Education, age and skills: An analysis using the PIAAC survey

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Abstract: This paper examines the evolution of adult skills, as captured by cognitive competencies assessed in the PIAAC, across age cohorts, explicitly considering that the quality of schooling might change by cohort. The specification of our model allows us to control for changes in the efficiency of the transformation of schooling into competencies. Our results show that the effect of ageing on skills, once isolated from cohort effects related to schooling, decreases monotonically across consecutive cohorts. The evolution of the efficiency of the transformation of schooling into both numeracy and literacy skills shows a similar pattern. Nonetheless, this evolution shows a steadier profile for secondary than it does for higher education. Finally, empirical evidence is provided for the decomposition of the differences in the skill levels of the older vs. the prime-age generations. The results suggest that the progressive expansion of schooling partially offsets the negative effect of ageing on skills.

1. Introduction

Studies dealing with human capital accumulation have traditionally relied upon such indicators as years of schooling or educational levels to proxy knowledge. However, as noted by Wöβmann (2013), although commonly used in empirical research, these proxies misspecify the link between education and the stock of human capital since they ignore schooling quality, leading by implication to inaccurate estimations. Focusing specifically on adult capabilities, conventional measures might fail in their attempt to gauge individuals' real knowledge for several reasons (Borghans et al., 2001). Knowledge might vary depending on the effectiveness of the transformation of schooling into competencies. Moreover, the evolution of these competencies beyond schooling, especially because of the use (or lack of use) of them in the labour market, might also determine how accurately attained education reflects individuals' actual skills. In this regard, direct measures of adult competencies provide a further advance in the attempt to give a reliable measure of individuals' skills as key drivers of economic development, with empirical evidence concluding that not only schooling but also actually acquired competencies have a robust and strong effect on individual earnings, income distribution and economic growth (Hanushek and Woessmann, 2008).

If we accept this distinction between schooling and competencies, then we need to determine how the latter are produced. Educational production functions have typically underpinned analyses of which factors influence students' achievements during their childhood and teens (Hanushek, 1979; 1997). In this context, there is a general consensus in concluding that not only years of education but other relevant features such as personal characteristics (e.g. gender) and family socioeconomic background drive the acquisition of competencies even beyond schooling (Björklund and Salvanes, 2011; Mazzona, 2014). Moreover, given that human capital is a dynamic concept, as individuals leave school and age other sources of knowledge emerge.

The evolution of competencies both over the life cycle and over time has attracted special attention in the literature. Competencies might increase as people enter the labour market and accumulate experience but competencies might also depreciate as a consequence of a lack of use. As De Grip and Van Loo (2002) stress, interruptions to employment or jobs below employees' attained level of education derive in a non-use or an insufficient use of abilities that cause skill obsolescence by atrophy. In this regard,

although skill gains and losses with ageing vary from one person to another, age-skill profiles tend to show a negative trend, with competencies declining from adulthood onwards (Hertzog et al., 2009).

Nonetheless, as noted by Desjardins and Warnke (2012), observed differences in competencies over time should not be attributed solely to ageing. This means *age differences* (between-person comparisons) differ from *age changes* (within-person comparisons). Cohort changes due to social factors and/or neurophysiological changes of successive birth cohorts might pollute purely ageing effects. By implication, differences in competencies over time might reflect more than one source of change. In practice, the scope of the analysis is conditioned by data design, with cross-sectional observations being suitable for examining differences in competencies between individuals belonging to different age cohorts at the same period and, by contrast, longitudinal data-sets being appropriate to determine the trajectory of an individual's competencies over her/his lifespan.

Assuming that skills can be proxied by competencies in adulthood, empirical evidence based on cross-sectional data from the International Adult Literacy Survey (IALS) and the Adult Literacy and Lifeskills Survey (ALL) provides age-skill profiles that decline from the age of 30 onwards (Willms and Murray, 2007; Green and Riddell, 2007). Moreover, on the basis of data from the Longitudinal Study of Adult Learning (LSAL), Reder (2009) reports a negative trend in literacy-age curves, with literacy peaking in the mid-30s and proficiency being lost from there onwards. Taken as a whole, these findings suggest that literacy skills decline not only over time but also over the lifespan, with both cross-sectional and longitudinal data providing a consistent negative empirical relationship between ageing and skills. More recently, combining information from the IALS, ALL and the first wave of the Programme for the International Assessment of Adult Competencies (PIAAC), Desjardins and Warnke (2012) find that unconditional age-skill profiles increase up to the early thirties and then decrease until retirement; nonetheless, when account is taken of education, the results provide monotonically decreasing age-skill profiles from the age of 16.

