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The evolution of gender gaps in numeracy and literacy between childhood and adulthood

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Abstract

Numeracy and literacy skills have become increasingly important in modern labour markets. The large gender differences that several studies have identified have therefore sparked considerable attention among researchers and policy makers. Little is known about the moment in which such gaps emerge, how they evolve and if their evolution differs across countries. We use data from large-scale international assessments to follow representative samples of birth-cohorts over time, and analyse how gender gaps in numeracy and literacy evolve from age 10 to age 27. Our results suggest that, across the countries examined, males' advantage in numeracy is smallest at age 10 and largest at age 27. The growth in magnitude of the gender gap is particularly pronounced between the age of 15 and 27. Such evolution stands in sharp contrast with the evolution of the gender gap in literacy, which is small at age 10, large and in favour of females at age 15, and negligible by age 27.

Résumé

Les compétences en numératie et en littératie sont devenues de plus en plus importantes sur les marchés du travail modernes. Les grandes différences entre les sexes que plusieurs études ont mises en évidence ont donc suscité beaucoup d'attention chez les chercheurs et les décideurs. On sait peu de choses sur le moment où de tels écarts apparaissent, comment ils évoluent et si leur évolution diffère d'un pays à l'autre. Nous utilisons des données provenant d'évaluations internationales à grande échelle pour suivre des échantillons représentatifs de cohortes de naissance au fil du temps et analyser comment les écarts entre les sexes en matière de numératie et de littératie évoluent de 10 à 27 ans. Nos résultats suggèrent que, dans l'ensemble des pays examinés, l'avantage des hommes en numératie est le plus faible à 10 ans et le plus élevé à 27 ans. La croissance de l'écart entre les sexes est particulièrement prononcée entre 15 et 27 ans. Cette évolution contraste fortement avec l'évolution de l'écart entre les sexes en matière d'alphabétisation, qui est faible à 10 ans, important et en faveur des femmes à 15 ans, et négligeable à 27 ans.

Introduction

Human capital is widely recognised as a fundamental ingredient for the economic (and non-economic) success of individuals, as well as of societies, and there are reasons to believe that its importance is bound to continue growing in the foreseeable future (Lucas, 1988[1]). Gender differences in human capital are therefore a crucial ingredient for any policy that aims at addressing the observed gender differences in economic and non-economic outcomes.

Despite major trends pointing towards a closing of the gender gap in educational attainment in favour of males and increasing concerns for emerging gender gaps in favour of females in a variety of educationally relevant outcomes (DiPrete and Buchmann, 2013[2]; Riordan, 1999[3]), the academic and career choices of young men and women remain remarkably different. For example, girls tend to opt for fields of study like education, the arts and the humanities, while men are over-represented in STEM careers (Anker, 1997[4]; Flabbi, 2012[5]; OECD, 2015[6]).

Recent analyses show the persistence of gender inequalities in the acquisition of different competencies (OECD, 2014[7]; OECD, 2015[6]). These studies, which usually focus at the secondary school level, indicate that boys tend to outperform girls in numeracy, while girls tend to do better than boys in literacy. Additionally, Machin and Pekkarinen (2008[8]) show that, in most countries, the skill distribution of 15-years old girls' is less dispersed than that of their male counterparts. This gender "specialisation" at early ages might have long term effects on the educational decisions and labour market outcomes of males and females.

Strikingly, although several studies document cross-country differences in the size (and sometimes also in the sign) of gender gaps in numeracy and literacy at specific ages, much less is known about how such gaps evolve over time and if such evolution differs across countries. Better knowledge of the timing of events is crucial to identify critical factors and circumstances that shape the evolution of the gaps, and to design effective policies accordingly.

We contribute to the literature by mapping cross-national differences in the magnitude and evolution of gender gaps in numeracy and literacy from childhood (around age 10) into young adulthood (around age 27).

Like any form of capital, human capital can be seen as a stock of capabilities that individuals possess at a given point in time. Like any other form of capital, this stock is not fixed over time: it can be increased through investment in education or other forms of learning, and it can decrease because it becomes obsolete, or because ageing induces a decline in cognitive ability (Paccagnella, 2016[9]). Given the importance of both schooling and post-schooling experiences for the evolution of individual skills, it is then possible that also gender gaps evolve considerably as a result.

The increasing differentiation of the educational and labour market experiences of males and females, which in some countries can start as early as the end of primary school, leads us to hypothesize that any initial advantage boys may have in numeracy and girls in literacy, is likely to progressively widen between the ages of 10 and 27. We test this hypothesis by examining the evolution of the gender gap in numeracy proficiency at ages 10, 15 and 27. There are reasons to believe that, just as the size of the gender gap in numeracy differs across countries because of cultural, social and educational factors (Bedard and Cho, 2010[10]; Hyde and Mertz, 2009[11]; Guiso et al., 2008[12]), so does the evolution of such gap over time. We then replicate the analyses looking at literacy and compare the evolution of gender gaps in the two domains. These analyses allow us to examine if educational and labour market segregation leads to increasing specialisation of men and women and result in divergence in gender gaps in the two domains, with widening advantages for men in numeracy and women in literacy.

In the second part of the paper we then look at the evolution of gender gaps across the skill distribution. Previous evidence has shown that gender gaps differ considerably between low- and high-achieving students, as males tend to be over-represented at both tails of the skill distribution (Hedges and Nowell, 1995[13]; Lindberg et al., 2010[14]; Machin and Pekkarinen, 2008[8]).

