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Education systems, education reforms, and adult skills in the Survey of Adult Skills (PIAAC)

Huacong Liu

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Education systems, education reforms, and adult skills in the survey of adult skills (PIAAC)

OECD Education Working Paper No. 182

Huacong Liu, OECD.

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Abstract

This study uses the PIAAC data to examine the relationships between education system characteristics (e.g. early tracking and vocational education orientation) and distributions of adult numeracy skills. It also investigates the effects of postponing the tracking age and easing university access for students on a vocational track on the average skills and different percentiles of the skills distribution.

Correlational analysis suggests that education systems with more students enrolled in vocational tracks have on average higher levels of numeracy skills and more compressed skills distributions between the 50th and 90th percentiles.

Further analysis suggests that postponing the tracking age among 14 European countries does not have a significant effect on the average skills of the population. However, it increases skills for individuals at the 10th, 20th, and 30th percentiles of the skill distribution.

Expanding university access is associated with an increase in numeracy skills, particularly for individuals at the bottom three deciles of the distribution.

Résumé

Cette étude utilise les données du PIAAC pour examiner les relations entre les caractéristiques du système d'éducation (par ex. dépistage précoce et orientation professionnelle) et la répartition des compétences en numératie des adultes. Il examine également les effets que le report du suivi de l'âge et un meilleur accès à l'université pour les étudiants en formation professionnelle ont sur les compétences moyennes et sur les différents percentiles de la répartition des compétences.

L'analyse corrélationnelle suggère que les systèmes d'éducation comptant un plus grand nombre d'élèves inscrits dans les filières professionnelles ont en moyenne des niveaux plus élevés de compétences en calcul et une répartition des compétences plus resserrée entre les 50e et 90e percentiles.

Une analyse plus poussée suggère que le report de l'âge de suivi dans 14 pays européens n'a pas d'effet significatif sur les compétences moyennes de la population. Toutefois, il permet d'accroître les compétences des personnes qui se situent aux 10e, 20e et 30e centiles de la répartition des compétences.

L'élargissement de l'accès à l'université est associé à une augmentation des compétences en numératie, en particulier chez les personnes se situant dans les trois derniers déciles de la répartition.

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Introduction

Schooling plays a fundamental role in the accumulation of foundational skills. Policy makers, intergovernmental organisations, and researchers look to education and training systems to provide students with the foundation skills required to engage in further learning, and adapting to changes in future labour demands. Yet recent evidence demonstrates a decline in literacy and numeracy proficiency of adults between mid-1990 and 2012 across a subset of the OECD countries (Paccagnella, 2016). The deterioration of these foundational skills is even acute for young adults (25-34 years old) and among individuals with upper-secondary and post-secondary degrees. This suggests that improving the effectiveness of schools in transmitting foundational skills, and at the same time designing institutions that can sustain those skills along the life cycle remain challenging for countries.

In taking up these challenges, it is important to understand the differences in the design of educational systems[1] and how these differences contribute to cross-country variations in the returns to schooling as measured by literacy and numeracy skills. Earlier studies suggested cross-country differences in school organisation contribute as much as family background does to the considerable difference in student achievement in early ages (i.e. 10, 14, and 15 years old in Woessmann, 2016)[2]. Among those, tracking and prevalence of vocational education are two salient features of school organisation that are most pertinent to the accumulation of foundational skills (Brunello and Checchi, 2007[8]; Brunello and Rocco, 2015[3]).

These two aspects of school organisation exert influence on the accumulation of skills through peer effects (Hoxby and Weingarth, 2005[3]), content of curriculum, and teacher efforts (e.g. Duflo, Dupas and Kremer, 2011[3];). Proponents of tracking systems stress the positive complementarity among peers with similar abilities, whereas opponents argue that tracking may exacerbate initial socio-economic disadvantages and thus prevent disadvantaged students from pursuing further learning. Vocational orientation of an education system not only affects the accumulation of general versus specific skills through the content of curriculum, but it can also change the composition of student body allocated to each track, therefore affecting skill accumulation through the channel of peer effect.

[1] The terms school design, education system design, or education system characteristics are used interchangeably in this paper, all referring to "the institutional set-up that characterises compulsory and post-compulsory education, starting from pre-primary and ending with tertiary education" as discussed in Brunello and Checchi (2007[2]) and Braga, Checchi and Meschi (2013[3]).

[2] In this comprehensive review of both descriptive studies and studies using casual inference methods, Woessmann (2016) compares the relative contributions of factors influencing international differences in student achievement. Apart from family background, these factors include inputs to the school systems (financial resources, class size, instruction time, and teacher quality), and institutional structures of school systems such as external exams, tracking, etc. Evidence strongly suggests that the considerable differences in student achievement across countries are systematically related to differences in the organisation and governance of school systems.

Because of their direct influence on the initial cycle of skill accumulation and the widely accepted view that initial *skill begets* further *skill* (Cunha and Heckman, 2006[7]; Heckman, 2000[1]; 2008[2]), these two aspects of school design lie at the centre of education policy debates in many countries.

Against the backdrop of these policy debates and following the earlier work by Brunello and Checchi (2007[8],) this paper provides new evidence on the correlational relationship between education system characteristics and the return to schooling (as measured by skills acquisition) and examines how education reforms affect the accumulation of foundational skills in the long run. To do so, the paper analyses data from the OECD PIAAC survey and aims to delineate a complete picture of the joint distribution of countries' education system characteristics and individuals' foundational skills in literacy and numeracy. More importantly, coupled with education reform data in 17 European countries (Braga, Checchi and Meschi, 2013[9]), the long-term effects of education reform towards de-tracking and opening up university access on foundational skills in numeracy and literacy are examined.

Two policy-relevant questions are addressed:

1. How are education system features such as early tracking and vocational education orientation correlated with the distribution of skills?
2. How do education reforms towards de-tracking and opening up university access affect individuals' skills and the skill distribution in the long run?

Previous studies investigating the role of school institutions on individuals' skills have mainly focused on cognitive skill tests taken at age 10, 13 or 15 before the impact of school designs get fully unfolded, or restricted the investigation to either early tracking or vocational education orientation. This paper follows Brunello and Checchi (2007[8]), Braga, Checchi and Meschi (2013[9]), and Heisig and Solga (2015[10]), improving over previous studies in the following ways. First, it updates Brunello and Checchi (2007[8]) by drawing evidence from more recent cross-country data on adult skills (PIAAC 2012 and 2014). Second, instead of examining the effects of education reforms on years of schooling, as done by Braga, Checchi and Meschi (2013[9]), this study investigates the long-term effects on adult skills—a more accurate measure of human capital (Hanushek et al., 2015[1]) and provides a complete picture of these relationships instead of focusing on a subgroup of the population as is the case in Heisig and Solga (2015[10]).

Thirdly, this paper focuses on the differences of skill distributions across types of school systems. It examines the effects of changing tracking age and easing university access for vocational tracked students on individuals at different percentiles of the distributions as well as the average skills of the population.

The main goal of this paper is to explore the relationships between schooling systems and individual skills. Educational system designs such as tracking regimes or vocational education concentration often vary slightly or not at all within countries (Braga, Checchi and Meschi, 2013[3]; Brunello and Checchi, 2007[2]; Hanushek and Woessmann, 2010[3]; Hanushek, Piopiunik and Wiederhold, 2014[4]). Therefore, it is difficult to identify the impact of school design just using national data sets; whereas an international perspective provides an opportunity for comparisons. This study exploits both the within- and across-country variation among 17 countries in education reforms to examine their effects on adult skills in the long run.

The rest of the paper is organised as follows. Section 2 reviews the existing literature on tracking, vocational education orientation, and the development of foundational skills. Section 3 describes the data sets used in this study and provides descriptive patterns of education systems and skills distributions. Section 4 presents the moderation models and econometrics strategy to study the effects of education reforms on adult skills. Section 5 presents the results. Discussions are in Section 6.

1. Related literature

Classic human capital theory identifies formal education as the major channel towards human capital accumulation, and is based on the idea that schooling enables to acquire productive skills (Becker, 1964[4]; Mincer, 1975[4]). In particular, education can provide students with general and specific skills, and the balance between these two differs across educational systems. Two aspects of education systems, early tracking and vocational education orientation are the most salient features of education systems that affect this balance in individuals' accumulation of skills and skill distributions at national level.

1.1. Evidence on vocational education orientation and skills

The United States is the classic example of an educational system strongly oriented towards providing general qualifications, while most European countries have established vocational training programmes as part of their education systems (Muller and Gangl, 2003[3]). Among European education systems, wide variations exist regarding the institutional structures of vocational training. Germany, Austria and the Netherlands exemplify the traditional vocation-oriented systems that feature extensive vocational training through apprenticeship programmes or occupationally specific training in vocational schools. England (United Kingdom), France, and Sweden rely on a mix of academic and vocational tracks and secondary level schools in conjunction with small apprenticeship programmes[3] (Muller and Gangl, 2003[3]). On average, 45% of upper-secondary students enrol in vocational programmes across OECD countries in 2012 (Kuczera, 2017).

