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Alison Cathles
UNU-MERIT and Maastricht University

Jo Ritzen
UNU-MERIT, Maastricht University and IZA

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Money Counts, but So Does Timing: Public Investment and Adult Competencies*

Numeracy skills of adults within and across 12 different countries in 2011 are strongly associated with the accumulated public investments in education received by these adults during their schooling. This paper confirms existing evidence that the timing of educational investments is important, with early investments playing the most fundamental role. Investment in primary education is associated with higher numeracy scores for those who went on to continue their education. Higher investments in tertiary education are needed in order to fully realize the benefit of the investments in primary school. Family background is a decisive factor in relation to numeracy skills of these adults, in line with all available evidence. Adults who received higher public investment in primary education were more likely to complete secondary school and attain tertiary education. This refutes earlier studies indicating that the amount of financial resources available for education may not be that important for the development of competences.

JEL Classification: H52, I25, I26, J01, J24

Keywords: government expenditures and education, human capital, education and economic development, returns to education, cognitive skills

Corresponding author:
Jo Ritzen
IZA
Schaumburg-Lippe-Str. 5-9
53113 Bonn
Germany
E-mail: Ritzen@iza.org

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1. Does money matter?

In 2013, on average, governments in OECD countries spent roughly 2,000 current PPP dollars per capita on education (OECD, 2015a, p. 71 & 73),[1] which represents more than 5 percent of the average per capita income of 37,074 PPP dollars (World Development Indicators, accessed June, 2016). Education is the fourth largest government expenditure in the OECD, after social protection, health, and general public services; it is twice as high as public spending on defense and almost triple the expenditure on public safety and order (OECD, 2015a, p. 73). So, is a larger public expenditure in education worth the extra money?

Politicians and public opinion alike have debated this question. Citizens are torn between, on the one hand, the notion of bloated salaries or bloated bureaucracy in schools and on the other hand, general awareness of the positive effects of investment in education. These effects include the competitiveness of teachers' labor conditions, a class size which allows for sufficient teacher-student interaction,[2] the commonly held perception that better educated individuals are better able to perform more complicated tasks, or adapt to changing conditions and tasks (Nelson and Phelps, 1966) and insight that a more educated population is beneficial for society.

Research in education economics has been inconclusive. Serious studies allege that additional public resources are not necessarily associated with better student performance (for example, OECD, 2013a, p. 42); ".. the PISA data show no relationship between increases in expenditure and changes in performance, not even for the countries where cumulative expenditure per student was less than USD 50 000 in 2003." This finding was based on data of the Project International Student Achievement, measuring competencies of 15 year olds and investments up to the age of 15, which is before the age in which they complete secondary school. Therefore, the finding does not account for how those investments may facilitate the learning of these individuals over their entire educational trajectory. Recent empirical evidence at the sub-national level finds that public investment may have another mechanism by which it influences student achievement – higher levels of educational attainment. Candelaria and Shores (2015) use a difference in difference approach to show that following financial reforms to per-pupil expenditure at the state level, there was an increase in public investment and an increase in graduation rates in the poorest areas. Hyman (forthcoming) finds that, because of a reform to redistribute per-pupil expenditure in Michigan in 1994, students who were subject to 10 percent more public investment in their primary education were 3 percentage points more likely to enroll in college and 2.3 percentage points more likely to complete a tertiary degree.

Woessmann (2003) argues that institutional differences explain a much greater part in international differences in student performance and resources are relatively unimportant for the development of competences. The indicator of public resources used in that study, however, is government expenditure per student which occurred in the same year as the assessment, ignoring the possible impact of the investments made in previous years. OECD (2013a) and Woessmann (2016) also conclude that it is institutional factors (like the degree of autonomy of the school and the accountability of the school, in combination with its goal orientation) which determine the degree of success of the school in developing competencies. In particular, Woessmann (2016) finds that in explaining large international differences in student achievement, resource inputs such as investment are only a small piece of the puzzle, while measures of teacher quality are much more important. These findings were not considered surprising against the background of the debate on

[1] In 2013, the weighted average of the 'General government expenditures per capita' in the OECD was 16,491 PPP (page 71) and 12.5 percent of those expenditures were allocated to education (page 73).
[2] For example, for remedial teaching.

class size. The educational community, including parents and (trade unions of) teachers, had successfully argued in favor of smaller class-sizes. All evidence showed that class-size in the range between 15 and 35 did not seem to matter for the development in competencies (Hattie, 2008 reviews 200 meta studies on this topic). The resources spent on the reduction of class size might then have been less important for competences than claimed by parents and teachers alike.

Around 90 percent of public expenditures per student are accounted for by teacher salaries and class size.[3] Teacher salaries are – within overall labor conditions, including class size, vacations, available time for retraining etc. - important in attracting those best qualified for the teaching profession. The conclusions from earlier studies – especially those using limited information on longitudinal investments - that resources are not too important for the development of competencies, then also pertain to teachers' salaries.

We were fortunate to be able to access data on the longitudinal investments made in each birth cohort and to relate them to the observed competences of adults in 2011 for 12 countries, refuting the earlier evidence and showing that indeed "money counts". Perhaps this is the first time that this finding can be presented as robust. Of course: the institutional settings of school autonomy, accountability and goal orientation are also important, as are the ways in which resources are used. Hence "money" only "explains" part of the development of competences.

Subsequently we ask ourselves whether the timing of the investment matters. Ritzen and Winkler (1977a, 1979) showed the time dependence of the development of competences in relation to educational investments. Earlier investments have been shown to have the highest rate of return, and skills gained due to larger investments in earlier periods that perpetuated beyond that period (Cunha & Heckman et al., 2006). We were able to confirm these findings using our longitudinal investment series in an analysis with international data for a small set of countries.

It is self-evident that other variables (i.e., family background, work experience) influence the competencies of adults, as found in many previous studies. There is no difference here. A striking result is that being born outside the country has such a strong negative impact on competencies as an adult. This result may be largely driven by the fact that individuals with foreign **educational** qualifications have been excluded from this analysis, since public investments can only be accurately assigned to people who obtained domestic educational qualifications. The data we have in our study refer to people who were born outside the country, but immigrated and obtained their highest educational qualification in the country in which they took the assessment of adult competencies (PIAAC), and therefore the result must be interpreted with caution.

We find that investments in education are contributing two ways (1) directly, in terms of higher numeracy scores among adult populations and (2) indirectly, because higher investments in earlier periods (primary education in particular) holding other things constant (like family background) increase the chances of persisting into higher levels of education attainment.

The paper is structured as follows. The next section will describe the model we use. It is the standard educational production function, used to assess the impact of education investments on competencies. We describe how we have made this general model fit for empirical estimation and introduce our key variables of interest. We also introduce a second approach which follows Cunha & Heckman (2006). We break investment into three periods to explore potential differences in the

[3] On average, compensation for teachers and other staff in OECD countries in 2012, represented from 67 percent (at the tertiary level) to 79 percent (at primary and secondary levels) of current expenditure (OECD, 2015b, p. 288).

relation with competences due to the timing of investment. In section 3 we present the data that have been used. These are derived from PIAAC (Project International Assessment of Adult Competencies) measuring numeracy skills of adults in 2011 and from UIS (UNESCO Institute of Education) data on educational investment. We detail how the UIS data have been converted into the cumulated investment in the educational lifetimes of individuals of the adults in PIAAC in 2011. In section 4 we will describe our empirical approaches and the empirical results. In section 5 we discuss the main conclusions and their policy implications, focusing on the need to ensure teachers' salaries remain competitive in national labor markets to attract those best suited for teaching jobs and to ensure sufficient time for teachers to keep up with their profession.

Competences are important for the individual and for society as a whole. We limit ourselves here to the relation between investments in education and competences well recognizing the substantial literature on the impact of competences on earnings, employment or on economic growth (i.e., Patrinos and Psacharopoulos, 2011, Hanushek & Woessmann, 2012, OECD, 2013b or Hanushek et al., 2015).

2. Modelling the Contribution of Public Investment to Competencies

We follow the traditional "Education Production Function" approach, developed since the 1960 (see for example Hanushek, 1986, for an overview of the literature) and augment this with a model which allows us to explore the notion of complementary periods of investment over time.

We use the simplest form (following Hanushek et al., 2015) as our point of departure:

$$H = \lambda F + \phi Q(S) + \delta A + \alpha X + v \qquad (1)$$

Here H is the output of the education system of an individual (say competencies). F denotes Family Background. Q(S) stands for the Quantity and Quality of schooling and A for individual ability. X is a vector of all other personal traits that may impact the person's competencies (like the individual's health or invested non-school resources). The term v indicates the stochastical nature of learning.

For our empirical specification we transform Eq. (1) into the following:

$$Num = \beta_0 + \beta_1 Inv + \beta_2 Family + \beta_3 Edu + \beta_4 Born\ Outside\ Country + \beta_5 Age + \beta_6 Age^2 + \beta_6 Work\ Exp + \beta_7 Work\ Exp^2 + Country\ dummies + \varepsilon \qquad (2)$$

Educational output H is proxied by *Numeracy skills* of adults as measured by PIAAC's assessment of numeracy skills.[4] In section 3.1 we describe the data used to measure this variable in detail.

Quality and Quantity of Schooling (Q(S)) of Eq. (1) are proxied by accumulated longitudinal investment (denoted by Inv) and level of education completed, Edu (with three categories: uncompleted secondary education, completed secondary education and completed tertiary education). Taken together these variables can be thought of as a quality-enhanced measure of the quantity of schooling.

[4] Although PIAAC assessed three domains; numeracy, literacy and problem solving in technology rich environments, the three measures are highly correlated. Hanushek et al., 2015 finds that numeracy and literacy are 0.85 correlated at the individual-level and the authors focus on numeracy which they deem the most internationally comparable domain area of the three. We follow suit.

Family is a set of three variables, (1) mother's education[5] (highly correlated with father's education) categorized into the same three broad educational groups (uncompleted secondary, secondary and tertiary), (2) a categorical variable for the estimated number of books in the household as a child, and (3) whether or not the respondent was born in the country.

Family background measured by parental education has been shown to be a good indicator of family income (Carneiro and Heckman, 2002) and to have far reaching consequences on returns to education and on the attitudes, abilities and beliefs of children (Brunello and Rocco, 2015). The number of books in a household is reflective of parents' attitude toward education (Brunello, Weber and Weiss, 2012).

The vector X (personal traits) is transformed into: the variable "Age" (the age of the individual at the time of the PIAAC assessment) and "Work Experience" is the number of years that the person has had paid employment for at least 6 months out of the year,[6] with a threshold imposed. The threshold stipulates that the age of the person must be at least 10 years greater than number of years of work experience.[7]

It is important to include "Age Squared" as a variable because literature suggests that both skill improvement and skill loss and obsolescence can be associated with age. Results from previous adult literacy assessments IALS and ALL found that the expected gains from increased quantity and quality of education could be offset by the 'depreciation' of skills (OECD, 2013; Chapter 3).

Work Experience is included here as 'costless' investment to either maintain or develop skills (Destré, Lévy-Garboua and Sollogoub, 2008). Adult competencies are found to be positively related to work experience (Hanushek et al., 2015). Since "Work Experience" refers to full-time or part-time work, everyone in the sample could have at least some work experience, but there are some people in our sample who have zero years of work experience. This could be because the person is still in school and does not work part time, or may never have entered the workforce. In the specification, we include a squared term for "Work Experience" because we expect a quadratic relationship for this variable; on average, we expect the effect of additional work experience on numeracy will lessen as work experience increases.

We cannot observe health or peer effects. Systematic differences in the distribution of health or of peer effects between the countries in our analysis are unlikely to exist.

We also include in Eq (2) "Born Outside Country", indicating whether the person is foreign born as a potentially relevant personal trait. Country dummies have been included to control for 'fixed effects' and other unobservable differences among the different countries, such as innate differences in the education system or GDP per Capita.