However, as discussed above, these results ignore the fact that social factors – in particular, the quality of schooling – might change from one cohort to the other. If this is the case, age-skill profiles might track not only the effects of ageing but also changes in the efficiency of the transformation of schooling into competencies through

successive cohorts. The aim of this paper is to provide some insight into this question. Using PIAAC data, we estimate a model that relates numeracy and literacy skills to education (both formal and non-formal), age, gender, a set of variables related to family background and another set of variables related to participation in the labour market. The specification allows us to control for changes in the efficiency of the transformation of schooling into competencies when drawing age-skill profiles for successive age cohorts.

The specification allows us to control for changes in the efficiency of the transformation of schooling into competencies when drawing age-skill profiles for successive age cohorts. To achieve this objective, the ideal information would be a data panel covering a large number of years, or repeated cross-sections for a long time span (see, for example, Desjardins and Warnke, 2012). However, PIAAC data does not satisfy either of these two possibilities. To overcome this difficulty, we adopt an indirect approach to disentangle cohort differences in competencies due to variations in schooling quality from those that result from ageing. Our approach is, however, an approximation that is dependent basically on the following assumption: that the covariates included in the model are precise enough to identify individuals from different cohorts with individuals in the different age-groups from our cross-section sample.[1] Under this assumption, by implementing a strategy based on a single cross-section sample, it is possible to carry out an indirect approximation of the cohort differences in competencies due to modifications in schooling quality.

By using educational level instead of years of attained schooling, our proposal allows for cohort changes in the quality of schooling to vary between upper secondary and higher education. As a consequence, evidence is provided as to (i) whether the efficiency of the transformation of schooling into competences has improved or not over time and (ii) whether there are remarkable differences in the evolution of the quality of schooling between upper secondary and higher education levels.

Previous studies have attempted to separate cohort effects from age effects by comparing single age cohorts on repeated, representative cross-sectional data from IALS, ALL and PIAAC (Willms and Murray, 2007; Green and Riddell, 2007; 2013;

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[1] In our case this implies introducing the hypothesis that the "beta" coefficients are the same for all cohorts, with the exception of the coefficient that measures the transformation of schooling levels in competencies, which varies from cohort to cohort and whose variation is captured by the interaction terms, as equation (1) in section 3 shows.

Desjardins and Warnke, 2012; Flisi et al., 2015). This strategy provides information as to whether a cohort as a whole and on average has gained or lost competencies with ageing and over time[2]. However, although these studies identify schooling as one of the main drivers of literacy skills, none of them focuses on the role played by changes in schooling quality in driving the results. Although it is beyond the scope of our research to identify which factors determine the observed changes in the efficiency of transformation of schooling into competencies, to the best of our knowledge our paper is among the first to explicitly consider these changes in schooling quality when defining age-skill profiles.

The rest of the paper is organized as follows. Section 2 briefly describes the dataset used in the empirical analysis. Section 3 is devoted to outline the formulation of the model. Sections 4 and 5 provide and discuss the main empirical results of the analysis, and finally Section 6 summarizes the main conclusions of the research.

2. A descriptive analysis of the data

This study makes use of the first round of PIAAC data, corresponding to 2012. Conducted by the OECD, this international survey provides high-quality information on the cognitive competencies of adults aged 16-65. Although linked to the two previous international surveys measuring adult competencies (IALS and ALL), the PIAAC includes a higher number of participating countries and assesses domains of cognitive competencies beyond that of literacy. Thus, it provides valuable data on adult proficiency and workplace requirements in numeracy, literacy and problem solving in technology-rich environments, all of which are key skill requirements for individuals to participate successfully in society and for economies to develop. In addition, the survey also provides a comprehensive set of variables concerning individuals' demographic characteristics, family background, educational attainment and labour market performance with the aim of supporting the main analytical goals of the survey, namely

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[2] As noted by Desjardins and Warnke (2012), comparisons of the different waves of IALS (1994, 1996 and 1998), ILL (2003, 2007) and PIAAC (2012) can conducted in two ways. On the one hand, the trajectory of, for example, those individuals born in 1965 and who were aged 33 in IALS-1998, 42 in ALL-2007 and 47 in PIAAC might be monitored. This comparison would reveal whether that cohort has gained or lost skills with ageing. On the other hand, individuals aged 33 in IALS-1994 might be compared with individuals aged 33 in ILL-2003 in order to determine whether there has been a positive or a negative cohort effect in terms of skills for this particular group.

(i) to determine the level and distribution of adult competencies and (ii) to better understand the factors driving these skills over the lifecycle (OECD, 2012).