Proponents of vocational education emphasise the easy transition from school to work (Quintini and Manfredi, 2009); while opponents argue that vocational education may harm individuals' employment and earnings prospects later in life because specific skills become quickly outdated in modern economies experiencing rapid technological changes (Krueger and Kumar, 2004[4]; Wolter and Ryan, 2011[4]). At the centre of the debate is the issue of how adaptable previously vocational educated individuals are when facing structural changes in the economy.

However, identifying the effect of general versus vocational education on employment outcomes is challenging. The ideal data will come from a random assignment of two groups of individuals into vocational and general education tracks, and allocating them to the same type of jobs. Then any difference in their labour market outcomes during an economic change could be attributed to the initial differences in the type of education. However, such dataset is non-existent.

In reality, the inherent challenge in using cross-sectional multi-country data to identify the impact of early education type on employment outcomes arises from the non-random sorting of students into different educational tracks. The assignment is a process

[3] See Kuczera (2017) for a cost and benefit analysis of apprenticeship programmes across a subset of OECD countries.

influenced by a number of individual characteristics such as family background, academic performances, parental expectation, individual ability, etc. Longitudinal cohort data containing rich individual information may overcome the self-selection issue by employing certain quasi-experimental methods. To the end of being able to control for pre-selection ability or academic performance, it has advantages over large-scale cross-country data which often lacks information.

The inherent challenge in using cross-sectional data to identify the impact of educational type on employment outcome partially explains the mixed findings in this line of literature. By and large, studies using large-scale cross-country data such as Brunello and Rocco (2015[3]), Hanushek et al., (2017[3]), Forster, Bol and van de Werhorst's (2016) and Hampf and Woessmann's (2017[4]) found a similar pattern: namely, that individuals with vocational education are more advantageous than individuals with general education in initial labour market outcomes, yet these advantages faded away later in life. It is worth noting that the cross-over age when general education becomes more advantageous differs when different labour market outcomes are examined. The turning point is earlier for lifetime income than for the probability of being employed.

Results from using pooled data (Brunello and Rocco, 2015; Hanushek et al., 2017) differ from those country-by-country (Forster et al., 2016) or by country-group analyses (e.g. Hampf and Woessmann, 2017). Due to the inability of fully addressing the non-random allocation of workers to jobs using cross-sectional data, any different results obtained across countries might be largely capturing the labour market structure differences instead of identifying the real impact of education type on employment outcomes.

As a matter of fact, the Hanushek et al. (2017) study found that the present value of lifetime earnings favors those with a general education in Germany and Denmark. However, workers in Switzerland with vocational education have eight percent higher lifetime earnings than workers with general education. The authors commented that these differences in age and lifetime earnings between the two education types across three countries might be attributed to differences in their economic structures.

Similarly, different results found in Brunello and Rocco (2017[4]) and Golsteyn and Stenberg's (2017) are due to the difficulty posed by using longitudinal cohort studies of a single country in addressing the non-random sorting into occupations. Brunello and Rocco (2017[5]) did not find any later employment disadvantages of vocational education among British individuals born in the United Kingdom in 1958. Golsteyn and Stenberg (2017) found a change to the disadvantage of vocational education at the start of the 1990s for a cohort of males born in Sweden between 1955 and 1963. Yet, this pattern was not found among Sweden's females.

This present study cannot overcome the self-selection issue in educational sorting either. Yet, it answers a different set of questions from those addressed in the above-mentioned studies, particularly in Brunello and Rocco (2015[3]) where the effect of education type on adult skills is examined. Brunello and Rocco focused on individual variations within countries to examine the relationship between different types of education and skills. This study exploits cross-country variations in the prevalence of vocational education and tracking intensity to examine the correlations between these two dimensions of education system and individuals skills.

In a further step, the paper investigates the effects on individual skills of easing university access for vocational-tracked high school students by exploiting the variations over time and across countries of these reforms.

1.2. Evidence on tracking and foundational skills

Early tracking has been found to exacerbate the impact of socio-economic background on educational attainment (e.g. Dustmann, 2004[7]; Meghir and Palme, 2005[5]; Pekkarinen, Uusitalo and Kerr, 2009[4]; Schnepf, 2002[6]) and postponing tracking tends to increase the average years of schooling completed by the population and decrease intergenerational persistence in educational attainment (Braga, Checchi and Meschi, 2013[4]). However, when it comes to the effect on average school performance or measured cognitive skills, there is no consensus among the existing empirical research (Duflo, Dupas and Kremer, 2011[4]; Figlio and Page, 2002[4]; Oosterbeek and Webbink 2004[4]).

Koerselman (2013) studied the incentive effects of curriculum tracking, and found robust evidence for such effects, reflected in higher test scores during the years before tracking starts. In the existence of incentive effects, the value-added specification controlling for pre-tracking achievement (e.g. Hanushek and Woessmann, 2006) leads to downward biased estimates of the mean effect of tracking.

Heisig and Solga (2015[13]) incorporated both features of school design - early tracking and vocational education orientation, and studied how these two features correlated with country variation in the mean numeracy skills of a subgroup of the population – individuals attained less than tertiary level of education. Their findings indicated that tracking amplified skills gaps between adults with less than upper-secondary degrees and adults with upper-secondary or non-tertiary post-secondary degrees. This gap in numeracy skills was mitigated by a greater emphasis on vocational education in the upper-secondary level. Their explanation is that the labour market in vocational education prevalent countries incentivises and reward individuals graduating from vocational tracks therefore there is a greater level of learning efforts exerted than in general education oriented countries.

1.3. Evidence on education systems and skills over the life cycle

A couple of studies examined the evolution of skills after compulsory schooling by comparing skills of 15-year old students in the Programme for International Student Assessment (PISA) 2000 and the 25-29 age cohort in the Programme for the International Assessment of Adult Competencies (PIAAC) 2012. Although it is hard to discern the mechanisms of skill evolution into early adulthood without longitudinal datasets, these descriptive studies shed light on the skill evolution patterns across country post compulsory schooling.

For instance, Borgonovi et al. (2017[13]) analysed the individual level PISA 2000 and PIAAC 2012 data sets, and found that between age 15 and 27 socio-economic disparities (measured by the number of books at home) in literacy increased in most countries that participated in both studies, the gap decreased in Germany and Korea.

Drawing upon the country-level PISA 2000 and PIAAC 2012 data, Green et al. (2015[9]), and Green and Pensiero (2016[10]) found that the distribution of literacy and numeracy skills became more dispersed in England (United Kingdom), Canada, Ireland, Northern Ireland (United Kingdom), and the United States, and narrowed in Austria, Belgium, Germany, Czech Republic, Estonia, Poland, and the Slovak Republic.

In a further analysis, the authors categorised countries by the percentage of students having college-educated parents in the academic or vocational track. The idea is the

higher the percentage, the higher the chance there is for social mixing among students with different social-economic background. By this grouping, they found that countries where greater decrease of inequality of skills was observed between the two cohorts, there was greater social mix in their vocational programmes, such as Norway, Denmark, Finland, Germany and Japan.

However, overall there is no clear pattern between countries education system characteristics and trends in skills evolution across socio-economic groups between 15-years-old in PISA and young adults in PIAAC. Although Germany sees shrinking of skill gaps between students with low and high socio-economic status, absent analysis using longitudinal data, it is hard to attribute this to Germany's strong vocational education training system.

2. Data

2.1. PIAAC

The primary data sources for this study are the first two rounds of PIAAC. Also called the Survey of Adult Skills, PIAAC is an ongoing data collection effort of the OECD, with 24 countries/subnational entities participating in the first round of data collection in 2008/13. The second round was administered in nine additional countries in 2012/16. Round three will be conducted in five additional countries and the United States between 2016 and 2019.

PIAAC is a household-based study. The target population is defined as "all non-institutionalised adults between the ages of 16 and 65 whose usual place of residence is in the country at the time of data collection. Adults are to be included regardless of citizenship, nationality or language" (OECD 2013[2]). Trained interviewers administered the background questionnaire and the direct assessment to representative samples of the target population. Sample sizes varied from 3 761 in Northern Ireland (United Kingdom) to 27 285 in Canada. PIAAC assesses three domains of foundation skills - literacy, numeracy, and problem-solving in a technology-rich environment. The background questionnaire collects rich information on participants' demographic characteristics, socio-economic status, educational attainment, etc.

The subsequent analysis includes two domains of foundational skills measured in PIAAC, literacy and numeracy. The proficiency of each respondent in these domains is expressed by 10 plausible values that were obtained from calibrating, analysing, and scaling PIAAC cognitive item responses (OECD 2013[2]). All analyses in this study took into account both the sampling error component and the variance due to imputation of proficiency scores.