[5] Commonly used as a measure of family inputs (i.e., Hanushek and Zhang, 2009) and a better predictor (in some contexts) than Father's education (Wamani et al., 2004).

[6] The exact wording of the question in the PIAAC background questionnaire is, "In total, approximately how many years have you had paid work? Only include those years where 6 months or more was spent in either full-time or part-time work." An version of the questionnaire is accessible at: http://www.oecd.org/edu/48442549.pdf

[7] This variable was noisy with some observations taking values greater than the person's age. It seems unlikely that anyone aged 46 or younger in these OECD countries would have begun working before the age of 10, although, some spot checking does show that for example someone who is 45 and has an occupation in agriculture, may have started working (part time) at a very young age.

Individual Ability (A) in Eq (1) is left out of Eq (2), as we have no measures of innate ability. This might imply that we have reverse causality as suggested by human capital theory (Becker, 1994). According to this theory people invest in themselves and educational expenditures are the result of this choice. However, in the compulsory school period the investment decisions are imposed and there is no choice. There is no reason to think that the initial overall distribution of innate abilities would differ systematically in the 12 relatively homogeneous OECD countries in our sample (i.e., why would the distribution of innate abilities in France systematically differ from those in Denmark?). Hence we do not have to fear for reverse causality for the non-compulsory period.

2-2. Multi-Period Approach

The awareness that competences at the end of the school career are the result of a long-run process of sequential investment was early on introduced by Ritzen and Winkler (1977) using pupil data on school progress and school input data over the full school career. Later Cunha and Heckman (2007) put this into a theoretical framework of a state space model: competency at some point in time is the result of the competency at some previous moment and the new inputs into competency at that point in time (what they call self-productivity). They argue with this model that investments in skill development are complementary. Of course, if this were not the case (as is the case in the simple linear model of Eq (1), then the wise investment decision would be to defer investment to the latest possible period. If, however, investments are complementary, two things happen – the early period investment is essential and cannot easily be made up for in a later period investment *and* later period investments are necessary to realize the payoff to the first period investment. In the context of education, this makes a lot of sense. If you only invest heavily in later periods in those who have already made it to secondary or tertiary education (recall the theories mentioned earlier that people who have higher cognitive skills are more likely to persist in education anyway), you may be unfairly jeopardize the chances of those with less cognitive skills by not sufficiently investing in them in the early period. On the other hand, if you only invest in the first period (i.e., primary school), the payoff (productivity of the investment) is contingent on later period investments. The next section presents a discussion of the data.

3. Data on competences and investments

There are 12 countries or regions[8] for which we have both sufficient UIS investment data and PIAAC data in order to assign cumulative investment to each individual. The 12 countries or regions are: Flanders (Region of Belgium), Denmark, Finland, France, Ireland, Italy, Japan, the Netherlands, Norway, Spain, Sweden, UK (only England and N. Ireland). Accumulated public investments can only be calculated for people aged 46 years or less[9] because we only have investment data starting in 1971. The 6 year olds of 1971 (having reached the age of 46 at "PIAAC-time" in 2011) are the first generations for which we have the full information on the investment trajectory applying to them.[10]

[8] In Belgium, only the Flanders region has been sampled by PIAAC (see OECD 2016, p. 13).

9 In other words, the earliest possible year for YearInv1 in equation 1 is set to 1971 which forces the maximum age X in equation 2 (2011-x+6=1971) equal to 46.

[10] We only kept individuals who attained at least some secondary education. We made this decision at the beginning of the analysis, in order to align our analysis with other studies on public investment and assessment based educational outcomes (i.e., Woesseman, 2003; OECD, 2013) this literature tends to draw on PISA, ALL, or IALS assessments conducted in schools at the age of 15. The fact that the assessments take place

3-1. Competences: numeracy

Numeracy[11] skills have recently been found to do a better job than other measures of human capital[12] when explaining differences in economic growth, wage differentials and employment outcomes (Hanushek & Woessmann, 2012; OECD, 2013b). Hanushek et al., 2015 finds that a one standard deviation increase in numeracy scores in adults is associated with a nearly 20 percent increase in wages for prime-age (ages 35-54) working adults. These authors also find considerable variation in the distribution of numeracy skills and their relative returns in the OECD both between and within countries.

Numeracy scores are imperfect measures of cognitive skills. Furthermore, they do not measure non-cognitive skills, which can be important for employment and earnings. Despite these limitations, the subsequent analysis improves upon previous analyses which faced even greater restrictions in their data.

Our data set (on numeracy) is from the OECD's Programme for the International Assessment of Adult Competencies (PIAAC). The PIAAC project was designed to provide internationally comparable measures of the cognitive skills of the adult population. In 2011, samples of at least 5,000 adults (from the ages 16 to 65) were surveyed. Although sampling methodologies can vary from country to country, sampling and replicate weights are used to get nationally representative and internationally comparable estimates.[13] The assessment in PIAAC was designed to be in line with previous assessments of adult numeracy especially the constructs and methodologies used in the Adult Literacy and Lifeskills Survey (ALL) and closely follows the definition of numeracy used in ALL: "Numeracy is the ability to access, use, interpret, and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life" (excerpted from Gal and Tout, 2014, page 15).[14]

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in schools means that, by default, individuals who are assessed have completed at least some secondary education (Gal and Tout, 2014 highlight that this is a key difference between PIAAC and PISA). In an extension of the present analysis, it would be possible to cautiously draw comparisons between investments and results in the two assessments. Alternatively, it would also be possible to incorporate individuals whose highest level of educational attainment is primary school in the analysis. In the countries in this analysis, however, this tends to represent less than two percent of the sample.

[11] In this paper, the terms 'numeracy'; 'numeracy skills', and 'numeracy competencies' are used as semantically interchangeable terms for the numeracy of adults as assessed by PIAAC. In fact, the precise definitions of these terms as they are conceived by the OECD project is that definition of numeracy used in PIAAC emerged from past experience in assessing adults and have been designed not only to assess 'pure' cognitive skills, but also attitudes and beliefs which reflect the OECD project's general conception of 'competencies' which, in turn, shapes their definition of numeracy. For a more detailed explanation of the process, see Rychen & Salganic, 2003, or Gal and Tout, 2014).

[12] Evidence of the contribution of Human Capital (measured by additional years of schooling) in cross-country economic growth comparisons is varied

[13] See the OECD's 2013 Technical Report of the Survey of Adult Skills (PIAAC) Chapter 14 on Sampling Design for more detailed information regarding the sampling design and weights used for each of the participating countries (OECD, 2013c).

[14] The definition of numeracy for ALL and PIAAC was part of the OECD's DeSeCo (Definition and Selection of Competencies) that places complex competencies of numerate behavior along a continuum of higher and lower levels. As listed in Gal and Tout (2014), numerate behavior and its facets are activated by "mathematical knowledge and conceptual understanding, adaptive reasoning and mathematical problem-solving skills, literacy skills, beliefs & attitudes, numeracy-related practices and experience, and [everyday] context and world knowledge" (page 16). For more information see PIAAC Numeracy Expert Group, 2009:21-22; the full Gal and Tout 2014 paper; the PIAAC technical report (OECD, 2013c); and Rychen & Salganic 2003.

PIAAC assessment tasks range from easy to challenging and are meant to capture the skills of adults with very different backgrounds and life experience. Examples of tasks and questions associated with each PIAAC numeracy level have been excerpted from the OECD's Technical report (to get a feel for range of questions and tasks, see Appendix 1).

The PIAAC assessment of adult numeracy employs the dominant methodology currently used for large scale assessments.[15] The scale is from zero to 500.[16] The PIAAC methodology is designed to achieve representative samples in each country and internationally comparable results of the distributions of numeracy skills.

The PIAAC survey also contains extensive background information collected about the respondents, such as data on educational attainment, work experience, age and family background. In Table 1 we present the PIAAC statistics.

People with foreign education qualifications are not included in this analysis, because we do not have information regarding investments made over the course of their schooling since we do not know which country the foreign education qualification comes from, therefore it would be impossible to assign accurate public investment information to those individuals. PIAAC does include the question whether persons are born in the country or not. This then only pertains to those who have gone through the domestic education system.

3-2. Cumulative investments

The second data set was provided by UNESCO's Institute for Statistics (UIS) and for a subset of OECD countries from 1971 to 2011, this dataset contains: (a) Government expenditure on education (LCU[17]) separated by primary, secondary and tertiary education levels, (b) enrolment in primary, secondary and tertiary education levels, and (c) GDP per capita in LCU[18] for all countries. These data are then used to calculate for each year from 1971 to 2011[19] the government expenditure per student enrolled as a percent of GDP per capita for each of the three different education levels (primary, secondary, tertiary).[20] (See Appendix 2 for details).

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[15] Many times – individual respondents completed only part of the assessment. **A set of ten plausible values** for individual respondents are derived from the assessments and the background questionnaire and these values can are then used to generate a distribution of numeracy skills. In other words, the data are noisy at the individual level, but less noisy when considering the average performance of the group. For more information regarding this methodology, please refer to the OECD's 2013 Technical Report of the Survey of Adult Skills (PIAAC) and von Davier, Gonzalez & Mislevy, 2009.

[16] The range of scores in the data is squeezed between 100 and 400. The distribution of each of the 10 plausible values is normal with very few plausible values falling below 100 or above 400 and absolutely no plausible values for scores that are either zero or 500. The scale is also divided into 6 levels, ranging from 'Below level 1' to 'Level 5'. These levels are not used in the present analysis.

[17] Both old LCU (Local Currency Unit).and current LCU-euro are available for Euro countries.

[18] From 1971-1997 data are also provided on GDP per capita in current LCU-Euro for those countries that now have the Euro as their currency.

[19] Linear interpolation and extrapolation were used to fill-in missing data over the time period; as long as there were sufficient data to do so. For example, Canada only had 11 years of data for the tertiary level over the 41 year period; these data were not extrapolated or interpolated, because they represent less than one third of the entire time period. There were even fewer data points at the secondary level and no government expenditure data for the primary level. Therefore, Canada is not included in the subsequent analysis.

[20] We make two strong assumptions when we assign the investment data. The first is that schooling is continuous, that means that there are no breaks, skips or repetitions. The second is that everyone begins

We only have information on public investment in education. Private investments are not captured in our analysis. Public expenditure per pupil in relation to GDP is a proxy for public effort.

We do not know how this money is allocated (i.e., whether it was spent on infrastructure or on teachers). We also do not have information about school systems' autonomy over managing their resources, a variable that was found to be highly relevant for 15 year-olds' performance in mathematics (OECD, 2013a). Nor do we know whether resources are evenly allocated throughout the country (i.e., Woessmann in 2003 was concerned about movement of resources in response to students' skills in national micro studies).

We use the UIS investment data to assign a proxy of public investment in each individual's on the basis of information about the respondent's age and highest level of educational attainment from the PIAAC data. The exact method is described as follows: "Public Investment" is the ***sum*** of 'Expenditure per Student as a percentage of GDP per Capita' for ***each year*** over the estimated time that the person was in school. To determine the year in which the person will start receiving public investment in his/her education ($Year_{Inv1}$), the following approach is used:

$$Year_{Inv1} = 2011 - X + 6 \quad (3)$$

Where X is the age of the individual recorded in the PIAAC data in 2011 (the year of the survey)[21] and a standard number of 6 years is added to the age, under the strong assumption that all individuals entered primary school at the age of 6 and standardized across countries rather than using actual entry ages that might differ among countries. This estimated time that a given person was in school is based on the further assumption that all sequencing of schooling was consecutive (i.e., no repeats, skips or breaks between secondary and tertiary).