Some of the 24 countries participating in the first round of PIAAC were excluded from our analysis either because the comparability of their data cannot be guaranteed or because of a lack of homogeneous information on some key variables in our model[3]. The analysis focused solely on numeracy and literacy competencies, as the problem solving in rich-technology environments domain has yet to be implemented by all the participating countries. The numeracy domain assesses "the ability to use, apply, interpret, and communicate mathematical information and ideas", while the literacy domain measures "the ability to understand and use information from written texts in a variety of contexts to achieve goals and develop knowledge and potential". In the original survey, both variables are scored from 0 to 500, although the scores were doubled in our analysis to facilitate the interpretation of the results. Together with these variables, information on (i) educational level, (ii) age, (iii) gender, (iv) immigrant status, (vi) native speaker condition, (vii) family educational background, (viii) labour market experience, (ix) occupation and (x) participation in non-formal education was used in the estimations.

Table 1 shows the descriptive statistics for the selected sample (which excludes individuals with no information regarding any of the variables considered in the analysis, resulting in around 79,000 observations). The average value of the numeracy (literacy) competency stands at about 542 (549) points, with a sizable standard deviation of around 96 (88) points. The average number of years of attained schooling reaches 12.73 in a population with an average age of 40 and an average labour market experience of 18.21 years. The proportion of first-generation immigrants in the sample is 7.9%, falling to 1.7% in the case of second-generation immigrants. As regards family socioeconomic background, 38% (22%) of those interviewed – 92% of whom responded to the questionnaire in their mother tongue – reports having at least one parent who has attained upper secondary (higher) education. Two thirds of the sample has a skilled occupation. Finally, almost 40% of the sample participated in non-formal education in the 12 months preceding the survey.

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[3] Homogeneous, complete data are available for Belgium, Czech Republic, Denmark, Estonia, Finland, Ireland, Italy, Japan, Korea, Netherlands, Norway, Poland, Slovak Republic, Spain, Sweden and the United Kingdom.

Table 2 shows the sample distribution by education level and by cohort. The intermediate level of education (upper secondary and post-secondary non-tertiary education) is the most frequently attained by individuals in the sample (43.38%), followed by higher education (29.79%) and, finally, basic education (26.83%). Adult participants are quite homogeneously distributed by cohort, each containing around 9-11% of the whole sample.

3. Formulation of the model

The aim of our model is to disentangle the impact of the efficiency in the transformation of levels of schooling into skills (a cohort effect), on the one hand, and the effect of ageing, on the other, on levels of numeracy and literacy. It should be noted that, although our model specifically enables us to isolate the effect of schooling quality on the acquisition of skills, the effect of ageing cannot be purely captured by our single cross-sectional database (see discussion in section 1). Thus, although we refer to the effect of ageing that our data is able to capture as a "direct effect of ageing", it should be borne in mind that cohort effects other than changes in the schooling quality might also be captured by this term[4].

The model is an educational production function, which can be stated as follows:

$$Skills_i(Pb1000m_i \text{ or } Pb1000l_i) = \mu + \underbrace{\sum_{h=1}^{10} \beta_h \cdot Int_{ih} + \sum_{k=1}^{10} \alpha_k \cdot Sup_{ik}}_{\text{Educational level dummies by age cohort}} + \underbrace{\sum_{j=2}^{65} \gamma_j \cdot D_{ij}}_{\text{Age dummies}} + \delta \cdot Gender_i +$$

$$+\phi_1 \cdot Inmig1_i + \phi_2 \cdot Inmig2_i + \theta \cdot Nativespeak_i + \tau_1 \cdot Pared1_i + \tau_2 \cdot Pared2_i + \tau_3 \cdot Pared3_i + \quad (1)$$

$$+\lambda_1 \cdot Exp_i + \lambda_2 \cdot Exp_i^2 + +\pi \cdot Skilled_i + \sigma \cdot Nonformaled_i + \underbrace{\sum_{z=2}^{16} \xi_z \cdot Countrydummy_{iz}}_{\text{Country fix effects}} + \varepsilon_i$$

where the dependent variable is an index between 0 and 1,000 referring, alternatively, to literacy $(Pb1000l_i)$ or numeracy skills $(Pb1000m_i)$. The selection of explanatory variables is related to the skill acquisition process, in which five factors interact. We use the following variables for each of the factors (our two variables of interest are marked with an asterisk and their construction is explained below)[5].

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[4] Nonetheless, it is reasonable to assume that in the period of time considered in our study (individuals in the sample were born between 1946 and 1995) no significant cohort effects, other than the one controlled for in the model, have come into play.