The PIAAC Background Questionnaire contains a wide range of information that can be used as independent variable in regression analyses, such as completed years of schooling and demographic characteristic such as gender, immigration status, and parental highest level of education. Country fixed effects are also used in the empirical analysis to control for country-specific time-invariant characteristics, such as education spending, teacher quality, etc. Birth-year fixed effects are used to account for common factors affecting individuals born in different countries in the same year (for instance the global financial crisis).

2.2. Analytical sample

In the subsequent analysis, two different subsamples are used. In the simple correlational analysis, 27 countries were matched between the PIAAC participating countries and those having education system measures constructed in Bol and Werfhorst (2013[1]). These countries are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, England (United Kingdom), Estonia, Finland, France, Germany, Ireland, Israel, Italy,

Japan, Korea, New Zealand, Netherlands, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, Turkey, and the United States.

The indicators are representative of countries' education system characteristics in 2002. The sample is restricted to respondents aged 20-35 at the time of survey for each of these 27 countries. Although covering a slightly broader age range, these individuals were most likely affected by education system features in 2002 when they faced upper-secondary level schooling decisions. Individuals who have lived in the surveyed country for less than five years are also excluded, as they were unlikely to be affected by the host country's secondary and upper-secondary school designs in 2002. These restrictions yielded a sample of 53 831 observations including 16 birth-year cohorts from 27 countries.

When estimating the effect of educational reforms, both over-time and across-country variations in reforms are exploited. Yet available data points of education reforms were originally drawn from the Eurydice whose coverage only extends to European countries. Observations from other parts of the world thus were excluded from this part of the analysis. This is not ideal given that a large part of the variation in these two dimensions of education system designs comes from countries outside Europe, such as the United States and Canada. It renders the risk of not having enough cross-sectional variations of education policy changes by dropping those observations. Fortunately, the results indicate that even within the 14 European countries where education reform data is available, heterogeneous effects of education reforms on adult skills are still evident. All birth cohorts contained in the PIAAC dataset are used for this step of the analysis. This yields a sample of 102 391 observations across 17 European countries in examining changing tracking age and expanding university access.

2.3. Tracking and vocational education orientation indices

Indices on tracking and vocational orientation of national education systems are drawn from Bol and Werfhorst (2013[7]). The authors gathered data from the OECD and United Nations Educational, Scientific and Cultural Organization (UNESCO), including cross-national student achievement tests such as Trend in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA). Indicators of early tracking and vocational orientation were compiled by conducting factor analysis using these data from the OECD and UNESCO across educational systems.

The level of tracking was constructed by performing a principal factor analysis on three country-level variables including the age of first selection, the percentage of the total tracked curriculum, and the number of tracks that are available for 15-year-olds. As discussed by Bol and Werfhorst, all three indicators emphasised different aspects of tracking and it made sense to use all three of them for the construction of a new indictor for tracking. A principal factor analysis was conducted and the factor loadings were saved as regression coefficients. By doing so, all countries got a relative score on the index of tracking with a mean of 0 and a standard deviation of 1. This indicator ranges from -1.32 for the United States and Canada to a positive value of 1.86 for Germany.

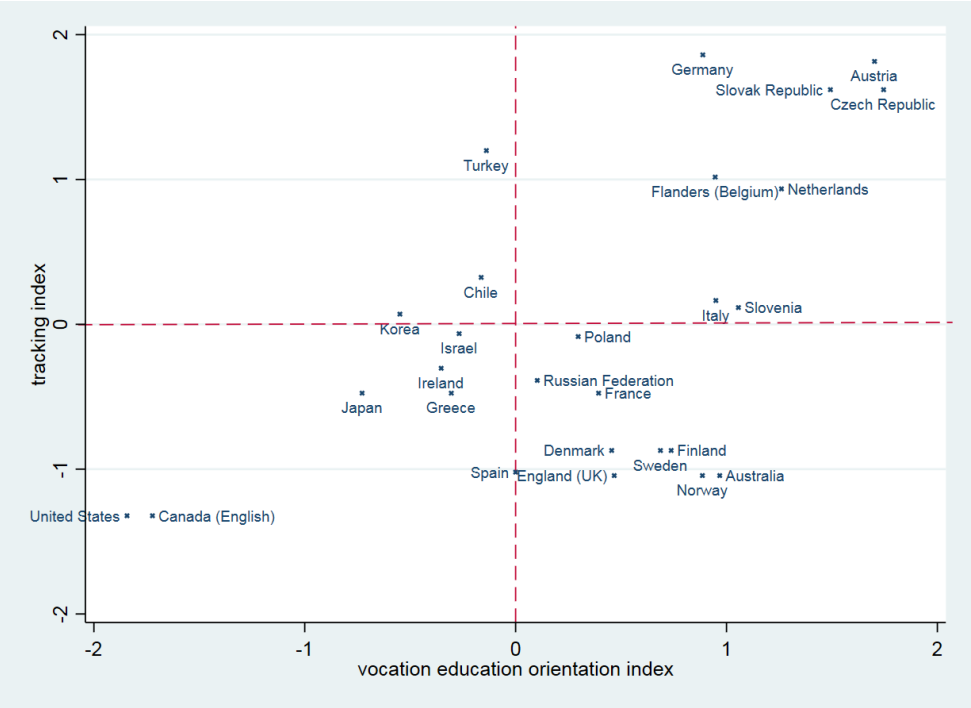
The vocational education orientation measures in Bol and Werfhorst's (2013[1]) intended to capture both the extent to which education provides students with vocational skills and the specificity of skills in education. The former was equated with the prevalence of vocational enrolment, which was measured by the percentage of students who are

enrolled in upper-secondary vocational programmes. For most countries examined in their study, vocational education occurred at the upper-secondary level, as is the case for the 27 countries examined in this study. Data on the enrolment in upper-secondary education was drawn from OECD's *Education at a Glance* 2005 report and UNESCO, and a principal factor analysis was performed using data from both sources to generate an index of the prevalence of vocational enrolment. Similar to the tracking index, the vocational education orientation index ranges from -1.84 to 1.74, with a mean of 0 and a standard deviation of 1.

The specificity of skills, reflecting the strength of the dual system, was proxied by the percentage of upper-secondary vocational education that took place in a dual system (Bol and Werfhorst, 2013). The data was drawn from OECD's *Education at a Glance* 2007 report which originally came from national statistics of upper-secondary students. Since data for a majority of countries analysed here are missing, the following analysis only uses the continuous index which measures the prevalence of vocational education.

Figure 1 displays those above-mentioned two dimensions of education systems. As shown in the graph, most education systems fall in quadrants I, III and IV with high-high or low-low, or low-high combinations of tracking and vocational education orientation. For example, the United States and Canada exhibit low level of early tracking (with a tracking index -1.32) and low level of vocational education orientation (-1.84 and -.72, respectively). Germany and Austria exemplify a combination of early tracking and high concentration of vocational education at the upper-secondary level (with vocational education orientation index being 0.887 and 1.701, respectively). Scandinavian countries follow the pattern of a high level of vocational education orientation and a low level of tracking. Education systems in Chile, Turkey and Korea provide examples of low orientation of vocational education yet high level of tracking. Overall, these two indicators are correlated with a Pearson correlation coefficient of 0.56 among these 27 education systems.

Figure 1. Education system indicators: tracking and vocational education orientation indicators



Note: The indicators are representative of countries' education system characteristics around 2002. As discussed in the paper, individuals' educational decisions at age 10 are usually influenced by these characteristics.
Source: Author's calculation using data compiled by Bol and Werfhorst (2013[7]), Hanushek, E. and L. Zhang (2011), http://thijsbol.com/data/.

2.4. Data on education reforms among 17 European countries

Taking a step further, this study investigates the long-term effects of postponing tracking and opening up university access on individuals' skills and the distribution of skills. To achieve this goal, education reform data compiled by Braga, Checchi and Meschi (2013[9]) is coupled with the PIAAC data. The educational reform data set covers reforms taking place in 17 European countries between 1929 and 2000. The primary data source was *Eurydice*, which provided detailed information on European education systems and policies. Country-specific descriptions of national education systems, and thematic studies on specific institutional features from *Eurybase* were used and integrated with data from other international sources such as OECD *Education at a Glance* and UNESCO country reports.

As shown in Annex Table 1, tracking ages range from age 6 (only in Spain between 1929 and 1969) to age 16 between 1929 and 2000 in the 17 European countries. Most common tracking ages were 14, 16, 11, and 10 during this period of time. Most countries experienced changes in tracking age, with exceptions of three countries – Austria (age 10), Germany (age 10), and the Netherlands (age 12). Braga, Checchi and Meschi (2013[9]) and previous empirical studies have shown that tracking age usually affects students'schooling choices at the age of 10. A tracking age is assigned to an individual based on the year when he/she was 10 years old.