Then, depending on which level of education the person attained the following investments are added:

$$Inv_j^i = \sum_{K=1}^{N} Public\ Investment_j^k \quad (4)$$

i = individual
j = country
k = year
N = Highest level of Educational Qualification (HLQ)

Where Inv_j^i is the total public investment in individual i in country j, which is equal to the sum of the public expenditure per student as a percent of the country's GDP per capita[22] for each level of

school at the age of 6. These assumptions and the method of assigning investment data from UIS to PIAAC respondents is detailed in the rest of this section.

[21] This is true for most of the countries. Some countries conducted the survey in 2012. The timing of the survey in the various countries can be found in the OECD's 2013 Technical Report of the Survey of Adult Skills (PIAAC). Considering that only the birth year is recorded, it seems as good a random whether the person would have been surveyed before or after his/her actual birthday and therefore using 2011 consistently for all countries (despite the fact that some countries may have conducted the survey in 2012), should actually compensate for early year versus late year birthdays.

[22] This addresses the issue of educational expenditure being related to and more costly in countries with higher GDP per capita (See Grigoli, 2015).

schooling the individual passed through after the year of entry until the year of highest level of educational qualification (HLQ). Appendix 2 provides more information about how the cumulative public investment was calculated and assigned to PIAAC survey respondents and in Appendix 3 the trends of investment in selected countries are presented. The investment trends illustrate the variation in investment patterns *between* the different countries and *within* the same country, over the four decade period.

The descriptive statistics for the variables used in the analysis are summarized below. The minimum value for cumulated public investment (measured by government expenditure per student as a percent of GDP summed over the individual's educational lifetime) for an individual in the dataset is almost 80 and the maximum value is 842.[23] The maximum age is 46 and the minimum age is 16) and the average work experience is 21 years with a minimum of zero work experience and a maximum of 36 years of work experience.

Table 1 | Descriptive Statistics

Variable	Mean	S. D.	Min	Max
Dependent Variable Numeracy	**278.30**	**50.44**	**40.52**	**462.95**
Public Investment	293.28	108.73	79.50	842.00
Family Background				
Mother's Education				
Uncompleted Secondary	*0.44*	*0.49*	*Reference Category*	
Completed Secondary	0.35	0.47		
Tertiary	0.21	0.40		
Books in the House (Childhood)				
10 or less	*0.11*	*0.32*	*Reference Category*	
11 to 25	0.14	0.35		
26 to 100	0.31	0.46		
101 to 200	0.18	0.39		
201 to 500	0.16	0.36		
More than 500	0.09	0.29		

[23] In Belgium, a person who was 32 years old in 2011 had attained a doctorate degree would have received a proxy of public investment in the first year of primary education estimated at 37.7, which is a linear extrapolation. In 1986, the person would have received a proxy of public investment in their second year of primary education estimated at 37.4 which is the amount that the Danish government invest in primary education that year 20,570,999,168 Krone (LCU) divided by the number of students enrolled in primary education in Denmark in that year 402,707 divided by the GDP per Capita in that year which was 136,467 (current LCU – derived from the Euro conversion). The public investments in that person over the 6 years (1985-1990) of primary education are cumulated (37.7 from 1985 + **37.4** (exact calculation described) from 1986 + 40.7 from 1987+ 42.5 from 1988 + 35.5 from 1989 + 28.5 from 1990 **= 222.5**). The same methodology is followed for the 6 years of secondary education (for a cumulated public investment proxy of 211.5 (31.6 from 1991 + 34.8 from 1992 + 38.1 from 1993 + 34.8 from 1994 + 35.0 from 1995 + 37.2 from 1996) and for tertiary a cumulated public investment proxy of 408.0 (59.9 from 1997 + 62.5 from 1998 + 65.9 from 1999 + 70.2 from 2000 + 75.6 from 2001 + 73.9 from 2002). The total public investment for this person would be 842 (222.5 + 211.5 + 408). Another illustrative example is provided in Appendix 2 for a person who was 43 in Italy at the time of the PIAAC survey.

Born Outside Country	0.12	0.32	*Dummy; 1 = yes*	
Personal Traits				
Education Group				
Uncompleted Secondary	*0.18*	*0.38*	*Reference Category*	
Completed Secondary	0.42	0.49		
Tertiary	0.40	0.49		
Age	31.97	8.95	16	46
Work Experience	21.26	4.55	0	36

Countries in our Sample

	N	**Mean Numeracy**	**S. D.**	**Min**	**Max**
Belgium (Flanders)	*2,866*	*290.11*	*47.29*	*106.96*	*423.48*
Denmark	3,566	*283.29*	*51.87*	*74.88*	*448.68*
Finland	3,105	*296.17*	*47.60*	*46.78*	*449.20*
France	3,826	*269.46*	*51.65*	*40.52*	*423.88*
Ireland	3,788	*266.56*	*48.73*	*53.44*	*427.12*
Italy	2,711	*259.60*	*46.74*	*92.22*	*408.56*
Japan	3,103	*294.76*	*40.85*	*131.90*	*440.89*
Netherlands	2,652	*292.61*	*45.18*	*48.76*	*424.25*
Norway	3,101	*287.19*	*52.68*	*55.51*	*430.95*
Spain	3,261	*260.64*	*44.42*	*64.16*	*395.90*
Sweden	2,614	*289.39*	*53.98*	*49.77*	*462.95*
United Kingdom	4,727	*270.03*	*49.27*	*63.60*	*445.20*

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: S.D. stands for Standard Deviation. We follow Hanushek and use first Plausible Value (PVNUM1) for Numeracy as the dependent variable. As described in footnote 15 and in further detail in the PIAAC Technical Report, each individual has 10 plausible values associated with his or her numeracy.

The plots of numeracy by mean public investment by country and at the different levels of educational attainment are presented in Appendix 4. As expected, numeracy scores increase as the level of educational attainment increases, but the clustering of countries vis-à-vis their relative investment efforts becomes more pronounced as we move up the educational ladder. We observe that Spain, Italy, Ireland and the UK tend to cluster together with lower overall investment for people who have attained tertiary education and lower average numeracy scores, even among the population with a tertiary education. On the other hand, Japan, Belgium, France, the Netherlands, Finland, Sweden, Norway and Denmark cluster together as relatively higher amounts of overall investment for people who have attained tertiary education and higher average numeracy scores for that sub-group as well.

4. Analysis

The model specification of Eq. 2 turns out to present an impressive relation between the accumulated stream of investments and the competence level as Table 2 shows. The results indicate that, controlling for other factors (column 4) for an increase in public investment per student over GDP per Capita by 1 percent in a given year, on average, competences would increase

by 0.05 on the numeracy scale. This might not seem like an overwhelming achievement, but that is why the second part of our analysis shows that this increase in investment is not only important for increasing numeracy through direct means, but it is also important for influencing higher levels of educational attainment which is indirectly important for increasing numeracy.

Table 2 | Baseline and Education Production Function Specifications

Dependent Variable - NUMERACY SCALE SCORE (PLAUSIBLE VALUE 1)				
	(1)	(2)	(3)	(4)
Total Investment	0.20***	0.16***	0.07***	0.05***
	(0.003)	(0.003)	(0.004)	(0.02)
Mother's Edu. Uncompleted Secondary		*Baseline*	*Baseline*	*Baseline*
Mother's Education Secondary		5.50***	5.86***	5.88***
		(0.53)	(0.56)	(0.56)
Mother's Education Tertiary		12.26***	13.38***	13.34***
		(0.65)	(0.71)	(0.71)
Books (0-10)		*Baseline*	*Baseline*	*Baseline*
Books (11-25)		10.16***	8.02***	8.07***
		(0.92)	(0.95)	(0.95)
Books (26-100)		20.28***	17.03***	17.16***
		(0.82)	(0.85)	(0.85)
Books (101-200)		27.18***	23.55***	23.66***
		(0.90)	(0.92)	(0.93)
Books (201-500)		33.40***	29.58***	29.66***
		(0.95)	(0.98)	(0.98)
Books (more than 500)		33.93***	30.49***	30.51***
		(1.09)	(1.13)	(1.13)
Born Outside Country		-29.30***	-27.30***	-27.28***
		(0.85)	(0.88)	(0.88)
Uncompleted Secondary			*Baseline*	*Baseline*
Completed Secondary			13.20***	16.57***
			(0.83)	(2.99)
Tertiary			27.66***	22.91***
			(1.14)	(2.80)
Age			-0.70**	-0.76**
			(0.30)	(0.31)
Age Squared			0.0008	0.0009
			(0.005)	(0.005)
Work Experience			1.38***	1.40***
			(0.14)	(0.14)
Work Exp. Squared			-0.02***	-0.02***
			(0.005)	(0.005)
Total Investment # Uncompleted Secondary				*Baseline*

Investment # Completed Secondary				-0.004
				(0.01)
Total Investment # Tertiary				0.03*
				(0.01)
Belgium	*Baseline*	*Baseline*	*Baseline*	*Baseline*
Denmark	-28.03***	-26.59***	-16.37***	-14.87***
	(1.19)	(1.11)	(1.27)	(1.33)
Finland	-2.51**	-9.50***	-3.16***	-2.65**
	(1.14)	(1.10)	(1.19)	(1.20)
France	-14.49***	-16.93***	-16.84***	-17.21***
	(1.10)	(1.07)	(1.15)	(1.15)
Ireland	-14.22***	-12.98***	-19.32***	-19.90***
	(1.10)	(1.08)	(1.16)	(1.17)
Italy	-17.77***	-17.19***	-12.66***	-13.28***
	(1.20)	(1.17)	(1.27)	(1.28)
Japan	11.52***	4.78***	1.23	0.81
	(1.07)	(1.05)	(1.13)	(1.13)
Netherlands	7.55***	2.71**	3.46***	2.80**
	(1.14)	(1.11)	(1.15)	(1.16)
Norway	-15.42***	-21.34***	-15.15***	-14.38***
	(1.21)	(1.14)	(1.23)	(1.24)
Spain	-9.05***	-12.18***	-14.72***	-15.86***
	(1.13)	(1.12)	(1.23)	(1.28)
Sweden	-18.68***	-23.72***	-12.76***	-11.57***
	(1.31)	(1.22)	(1.32)	(1.36)
United Kingdom	-14.86***	-16.97***	-20.64***	-21.21***
	(1.06)	(1.04)	(1.09)	(1.10)
Constant	231.64***	224.43***	243.34***	249.71***
	(1.18)	(1.25)	(4.48)	(5.79)
N	39309	37776	34111	34111
Adj. R-squared	0.18	0.28	0.30	0.30

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: We follow Hanushek and use Plausible Value 1 for Numeracy as the dependent variable. These results lack the proper replicate weights respective to different countries' sampling methods. Country dummy variables were included to control for 'fixed effects', Belgium (Flanders) is taken the reference country. Work Exp. stands for Work Experience. Investment##Secondary and Investment##Tertiary are interaction terms.
Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01

We tried including Father's education as well as and instead of Mother's education and the two variables perform very similarly. We decided to keep only Mother's education, due to their high levels of correlation between the mother's and the father's education and literature that suggests the child's education is more closely related to the mother than the father's education (Haveman and Wolfe, 1995).

Not being born in the country is strongly negatively associated with numeracy skills. So, this captures people who immigrated sometime before 2011 and might still be in the school system, or attended at least some schooling in the country. Recall that those who were born outside the

country and have a *foreign education qualification* from their home country or elsewhere have been excluded from this analysis, because we cannot accurately assign investment data in those cases. Work experience is positively associated with numeracy skills, but as expected, the square of the Work experience indicates a concave quadratic function. In this case, age is found to be negatively associated with numeracy skills for the age groups up to 46 included here, but the age squared term is positive (although not statistically significant) indicating a convex shape in the relationship between age and numeracy for the people in this sample, controlling for other factors. This result is not robust to different specifications. In the models that follow we find that age and the quadratic age squared term appear to have a concave relationship with numeracy, which is more in line with expectation, but the findings with respect to age in these regressions cannot be said to be robust. We found that when we added our other explanatory variables public investment remains strongly and significantly associated with numeracy skills and was remarkably robust in all of the specifications we tried.