In the absence of cross-country comparable longitudinal data, we combine information from existing cross-sectional large-scale international assessments: the Trends in International Mathematics and Science Study (TIMSS) and the Programme in Reading and Literacy Skills (PIRLS) (managed by the IEA), as well as the OECD Programme for International Student Assessment (PISA) and the OECD Programme for the International Assessment of Adult Competencies (PIAAC). In this way, we are able to track the evolution of gender gaps within cohorts of students that participated in different waves of different surveys.

Our findings suggest that the gender gap in numeracy in favour of males tends to grow as individuals age and that such growth is particularly pronounced after males and females leave compulsory schooling and enter post-compulsory education and the labour market. The gender gap in literacy, on the other hand, follows an inverted-U profile, being highest during teenage years and lowest among young adults.

Gender gaps evolve in similar ways at both ends of the skill distribution. The variability of performance is always higher among male students, peaking during the teenage years in both numeracy and literacy.

The remainder of the paper is structured as follows. Section 2 provides a brief literature review on gender inequalities in numeracy and literacy proficiency. Section 3 describes the data we use and the empirical strategy we adopt to analyse the evolution of gender gaps. Section 4 presents the main results and discusses its implications. Section 5 concludes.

Table of contents

Tables

Figures

1. Gender disparities in literacy and numeracy skills

While the existence of gender gaps in academic achievement has been extensively documented, the evolution of such gaps over the life cycle has not attracted the same level of attention and analysis. Existing evidence on the evolution of gender gaps in the acquisition of competencies across life is scarce, focuses on early childhood and is generally restricted to English-speaking countries. It tends to show that gender differences in quantitative abilities arise during primary school. For example, males and females appear to perform similarly in tests of mathematical reasoning between the ages of 4 and 10 (Spelke, 2005[15]) but a gender gap starts to appear as children complete primary school and move into secondary education (Beilstein and Wilson, 2000[16]).

The teenage years are generally identified as the point when gender gaps in quantitative abilities widen (Lindberg et al., 2010[14]; Machin and McNally, 2005[17]; Wai et al., 2010[18]). The consensus in the literature is that by the end of secondary school males generally outperform females in quantitative abilities (Rampey, Dion and Donahue, 2009[19]), that the difference is more pronounced among high achieving students (Machin and Pekkarinen, 2008[8]) and that this difference tends to be more pronounced in tests that are not directly tied to a curriculum and reflect problem solving skills (Halpern, 2012[20]; Halpern et al., 2007[21]; Halpern et al., 2007[22]).

Several theories can explain the emergence of gender differences in numeracy, as well as their differential evolution in the transition from childhood to teenage years. There is evidence, for instance, that males tend to be identified and to self-identify as being "math-oriented", although this is not the case in all countries (Aronson, 2002[23]; Benbow, 1988[24]; Cvencek, Meltzoff and Greenwald, 2011[25]; Hedges and Nowell, 1995[13]; Shih, Pittinsky and Ambady, 1999[26]). As a consequence, males could have more incentives to invest in more quantitative subjects.

Other factors can shape the evolution of gender gaps (Buser, Niederle and Oosterbeek, 2014[27]; Niederle and Vesterlund, 2010[28]; Jurajda and Münich, 2011[29]). Different levels of self-efficacy (Bandura, 1993[30]) and different neurological or behavioural maturing processes have been observed across males and females (Arain et al., 2013[31]; Bramen et al., 2012[32]), which could contribute to explaining variation in gender gaps at different stages of the lifecycle.

A different set of explanations is related to institutional features of the education system. The schooling experience of males and females can differ in important ways. Vertical and horizontal stratification policies either by gender (single-sex schooling) or by ability may influence the evolution of gender gaps, as they would tend to reinforce any gap that is present at the moment in which important educational choices have to be made (Bedard and Cho, 2010[10]). Even the gender of teachers may have differential effects on the accumulation of skills of male and female students (Carrell, Page and West, 2010[33]; Cho, 2012[34]; Holmlund and Sund, 2008[35]; Lim and Meer, 2017[36]).

Several additional reasons can explain how gender gaps evolve during young adulthood. As students move into upper secondary schooling, and certainly once they enrol in post-secondary education, the likelihood that males and females will be differentially exposed to course content designed to foster the acquisition of quantitative abilities increases (Clark, 1986[37]).

In young adulthood other factors come into play, such as processes governing the school-to-work transition. Working experience, on the job training, and informal learning are often pinpointed as important for the acquisition of new skills, or for avoiding age-related skills atrophy (OECD, 2012[38]; OECD, 2013[39]; Paccagnella, 2016[40]). Furthermore, the existence of gender discrimination in hiring processes has been consistently reported in a number of countries, even in experimental environments (Azmat and Petrongolo, 2014[41]). Gender stereotypes and psychosocial traits also play a key role in labour supply decisions (Bütikofer, 2013[42]; Kiefer and Sekaquaptewa, 2007[43]; Antecol and Cobb-Clark, 2013[44]). Asymmetric access to the labour market is therefore a channel through which gender gaps in competencies may vary among adults Black & Spitz-Oener (2010[45]).

All these factors lead us to hypothesise that the gender gap in numeracy in favour of males will widen between age 10 and age 27 and, conversely, than gender gaps in literacy in favour of females will widen between age 10 and age 27. Essentially we hypothesise that the increasingly different experiences males and females experience in school, education, training, the labour market and society, will lead to increased specialisation of genders in different areas.

