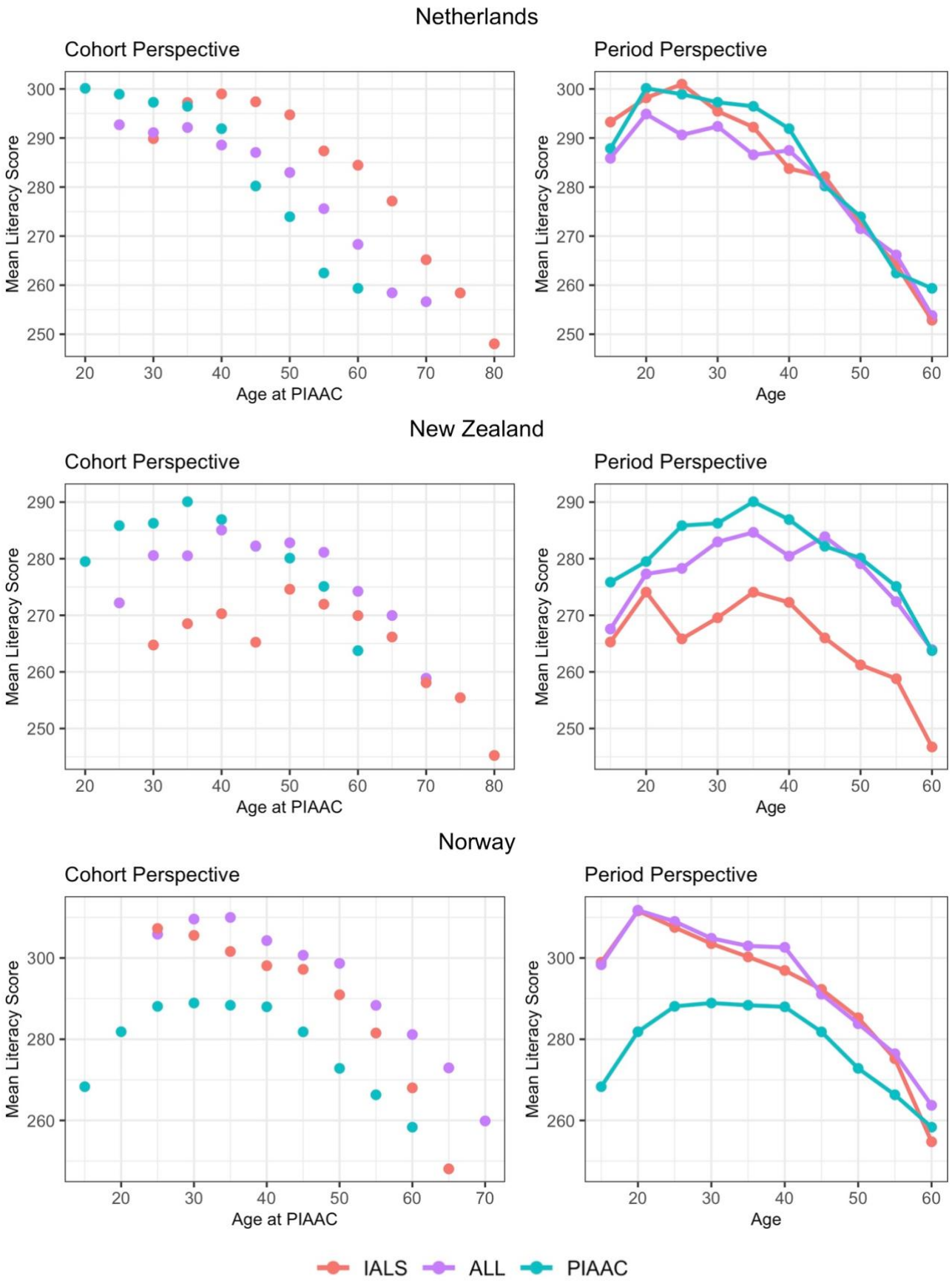
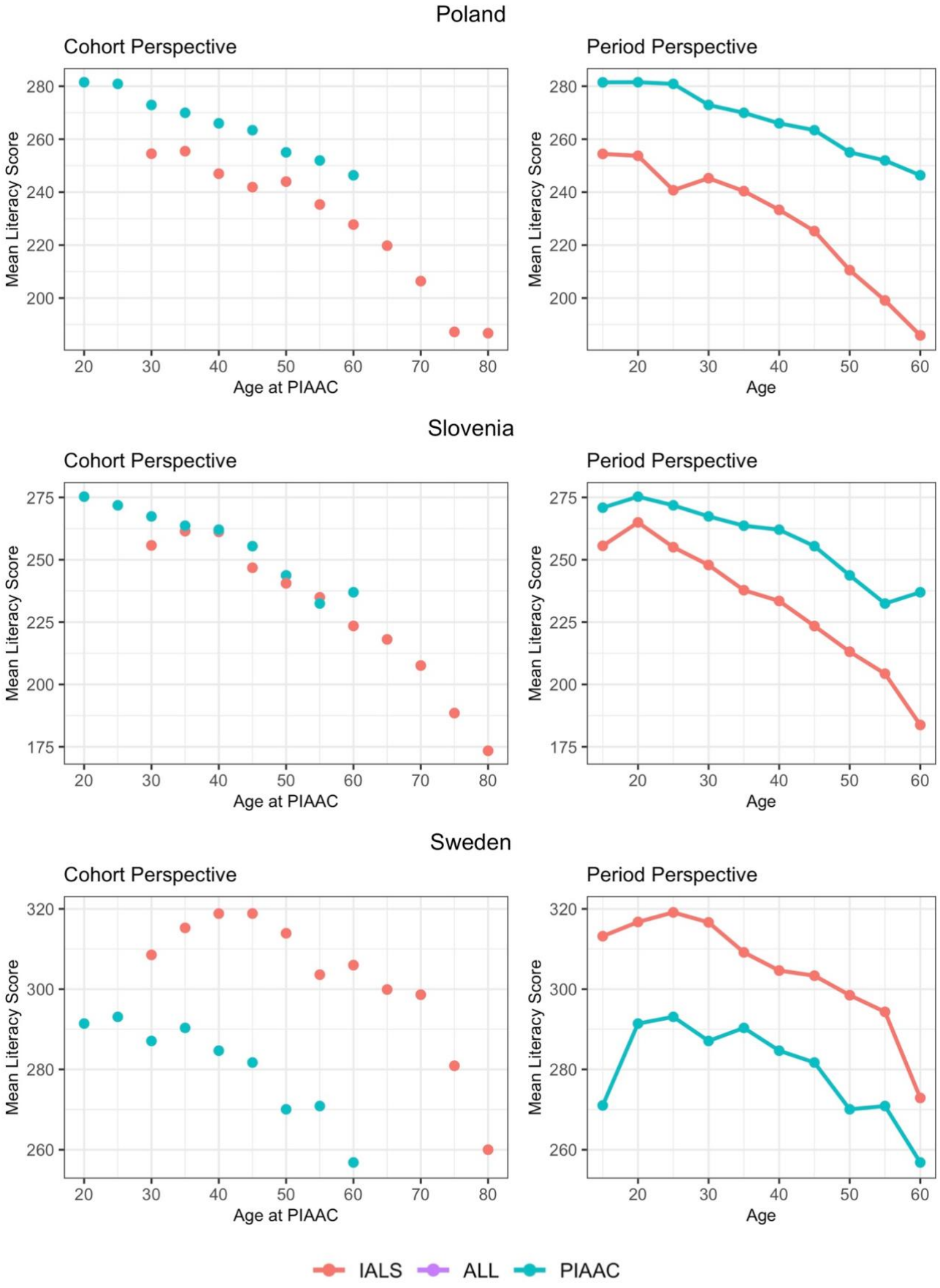
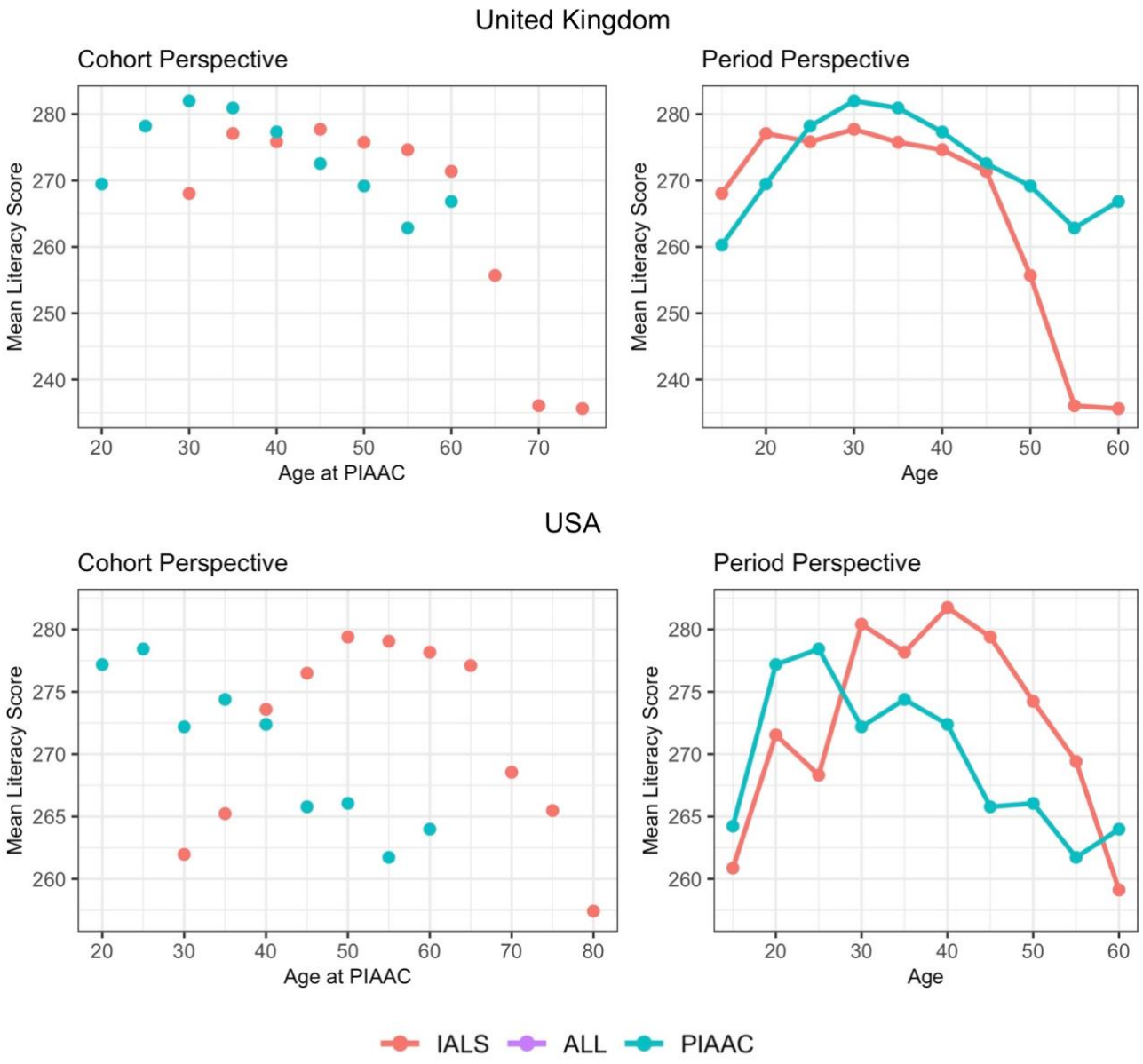
Age
IALS
ALL
PIAAC


Netherlands
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
New Zealand
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
Norway
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
IALS
ALL
PIAAC


Poland
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
Slovenia
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
Sweden
Cohort Perspective
Period Perspective
Mean Literacy Score
Age at PIAAC
Age
IALS
ALL
PIAAC



Source: Author's elaboration.