Explained variance is low, indicating that many other factors might be at work. These are likely to be the organization of the school system and the distribution of funds over pupils. PISA 2012 finds that the highest-performing school systems are those that allocate educational resources more equitably among advantaged and disadvantaged schools and that grant more autonomy over curricula and assessments to individual schools. A belief that all students can achieve at a high level and a willingness to engage all stakeholders in education – including students, through such channels as seeking student feedback on teaching practices – are hallmarks of successful school systems. (OECD, 2013 a, pp. 4).

It is important to point out that while we control for educational attainment, we do so with a broad categorical variable,[24] our cumulative measure for investment (summed over the number of years in which the person attends school) means that we have not fully distinguished quality from quantity. We do not perfectly control for each additional year of investment in education at the tertiary level, because at this level you can have individuals who have a varying levels of qualifications that all fall within the category of higher or tertiary education.

We also added an interaction term in investment and education levels. We interacted our investment variable with the categorical variable that controls for education qualifications, because we hypothesized that the relationship between investment and numeracy may have different slopes according to broad levels of educational attainment. Investment#Secondary and Investment#Tertiary are interaction terms and the reference group is Investment#Uncompleted Secondary education. We find that the slopes do differ. The relationship between investment and numeracy is steeper for the group of people who have attended tertiary education than the relationship between investment and numeracy for those whose highest educational qualification is 'uncompleted secondary'. The introduction of the interaction term produced quite different results among the different countries, as might be expected given the stark differences in investment patterns between them. These results were our first clue that for those people who make it to tertiary education, the marginal effect of additional investment is greater.

This spurred us to think about the lifecycle of learning, investment and skill accumulation and how investments in different periods related to each other and the resulting overall skill levels;

[24] See Appendix 1 for detailed information about the ISCED highest levels of educational qualification that can be found within the category of 'Tertiary' and Appendix 5 for details about how the number of years of investment have been standardized to match the ISCED classification system to assign consistent investments across the different countries in our sample.

following Cunha and Heckman (2006), we look for complementarity between investments in the three periods we can observe in our data, primary, secondary and tertiary. See Cunha and Heckman (2006) for clear presentation of the theoretical role of complementarity or substitutability in the relative productivity of investments. As the authors describe, in the polar case where investments in different periods are perfect substitutes, then deficiencies in early period investments can be made-up for in later period investments (equalized). On the other hand, if investments are complementary, then there is an equity-efficiency trade off, because when there is strong complementarity (the authors point to the 'Leontief case') it is not possible to make up for deficient early period investments in later periods. When investments in different periods are complements, then the first period investment acts as a bottleneck from the investment *and* skill standpoint. Since skill begets skill, the skills gained in the first period are the foundation for skills gained in all subsequent periods. Under these conditions, the social planner is confronted with a dilemma, efficient investment would dictate that higher levels of investment should go to those who already received higher investment in period one (and thus are endowed with greater skills at the end of that period), but equity would dictate that an equalizing effort should occur to make up for deficient investments (and lower skills) in period one. This dilemma is further complicated by the notion that if the investments in different periods are equally productive - considering discounting, later period investments would be preferred to early investments (deferring costs). But, and this is a big but, without sufficient investments in period one, when investments are strongly complementary, the harder it will be for later period investments to make up for inadequate investment in the early periods. Furthermore, investment in early periods will not be realized until the later period investment is also made. (Cunha and Heckman, 2006)

4-1. Analysing complementarity

In order to operationalize the analysis of complementarity of investments in different periods in our sample we began by introducing a triple interaction term for the three periods of investment available in our data; investment in primary, investment in secondary and investment in tertiary. The introduction of the interaction term guarantees that the derivative of y with respect to investment in tertiary (for example) will depend on investment made at the primary and secondary levels; similar to a two-way interaction, this three-way interaction term indicates how the relationship between investment in tertiary (X_3) and numeracy scores (y) varies across levels of investment in primary (X_1) and investment in secondary (X_2), and/or the combination of the two (X_1 X_2) (see Dawson and Richter, 2006). When a multiplicative interaction term is introduced in symmetric models, it is not possible to tell whether one of the variables is the moderator variable, this must be determined by theory (Brambor et al., 2005; Dawson and Richter, 2006). Since theoretically Cunha and Heckman identify period one investments as the 'bottleneck' period, we first assume that investment in primary education is the moderator variable and then we test the other relationships as well. At the same time, we introduced squared terms for our investment variables for each period, because preliminary analysis showed a concave pattern with respect to investment and marginal returns, especially in the case of tertiary investment. For the time being, we maintain our linear least squares approach and estimate the following:

$$Num = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_1 X_2 + \beta_5 X_1 X_3 + \beta_6 X_2 X_3 + \beta_7 X_1 X_2 X_3 + \beta_8 X_1^2 + \beta_9 X_2^2 + \beta_{10} X_3^2 + Controls_i + \varepsilon \quad (5)$$

Where the controls are the same as they were in Eq. 2:

$$Controls = \beta_{11}Family + \beta_{12}Born\ Outside\ Country + \beta_{13}Edu + \beta_{14}Age + + \beta_{15}Age^2 + \beta_{16}Work\ Exp + \beta_{17}Work\ Exp^2 + Country\ Dummies$$

We find that the three-way interaction term is statistically different from zero at the one percent level (see the first column of regression results in Table 3). This provides empirical evidence for the notion that the effect of investment in a particular period does differ across the range of investments made in the other periods. We then implement a practical test for complementarity of the different investments in the cross terms.

Carree, Lokshin and Belderbos (2011) developed an empirical test for ascertaining the complementarity (or substitutability) of two continuous variables in the presence of a three-way interaction term. Their test is designed to suit the context of multiple practices that can be adopted by firms and how they relate to firm level performance, but we apply the test in the context of 3 periods of investment and the effect on numeracy scores. As the authors describe the mechanics of the test; X_1 and X_2 are considered complementary if the cross-derivative of the cross-term ($\partial^2 f/\partial x_1 \partial x_2$) is greater than or equal to zero. The operationalization of this test suggests that using linear regression and considering the significance of the coefficients of variables $X_1\ X_2$ - $X_1\ X_2\ X_3$ and $X_1\ X_2\ X_3$ and a one sided t-test for the critical values, we can ascertain whether the cross-term indicates complementarity or substitutability (Carree, Lokshin and Belderbos, 2011).

We have tested each of the cross terms in the regression results presented in columns 2, 3, and 4 of Table 3 and we summarize the results of the complementarity test in Table 4. After the full specification regression (Eq. 5) in column 1 was run, we can observe two things. First, the three-way interaction term is significant at the 1 percent level, and that the cross term Investment in Primary multiplied by Investment in Tertiary is also statistically significant at the 10 percent level. In order to test the complementarity between the two periods of investment, a new variable was created [$X_1\ X_3$ - $X_1\ X_2\ X_3$]. This new variable is the result of the cross-term Investment in Primary multiplied by Investment in Tertiary minus the three-way interaction term of Investment in Primary multiplied by Investment in Secondary multiplied by investment in tertiary. This new variable [$X_1\ X_3$ - $X_1\ X_2\ X_3$] is then run in the second regression whose results are in column 2 and it takes the place of the original cross term [$X_1\ X_3$]. The newly generated variable is also statistically different from Zero at the 10 percent level, and when it takes the place of the original cross term, the sign on the three-way interaction term changes to positive and statistically different from Zero.

Although, from the signs and significance we might infer that these coefficients are both greater than zero, the one-sided t-test had to be implemented manually (because Stata runs a two-sided t-test by default). The one sided t-test in the case of the cross term on Investment and Primary and Investment in Tertiary shows that the two investments are complementary because the newly generated variable and the three-way interaction term (in the second regression) are both greater than zero.

Table 3: Complementarity between Investments: Full Sample

Dependent Variable = Numeracy scale score - Plausible value 1

	(1)	(2)	(3)	(4)
Investment Primary	-0.1195**	-0.1195**	-0.1195**	-0.1195**
	(0.0535)	(0.0535)	(0.0535)	(0.0535)
Investment Secondary	-0.0772*	-0.0772*	-0.0772*	-0.0772*
	(0.0441)	(0.0441)	(0.0441)	(0.0441)
Investment Tertiary	0.2348***	0.2348***	0.2348***	0.2348***
	(0.0447)	(0.0447)	(0.0447)	(0.0447)
Cross-terms				
Inv. Primary # Inv. Secondary [x1x2]	0.0002	0.0002		0.0002
	(0.0002)	(0.0002)		(0.0002)
Inv. Primary # Inv. Tertiary [x1x3]	0.0004*		0.0004*	0.0004*
	(0.0002)		(0.0002)	(0.0002)
Inv. Secondary # Inv. Tertiary [x2x3]	0.0007**	0.0007**	0.0007**	
	(0.0003)	(0.0003)	(0.0003)	
Inv. Primary # Inv. Secondary # Inv. Tertiary [x1x2x3]	-0.000005***	0.0004*	0.0002	0.0006**
	(0.0000)	(0.0002)	(0.0002)	(0.0003)
Testing Complementarity				
[x1x2 - x1x2x3]			0.0002	
			(0.0002)	
[x1x3 - x1x2x3]		0.0004*		
		(0.0002)		
[x2x3 - x1x2x3]				0.0007**
				(0.0003)
Squared Terms				
Inv. Primary # Inv. Primary	0.0001	0.0001	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Inv. Secondary # Inv. Secondary	0.00003	0.00003	0.00003	0.00003
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Inv. Tertiary # Inv. Tertiary	-0.0005***	-0.0005***	-0.0005***	-0.0005***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Controls				
Mother's Education Secondary	5.4998***	5.4998***	5.4998***	5.4998***
	(0.5611)	(0.5611)	(0.5611)	(0.5611)
Mother's Education Tertiary	12.2988***	12.2988***	12.2988***	12.2988***
	(0.7092)	(0.7092)	(0.7092)	(0.7092)
Books (11-25)	7.9301***	7.9301***	7.9301***	7.9301***
	(0.9461)	(0.9461)	(0.9461)	(0.9461)
Books (26-100)	16.7055***	16.7055***	16.7055***	16.7055***
	(0.8428)	(0.8428)	(0.8428)	(0.8428)