University access expansion data is presented in Annex Table 2. The data points are step dummies that were created when reforms towards opening university access were repeated over the sample period. For instance, records showed that Germany had significant reforms in expanding university access for vocational high schools students in 1950, 1960, and 1989. A reform variable was constructed with zero before 1950, 1/3 between 1950 and 1959, 2/3 between 1960 and 1988 and 1 afterward. The compiled reform data indicated that all the 17 countries experienced some changes in university access for vocation high school students between 1929 and 2000.

2.5. Descriptive patterns of skills distributions

Table 1 displays Pearson correlation coefficients between education system indices of 2002 and average PIAAC scores and gaps at different percentiles of the numeracy and literacy distributions for 20-35-year-olds in 2012 or 2014/15 when the PIAAC interview was conducted. As far as vocational education orientation is concerned, the descriptive statistics indicate that countries with high prevalence of vocational education display high average skills in numeracy and literacy. In particular, the Pearson correlation coefficient for vocational education orientation and average PIAAC numeracy scores is 0.343 and significant at 95 percent confidence level. Highly tracked education systems have smaller gaps between the top (90^{th} percentile) and the bottom (10^{th} percentile) as well as gaps between the top (90^{th} percentile) and the median (50^{th} percentile) skills.

To give examples of skill distribution differences across countries, Figure 2, 3 and 4 plotted density distributions of numeracy skills among 20-35-year-old in countries with varying combinations of tracking and vocational education orientation. For instance, as shown in Figure 2, Germany displays a less dispersed upper tail of numeracy skill distribution than Finland does. These two countries exhibit similar levels of vocational education prevalence; yet Finland has a lower level of tracking than Germany does.

The contrast between the Netherlands and Korea in Figure 3 illustrates that although with similar levels of tracking, the Netherlands exhibits stronger mean and upper tail of numeracy skills than Korea does.

Germany and the United States are two extreme cases in these two dimensions of education system design. Germany has both higher tracking level and higher prevalence of vocational education than the United States. As indicated in Figure 4, Germany has a higher mean score of numeracy skills and a less dispersed upper tail of the skill distribution than the United States does. Yet, when it comes to top performers, Germany does not outnumber the United States.

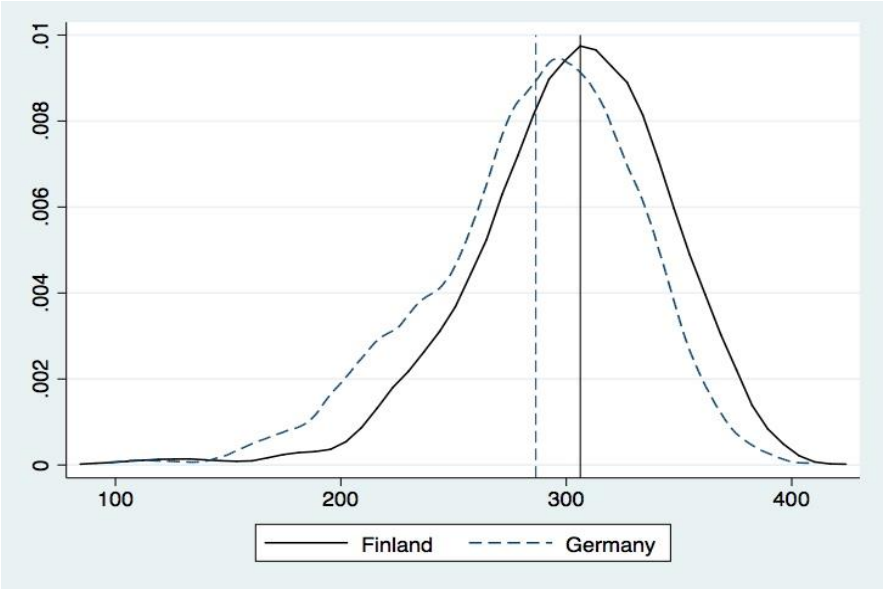
These descriptive statistics demonstrate only correlational patterns along two dimensions: countries' education system measures and average skills or skill gaps. Yet from these relationships we developed rational hypotheses that education system designs may change the relationships between years of schooling and skills at an individual level. The following analysis examined how each of these two schooling design features is correlated with the return to education measured by skills.

Table 1. Pearson correlations between education system characteristics and gaps in numeracy and literacy at different percentiles

	tracking	vocational education orientation
average numeracy	0.062	0.343*
	(0.767)	(0.086)
average literacy	-0.199	0.060
	(0.309)	(0.760)
numeracy gap 90th/10th percentile	-0.338	-0.265
	(0.098)	(0.191)
numeracy gap 90th/50th percentile	-0.427*	-0.349*
	(0.033)	(0.081)
literacy gap 90th/10th percentile	-0.445*	-0.230
	(0.025)	(0.257)
literacy gap 90th/50th percentile	-0.432*	-0.296
	(0.030)	(0.141)
number of countries	26	26

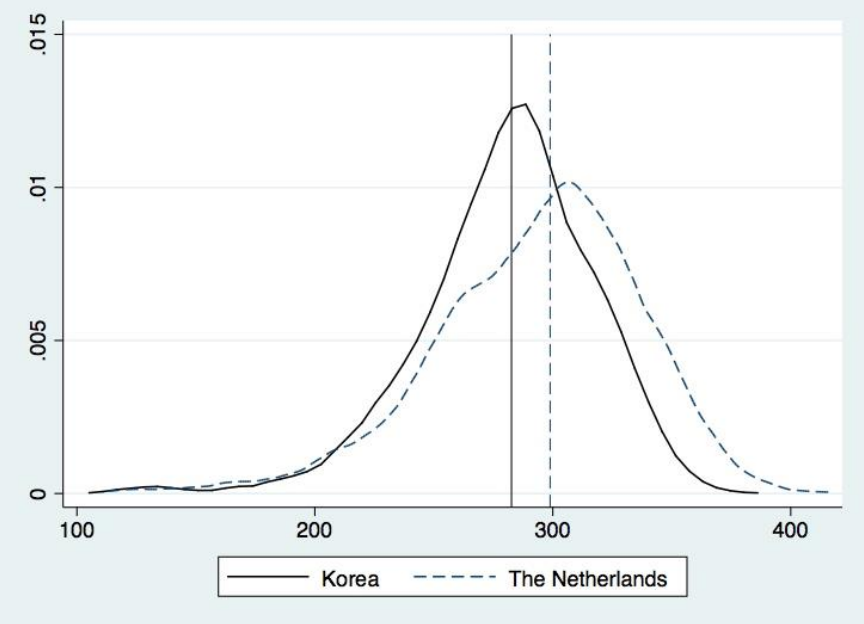
Note: Standard deviations in parentheses; * p<0.005.
Source: Tracking and vocational education orientation indicators, drawn from Bol and Werfhorst (2013) represent countries' education systems in 2002. Adult skills of the 20-35 age group in PIAAC 2012 and 2014 in the 27 countries examined are analysed, www.oecd.org/site/piaac/publicdataandanalysis.htm.

Figure 2. PIAAC numeracy skill density distributions and medians of 20-35-year-old in Finland and Germany



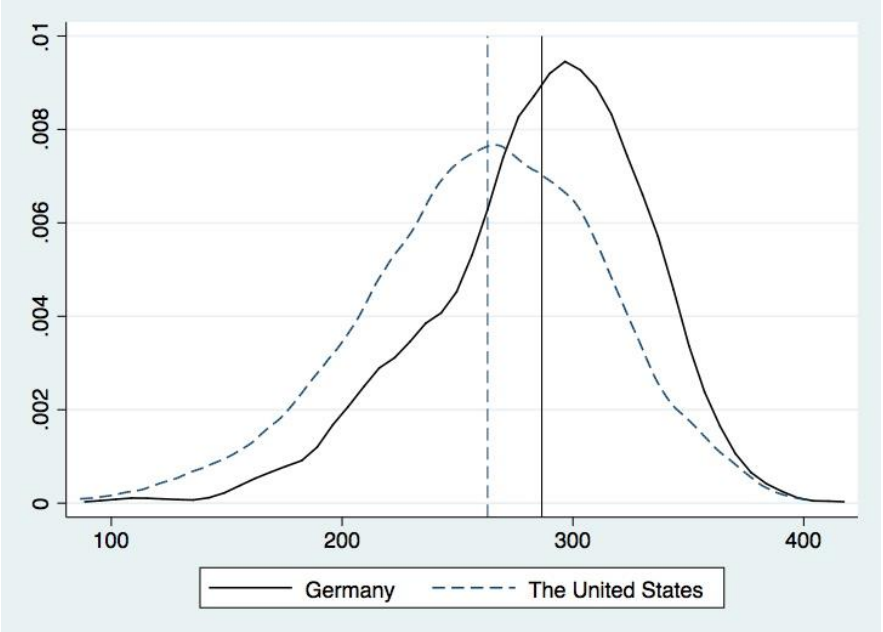
Source: Survey of Adult Skills (PIAAC) (2012), www.oecd.org/site/piaac/publicdataandanalysis.htm.