2. Methodology and data

Ideally, identifying the evolution of gender gaps in numeracy and literacy would require the availability of individual-level longitudinal data for cross-country comparable assessments. Unfortunately, such data do not exist. Therefore, we follow an alternative analytical strategy that allows us to monitor the evolution of gender gaps at the population level, by examining changes in the gender gap in numeracy and literacy of a pseudo-panel sitting different international large-scale assessments at different points in time.

We therefore combine information from different international cross-sectional assessments of numeracy and literacy performance that were designed to monitor academic achievement at key developmental stages. The main challenge is to maximise comparability across the different assessments.

In a first step, we identify a set of international assessments that contain standardised tests of numeracy and literacy at different ages. We select the Trends in International Mathematics and Science Study (TIMSS), the Programme in Reading and Literacy Skills (PIRLS), the Programme for International Student Assessment (PISA) and the Programme for the International Assessment of Adult Competencies (PIAAC), because these studies aim to be representative of their respective target populations at the country level and assess the proficiency of individuals through similar assessments taken at different ages: age 9-10 (TIMSS and PIRLS), age 15 (PISA) and age 16-to-65 (PIAAC). TIMSS contain an assessment of numeracy proficiency, PIRLS assesses literacy proficiency, and PISA and PIAAC assess both domains.

Because TIMSS, PIRLS, and PISA are repeated cross-sectional studies which have been implemented on multiple occasions over the past decades, we are able to identify a number of countries that took part in the different assessments at different points in time. As PIAAC cover the entire adult population aged 16 to 65, we are able to identify in the PIAAC data the cohorts that were assessed at earlier ages in the other studies.

Thirteen countries took part in both TIMSS 1995, PISA 2000 and PIAAC 2011/12. We can therefore follow across the various studies the cohort of individuals born 1984-85 and assess how the gender gap in numeracy evolved between age 10 and age 27 for the individuals belonging to this birth cohort.

One limitation of this approach is that the conceptual frameworks on which the different assessments are based differ across studies. Although data from PISA and TIMSS have been used to conduct joint analyses before (Jerrim and Choi, 2014), differences in the assessment frameworks (as well as in the test administration procedures) may have a bearing for the estimation of gender gaps. We will return to these issues in Section 5.

We also identify 12 countries that took part in PIRLS 2001, PISA 2000 and PIAAC 2011/12 and use these data to identify the evolution of the gender gap in literacy proficiency. The PIRLS, PISA and PIAAC literacy frameworks have a stronger alignment. However, analyses based on the PIRLS-PISA-PIAAC data rely on the use of PIRLS 2001 results as a proxy for those that the 1984-85 cohort would have obtained in a hypothetical PIRLS 1995 assessment (which did not take place).

For both analyses we had to widen the cohorts that we use for estimations using PIAAC data to all cohorts in the 1983-1986 interval because PIAAC has a small country specific-age-specific sample size (given the overall sample of around 4 500 individuals for the whole adult population).

All four studies are conducted on nationally representative samples of their respective target populations and provide standardised measures of performance in information processing abilities. TIMSS, PIRLS and PISA have similar response rates and survey designs: the target population consists of students, and participants are selected through a two-stage sampling design, whereby schools are selected first and then students are sampled from selected schools. However, there are also important differences in the sampling design: TIMSS and PIRLS have a grade-based sampling strategy (effectively surveying 4th grade students) that considers schools and classrooms as sampling units, while PISA has an age-based sampling (students who are between the ages of 15 years and three months and 16 years and two months at the time of testing) with schools as the primary sampling unit (OECD, 2002[46]; Mullis et al., 2012[47]; Mullis et al., 2012[48]). The PIAAC target population is the non-institutionalised adult population living in the country. PIAAC also uses complex survey designs (which are often country-specific) to select households, and then individuals within households (OECD, 2013[49]).

In all studies, proficiency is estimated using Item Response Theory. The individual responses to the assessment questions are combined with background information to predict "plausible values", which provide an unbiased estimate of the underlying ability of respondents. Scaling depends on the countries that are taking part in the assessments and the specific Item Response Theory (IRT) model used for each assessment (a one-parameter Rasch model for PISA, a two-parameter Rasch model for PIAAC, for TIMSS and PIRLS two and three IRT models were applied). As a consequence, raw scores are not directly comparable across different studies (Jacob and Rothstein, 2016[50]). For this reason, all our analyses are based on standardised gender gaps.

The analysis of the evolution of gender gaps is carried out as follows. For each assessment, let Y_{ijk} represent the performance of individual i from school j in country k. Let G_i be a gender dummy (1=female). We estimate the following model, which we will refer to as baseline model, on data from the repeated cross-sectional assessments:

$$Y_{\mathrm{ijk}} = \alpha + \beta_1 G_i + \varepsilon_{ij} \ \forall k \qquad (1)$$

The parameter of interest is β_1, which provides a country- and survey-specific estimate of the gender gap. This coefficient is then standardised using the pooled standard deviation (pooling gender and countries) for each individual study, in order to allow for comparisons across studies. Jackknife or Balanced-Repeated Replication (BRR) weights were applied to compute standard errors, depending on the assessment. Survey weights were used throughout to obtain estimates that are representative of the underlying target population.

In order to see how gender differences at different parts of the skills distribution evolve over time we estimate equation (1) using quantile regressions, computing gender gaps at the 1st and at the 9th decile of the skills distribution.