Books (101-200)	22.8560***	22.8560***	22.8560***	22.8560***
	(0.9217)	(0.9217)	(0.9217)	(0.9217)
Books (201-500)	28.6474***	28.6474***	28.6474***	28.6474***
	(0.9732)	(0.9732)	(0.9732)	(0.9732)
Books (more than 500)	29.5830***	29.5830***	29.5830***	29.5830***
	(1.1226)	(1.1226)	(1.1226)	(1.1226)
Born Outside Country	-27.258***	-27.258***	-27.258***	-27.258***
	(0.8793)	(0.8793)	(0.8793)	(0.8793)
Completed Secondary	22.6456***	22.6457***	22.6456***	22.6457***
	(1.3559)	(1.3559)	(1.3559)	(1.3559)
Tertiary	21.0286***	21.0286***	21.0286***	21.0286***
	(1.7129)	(1.7129)	(1.7129)	(1.7129)
Age	0.0789	0.0789	0.0789	0.0789
	(0.3167)	(0.3167)	(0.3167)	(0.3167)
Age Squared	-0.0157***	-0.0157***	-0.0157***	-0.0157***
	(0.0047)	(0.0047)	(0.0047)	(0.0047)
Work Experience	1.2812***	1.2812***	1.2812***	1.2812***
	(0.1429)	(0.1429)	(0.1429)	(0.1429)
Work Exp. Squared	-0.0121**	-0.0121**	-0.0121**	-0.0121**
	(0.0048)	(0.0048)	(0.0048)	(0.0048)
Denmark	-3.3094*	-3.3094*	-3.3094*	-3.3094*
	(1.8459)	(1.8459)	(1.8459)	(1.8459)
Finland	1.4456	1.4456	1.4456	1.4456
	(1.3700)	(1.3700)	(1.3700)	(1.3700)
France	-19.389***	-19.389***	-19.389***	-19.389***
	(1.1669)	(1.1669)	(1.1669)	(1.1669)
Ireland	-24.851***	-24.851***	-24.851***	-24.851***
	(1.2731)	(1.2731)	(1.2731)	(1.2731)
Italy	-15.368***	-15.368***	-15.368***	-15.368***
	(1.3302)	(1.3302)	(1.3302)	(1.3302)
Japan	0.6570	0.6570	0.6570	0.6570
	(1.3071)	(1.3071)	(1.3071)	(1.3071)
Netherlands	-2.4162*	-2.4161*	-2.4161*	-2.4161*
	(1.2590)	(1.2590)	(1.2590)	(1.2590)
Norway	-6.7704***	-6.7704***	-6.7704***	-6.7704***
	(1.8180)	(1.8180)	(1.8180)	(1.8180)
Spain	-22.853***	-22.853***	-22.853***	-22.853***
	(1.5442)	(1.5442)	(1.5442)	(1.5442)
Sweden	0.1088	0.1088	0.1088	0.1088
	(1.9443)	(1.9443)	(1.9443)	(1.9443)
United Kingdom	-24.754***	-24.754***	-24.754***	-24.754***
	(1.1330)	(1.1330)	(1.1330)	(1.1330)
Constant	265.26***	265.26***	265.26***	265.26***

	(6.8102)	(6.8102)	(6.8102)	(6.8102)
Observations	34,111	34,111	34,111	34,111
R-squared	0.307	0.307	0.307	0.307

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: We follow Hanushek in the 'Pooled' regression and use Plausible Value 1 for Numeracy as the dependent variable. These results lack the proper replicate weights respective to different countries' sampling methods. Country dummy variables were included to control for 'fixed effects'. Belgium (Flanders) is taken the reference country. Work Exp. stands for Work Experience. "#' indicates and interaction term. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

We then ran the same test on the other two cross terms. In Column 3 of Table 3 the results from testing the complementarity between investments in primary and secondary are calculated and presented. In this case, the results are not statistically different from zero, so it is not possible to conclude whether there is complementarity (or substitutability) between these two investments. The results from testing the complementarity between investments in secondary and tertiary are calculated and presented in Column 4 of Table 3. These results suggest that there is indeed complementarity between secondary and tertiary investments, as there was between primary and tertiary. The results from the testing after the regressions from Table 3 are summarized in Table 4 below. The tests offer empirical support for Cunha and Heckman's notion that later period investments are needed in order to realize the benefits of the first period investments.

Table 4: Full Sample (1 tail t-test)

	Cross-term Coefficient ≥ 0	**3-way Interaction Coefficient ≥ 0**	**Evidence of:**
Cross-term		x1x2x3	
Primary * Tertiary	fail to reject null, significant at 5%	fail to reject null, significant at 5%	**Complementarity**
Secondary * Tertiary	fail to reject null, significant at 5%	fail to reject null, significant at 5%	**Complementarity**
Primary * Secondary	Not statistically different from Zero	Not statistically different from Zero	Not possible to evaluate

Notes: Following Carree, Lokshin and Belderbos (2011), this analysis uses the coefficients from the regressions to test whether the cross terms (between two types of investment have complementarity or substitutability.

Turning the question of investment on its head using logit regressions we explore whether greater amounts of investment at one stage increase the probability of making it to further stages of education. The first and second columns in Table 5 report the effects of an increase in primary investment on the chances of completing secondary education. Holding everything else constant, a one unit[25] increase of investment in primary education increases the changes of completing secondary education by a little more than one percent. The second column calibrates these results by showing that at some points in the distribution a one percent unit increase in investment would increase the odds of completing secondary education by more than 2 percent, but that this has a slightly concave shape. The remaining three columns report how the chances of attaining tertiary education (a binary outcome variable taking the value 1 if the individual achieved tertiary education levels and a zero if not) could be related to relatively higher amounts of investment in the first or second periods (primary and secondary education respectively). When we consider only the people in the sample who have completed secondary education, we see that while increase investments in primary education are consistently positive and significantly increasing the odds of making it to tertiary education, investment in secondary is less consistent. When we consider the full sample, the results show that investments in primary and secondary both increase the odds of making it to tertiary education; see column 5 from the Logit regressions presented in Table 5.

[25] A one unit increase in the proxy for investment in primary education represents a one percent increase in the public expenditure per student enrolled in a given year over GDP per capita in that same year.

Table 5: Logit Regressions

Dependent Variable: Educational Attainment					
	Completed Secondary		Tertiary		Tertiary
			Restricted to those who Completed Secondary		Full Sample
	(1)	(2)	(3)	(4)	(5)
Investment Primary	0.0132***	0.0218***	0.0063***	0.0168***	0.0084***
	(0.0010)	(0.0036)	(0.0008)	(0.0032)	(0.0031)
Investment Secondary			0.0008	-0.0127***	0.0696***
			(0.0006)	(0.0035)	(0.0022)
Inv. Primary # Inv.Secondary				0.0000	-0.0001***
				(0.0000)	(0.0000)
Inv.Primary # Inv. Primary		-0.0000**		-0.0000***	0.0000*
		(0.0000)		(0.0000)	(0.0000)
Inv. Secondary # Inv. Secondary				0.0000***	-0.0002***
				(0.0000)	(0.0000)
Mother's Education Secondary	0.7707***	0.7716***	0.4236***	0.4239***	0.4645***
	(0.0492)	(0.0492)	(0.0324)	(0.0324)	(0.0321)
Mother's Education Tertiary	0.8854***	0.8885***	0.9688***	0.9695***	1.0119***
	(0.0593)	(0.0593)	(0.0412)	(0.0412)	(0.0404)
Books (11-25)	0.5557***	0.5559***	0.3826***	0.3806***	0.4311***
	(0.0632)	(0.0633)	(0.0606)	(0.0607)	(0.0592)
Books (26-100)	1.0881***	1.0869***	0.8297***	0.8291***	0.9034***
	(0.0579)	(0.0580)	(0.0536)	(0.0537)	(0.0526)
Books (101-200)	1.3625***	1.3614***	1.0671***	1.0675***	1.1537***
	(0.0668)	(0.0669)	(0.0578)	(0.0578)	(0.0567)
Books (201-500)	1.5261***	1.5236***	1.2975***	1.2979***	1.3887***
	(0.0725)	(0.0725)	(0.0601)	(0.0602)	(0.0591)
Books (more than 500)	1.7248***	1.7230***	1.3673***	1.3682***	1.4658***
	(0.0913)	(0.0913)	(0.0678)	(0.0678)	(0.0665)
Born Outside Country	-0.2505***	-0.2466***	-0.0548	-0.0526	-0.0702*
	(0.0566)	(0.0565)	(0.0445)	(0.0445)	(0.0425)
Age	0.6831***	0.6830***	0.6497***	0.6535***	0.6365***
	(0.0227)	(0.0226)	(0.0206)	(0.0213)	(0.0196)
Age Squared	-0.0093***	-0.0092***	-0.0076***	-0.0077***	-0.0072***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Work Experience	0.0016	0.0023	-0.0892***	-0.0904***	-0.0661***
	(0.0115)	(0.0115)	(0.0093)	(0.0093)	(0.0087)
Work Exp. Squared	-0.0013***	-0.0013***	-0.0002	-0.0002	-0.0009***
	(0.0004)	(0.0004)	(0.0003)	(0.0003)	(0.0003)
Belgium	*Baseline*	*Baseline*	*Baseline*	*Baseline*	*Baseline*

Denmark	-2.0105***	-2.0711***	-1.0369***	-1.4428***	-0.2457**
	(0.1201)	(0.1222)	(0.1047)	(0.1273)	(0.1135)
Finland	-1.0409***	-1.0940***	-0.7993***	-0.9972***	-0.6733***
	(0.1064)	(0.1088)	(0.0721)	(0.0835)	(0.0819)
France	-0.3406***	-0.2944***	-0.3153***	-0.2286***	-0.3374***
	(0.1028)	(0.1043)	(0.0656)	(0.0676)	(0.0683)
Ireland	-0.3526***	-0.2722**	1.2130***	1.3041***	1.4952***
	(0.1030)	(0.1107)	(0.0761)	(0.0847)	(0.0800)
Italy	-1.4621***	-1.4537***	-1.3962***	-1.4039***	-1.0655***
	(0.0965)	(0.0966)	(0.0766)	(0.0795)	(0.0772)
Japan	0.0898	0.0522	-0.0515	-0.1510*	0.4941***
	(0.1227)	(0.1238)	(0.0708)	(0.0789)	(0.0750)
Netherlands	-0.9179***	-0.8925***	-0.4451***	-0.4269***	-0.2173***
	(0.1010)	(0.1019)	(0.0728)	(0.0768)	(0.0735)
Norway	-1.5916***	-1.6573***	-0.7703***	-1.0958***	-0.1945*
	(0.1227)	(0.1249)	(0.0955)	(0.1160)	(0.1085)
Spain	-1.6687***	-1.6034***	0.3845***	0.3182***	1.5347***
	(0.0962)	(0.0996)	(0.0861)	(0.0989)	(0.0895)
Sweden	-1.7852***	-1.8012***	-1.2190***	-1.4811***	-0.5670***
	(0.1291)	(0.1297)	(0.1182)	(0.1270)	(0.1170)
United Kingdom	2.2457***	2.2962***	-0.1973***	-0.1141*	-0.0727
	(0.1816)	(0.1830)	(0.0628)	(0.0663)	(0.0656)
Constant	-11.3971***	-12.0270***	-13.2681***	-13.1259***	-19.5809***
	(0.3355)	(0.4172)	(0.3521)	(0.4836)	(0.4191)
N	34112	34112	29620	29620	34112
Pseudo R-squared	0.248	0.248	0.168	0.168	0.234

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: We follow Hanushek in the 'Pooled' regression and use Plausible Value 1 for Numeracy as the dependent variable. These results lack the proper replicate weights respective to different countries' sampling methods. Country dummy variables were included to control for 'fixed effects'. Belgium (Flanders) is taken the reference country. Work Exp. stands for Work Experience. "#' indicates and interaction term. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

The results from the logistic regression suggest that when we hold all our other explanatory variables constant, and interacting our primary and secondary investments, relatively higher amounts of investment in primary school actually increase the chances of making it to tertiary education by 1% and relatively higher amounts of investment in secondary education increase the chances by 7%. We cannot perform the same test that we used in the OLS regressions to test the complementarity of primary and secondary investments in determining whether or not a person makes it to the tertiary level, but from the sign and significant of the interaction term, it appears that while both higher primary and secondary investments are important in leading people to tertiary as investment in primary increases, the marginal effect of secondary investment on whether or not someone enters tertiary decreases – but taken together, they still have a positive overall effect.

Conditional on making it to Tertiary, the investments between each of the cross-terms indicate substitutability (Tables 6 and 7). In other words, if we could be sure people would make it to tertiary, then the timing of the investment from an empirical perspective could be considered inter-changeable. From models 1-4 in Table 7 we can see that investments in primary and tertiary, as well as investments in secondary and tertiary, seem to act as substitutes rather than as complements. This empirical result is misleading, because it neglects to consider the self-productivity aspect of skill formation, as Cunha and Heckman phrase it, 'skill begets skill'. Learning new mathematical competencies at the tertiary level depends on how well you learned foundational mathematical competencies usually taught in primary and/or secondary school. Public investment as a proxy for quality of education cannot easily be deferred for only the group of people who will make it the farthest in school. It is not possible to know a priori which people will definitely attain and complete tertiary education. Even if it was possible to identify people a priori, then we would indeed run into an equity-efficiency tradeoff.