Figure 3. PIAAC numeracy skill density distributions and medians of 20-35-year-old in Korea and the Netherlands



Source: Survey of Adult Skills (PIAAC) (2012), www.oecd.org/site/piaac/publicdataandanalysis.htm.

Figure 4. PIAAC numeracy skill density distributions and medians of 20-35-year-old in Germany and the United States.



Source: Survey of Adult Skills (PIAAC) (2012), www.oecd.org/site/piaac/publicdataandanalysis.htm.

3. Correlational analysis and identification of the impact of education reforms

3.1. Education systems and individual skills

A basic model specification in equation [1] is followed to explore how individuals' characteristics are correlated with skills:

$$Skills_{ij} = \beta_0 + \beta_1 X_{ij} + \beta_2 Years_{ij} + \tau_c + \tau_t + \xi_{ij} \quad [1]$$

where $Skills_{ij}$ represents individual i's PIAAC numeracy or literacy scores; X_{ij} is a vector of individual i's demographic characteristics including gender, either parents has a university degree or not, and immigration status; $Years_{ij}$ indicates a continuous variable of individual i's years of schooling. Country fixed effects τ_c, and birth-year fixed effects τ_t are also included in this basic model. Country fixed effects control for country specific characteristics that could affect individuals' skills, for instance, average school quality, expenditure on education, etc. Birth-year fixed effects account for cohort effects influencing skills of individuals born in the same year.

In exploring the correlational relationships between schooling characteristics and skills, equation [2] includes either tracking or vocational education index as discussed in the previous section, removing the country fixed effects from equation [1]. This is because the country fixed effects dummies in Equation [1] would otherwise be perfectly collinear with the education system indicators.

$$Skills_{ij} = \beta_0 + \beta_1 X_{ij} + \beta_2 Years_{ij} + \beta_3 education_system_index_c + \tau_t + \xi_{ij} \quad [2]$$

Where $education_system_index$ refers to either the tracking index or the vocational education orientation index of country j.

The underlying idea is that the structure of educational institutions affect skills accumulated through formal schooling. In the case when students are streamed into different classrooms or school tracks based on previous academic achievements or future career aspirations, they are exposed to different peer groups from an early age. Extensive research has suggested the critical role peer effect plays in the education production function. Teaching content also varies between vocational- and academic-focused depending on the orientation of a track.

It is important to note that this analysis only reveals the correlational relationships between these two characteristics of schooling and individual skills. Such specifications in equation [2] suffer from omitted variable bias. Unlike equation [1] where country fixed effects could be included, in this specification, education system dummies lack within country variations, thus perfectly collinear with country dummies. Other country-level factors such as education expenditure which are not included here could also affect individuals' skills.

This step of analysis includes 27 countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, England (United Kingdom), Estonia, Finland, France, Germany, Ireland, Israel, Italy, Japan, Korea, New Zealand, Netherlands, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, Turkey, and the United States. Estonia does not have a tracking index due to missing values in PISA 2002, and New Zealand does not have a vocational education orientation index. When each of the two aspects of education system features was entered into the regression models, one of the two countries was dropped from the analysis. Since the indicators by Bol and Werfhorst (2013[7]) represented education system characteristics for years around 2002, the analytical sample is restricted to individuals aged 20-35 who were most likely to be exposed to schooling institutions around 2002.

3.2. Education reforms and individual skills in the long run

The average effects of the educational reforms on skills are obtained first from Ordinary least square (OLS) regressions. In addition, quantile regressions are conducted to test the heterogeneous impact of educational reforms along the distribution of skills because the distributional effects of education reforms are more of a concern here. It is possible that some reforms did not affect the mean level of skills, yet they only impacted skills of people at some parts of the distribution. For example, increasing the tracking age might potentially affect individuals at either the bottom or the top of the skill distributions but not individuals at the middle of the distributions. Therefore, unconditional quantile regression is a suitable strategy for this purpose (Firpo, Fortin and Lemieux, 2009[5]).

Unconditional quantile regressions allow an estimation of the impact of a small change in an independent variable on the entire unconditional distribution of the dependent variable (Firpo, Fortin and Lemieux, 2009[5]). This makes it possible to study the impact of a certain variable on inequality of the distribution of the outcome variable (in this case it is the skill inequality, similar to the case of wage inequality as studied by Paccagnella (2015[5])). For instance, if the estimated effect is larger at the bottom of the skill distribution than at the top, a marginal increase in the independent variable being examined will decrease skill inequality. So nine different unconditional quantile regressions are estimated, covering percentiles from the 10th to the 90th along the numeracy skills distribution for the pooled sample.

The specification is shown in the following equation:

$$Skills_{ict} = \gamma_0 + \gamma_1 X_{ict} + \gamma_2 schooling_years_{ict} + r_3 education_reform_{c,t+n} + \tau_c + \tau_t + \epsilon_{ict} \quad [3]$$

where $Skills_{ict}$ represents individual i's PIAAC numeracy or literacy scores; X_{ict} is a vector of individual i's demographic characteristics including gender, age, either parents has a university degree or not, and immigration status; $Years_{ict}$ indicates a continuous variable of individual i's years of schooling; and $education_reform_{c,t+n}$ representing country c's education reforms at time $(t+n)$ with n indicating the age when the reforms are supposed to affect individuals educational choices.

Specifically, two indices of reforms (change in tracking age and expansion of university access for vocational high schools) were included sequentially in the models. The former affects students' education choices at age of 10 and the latter at age of 15. Also included in the model were 50 birth-year cohort dummies indicated by τ_t, and 17 country/region dummies indexed by τ_c. These countries/regions are Austria, Czech Republic, Denmark,

Estonia, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Poland, Slovak Republic, Spain, Sweden, England (United Kingdom), Flanders (Belgium).

4. Results

4.1. Education systems and PIAAC skills

The investigation begins with a basic model of how years of schooling and other individual characteristics such as gender, parental education, and immigration status are correlated with numeracy skills. Model 1 in Table 2 has the most basic specification, where an individual's numeracy skills is a function of years of schooling, gender, parental education, immigration status, country and birth year fixed effects. Results show that each additional years of schooling is associated with about eight points increase in PIAAC numeracy scores, which are equal to 0.2 of a standard deviation (1 standard deviation equals 50 score points among all adults in PIAAC participating countries).

Females have lower numeracy skills on average than males, the gap being 13 points measured by PIAAC numeracy score. First-generation immigrants perform worse in numeracy tests than the native-born, the average gap being twice as large as the gender gap. Although the estimated coefficient is still negative for second-generation immigrants, it is no longer statistically significant. Socio-economic status, measured by whether either parent has a tertiary education, has a large, positive and statistically significant association with PIAAC numeracy.

Model 2 and 3 in Table 2 reports OLS regression results of equation 2, in which the correlational relationships between the return to education measured by PIAAC numeracy scores and education system characteristics in early tracking and vocational education orientation are presented. The sample included individuals aged 20-35 at the time of survey from 27 PIAAC participating countries. Due to the lack of data on tracking index for Estonia and vocational education orientation index for New Zealand, model 2 excluded participants from Estonia, and model 3 excluded observations from New Zealand.

Results from Model 2 and Model 3 suggest that each educational system characteristics is positively associated with individual skills, indicating that all else equal, individuals in countries with higher level of tracking and concentration of vocational education possess stronger numeracy skills. In particular, comparing the coefficients of the two education system characteristics suggests that vocational education orientation has a stronger association with skills than tracking does. The association between vocational education orientation and numeracy skills is 5.586, about 0.125 of a standard deviation. As mentioned in the previous section, albeit omitting other country-level factors that could affect skills, the coefficient of vocational education prevalence in this model specification indicates a positive correlation between the vocational education index and country fixed effects.

The cross-sectional data such as PIAAC does not allow for an understanding of the mechanisms underlying the high performances of vocational-oriented educational systems. Yet, using individuals' background information in the PIAAC data enables

hypothesis testing regarding possible channels of high proficiency of adults in vocational-oriented education systems.

First, high average PIAAC performances of adults in vocational-oriented education systems could be because of their high primary and secondary school quality. To test this, PISA 2000 scores were used as a proxy for primary and secondary school quality for the 20-35 years old in PIAAC. Regressing PIAAC numeracy scores on PISA mathematics scores suggested that PISA scores explained more than 60 percent of variations in average PIAAC numeracy performances across 27 countries. Furthermore, using teacher as a proxy for compulsory education quality, Hanushek et al. (2014[5]) found that teachers in vocational education oriented systems such as Germany, Finland, Belgium, Austria, and Sweden scored significantly higher in PIAAC literacy and numeracy than in countries like Canada and the United States. In this study, teachers were identified by the International Standard Classification of Occupations (ISCO) code from the PIAAC background questionnaire.