Following Machin and Pekkarinen (2008[8]), we also compute the male-female variance ratio and the male female ratio at the top and at the bottom decile.

Finally, we perform a complementary analysis using a "moving cohorts" approach based solely on PISA and PIAAC in which we look at the evolution of gender gaps between ages 15/16 and 26/27 following the performance of three different birth-cohorts. The youngest cohort was born in 1989/90 and we look at their performance between age 15 (in PISA 2006) and age 20/21 (in PIAAC). The second cohort was born in 1987/88 and was tested at age 15 in PISA 2003 and at age 23/24 in PIAAC. The oldest cohort is our reference cohort for the main analysis (the cohort that was born in 1984/85 and was tested in PISA 2000). This exercise might also be seen as a test of the consistency of results obtained with the pseudo-panel approach focused on the single 1984/85 cohort. As in the first part of the analysis, we use a larger age band in PIAAC in order to increase the number of observations.

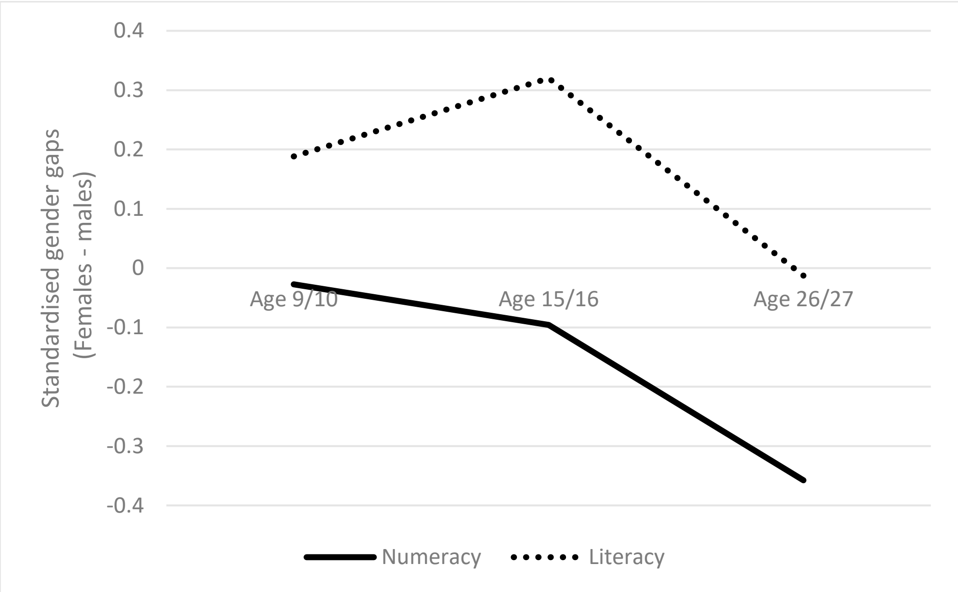
3. Empirical results

This Section is structured into three subsections. Subsection 3.1 presents the evolution of the average gender gap in numeracy and literacy between age 10 and age 27. Subsection 3.2 describes the evolution of the gaps at the top and at the bottom deciles of the skills distribution, as well as looking at variance ratio and at differences in the representation of the two genders at the top and at the bottom of the skills distribution. Subsection 3.3 presents the results of the "moving cohorts" analysis.

3.1. The evolution of gender gaps

Gender gaps between ages 10 and 27 follow a different pattern depending on the domain we look at. The results of the analysis are summarised in Figure 3.1

Figure 3.1. Evolution of gender gaps in numeracy and literacy



Note: The analysis is run on the cohort born in 1984/85, followed through three different assessments at different points in time. The analysis of gender gaps in literacy is based on 12 countries. The analysis of gender gaps in numeracy is based on 13 countries.
Source: TIMSS 1995 (TIMSS & PIRLS International Study Center, Boston (MA), (1995), https://timssandpirls.bc.edu/timss1995i/Database.html), PIRLS 2001 (TIMSS & PIRLS International Study Center, Boston (MA), (2001), https://timssandpirls.bc.edu/pirls2001i/PIRLS2001_Pubs_UG.html), PISA 2000 (PISA Results (Database 2000), www.oecd.org/pisa/pisaproducts/database-pisa2000.htm), PIAAC 2012 (OECD. (2016) Survey of Adult Skills (PIAAC), www.oecd.org/site/piaac/publicdataandanalysis.htm).

In the case of numeracy, the gap is negative (meaning that boys are more proficient than girls) but very small at age 9/10, grows in magnitude at age 15/16, and grows even more negative at age 26/27. In the case of literacy, the gender gap is positive (meaning that female students perform better than male students) at age 9/10, is even larger at age 15/16, and shrinks to zero at age 26/27.