[5] A description of the selected explanatory variables is provided in Table A.1.

1) Education level. A functional form of schooling (*).

2) Personal: a functional form of age (*), gender.

3) Family background: Immigrant status (national, first or second-generation immigrant), native speaker, parents' educational levels.

4) Participation in the labour market: experience, skilled occupation.

5) Participation in non-formal education programs.

The high number of observations in our sample (around 79,000) enables us to use a non-constrained functional form for the effect of age on skills. Instead of using a quadratic form or creating dummy variables for decennial or quinquennial age groups, for each year of age a dummy variable has been created. This implies the creation of 49 dummies (from 17 to 65 years), using the age of 16 as the reference category. Using this approach, we avoid imposing a specific functional form for the effects of age on skills, which constitutes in itself an added value with regard to previous studies in the same line that use age as a continuous variable or a variable in intervals (see, e.g., Green and Riddell, 2013).

The functional form of schooling that we use aims to identify different effects of schooling on competencies depending on the individual's year of birth. Coefficients of schooling, which can be interpreted as the efficiency in the transformation of levels of schooling into skills, are, thus, specific for each age group. This makes the analysis of the evolution of that efficiency over time possible. We use ten five-year age groups: the first including individuals born between 1991 and 1995 (aged between 16 and 20 when assessed on the PIAAC), and the last including individuals born between 1946 and 1950 (aged between 61 and 65 years when assessed).

We establish three categories for schooling level[6]: 'basic' (up to lower secondary education) 'intermediate' (upper secondary, both academic and vocational, and post-secondary non-tertiary education) and 'higher education' (both academic and vocational). The model, thus, includes two sets of schooling level variables interacting with the age groups, since 'basic' education is the category of reference. In the case of 'intermediate' education, for example, we include ten dummy variables, one for each age group: 'Int_{i1}' takes a value of 1 if the individual has an upper secondary certificate

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[6] The choice of these categories is endorsed by the evidence provided in Table 3. Thus, the rate of return to schooling in terms of acquired competencies differs notably between the intermediate and higher education levels.

and was born between 1991 and 1995 and 0 otherwise. 'Int$_{i10}$' takes a value of 1 if the individual has an upper secondary certificate and was born between 1946 and 1950 and 0 otherwise. For 'higher education', likewise, we include nine dummy variables ranging from 'Sup$_{i2}$' to 'Sup$_{i10}$', since in this specific case 'Sup$_{i1}$' corresponds to the null combination of people aged between 16 and 20 having obtained a higher education degree.

As discussed above, the coefficients of the dummy variables describing the interaction between schooling level and age group can be interpreted as the level of efficiency in the transformation of schooling into skills. This interpretation is possible because the model also includes age dummies which capture the direct effect of age on skills, attributable to both biological and behavioural maturation (Desjardins and Warnke, 2012). Keeping age constant, dummy variables like 'Int$_i$' through 'Int$_{i10}$' capture the time evolution of the efficiency in the transformation of upper secondary education into skills. For example, a positive trend in the coefficients accompanying these dummy variables points to an increase in the efficiency of the transformation of upper secondary education into skills.

The model includes, as part of the family background variables, three dummies related to the parents' educational level, adhering to the same three categories used in the case of the individual. Immigrant status is described using two variables: 'immigrant1' for first generation immigrants (with a value of 1 if the individual was born abroad, 0 otherwise) and 'immigrant2' for second generation immigrants (with a value of 1 if both parents of the individual were born abroad, 0 otherwise).

The model also includes labour market experience in a quadratic form, by analogy with the human capital model used to explain wages. An alternative approach, using 55 dummy variables to capture the individual's years of work experience, was tested. Both approaches offered almost identical coefficients for our variables of interest. However, we opted for the quadratic form, as a more parsimonious approach, and in consideration of the better results of the Bayesian Information Criteria (or Schwartz Statistic).

The remaining explanatory variables do not require any additional explanation. They are included to cover the most relevant factors influencing the process of skills acquisition. Additionally, the model includes fifteen country dummies (with Belgium as the category of reference).

4. The transformation of education into skills. Results of the estimation of the model

The results of the estimation of equation 1 for both numeracy and literacy skills are shown in Table 4 (a complete version of the estimation is provided in Table A.2). The effect of gender is significant for both skills. Keeping the remaining variables constant, men score 21 points higher than women in the case of numeracy and 4 points higher in the case of literacy. Being a first- or second-generation immigrant also entails a penalty for both skills. However, the negative effect of being a first-generation immigrant almost triples that of being a second-generation immigrant. Native speakers have a clear advantage in the acquisition of both numeracy and literacy skills, an advantage that roughly translates into an additional 30 points. The effects of cultural capital, proxied by the parents' education level, are also clear: having parents that attained upper secondary education is associated with increases of 16 and 15.4 points (for numeracy and literacy skills, respectively) in relation to having parents with lower secondary education, which is the reference category. Having parents that attained higher education is associated with increases of 35.9 and 33.9 points in the same domains, respectively.