Second, the descriptive statistics from Section 3 and the correlational analysis indicated a high average performance and a compressed upper part of the skills distribution among adults in vocational education focused systems. This could indicate a lower skill premium associated with obtaining a tertiary education in vocational education prevalent countries than others. Skill premium is the difference between what skills would be in the absence of the tertiary education and what skills are in the presence of the tertiary education.

This hypothesis could be tested by splitting the sample between individuals whose highest educational attainment is a tertiary education (ISCED 5 and ISCED 5A) and those who have only obtained a highest level of upper-secondary (ISCED 3A-B, C long) or post-secondary, non-tertiary (ISCED 4A-B-C) education. Comparing numeracy score differences between these two categories of educational attainment across high VET countries (Germany and Austria) and low VET countries (Canada and the U.S.), the score differences are significantly lower in high VET countries compared to low VET countries (18 numeracy scores versus 37). It might be the case that vocational education concentrated systems have high-quality non-academic tracks and this increases the skills of individuals who do not acquire a tertiary education and consequently decreases the skill premium related to obtaining a tertiary education.

Third, the high proficiency in numeracy among adults in vocational education focused systems could be related to their frequent use of numeracy skills at work and in everyday life. Analysing the skill use information collected in the background questionnaire in PIAAC demonstrated some interesting patterns across education systems. Comparing the numeracy skill use at work between high VET countries (Germany and Austria) and low VET countries (Canada and the U.S.) among 20-35 year olds indicated that young adults in Germany and Austria exercise advanced mathematics skill such as simple algebra or formulas more often than young adults in the United States and Canada do. The former group on average practices these skills between less than once a month and less than once a week but at least once a month; whereas individuals in the latter group never or only use those skills less than once a month. These differences are statistically significant when skill use frequency at work or in everyday life is examined.

At the same time, young adults in the United States and Canada practice simple numeracy tasks more often than young adults in Germany and Austria do. These simple tasks involve calculating costs or budgets, and using or calculating fractions or percentages.

This step of simple correlational analysis inevitably suffers from omitted variable bias, nevertheless interesting patterns of skills distribution and education systems are revealed. The high mean and low variance, especially for the upper half of the skills distributions, of high VET countries are associated with a high-quality compulsory education, a high skill premium, and frequent use of advanced mathematics skills at work and in everyday life.

Table 2. Education system characteristics and individuals' numeracy skills

	Model 1	Model 2	Model 3
Years of schooling	8.123***	8.590***	8.433***
	(0.205)	(0.218)	(0.215)
Early tracking		3.138***	
		(0.526)	
Vocational education orientation			5.586***
			(0.572)
Female	-13.442***	-13.734***	-13.553***
	(0.910)	(0.933)	(0.922)
Either parent has college degree	13.870***	15.930***	17.321***
	(1.151)	(1.172)	(1.183)
1st generation immigrant	-26.762***	-27.420***	-28.197***
	(2.184)	(2.033)	(2.030)
2nd generation immigrant	-4.773	-5.548*	-5.063
	(2.903)	(2.757)	(2.813)
N (Observations)	53,831	51,457	52,183
N (Countries)	27	26	26
R-squared	0.380	0.324	0.332

Note: Not reported but included in all models are birth-year fixed effects, missing data dummy variables for parental education and immigration status. Model 1 also includes country fixed effects.
27 countries reported in Model 1 are Australia, Austria, Belgium (Flanders), Canada, Chile, Czech Republic, Denmark, England (United Kingdom), Estonia, Finland, France, Germany, Ireland, Israel, Italy, Japan, Korea, New Zealand, the Netherlands, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, Turkey, and the United States. New Zealand is excluded from Model 2 for lack of data on the vocational education index. Estonia is excluded from Model 3 for lack of the tracking index.
Standard errors in parentheses; * $p<0.05$ ** $p<0.01$ *** $p<0.001$.
Source: Survey of Adult Skills (PIAAC) (2012, 2014), www.oecd.org/site/piaac/publicdataandanalysis.htm.

4.2. Education reforms and effects on skills

A further step of this paper examined the long-term effects of education reforms towards de-tracking and opening access to universities on adult skills. This is achieved by combining the education reform data across 17 European countries (Braga, Checchi and Meschi, 2013[10]) with PIAAC. OLS regressions are run to first gauge the average effects of education reforms on numeracy and literacy skills. More importantly, unconditional quantile regressions analysis is conducted to estimate the impact of each of the education reforms on the unconditional distribution of skills.

4.2.1. Raising tracking age and long-term effects on skills

The OLS regression results following equation [3] indicate that postponing tracking by one year is associated with 0.083 points increase in numeracy skills (results in Table 3). Yet the coefficient of tracking age is not statisticially significant, implying that tracking on average does not alter the return to education measured by skills.

This could happen when early tracking hurts low performing students by putting them on tracks where schooling stops early or by preventing them from interacting with high-performing students. Whereas high performing students may benefit from early tracking and interacting with other strong peers; thus positive complimentarity may arise as a result of the early tracking for high performers. If this is the case, tracking on average does not affect the returns to education for the population.

Results from the unconditional quantile regression analysis following equation [3] confirmed these hypotheses. The results are plotted in Figure 5. They suggest that most of the benefits of increasing tracking age accrues to individuals with lower numeracy skills. The associations between postponing tracking and the increase in numeracy skills for individuals at the bottom 20 percentile of the distribution are higher than the average effect on the population. The effects of delaying tracking on individuals whose skills are between the 20^{th} and 50^{th} percentile are not significantly different from zero. For individuals at the upper half of the numeracy skill distribution (70^{th} – 90^{th} perentile), raising tracking age has negative associations with their numeracy skills, with the coefficient at the 90^{th} percentile being the smallest.

Overall unconditional quantile regression results suggest a tradeoff between equality and efficiency of affecting skills through postponing tracking age. Although on average raising tracking age does not affect the numeracy skills of the population, heterogenous effects along the distribution of skills are evident. In the long run, raising tracking age benefited individuals at the bottom of the skill distribution. Yet individuals with high proficiency level in numeracy benefited from tracking at an early age.

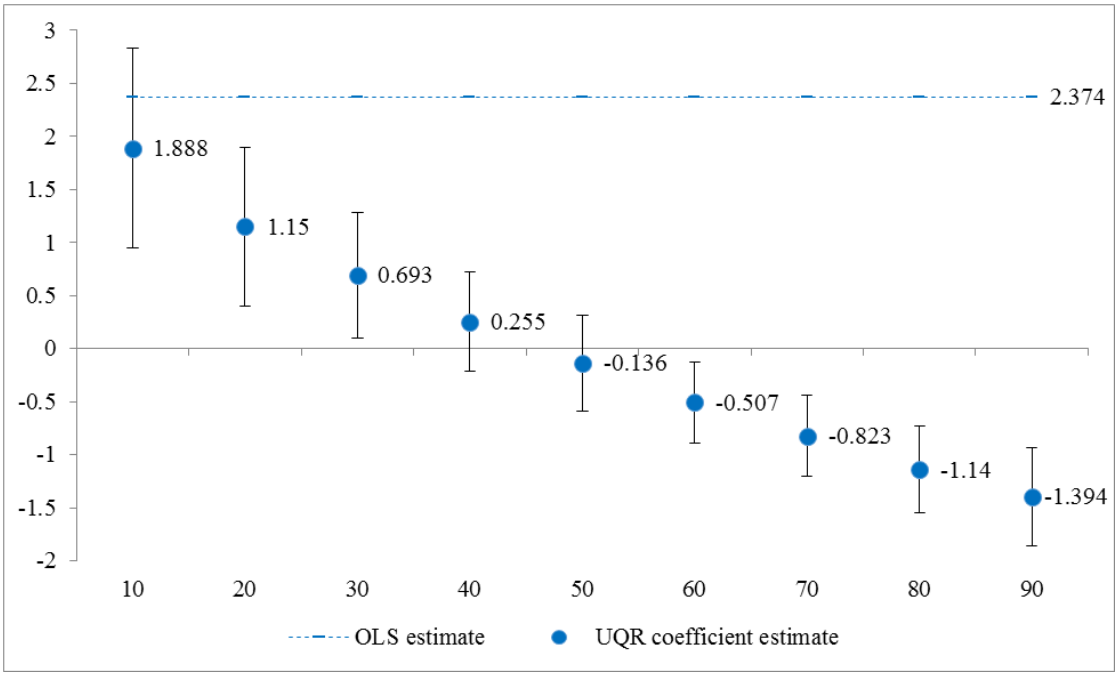
4.2.2. Expanding university access and effects on skills in the long run

The OLS regression results indicated that opening university access, on average, increased numeracy skills by 2.37 points (the first column in Table 4). Results from the unconditional quantile regressions are both presented in Table 4 and plotted in Figure 6. They indicate that individuals whose numeracy skills are between the 10^{th} and 30^{th} deciles benefited the most from expanding university access reforms. The size of the effects on the 10^{th} and 20^{th} percentiled individuals is equivalent to the effect of an additional year of schooling.