This pattern is common to most countries in the sample (see Table 1)

Table 3.1. Evolution of gender gaps in numeracy and literacy, country-specific results

	Numeracy				Literacy		
Country	9/10	15/16	26/27	Country	9/10	15/16	26/27
AUS	-0.026	-0.109	-0.084	CZE	0.147**	0.391**	0.020
AUT	-0.046	-0.245**	-0.236	FRA	0.125**	0.307**	0.053
CAN	-0.030	-0.093**	-0.191	DEU	0.134**	0.329**	0.018
CZE	-0.032	-0.106*	-0.008	ISR	0.260**	0.156	0.022
IRE	0.067	-0.117*	-0.293*	ITA	0.105**	0.395**	0.238
ISR	-0.076	-0.111	-0.148	NET	0.189**	0.241**	0.119
JAP	-0.043**	-0.074	-0.235*	NZL	0.382**	0.443**	-0.258
KOR	-0.112**	-0.241**	-0.157	NOR	0.269**	0.447**	0.019
NET	-0.092**	-0.096	-0.067	RUS	0.168**	0.353**	0.151
NZL	0.069*	0.024	-0.546**	SWE	0.283**	0.311**	0.082
NOR	-0.057	-0.095**	-0.212	ENG	0.290**	0.310**	-0.099
ENG	-0.065	-0.073	-0.408**	USA	0.216**	0.290**	-0.165
USA	0.013	-0.065	-0.484**				
Pooled	**-0.027***	**-0.096****	**-0.358****	Pooled	**0.182****	**0.320*****	**-0.013**

Note: Asterisks denote statistical significance at the 5% level (*) or at the 1% level (**). The analysis is run on the cohort born in 1984/85, followed through three different assessments at different points in time. The analysis of gender gaps in numeracy is based on 13 countries. The analysis of gender gaps in literacy is based on 12 countries.
Source: TIMSS 1995 (TIMSS & PIRLS International Study Center, Boston (MA), (1995), https://timssandpirls.bc.edu/timss1995i/Database.html), PIRLS 2001 (TIMSS & PIRLS International Study Center, Boston (MA), (2001), https://timssandpirls.bc.edu/pirls2001i/PIRLS2001_Pubs_UG.html), PISA 2000 (PISA Results (Database 2000), www.oecd.org/pisa/pisaproducts/database-pisa2000.htm), PIAAC 2012 (OECD. (2016) Survey of Adult Skills (PIAAC), www.oecd.org/site/piaac/publicdataandanalysis.htm).

At age 9/10 the gender gap in numeracy is very close to zero in most countries (New Zealand, Japan and Korea are the exceptions). The gender gaps in literacy are much larger and are statistically significant in all countries.

By age 15/16, the gender gap in mathematics competencies is statistically significant in about half of the countries in the sample and even though the gender gap in literacy is more consistent, with girls outperforming boys in all countries considered, there is a large degree of heterogeneity across countries in the size of the gender gaps in both literacy and numeracy. This finding suggests that context can play an important role in determining gender gaps in information processing abilities.

Finally, by age 26/27 the gender gap in numeracy widens in most countries, while the gap in the literacy competencies fades. Remarkably, there does not seem to be, at the country level, a direct relationship between the size of the gender gap at early ages and the size of the gender gap at age 26/27. This points, again, to the role of external factors such as the larger educational choices available during young adulthood, the structure of the labor market and institutions.

3.2. How gender gaps in numeracy and literacy vary across the skills distribution

Table 3.2 shows how gender gaps vary at different parts of the skills distribution and how the variability of scores differ between males and females.

Country-specific results are available in Table A.1

Table 3.2. The evolution of gender gaps across the skills distribution

	Numeracy			Literacy		
	9/10	15/16	26/27	9/10	15/16	26/27
Mean gender gap	-0.027*	-0.096**	-0.358**	0.188**	0.312**	-0.013
Gender gap at 10th percentile	0.009	0.038	-0.194	0.283**	0.477**	0.083
Gender gap at 90th percentile	-0.074*	-0.191**	-0.396*	0.139**	0.191**	-0.032
M/F ratio at 10th percentile	1.105**	1.031**	0.628**	1.571**	2.050**	1.258**
M/F ratio at 90th percentile	1.217**	1.550**	2.440**	0.737**	0.675**	1.134**
M/F variance ratio	1.088**	1.179**	1.030	1.103**	1.219**	1.130**

Note: Asterisks denote statistical significance at the 5% level (*) or at the 1% level (**). For the M/F ratio at the 10th and 90th percentile and for the M/F variance ratio the test is whether is the ratio is different from 1.
Source: TIMSS 1995 (TIMSS & PIRLS International Study Center, Boston (MA), (1995), https://timssandpirls.bc.edu/timss1995i/Database.html),), PISA 2000 (PISA Results (Database 2000), www.oecd.org/pisa/pisaproducts/database-pisa2000.htm), PIAAC 2012 (OECD. (2016) Survey of Adult Skills (PIAAC), and, for reading, from PIRLS 2001 (TIMSS & PIRLS International Study Center, Boston (MA), (2001), https://timssandpirls.bc.edu/pirls2001i/PIRLS2001_Pubs_UG.html), PISA 2000 and PIAAC.

At all ages, the gender gap in numeracy is primarily due to males outperforming females (and being over-represented) at the top of the proficiency distribution. The relative advantage of males over females in numeracy at the top tail of the performance distribution appears to become more pronounced with age. At age 26/27, the standardised gender gap at the top decile of the distribution amounts to around -0.4 (around 40% of a standard deviation), and men are almost 2.5 times more likely than women to be in the top decile of the numeracy distribution. By contrast, gender differences in performance variability in numeracy appear to be most pronounced at age 15.

In the case of literacy, females outperform males at age 9/10 and 15/16 at both ends of the skills distribution. By age 26/27, though, gender gaps are not statistically significant and very close to 0. At all ages, males are over-represented at the bottom of the skills distribution (and this over-representation is particularly striking at age 15/16). At age 10 and 15 males are also under-represented at the top end of the literacy distribution, while at age 26/27 males are slightly over-represented at the top of the distribution. Males appear to have a more variable literacy performance than females at all ages, but particularly so during the teenage years.