It is essential to note that investments in primary and in secondary seem to play a central role in determining whether or not an individual gets a tertiary education. These results must be further calibrated, since Tertiary is consistently strongly and positively associated with higher numeracy scores, the key is the spread of investments. They are not truly substitutes, because earlier period investments facilitate arrival at Tertiary.

Table 6: Substitutability between Investments: TERTIARY ONLY

Dependent Variable = Numeracy scale score - Plausible value 1				
	(1)	(2)	(3)	(4)
Investment Primary	0.2430***	0.2430***	0.2430***	0.2430***
	(0.0935)	(0.0935)	(0.0935)	(0.0935)
Investment Secondary	-0.1479*	-0.1479*	-0.1479*	-0.1479*
	(0.0831)	(0.0831)	(0.0831)	(0.0831)
Investment Tertiary	0.5136***	0.5136***	0.5136***	0.5136***
	(0.0738)	(0.0738)	(0.0738)	(0.0738)
Cross-terms				
Inv. Primary # Inv. Secondary [x1x2]	-0.0007*	-0.0007*		-0.0007*
	(0.0004)	(0.0004)		(0.0004)
Inv. Primary # Inv. Tertiary [x1x3]	-0.0013***		-0.0013***	-0.0013***
	(0.0004)		(0.0004)	(0.0004)
Inv. Secondary # Inv. Tertiary [x2x3]	-0.0011**	-0.0011**	-0.0011**	
	(0.0005)	(0.0005)	(0.0005)	
Inv. Primary # Inv. Secondary # Inv. Tertiary [x1x2x3]	0.0000*	-0.0013***	-0.0007*	-0.0011**
	(0.0000)	(0.0004)	(0.0004)	(0.0005)
Testing Complementarity				
[x1x2 - x1x2x3]			-0.0007*	
			(0.0004)	
[x1x3 - x1x2x3]		-0.0013***		
		(0.0004)		

[x2x3 - x1x2x3]				-0.0011**
				(0.0005)
Squared Terms				
Inv. Primary # Inv. Primary	-0.0003	-0.0003	-0.0003	-0.0003
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Inv. Secondary # Inv. Secondary	0.0007**	0.0007**	0.0007**	0.0007**
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Inv. Tertiary # Inv. Tertiary	-0.0004***	-0.0004***	-0.0004***	-0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Controls				
Mother's Education Secondary	3.5179***	3.5179***	3.5179***	3.5179***
	(0.8062)	(0.8062)	(0.8062)	(0.8062)
Mother's Education Tertiary	7.8709***	7.8709***	7.8709***	7.8709***
	(0.9393)	(0.9393)	(0.9393)	(0.9393)
Books (11-25)	6.9230***	6.9230***	6.9230***	6.9230***
	(1.6914)	(1.6914)	(1.6914)	(1.6914)
Books (26-100)	13.8087***	13.8087***	13.8087***	13.8087***
	(1.4993)	(1.4993)	(1.4993)	(1.4993)
Books (101-200)	18.6106***	18.6106***	18.6106***	18.6106***
	(1.5729)	(1.5729)	(1.5729)	(1.5729)
Books (201-500)	23.3056***	23.3056***	23.3056***	23.3056***
	(1.6095)	(1.6095)	(1.6095)	(1.6095)
Books (more than 500)	25.4102***	25.4102***	25.4102***	25.4102***
	(1.7418)	(1.7418)	(1.7418)	(1.7418)
Born Outside Country	-28.6436***	-28.6436***	-28.6436***	-28.6436***
	(1.2852)	(1.2852)	(1.2852)	(1.2852)
Age	1.9428***	1.9428***	1.9428***	1.9428***
	(0.6304)	(0.6304)	(0.6304)	(0.6304)
Age Squared	-0.0405***	-0.0405***	-0.0405***	-0.0405***
	(0.0091)	(0.0091)	(0.0091)	(0.0091)
Work Experience	0.9095***	0.9095***	0.9095***	0.9095***
	(0.2246)	(0.2246)	(0.2246)	(0.2246)
Work Exp. Squared	-0.0124	-0.0124	-0.0124	-0.0124
	(0.0077)	(0.0077)	(0.0077)	(0.0077)
Denmark	-20.0147***	-20.0148***	-20.0147***	-20.0148***
	(3.6763)	(3.6763)	(3.6763)	(3.6763)
Finland	-8.2067***	-8.2067***	-8.2066***	-8.2067***
	(2.2709)	(2.2709)	(2.2709)	(2.2709)
France	-11.9469***	-11.9470***	-11.9470***	-11.9469***
	(1.5951)	(1.5951)	(1.5951)	(1.5951)
Ireland	-26.4048***	-26.4048***	-26.4047***	-26.4048***
	(1.7234)	(1.7234)	(1.7234)	(1.7234)
Italy	-25.0028***	-25.0028***	-25.0028***	-25.0028***

	(2.3239)	(2.3239)	(2.3239)	(2.3239)
Japan	-4.1706**	-4.1706**	-4.1705**	-4.1706**
	(1.8228)	(1.8228)	(1.8228)	(1.8228)
Netherlands	-15.5373***	-15.5373***	-15.5373***	-15.5373***
	(1.9052)	(1.9052)	(1.9052)	(1.9052)
Norway	-18.1010***	-18.1010***	-18.1009***	-18.1010***
	(3.2733)	(3.2733)	(3.2733)	(3.2733)
Spain	-28.3701***	-28.3701***	-28.3701***	-28.3701***
	(2.1825)	(2.1825)	(2.1825)	(2.1825)
Sweden	-11.1624***	-11.1625***	-11.1623***	-11.1624***
	(3.8182)	(3.8182)	(3.8182)	(3.8182)
United Kingdom	-21.5775***	-21.5775***	-21.5775***	-21.5775***
	(1.5845)	(1.5845)	(1.5845)	(1.5845)
Constant	241.2570***	241.2580***	241.2562***	241.2575***
	(13.4887)	(13.4887)	(13.4887)	(13.4887)
Observations	15718	15718	15718	15718
R-squared or Pseudo R-squared	0.221	0.221	0.221	0.221

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: We follow Hanushek in the 'Pooled' regression and use Plausible Value 1 for Numeracy as the dependent variable. These results lack the proper replicate weights respective to different countries' sampling methods. Country dummy variables were included to control for 'fixed effects'. Belgium (Flanders) is taken the reference country. Work Exp. stands for Work Experience. "#' indicates and interaction term. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 7: Tertiary Only (1 tail t-test)

	Cross-term Coefficient ≥ 0	3-way Interaction Coefficient ≥ 0	Evidence of:
Cross-term		x1x2x3	
Primary * Tertiary	reject the null, significant at 1%	reject the null, significant at 1%	**Substitutability**
Secondary * Tertiary	reject the null, significant at 1%	reject the null, significant at 1%	**Substitutability**
Primary * Secondary	reject the null, significant at 5%	reject the null, significant at 5%	**Substitutability**

Notes: Following Carree, Lokshin and Belderbos (2011), this analysis uses the coefficients from the regressions to test whether the cross terms (between two types of investment have complementarity or substitutability.

These are rather striking results that support the Ritzen and Winkler's notion (1977) that the spread and timing of investments matter as well as the Cunha and Heckman's notion (2007)that early (primary and secondary and later (tertiary) period investments in education are complementary.

5. Conclusions and Policy Implications

The purpose of the PIAAC data is to have internationally comparable measures of cognitive skills among adult populations in different countries. The results are reassuring, because they confirm what we would intuitively suspect – to a large extent, larger amounts of public investment in education do correspond with higher skill levels. This paper contributes to the literature in three ways. First, using cumulated investments, we find a positive relationship between Public

investment and numeracy scores. Second, we further find that this relationship is not the same at all levels of education. Third, when we break investments into three periods: we see that first period investments (in primary education) are strongly and significantly related to the numeracy scores of people who achieved tertiary education. That is to say that when governments invest in primary education, those investments may be realized by (a) the help of strong later period investments and (b) by pushing more people to continue in education and shifting the overall distribution of numeracy skills and the means towards higher levels of achievement.

There are two potentially virtuous circles that arise in the context of this paper. The first virtuous circle is a simple investment circle. If, as recent empirical evidence shows, higher numeracy skills are associated with higher wages and economic growth, it implies that higher numeracy scores can grow the economy which will provide a larger tax base for the public sector. This larger tax base can be used to increase public investment in education. If these larger public investments are associated with higher numeracy scores, those countries that invest more will continually have a larger economy from which to perpetuate the investment. The second virtuous circle is in national innovation systems described by Soete (2006) where four key elements (research capacity, technology and innovation performance, absorptive capacity and social and human capital) are dynamically inter-related. Although this second circle is not addressed by the analysis conducted in this paper, it ought to be considered as motivation for understanding influences that help foster higher numeracy skills, since greater proportions of higher numeracy skills in the overall distribution could be easily associated as important for any of the four key elements .In particular, labor productivity appears to be strongly associated with workers who are top numeracy performers, especially in high-tech sectors (Ritzen and Sasso, 2017).

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Appendix 1

An example of a question that has a difficulty of 228 (which is at the low end of Level 2), asks respondents to look at a picture of a gas tank gauge that has needle indicating that the tank is three quarters full and asks "The full tank holds 48 gallons, how many gallons remain in the tank?" Figure 2 shows that, on average, people in the 12 OECD countries can answer that question, but not a question that asks them to detect a pattern and formula (as illustrated by the example question indicative of a difficulty level of 307 in Appendix 4).

Score	Level	Task Description	Example	Photo
0-175	Below Level 1	Concrete, familiar contexts. Simple processes, counting, sorting, basic arithmetic.	How many water bottles?	
176-225	Level 1	Tasks usually require simple one-step or two-step processes involving basic arithmetic operations.	Respondent is shown a picture of Tea candles (100 candles) - it can be seen the candles are packed 5 rows of 5 candles each how many layers of candles are there?	
226-275	Level 2	Tasks tend to require the application of two or more steps or processes involving calculation with whole numbers and common decimals, percents and fractions.	The full tank holds 48 gallons, how many gallons remain in the tank? (Low end of Level 2 | 228)	
276-325	Level 3	Tasks in this level require the respondent to understand mathematical information which may be less explicit not always familiar, and represented in more complex ways.	Discern the pattern and the formula. (Difficulty: 307)	
326-375	Level 4	These tasks involve undertaking multiple steps and choosing relevant problem-solving strategies and processes.	Compound interest. Respondents are shown the advertisement and asked whether it is possible to double $1,000 and support the answer with relevant calculations.	**Advertisement:** Double the amount invested in 7 years based on a 10% fixed interest rate each year.
376-500	Level 5	Tasks in this level require a broad range of mathematical information that may be complex, abstract or embedded in unfamiliar contexts.	No example given.	

	Single Ticket Price	Season Ticket Price
Orchestra	10	45
Sporting Event	16	72
Movies	5	22.5
Concert	250	1125

Source: All except the 5th column was excerpted from the OECD PIAAC Technical Report (OECD, 2013c).

Appendix 2:
This analysis excludes individuals who have not attained at least some secondary schooling; it is assumed that all individuals have completed a standard 6 years of primary education.

For the sub-group in 'Uncompleted Secondary': according to the HLQ in the PIAAC data, the individual has attained ISCED 2[26], and is therefore assumed to have 3 years of secondary school.

For the sub-group in 'Completed Secondary': according to the HLQ in the PIAAC data, the individual has attained ISCED 3, and is therefore assumed to have 6 years of secondary school.