Overall, results from the unconditional quantile regressions demonstrate that education reforms towards de-tracking and opening access to university benefited individuals at the bottom more than at the top of the skill distributions. These reforms therefore reduced the skill gaps between the bottom and the top. Especially in the case of changing tracking ages, those changes significantly reduced skill inequalities in numeracy, the reduction mainly coming from increasing numeracy scores of individuals at the lower half of the skill distribution. The reforms towards opening up university access benefited individuals towards the lower end of the skills distribution, as well as elevating the average performance of the population.

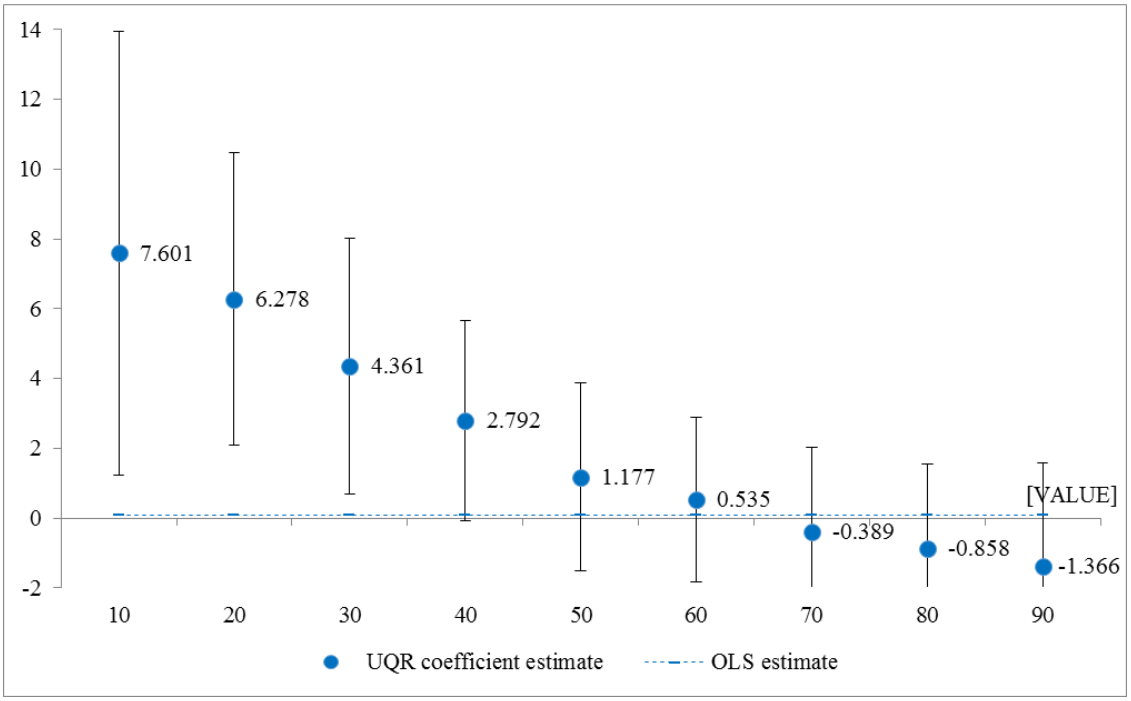
It is worth noting that in the majority of these 17 European countries being examined, the tracking age changes happened around the time that compulsory schooling laws also changed (Dincer, 2016) (see Appendix table 3 for years of law changes). For instance, Koerselman (2013) reported that the Swedish education reform in 1962 included pre-test curriculum, teaching style, and amount of compulsory education. So the coefficient estimates of changing tracking age are the combined effects of multiple mechanisms. As commented in Koerselman (2013), a policy experiment more relevant to tracking polices today would be if a country such as Germany with a modern vocational track were to postpone its tracking age.

Figure 5. Unconditional quantile regression estimates of the effect of tracking age change on numeracy skills across 17 European countries



Note: The horizontal axis represents the 10th to the 90th percentile points of the numeracy skills distribution among 17 European countries including Austria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Poland, Slovak Republic, Spain, Sweden, England (United Kingdom), Flanders (Belgium). The vertical axis marks the coefficient of each of the percentile in the unconditional quantile regressions specified in Model [3] when the effects of changing tracking age on adult numeracy skills were examined.
Source: Survey of Adult Skills (PIAAC) (2012, 2014), www.oecd.org/site/piaac/publicdataandanalysis.htm

Figure 6. Unconditional quantile regression estimates of the effect of opening university access on numeracy skills across 17 European countries



Source: Survey of Adult Skills (PIAAC) (2012, 2014), www.oecd.org/site/piaac/publicdataandanalysis.htm.
Note: The horizontal axis represents the 10th to the 90th percentile points of the numeracy skills distribution among 17 European countries including Austria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Poland, Slovak Republic, Spain, Sweden, England (United Kingdom), Flanders (Belgium). The vertical axis marks the coefficient of each of the percentile in the unconditional quantile regressions specified in Model [3] when the effects of expanding university access on adult numeracy skills were examined.

Table 3. Unconditional quantile regression estimates of the effect of tracking age change on numeracy skills across 17 European countries

	OLS	10th quantile	20th quantile	30th quantile	40th quantile	50th quantile	60th quantile	70th quantile	80th quantile	90th quantile
Schooling years	7.128***	9.553***	8.491***	7.860***	7.421***	6.951***	6.625***	6.106***	5.484***	4.736***
	(0.094)	(0.415)	(0.305)	(0.227)	(0.232)	(0.194)	(0.181)	(0.203)	(0.167)	(0.204)
Tracking age	0.083	1.888***	1.150**	0.693*	0.255	-0.136	-0.507**	-0.823***	-1.140***	-1.394***
	(0.161)	(0.471)	(0.374)	(0.295)	(0.234)	(0.226)	(0.190)	(0.190)	(0.203)	(0.231)
Female	-12.218***	-8.750***	-9.437***	-10.253***	-11.374***	-12.489***	-13.604***	-14.315***	-14.891***	-14.980***
	(0.510)	(1.406)	(0.962)	(0.846)	(0.769)	(0.717)	(0.749)	(0.795)	(0.891)	(0.862)
Either parent has college degree	13.971***	2.906*	8.059***	11.007***	13.611***	15.810***	17.887***	18.896***	20.034***	21.512***
	(0.759)	(1.480)	(1.199)	(0.973)	(1.052)	(1.005)	(1.172)	(1.182)	(1.365)	(1.536)
1st generation immigrant	-33.550***	-55.301***	-43.262***	-36.965***	-32.753***	-28.786***	-25.980***	-22.717***	-19.580***	-16.119***
	(1.194)	(3.944)	(2.444)	(2.158)	(1.725)	(1.435)	(1.361)	(1.282)	(1.273)	(1.218)
2nd generation immigrant	-11.678***	-12.655**	-11.132***	-12.064***	-12.919***	-13.872***	-14.695***	-13.327***	-10.559***	-7.183**
	(1.674)	(4.331)	(3.082)	(2.669)	(2.551)	(2.567)	(2.415)	(2.058)	(2.401)	(2.701)
Observations	102,391	102,391	102,391	102,391	102,391	102,391	102,391	102,391	102,391	102,391
R-squared	0.342	0.136	0.181	0.210	0.225	0.228	0.222	0.201	0.167	0.111

Note: Not reported but included in all models are individual's age, country fixed effects, birth-year fixed effects, missing data dummy variables for parental education and immigration status. 17 European countries include Austria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Poland, Slovak Republic, Spain, Sweden, England (United Kingdom), Flanders (Belgium).
Standard errors in parentheses; * p<0.05 ** p<0.01 *** p<0.001.
Source: Survey of Adult Skills (PIAAC) (2012, 2014), www.oecd.org/site/piaac/publicdataandanalysis.htm..