3.3. Understanding what happens between age 15 and age 27: a moving cohort approach

In this last part of the analysis we draw on data from multiple PISA waves (and therefore multiple cohorts), and we match them with respondents from the same cohorts that participated in the PIAAC assessment in 2011/12. This allows to investigate: (a) whether the gender gap at age 15 changes over time; (b) under the assumption that there are no cohort-effects, how gender gaps evolve from age 20 to age 26 (approximately). Moreover, by using only data from PISA and PIAAC we are able to substantially enlarge the number of countries used in the analysis, from 12/13 in sections 3.1 and 3.2 to 22.

Table 3.3. Evolution of gender gaps: moving cohort analysis

	Numeracy				Literacy			
Pooled	15-16	20-21	23-24	26-27	15-16	20-21	23-24	26-27
PISA 2000 - PIAAC	-0.087**	X	X	-0.244**	0.322**	X	X	-0.016
PISA 2003 - PIAAC	-0.096**	X	-0.232**	X	0.307**	X	-0.006	X
PISA 2006 - PIAAC	-0.115**	-0.160**	X	X	0.347**	-0.007	X	X

Note: Pooled results with country fixed effects. Country-level results reported in Table A.A.3. Asterisks denote statistical significance at the 5% level (*) or at the 1% level (**).
Source: PISA 2000 (OECD. (2006) PISA Results (Databases 2000, 2003, 2006), http://www.oecd.org/pisa/data/), PISA 2003, PISA 2006 and PIAAC (OECD (2016) Survey of Adult Skills (PIAAC) (Database 2012, 2015), www.oecd.org/site/piaac/publicdataandanalysis.htm).

Table 3.3 shows that gender gaps in numeracy and literacy at age 15 have not changed much from 2000 to 2006, supporting the assumption of stableness of gender gaps across the cohorts examined. Results for numeracy indicate that the gender gap in favour of males grows in particular between age 15 and age 23-24: the gender gap in numeracy was in fact around -0.10 at age 15-16, -0.16 at age 20-21, -0.23 at age 23-24 and -0.24 at age 26-27. By contrast the gender gap in literacy appears to close between age 15-16 and 20-21 and then remain stable up to age 26-27.

4. Discussions and conclusions

In this paper we set out to examine the evolution of gender gaps in numeracy and literacy from childhood to early adulthood. We hypothesised that males' advantage in numeracy and females' advantage in literacy would become progressively more pronounced between age 10 and 27.

The results presented in this paper suggest that gender gaps in information processing skills evolve very differently across the two domains. Analyses of achievement data from large-scale international assessments reveal that boys have a higher mean performance in numeracy at age 10 and that this advantage grows larger over time. By contrast, girls appear to have an initial advantage in literacy that grows larger between age 10 and age 15, but then disappears as soon as individuals enter young adulthood. While large differences between countries exist in the size of the gender gaps in literacy and numeracy at particular age groups, there is a remarkable level of consistency across countries in how gender gaps evolve over the lifecycle.

At this stage, only some suggestive explanations for these patterns can be put forward. The existence of gender gaps at age 9/10 could be linked to both social gender roles and to differences in psychological traits, as well as in timing of cognitive and emotional development. As children grow and enter the teenage years, they are subjected to a set of stimuli that are likely to differ by gender.

Increasing gender gaps in numeracy are then consistent with a greater specialisation of men in fields of studies and/or occupations that make more intensive use of numeracy skills. Indeed, women are under-represented in STEM education in most OECD countries (DiPrete and Buchmann, 2013[2]). As a consequence, gender segregation is then reproduced in the labour market, where men occupy more frequently jobs which allow them to apply and develop their numeracy competencies (Sassler et al., 2017[51]). The narrowing of gender gaps in literacy can instead be explained by the fact that literacy is a more transversal skills that everybody is called to master in order to succeed in education and in the labour market, irrespective of the chosen field of study or occupation.

Future research should focus on disentangling the underlying causes of these descriptive patterns. In particular, differences in the design of different surveys can contribute to the results.

Despite important similarities between these studies (which result from a high degree of cross-fertilisation), there are important differences between the different assessment frameworks (Borgonovi et al., 2017[52]). Such differences may play a role in shaping the results we present. The small age-specific sample at the country level for PIAAC also means that estimates for young adults are inevitably imprecise.

The PIAAC test was conducted as a one-to-one study in respondents' homes in the presence of a trained interviewer rather than as a group exercise in a school setting. This setting may entice greater engagement with the test material, greater motivation and greater effort among males than among females. Although we cannot directly test the effect administration procedures and settings have on differences across genders, it is possible that boys may need stronger motivational incentives to display their knowledge and skills and that their performance in standardised, low-stakes assessments may be more dependent on motivation and engagement than girls' performance. The presence of a trained interviewer supervising the test-taking session on a one-to-one basis may provide such incentive. Furthermore, in the teenage years many boys may display lack of engagement with school, and with reading in particular as a way to build their social identity and status among peers (Paechter, 1998[53]; Francis, 2000[54]; Warrington, Younger and Williams, 2000[55]; Smith and Wilhelm, 2002[56]; Smith and Wilhelm, 2006[57]).