Tertiary: according to the HLQ in the PIAAC data, the individual has attained ISCED 4 the following assignments have been made:

- If the individual has attained ISCED 4: 1 year of tertiary public expenditure (Tertiary 1),
- If the individual has attained ISECD 5a, Bachelor's: 3 years of tertiary public expenditure (Tertiary Bachelor's),
- If the individual has attained ISECD 5b: 2 years of tertiary public expenditure (Tertiary Vocational),
- If the individual has attained ISECD 5a, Master's: 4 years of tertiary public expenditure (Tertiary Masters), or
- If the individual has attained ISECD 6: 6 years of tertiary public expenditure (Tertiary Doctorate).

In the subsequent analysis all individuals who have attained at least ISCED 4 have been grouped together in one category call 'tertiary', but the assignment of public expenditure has been done on the basis of their individual levels of educational attainment (HLQ). The nominal years of schooling in each country that are associated with each ISCED level of schooling are compiled the Technical Report for the PIAAC database (OECD, 2013). A summary of the relevant information for the preliminary analysis is presented in this paper in Appendix 3.[27]

[26] ISCED stands for International Standard Classification of Education. The OECD has already undertaken the effort to standardize the educational attainment across the countries participating in PIAAC and has classified the nominal years of schooling in each country according to the ISCED standards and recorded this in the variable 'Highest Level of Qualification' which we use to ascertain the amount of public investment, specifically from which streams of funding (either the primary, secondary or tertiary levels) that should be assigned to each individual.

[27] As can be seen in Appendix 3, there is variation between the number of years associated with certain levels of schooling (i.e., in Belgium (Flanders) 16 years of schooling are associated with a Master's degree, while in Denmark 17 years of schooling are generally required for a Master's degree). Therefore, when investments were imputed for individuals within countries, the number of years of investment for a particular level can vary according to national standards. Furthermore, sometimes it is impossible to distinguish exactly how many years would be required to reach a particular level. We made the decision to assign a consistent number of years of public expenditure across all countries for the HLQ (Highest Level of Qualification).

Appendix 2 (continued):

Example of how public investment in Person$_i$ in Italy who was 43 years of age at the time of the PIAAC survey, has been cumulated and assigned.

1) 2011 – 43 = 1968 (calculated year of birth)

2) 1968 + 6 = 1974 (assumed age at which Person$_i$ begins Primary School)

Year	Gov. Expenditure on Primary Education (LCU) (i.e., Lira)	Enrolment in Primary Education (i.e., in Italy)	Expenditure per Pupil for Primary Edu (i.e., in Italy)	GDP per capita, old LCU for EUR countries (i.e., Lira)	Public Expenditure per Pupil as % of GDP
1974	1,456,467,992,580	4,969,667	293,072	2,269,171	12.9
1975	1,656,310,022,140	4,927,452	336,139	2,583,585	13.0
1976	2,041,771,933,700	4,833,415	422,428	3,234,577	13.1
1977	m	4,735,301	m	3,913,702	13.4
1978	2,925,500,088,320	4,648,504	629,342	4,587,585	13.7
1979	3,801,362,923,520	4,562,441	833,186	5,595,832	14.9
				Sum Primary Person$_i$	**81.0**

Source: Data provided by UIS.
Notes: Our interpolation for 1977 is in red. 'm' stands for missing.

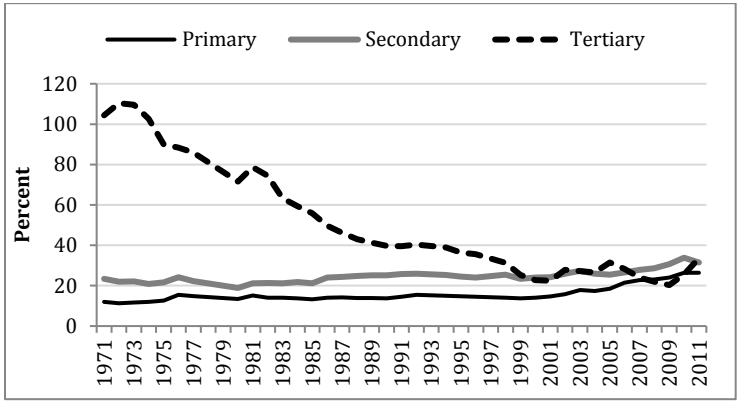
3) Repeat for Secondary and Tertiary *(Depending on the Highest Level Qualification of Person$_i$). Assuming no breaks, skips or repeats.

4) Sum the expenditures over the person's education lifetime:

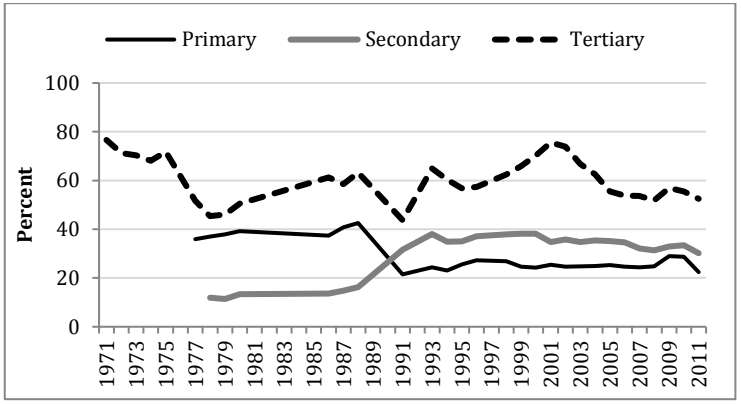
- amount for primary (in this example 81.0)
- plus amount for secondary
- plus amount for tertiary (if tertiary is attained).

Appendix 3: Descriptive analysis - *Public Investment in Education:* Figure 1 portrays trends in public expenditure per student as a fraction of the country's GDP in the three levels of schooling for a subset of countries in the sample. The figure shows substantial variation between the different countries and within countries over time. Looking at the marked decrease in investment in tertiary education in the UK since the 1970s, it's possible that the older population in the UK who achieved the tertiary level of education, benefited from stronger public support than younger cohorts. In Denmark, funding for tertiary education has consistently remained a priority over the 40 year period. Italy and France show relatively low and flat levels of investment over the time period, with Italy's public investment per student tapering out at about 20 percent.

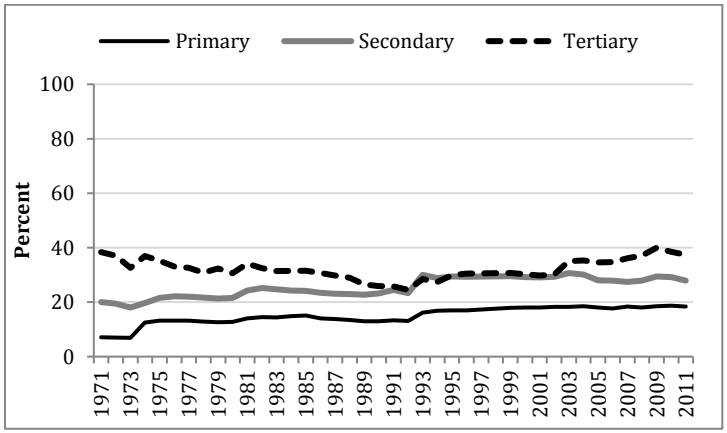
UK: Government Expenditure as a % of GDP per Capita



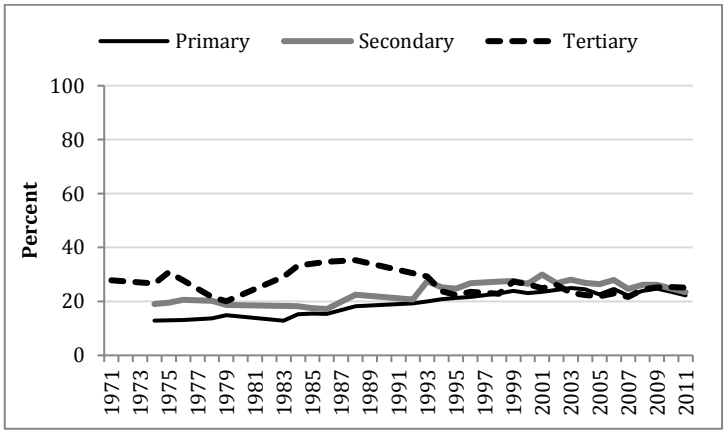
Denmark: Government Expenditure as a % of GDP per Capita



France: Government Expenditure as a % of GDP per Capita



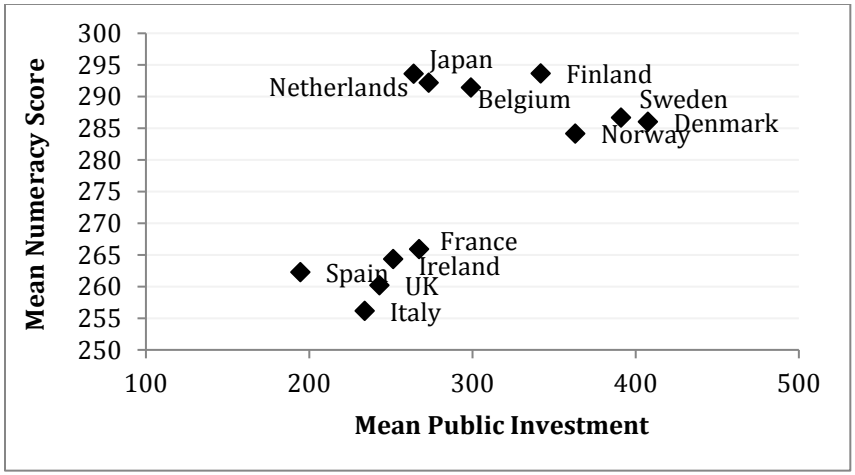
Italy: Government Expenditure as a % of GDP per Capita



Source: **Own elaboration based on data provided by UIS.**

Figure 2 plots the mean numeracy score against the average public investment for each country. We see some clustering of countries with respect to numeracy scores. There are the countries clustered toward the lower-left; Italy, the UK, Ireland, Spain and France. These countries are the ones with a higher proportion of people with skills that are 'Level 1' and below (which is you look at the examples given in Appendix 1 is practically innumerate) dragging the overall mean numeracy score down in these countries. The other cluster of countries; Norway, Sweden, Denmark, Belgium (Flanders), Finland, the Netherlands and Japan are clustered to the upper-right and these are the countries with a relatively higher proportion of people with skills that are 'Level 2' and above bringing the mean numeracy scores in those countries up. It is notable that there is very small proportion of people (for which we have data) with 'Level 5' numeracy skills in any of the countries. When we simply compare the mean numeracy with relative public effort some countries, such as France and the Netherlands are, on average, investing similar amounts (vis-à-vis) their respective GDPs), but the Netherlands appears to be getting better results in terms of the average numeracy of its adult population.