Table 4. Unconditional quantile regression estimates of the effect of opening university access on numeracy skills across 17 European countries

	OLS	10th quantile	20th quantile	30th quantile	40th quantile	50th quantile	60th quantile	70th quantile	80th quantile	90th quantile
Schooling Years	7.130***	9.589***	8.506***	7.867***	7.419***	6.942***	6.606***	6.079***	5.448***	4.694***
	(0.094)	(0.414)	(0.307)	(0.227)	(0.232)	(0.193)	(0.181)	(0.201)	(0.165)	(0.204)
University Access Reform	2.374*	7.601*	6.278**	4.361*	2.792	1.177	0.535	-0.389	-0.858	-1.366
	(0.988)	(3.179)	(2.099)	(1.829)	(1.436)	(1.349)	(1.180)	(1.205)	(1.204)	(1.470)
Female	-12.236***	-8.730***	-9.424***	-10.245***	-11.370***	-12.489***	-13.608***	-14.322***	-14.901***	-14.992***
	(0.508)	(1.403)	(0.960)	(0.844)	(0.768)	(0.717)	(0.749)	(0.796)	(0.892)	(0.861)
Either parent Has College Degree	13.936***	2.769+	7.985***	10.966***	13.603***	15.831***	17.939***	18.974***	20.139***	21.639***
	(0.761)	(1.479)	(1.202)	(0.973)	(1.051)	(1.005)	(1.170)	(1.182)	(1.367)	(1.540)
1st generation immigrant	-33.531***	-55.036***	-43.117***	-36.883***	-32.735***	-28.822***	-26.077***	-22.861***	-19.777***	-16.357***
	(1.199)	(3.946)	(2.440)	(2.159)	(1.725)	(1.443)	(1.365)	(1.293)	(1.279)	(1.221)
2nd Generation Immigrant	-11.682***	-12.436**	-11.050***	-12.032***	-12.944***	-13.942***	-14.835***	-13.514***	-10.808***	-7.478**
	(1.687)	(4.343)	(3.086)	(2.675)	(2.551)	(2.571)	(2.421)	(2.059)	(2.406)	(2.693)
Observations	102,391	102,391	102,391	102,391	102,391	102,391	102,391	102,391	102,391	102,391
R-squared	0.343	0.136	0.181	0.210	0.225	0.228	0.222	0.201	0.167	0.111

Note: Not reported but included in all models are individual's age, country fixed effects, birth-year fixed effects, missing data dummy variables for parental education and immigration status. 17 European countries include Austria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Poland, Slovak Republic, Spain, Sweden, England (United Kingdom), Flanders (Belgium).
Standard errors in parentheses; * p<0.05 ** p<0.01 *** p<0.001.
Source: Survey of Adult Skills (PIAAC) (2012, 2014), www.oecd.org/site/piaac/publicdataandanalysis.htm.

5. Discussion

This study set out to examine how different education systems fare in equipping individuals with foundational skills. It is well acknowledged and accepted that *skills beget skills,* and that foundation skills will help individuals regain new skills quickly in a fast changing technology-rich environment. The lack of ability to re-learn new skills prevents individuals from taking advantage of technological advances and from fully participating in the labour market. Thus, the strength of initial cycle of formal schooling in cultivating foundation skills in literacy and numeracy becomes a concern for policy makers, and an important issue to examine for researchers. In particular, education systems differ substantially in the level of tracking students by ability or career aspirations, and the prevalence of vocational education. These two aspects of school system designs are likely to affect skill accumulation in important ways, e.g. through peer effect or curriculum content. This study investigated how these features of formal education systems contribute differently to the accumulation of foundational skills in literacy and numeracy across education systems.

To do so, this study coupled PIAAC 2012 and 2014 data with data on education system characteristics and education reforms to examine these relationships. Results suggested that education systems with strong orientation towards vocational training exhibit high mean scores in both numeracy and literacy. These systems also demonstrated compressed upper part of the skill distribution compared to education systems that are not vocational-oriented. These patterns were related to the high quality of compulsory education of vocation education oriented systems, and smaller skill gap between college-educated individuals and those with only high school diplomas. By analysing the background information collected by the PIAAC, results also indicated that young adults in high VET countries such as Germany and Austria are more frequently exercising advanced mathematics skills such as algebra or formulas than young adults do in countries such as the United States and Canada.

With the data at hand, this study could not distinguish whether the high performances of vocational education focused systems were due to their educational system design. Yet, pairing the PIAAC data with education reforms data on raising tracking age and opening up university access showed interesting results.

The analysis on the impact of education reforms towards easing university access for vocational high schools suggested that these reforms significantly affected individuals at the lower deciles of the skill distribution rather than the top decile when numeracy was concerned. Thus, these reforms reduced skills inequalities between individuals at the top and bottom of the numeracy skill distributions.

The age at which tracking takes place was not found to have a significant effect on the average performance in numeracy. This is consistent with studies using longitudinal data of a single country. For instance, Kerr, Pekkarinen and Uusitalo's (2015[9]) found that the

de-tracking reform had no effect on the mean performance in the arithmetic or logical reasoning tests in Finland.

In examining the effect of changing tracking age along the skills distribution, results from this present study suggested that raising tracking age positively affected individuals at the bottom three deciles; yet the effects on individuals at the top deciles were negative. Overall, postponing tracking significantly reduced skill inequalities both in literacy and numeracy. The reduction comes from significantly increase skills of individuals at the lower half of the distribution.

It is worth noting that the majority of these 17 European countries being examined changed compulsory schooling laws around the time that the tracking age changed. So the coefficient estimates of changing tracking ages captured the combined effects of multiple mechanisms.

This exercise answered the questions this paper proposed to investigate, and it also leaves remaining questions for further investigation when richer individual longitudinal data becomes available. For instance, these results call for further examination of the black box of early tracking. One pattern observed in this study is that countries with high levels of tracking have less dispersed skill distributions at the upper half. Empirical studies such as Green and Pensiero (2016[5]) and Borgonovi et al. (2017[6]) shed light on different patterns of skill evolution among countries with varying levels of tracking. However, without longitudinal micro-level data, it is hard to further analyse how patterns of skill distribution can be attributed to the tracking feature of education system design. Moreover, other features of an educational system might interact with tracking or de-tracking policies in an important way. A field study by Duflo, Dupas and Kremer (2011) suggested that teachers' efforts can crucially affect the success or otherwise of reforms that target the tracking age. Providing incentives to teachers to tailor their instruction level and to teach to the median students, even low-achieving students in the lower track would benefit from tracking (Duflo, Dupas and Kremer, 2011).

Thiemann (2017) also focused on the school design and distribution of students' performances. She developed a model of student decision making that shows that it depends on the culture of competitiveness in a country or region whether it is optimal to choose a school design with ability tracking or comprehensive schooling. Taking into account students with heterogeneous abilities, Thiemann (2017) showed that the average performance in competitive cultures is maximised under comprehensive schooling and in non-competitive cultures under ability tracking. Segregation of abilities in non-competitive cultures, however, leads to a higher dispersion of performances.

These recent empirical and theoretical work related to tracking indicate that much is still unknown about tracking itself and the effects of tracking on student performances or measured skills. This paper can be seen as setting the stage for future research on examining the long term effects of early tracking on skills.

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Annex A.

Table A A.1. Tracking age changes in 17 European countries between 1929 and 2000

Country	Year	Tracking Age
Austria	1929	10
Flanders (Belgium)	1929	14
Flanders (Belgium)	1971	15.5
Flanders (Belgium)	1985	12
Czech Republic	1929	11
Czech Republic	1948	15
Czech Republic	1990	11
Denmark	1929	14
Denmark	1975	16
England (UK)	1929	14
England (UK)	1944	11
England (UK)	1966	16
Estonia	1929	16
Estonia	1935	14
Estonia	1941	15
Estonia	1959	16
Finland	1929	13
Finland	1972	16
France	1929	11
France	1975	15
Germany	1929	10
Ireland	1929	12
Ireland	2000	15
Italy	1929	11
Italy	1963	14
Netherlands	1929	12
Norway	1929	14
Norway	1969	16
Poland	1929	14
Poland	1999	16
Slovak Republic	1929	14
Slovak Republic	1944	15
Slovak Republic	1953	14
Slovak Republic	1990	10
Spain	1929	6
Spain	1970	14
Spain	1990	16
Sweden	1929	12
Sweden	1962	16

Table A A.2. Education reform towards opening up university access in 17 European countries between 1929 and 2000

Country	Year	University Access Reform Index
Austria	1997	1
Flanders (Belgium)	1965	1
Czech Republic	1990	1
Denmark	1967	0.3
Denmark	1981	0.67
Denmark	1991	1
England (UK)	1963	0.5
England (UK)	1987	1
Estonia	1995	1
Finland	1966	0.5
Finland	1991	1
France	1986	0.5
France	1993	1
Germany	1950	0.3
Germany	1960	0.67
Germany	1989	1
Ireland	1992	0.5
Ireland	1995	1
Italy	1969	1
Netherlands	1978	1
Norway	1969	1
Poland	1945	0.25
Poland	1949	0.5
Poland	1991	0.75
Poland	1997	1
Slovak Republic	1948	1
Slovak Republic	1990	0
Spain	1972	0.5
Spain	1976	1
Sweden	1967	0.5
Sweden	1977	1

Table A A.3. Change in compulsory schooling laws in 15 European countries

Country	Year	Pre-reform CS	Post-reform CS
Austria	1966	8	9
Belgium	1983	8	12
Czech Republic	1990	8	9
Denmark	1971	7	9
Estonia	1992	8	9
Finland	1972	6	9
France	1959	8	10
Ireland	1972	8	9
Italy	1963	5	9
Netherlands	1975	9	10
Poland	1961	8	9
Slovak Republic	1984	9	10
Spain	1970	6	8
Sweden	1962	7	9
United Kingdom	1972	10	11

Source: Dincer, M. A., (2016)