Another important difference between TIMSS, PIRLS, PISA and PIAAC relates to the length of the test session: TIMSS, PIRLS and PISA are designed to have a strict time limit. The PIAAC study is designed to be completed within around one hour, but respondents can engage with the test for as long as they want to. Previous research has indicated that males appear to be particularly prone to fatigue and engagement effects, in particular in the literacy domain (Borgonovi and Biecek, 2016[58]).

Introducing a longitudinal component in existing surveys and/or statistical linkages between large-scale assessments can also be of great help in shedding more light on issues of achievement growth and the evolution of such growth across genders.

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Annex A.

Table A.1. Variance ratios at different ages – country specific results

	Numeracy				Literacy		
	9/10	15/16	26/27		9/10	15/16	26/27
AUS	1.053	1.082	0.870	CZE	1.085	1.263	0.883
AUT	1.152	1.173	0.961	FRA	1.037	1.268	1.106
CAN	1.021	1.134	1.195	DEU	1.003	1.051	0.941
CZE	0.960	1.183	0.696	ISR	1.178	1.339	1.042
IRL	1.159	1.082	0.934	ITA	1.034	1.219	1.197
ISR	0.946	1.207	0.947	NLD	1.113	1.080	1.017
JPN	1.176	1.309	0.953	NZL	1.149	1.300	1.088
KOR	1.154	1.060	0.888	NOR	1.209	1.405	1.045
NLD	1.098	1.076	1.046	RUS	1.048	1.214	1.264
NZL	1.276	1.235	1.166	SWE	1.045	1.081	1.278
NOR	1.062	1.223	1.049	USA	1.181	1.267	1.136
ENG	1.094	1.168	1.236	ENG	1.083	1.197	1.170
USA	1.034	1.201	1.240				

Note: Variance ratios defined as the ratio of male and female variances.
Source: TIMSS 1995 (TIMSS & PIRLS International Study Center, Boston (MA), (1995), https://timssandpirls.bc.edu/timss1995i/Database.html), PISA 2000 (PISA Results (Database 2000), www.oecd.org/pisa/pisaproducts/database-pisa2000.htm), PIAAC 2012 (OECD. (2016) Survey of Adult Skills (PIAAC) www.oecd.org/site/piaac/publicdataandanalysis.htm) and, for reading, from PIRLS 2001 (TIMSS & PIRLS International Study Center, Boston (MA), (2001), https://timssandpirls.bc.edu/pirls2001i/PIRLS2001_Pubs_UG.html), PISA 2000 and PIAAC.

Table A.2. Evolution of gender gaps in literacy and numeracy, country-specific results – top and bottom decile

Q10	Numeracy				Literacy		
	9/10	15/16	26/27		9/10	15/16	26/27
AUS	4.006	-11.324	-2.042	CZE	18.935*	59.810**	4.473
AUT	4.884	-17.934	-13.991	FRA	13.769	54.480**	9.362
CAN	0.116	-2.942	0.440	DEU	9.265	38.064**	3.683
CZE	-7.302	-1.810	-5.524	ISR	29.020**	48.448*	9.233
IRL	18.768*	-6.180	-16.108	ITA	8.477	49.108**	17.973
ISR	-10.592	-3.532	-7.904	NLD	16.379*	31.124*	3.127
JPN	4.860	11.728	-9.416	NZL	39.477**	74.168**	-9.422
KOR	-11.478*	-25.482**	-11.077	NOR	33.304**	76.516**	5.043
NLD	-5.156	-3.408	4.352	RUS	17.571**	47.922**	18.034
NZL	22.756**	17.848	-24.262	SWE	29.051**	41.484**	7.325
NOR	0.004	4.904	-12.876	USA	29.548*	55.314**	0.136
ENG	4.874	-2.248	-21.793	ENG	31.134**	44.174**	-7.170
USA	1.242	9.202	-12.531				
Q90	**Numeracy**				**Literacy**		
	9/10	15/16	26/27		9/10	15/16	26/27
AUS	-5.534	-12.840	2.361	CZE	6.680	25.084**	6.471
AUT	-7.630	-35.140**	-10.002	FRA	9.743*	20.996**	-1.503
CAN	-2.678	-17.020**	-17.615	DEU	10.701*	30.424**	-1.688

CZE	-1.398	-28.070**	6.389	ISR	13.054*	-0.744	0.163
IRL	-0.442	-17.218*	-10.090	ITA	3.133	28.090**	2.483
ISR	-0.160	-27.532	-7.263	NLD	11.171**	19.562*	5.486
JPN	-14.278**	-22.330**	-11.762	NZL	27.184	30.520**	-11.942
KOR	-12.054**	-22.284*	-5.541	NOR	15.612	28.228**	0.222
NLD	-11.892*	-17.512*	-3.221	RUS	8.663	23.720**	2.782
NZL	-3.884	-10.238	-33.433	SWE	19.161**	31.174**	0.672
NOR	-12.098	-19.280*	-11.149	USA	13.328	11.622	-6.723
ENG	-14.346	-16.128*	-27.247	ENG	14.057	19.640*	-10.852
USA	-1.834	-18.440*	-29.969				

Note: Asterisks denote statistical significance at the at the 5% level (*) or at the 1% level.
Source: TIMSS 1995 (TIMSS & PIRLS International Study Center, Boston (MA), (1995), https://timssandpirls.bc.edu/timss1995i/Database.html), PISA 2000 (PISA Results (Database 2000), www.oecd.org/pisa/pisaproducts/database-pisa2000.htm), PIAAC 2012 (OECD. (2016) Survey of Adult Skills (PIAAC) www.oecd.org/site/piaac/publicdataandanalysis.htm) and, for reading, from PIRLS 2001 (TIMSS & PIRLS International Study Center, Boston (MA), (2001), https://timssandpirls.bc.edu/pirls2001i/PIRLS2001_Pubs_UG.html), PISA 2000 and PIAAC.