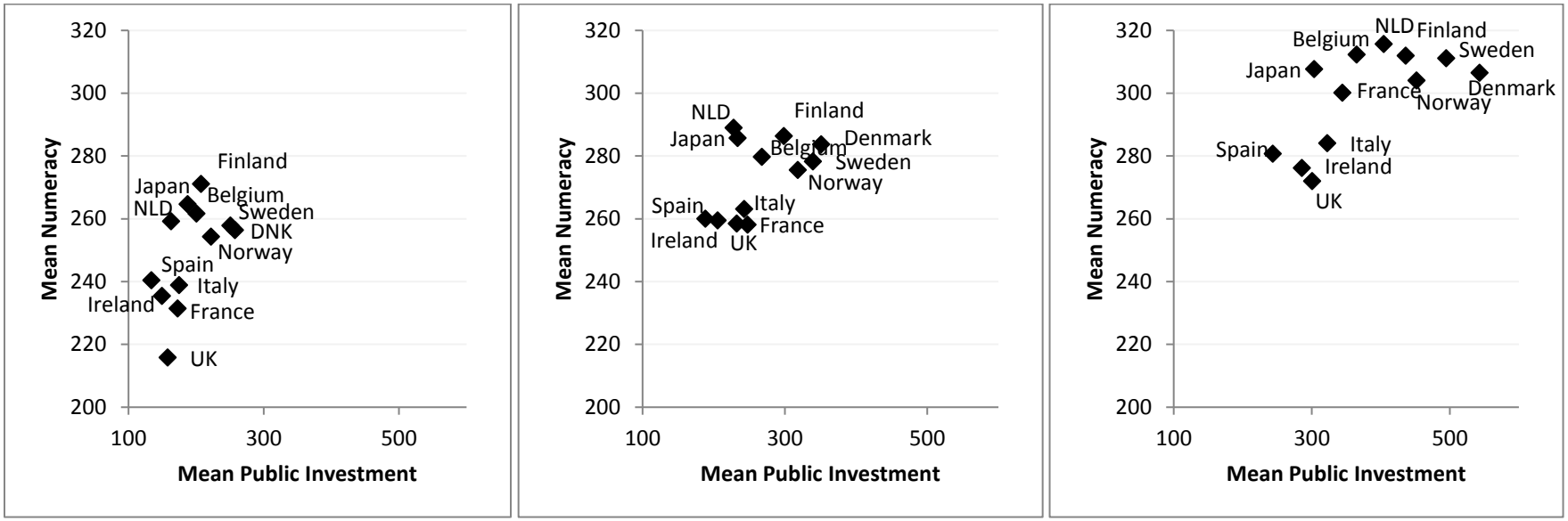
Figure 2: Relationship between Mean Numeracy Score and Average Public Investment



Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: The UK is England/N. Ireland; Belgium is actually Flanders (Belgium). The possible numeracy scores range from 0 to 500, but the scale shown on the axis for both numeracy scores and mean public investment has been truncated for visualization purposes. The numeracy scores in this figure differ slightly from the ones presented in the descriptive statistics presented in Table 1, because these numeracy scores were calculated using all plausible values and replicate weights, rather than using the first Plausible Value. In the case of the UK, there is an additional difference, because due to a coding issue with the data in the UK, mean scores and investments for individuals with ISCED level 6 (tertiary) are not included in this figure. These individuals are included in the analysis and tables in the main text.

Figure 3 plots mean numeracy by our three educational attainment groups. As we would expect, the mean numeracy scores increase with the levels of educational attainment for all of the countries in this analysis. In France we see that the mean numeracy scores are relatively low at the uncompleted and completed secondary levels, the mean numeracy of those who have attained a tertiary education is closer to that of the countries with overall higher average numeracy scores.

Figure 3: Mean Numeracy Score and Average Public Investment per Student by Education Level



Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: The UK is England/N. Ireland; Belgium is actually Flanders (Belgium). The numeracy scores in this figure differ slightly from the ones the ones used in the analysis in the main text, because these numeracy scores were calculated using all plausible values and replicate weights, rather than using the first Plausible Value. In the case of the UK, there is an additional difference, because due to a coding issue with the data in the UK, mean scores and investments for individuals with ISCED level 6 (tertiary) are not included in the tertiary panel in this figure. These individuals are included in the analysis in the main text.

The relationship between mean public investment and the mean numeracy score seems to change as we move up the educational ladder. The variation among countries mean scores is highest at the lowest levels of educational attainment (uncompleted secondary), but the variation in relative public investments (relative to each country's GDP) is the smallest. At the secondary level the mean scores cluster together more; but some countries start to emerge as bigger investors. By the time we reach the tertiary level, some countries are clearly investing more, and for the most part, those that invest more seem to be getting better results.

Appendix 4: Table 8 | Describing Countries' Data Availability

Country	UIS Investment Data	PIAAC Data
Australia	*Only after ~ 1993 (consistently)*	*Missing a STATA file for AUS*
Austria	*Yes*	*Missing AGE variable*
Belgium (Flanders)	**Yes**	**Yes**
Canada	*Insufficient Investment Data*	*Missing AGE variable*
Czech Republic	*Insufficient Investment Data*	*Yes*
Denmark	**Yes**	**Yes**
Estonia	*Insufficient Investment Data*	*Missing ISCED classification*
Finland	**Yes**	**Yes**
France	**Yes**	**Yes**
Germany	*Insufficient Investment Data*	*Yes (but not in the public use file)*
Ireland	**Yes**	**Yes**
Italy	**Yes**	**Yes**
Japan	**Yes**	**Yes**
Korea	*Insufficient Investment Data*	Yes
Netherlands	**Yes**	**Yes**
Norway	**Yes**	**Yes**
Poland	*Insufficient Investment Data*	*Yes*
Slovak Republic	*Insufficient Investment Data*	*Yes*
Spain	**Yes**	**Yes**
Sweden	***Although Inv. Data are sparse**	**Yes**
United States	*Insufficient Investment Data*	*Missing AGE variable*
UK (England / N. Ireland)	**Yes**	**Yes**
Partners		
Cyprus	*No Investment Data*	Missing PIAAC data
Russian Federation	*No Investment Data*	*Yes*

Sources: Data provided by UIS and PIAAC (OECD, 2015).

Appendix 5: Table 9 | Describing Educational Category and Corresponding Years

		BELGIUM			DENMARK			FINLAND			FRANCE			IRELAND			ITALY		
ISCED Level	B_Q01a (PIAAC)	N_Yrs	EDU_G	S_Yrs INV	N_Yrs	EDU_G	S_Yrs INV	N_Yrs	EDU_G	S_Yrs INV	N_Yrs	EDU_G	S_Yrs INV	N_Yrs	EDU_G	S_Yrs INV	N_Yrs	EDU_G	S_Yrs INV
No formal qualification or below ISCED 1	**1**										5						0		
ISCED 1	**2**	6			6			6			5			8			5		
ISCED 2	**3**	8	1	9	9	1	9	9	1	9	5,9*	1	9	11,12*	1	9	8	1	9
ISCED 3C Shorter than 2 years	**4**	n.a.			10		n.r.	n.a.			11		n.r	n.a.			9	2	12
ISCED 3C 2 Years or more	**5**	12	2	12	12	2	12	n.a.			14	2	14	n.a.			11	2	12
ISCED 3A-B	**6**	12	2	12	12	2	12	n.a.			13	2	13	n.a.			13	2	12
ISCED 3 (without distinction A-B-C 2y+)	**7**	12	2	12	12	2	12	11,12*	2	12	12	2	12	14	2	12	n.a.		
ISCED 4C	**8**	n.a.				3	13	n.a.			n.a.			15,18*	3	13	n.a.		
ISCED 4A-B	**9**	13	3	13	13	3	13	n.a.			n.a.			n.a.			n.a.		
ISCED 4 (without distinction A-B-C)	**10**	13	3	13	13	3	13	12	3	13	n.a.			n.a.			15	3	13
ISCED 5B	**11**	15	3	14	15	3	14	14	3	14	14	4	14	16,17*	3	14	16	3	14
ISCED 5A, bachelor's degree	**12**	15	3	15	15	3	15	16,15*	3	15	14,15*	5	15	18	3	15	18	3	15
ISCED 5A, master's degree	**13**	16	3	17	17	3	17	17	3	17	17**	6	17	19	3	17	19	3	17
ISCED 6	**14**	20	3	18	20	3	18	19,21*	3	18	20	7	18	21	3	18	21	3	18

Sources: OECD, 2013 and the PIAAC (OECD, 2015).

Notes: 'N_Yrs' stands for Nominal Years of School'; 'Edu_G' stands for the Educational Group to which individuals with this level of educational attainment have been assigned; 1 = Uncompleted Secondary, 2 = Secondary, and 3 = Tertiary; 'S_Yrs INV' stands for the standard years of investment that have been assigned to each of the individuals. In the case of Uncompleted Secondary, for example, 9 total years of public investment have been assigned; 6 from the primary stream of funding and 3 from the secondary stream of funding. 'n.a.' stands for not applicable; there were no corresponding school levels in that country. 'n.r.' stands for no response - no observations received that code for that country. 'n.s.' stands for not stated (in Appendix 5 of the technical report).

*in these cases, the same B_Q01a code could correspond to different years of schooling, but since the data were coded by PIAAC, it is impossible to know which observations had which years; the most standard (across other countries) # of years was chosen and used for imputing investment.

** For France, it is believed that 18 observations were miscoded in B_Q01a with '16', but tabulating B_Q01a for France revealed that they were labeled as 5A Bachelor's/Master's; these 18 observations were treated as Master's and received 17 years of imputed investment.

Table 9 | Describing Educational Category and Corresponding Years, continued

		JAPAN			NETHERLANDS			NORWAY			SPAIN			SWEDEN			UK (GBR)		
ISCED Level	B_Q01a (code)	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV
No formal qualification or below ISCED 1	**1**													6					
ISCED 1	**2**	6			7			7			6			6			6		
ISCED 2	**3**	9	1	9	11	1	9	10	1	9	10	1	9	9	1	9	11	1	9
ISCED 3C Shorter than 2 years	**4**	10	2	12	n.a.			12	2	12	11	2	12	10	2	12	11	2	12
ISCED 3C 2 Years or more	**5**	12	2	12	13,14*	2	12	14	2	12	12	2	12	12	2	12	11	2	12
ISCED 3A-B	**6**	12	2	12	12,13,14 *	2	12	13	2	12	12	2	12	11	2	12	13,12*	2	12
ISCED 3 (without distinction A-B-C 2y+)	**7**	9	2	12	n.a.			n.a.			n.a.			12	2	12	n.a.		
ISCED 4C	**8**	n.a.			n.a.			15	3	13	n.a.			n.a.			n.a.		
ISCED 4A-B	**9**	n.a.			n.a.			14	3	13	14	3	13	n.a.			n.a.		
ISCED 4 (without distinction A-B-C)	**10**	13	3	13	n.a.			n.a.			n.a.			13	3	13	13	3	13
ISCED 5B	**11**	14	3	14	14	4	14	15	3	14	14	3	14	14	3	14	15	3	14
ISCED 5A, bachelor's degree	**12**	16	3	15	16	5	15	16	3	15	15	3	15	15	3	15	n.s.	3	15
ISCED 5A, master's degree	**13**	18,21*	3	17	17	6	17	18	3	17	17	3	17	16	3	16	n.s.	3	17
ISCED 6	**14**	21, 9*	3	18	20	7	18	20	3	18	21	3	18	20	3	18	15,16,19*	3	16

Sources: OECD, 2013 and the PIAAC (OECD, 2015).

Notes: 'N_Yrs' stands for Nominal Years of School'; 'Edu_G' stands for the Educational Group to which individuals with this level of educational attainment have been assigned; 1 = Uncompleted Secondary, 2 = Secondary, and 3 = Tertiary; 'S_Yrs INV' stands for the standard years of investment that have been assigned to each of the individuals. In the case of Uncompleted Secondary, for example, 9 total years of public investment have been assigned; 6 from the primary stream of funding and 3 from the secondary stream of funding. 'n.a.' stands for not applicable; there were no corresponding school levels in that country. 'n.r.' stands for no response - no observations received that code for that country. 'n.s.' stands for not stated (in Appendix 5 of the technical report).

*in these cases, the same B_Q01a code could correspond to different years of schooling, but since the data were coded by PIAAC, it is impossible to know which observations had which years; the most standard (across other countries) # of years was chosen and used for imputing investment.

** For France, it is believed that 18 observations were miscoded in B_Q01a with '16', but tabulating B_Q01a for France revealed that they were labeled as 5A Bachelor's/Master's; these 18 observations were treated as Master's and received 17 years of imputed investment.