Table A.3. Evolution of gender gaps by country – moving cohort analysis

	Numeracy		Literacy	
	15-16	26-27	15-16	26-27
Australia	-0.230	-0.087	0.761**	0.182
Austria	-0.564**	-0.244*	0.666**	-0.069
Belgium-Flanders	-0.122	-0.244*	0.887**	-0.079
Canada	-0.209**	-0.197	0.750**	0.080
Czech Republic	-0.241*	-0.008	0.923**	0.021
Denmark	-0.290**	-0.370**	0.613**	-0.158
Finland	-0.012	-0.256*	1.279**	0.049
France	-0.279**	-0.133	0.748**	0.055
Germany	-0.244*	-0.148	0.844**	0.019
Ireland	-0.225*	-0.302*	0.685**	-0.149
Italy	-0.180	-0.092	0.928**	0.247
Japan	-0.164	-0.242*	0.715**	-0.088
Korea	-0.536**	-0.162	0.353*	-0.075
Netherlands	-0.159	-0.069	0.633**	0.124
Norway	-0.213**	-0.218	1.078**	0.019
Poland	-0.098	-0.135	0.961**	0.113
Russian Republic	0.038	0.121	0.836**	0.156
Spain	-0.352**	-0.156	0.552**	0.050
Sweden	-0.141	-0.185	0.747**	0.085
England (UK)	-0.157	-0.421**	0.743**	-0.102
United States	-0.177	-0.499**	0.653**	-0.171
Panel B	**Numeracy**		**Literacy**	
	15-16	**23-24**	**15-16**	**23-24**
Australia	-0.039	-0.053**	0.407**	0.089
Austria	-0.075	-0.338	0.460**	-0.114
Belgium-Flanders	-0.136*	-0.174**	0.277**	0.006
Canada	-0.107**	-0.395	0.311**	-0.139
Czech Republic	-0.133**	-0.126	0.311**	-0.162
Denmark	-0.160**	-0.087**	0.247**	0.108
Finland	-0.062*	-0.407*	0.436**	-0.125
France	-0.080*	-0.249	0.374**	0.074
Germany	-0.065	-0.270	0.443**	-0.031
Ireland	-0.124**	-0.243	0.295**	-0.096
Italy	-0.163**	0.154	0.381**	0.312
Japan	-0.078	-0.148*	0.221**	0.003

Korea	-0.210**	-0.222	0.210**	-0.121
Netherlands	-0.036	-0.186	0.217**	-0.015
Norway	-0.063*	-0.211	0.482**	-0.020
Poland	-0.049	-0.053	0.395**	0.148*
Russian Republic	-0.097*	0.007	0.282**	0.161
Slovakia	-0.169**	-0.060	0.321**	0.028
Spain	-0.080**	-0.053	0.391**	0.091
Sweden	-0.052	-0.048	0.375**	0.209
England (UK)	-0.071	-0.211**	0.269**	0.044
United States	-0.055*	-0.456**	0.311**	-0.142

Panel C	**Numeracy**		**Literacy**	
	15-16	**20-21**	**15-16**	**20-21**
Australia	-0.145**	-0.361*	0.365**	-0.087
Austria	-0.241**	-0.273**	0.433**	-0.121
Belgium-Flanders	-0.104*	-0.241*	0.350**	-0.031
Canada	-0.146**	-0.208*	0.306**	0.021
Czech Republic	-0.105	-0.180	0.449**	-0.151
Denmark	-0.113**	-0.130	0.285**	0.052
Estonia	-0.015	0.086	0.435**	0.220
Finland	-0.124**	-0.214	0.489**	0.106
France	-0.064	-0.302**	0.338**	-0.044
Germany	-0.200**	-0.229*	0.404**	-0.014
Ireland	-0.135**	-0.411**	0.314**	-0.185
Italy	-0.184**	-0.151	0.395**	0.021
Japan	-0.209**	-0.209	0.296**	-0.165
Korea	-0.101	-0.120	0.335**	-0.067
Netherlands	-0.152**	-0.136	0.220**	0.119
Norway	-0.067*	-0.218	0.439**	-0.061
Poland	-0.098**	-0.045	0.384**	0.133*
Russian Republic	-0.037	0.024	0.376**	0.083
Slovakia	-0.155**	0.008	0.400**	0.089
Spain	-0.089**	0.029	0.340**	0.135
Sweden	-0.050	-0.071	0.396**	0.124
England (UK)	-0.193**	-0.274	0.274**	-0.180
United States	-0.093**	-0.243		

Note: Asterisks denote statistical significance at the at the 5% level (*) or at the 1% level (**).
Source: PISA 2000 (OECD. (2006) PISA Results (Databases 2000, 2003, 2006), http://www.oecd.org/pisa/data/) and PIAAC for the 1984/85 cohort (www.oecd.org/site/piaac/publicdataandanalysis.htm); PISA 2003 and PIAAC for the 1987/88 cohort; and PISA 2006 and PIAAC for the 1990/91 cohort.