Years of experience in the labour market and its square present the expected positive and negative signs, respectively. Being employed in a job that demands qualifications has a positive effect on numeracy and literacy skills. Likewise, having completed a non-formal training program adds around 12 points to both numeracy and literary skills. However, it should be noted that the effect of life-long learning on skills cannot be properly addressed using PIAAC data, since the only variable in the dataset which can be used refers to training during the last twelve months.

The effect of our two variables of interest (age and schooling quality) will be shown graphically. But, beforehand, in order to fully understand the implications of our results, we show the evolution of the effects of age on skills without conditioning this evolution to any other explanatory variable. This unconditioned effect is shown in Graph 1 with a confidence interval of 95%. In line with the empirical evidence reported in previous studies (see, e.g., Desjardins and Warnke, 2012), both numeracy and literacy skills tend to increase up to an age of about 25-30 years. After this age, both skills tend to decrease continuously.

Graphs 2 and 3 show the effects of the two variables of interest in our complete model, for different age groups. These effects decompose the aggregate effect of age shown in Graph 1. Specifically, Graph 2 plots the effects of the variable 'age' on skills,

which captures the direct effect of ageing in the model. As discussed above, this direct effect may be caused by processes related simultaneously to biological and behavioural maturation and in our model it is isolated from the cohort effect, i.e., possible changes in the way in which the education system is able to transform schooling levels into skills. It seems apparent that the kind of skills measured by the PIAAC is negatively affected by this direct effect. The trend appearing in the graph is monotonically decreasing for both skills, showing, in both cases, a steep drop at around the age of 20. This drop might be related to the existence of skills that the individual is able to keep only for a short period of time after leaving formal education. When comparing this trend with that shown in Graph 1, it should be stressed that the change is directly linked to the introduction into the model of those variables in which age interacts with the education level, the contribution of the remaining explanatory variables being less relevant.

Graph 3 plots the effects of the dummy variables in which the level of schooling interacts with the age group (cohort effects due to changes in the quality of schooling), for different age groups. The evolution over time of these effects provides us with information about changes in the efficiency in the transformation of levels of schooling into skills. For each skill, the upper panel of the graph refers to the intermediate level of education (upper secondary education), while the lower panel refers to higher education. In all four cases, the corresponding 95% confidence interval is shown between dashed lines.

Graph 3 shows that the effects on numeracy and literacy skills in the case of intermediate education are very similar, as they are also in the case of higher education. However, these trends differ markedly if we contrast the two education levels. In the case of intermediate education, a significant deterioration occurs for the age group born between 1991 and 1995. For this age group, the attainment of intermediate education (relative to basic education) adds 33 points to their numeracy skills; by contrast, for the age group born between 1946 and 1950 (i.e., the last cohort) the equivalent increase was of 42 points[7]. However, for the rest of the age groups the efficiency of transformation of

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[7] When applying a formal test of equality of coefficients on intermediate education, the null hypothesis is rejected with a p-value of 1.77%. Moreover, the specific null hypothesis of equality between the coefficient of the first age group and the coefficient of the rest of the age groups is also rejected, with a zero p-value. Nonetheless, the pronounced fall in the coefficient associated with the first cohort should be interpreted with caution, as some sample effects might contaminate the result. Thus, the percentage of individuals belonging to both this cohort and this educational level varies greatly by country, a feature that is exclusive to this age group. As a consequence, the lower coefficient might be the result of an overrepresentation of those countries in which intermediate education shows a poorer efficiency in the transformation of schooling into competencies.

the intermediate level of education into skills remains steady, with only a significant increase being recorded in the age group born between 1970 and 1975.

In the case of higher education the pattern is quite different, showing a monotonic increase in the efficiency in transformation of schooling into skills for all the age groups born between 1945 and 1975 and, thereafter, a steady evolution with only a slight but significant decrease for the two youngest age groups, corresponding to those born between 1980 and 1990[8].

The results of our model, then, can be summarized in terms of four patterns: (i) the direct effect of ageing, isolated from cohort effects related to schooling, decreases monotonically for all the age groups considered; (ii) the cohort effects we identify, relating to the efficiency of transformation of schooling into skills, are very similar in the case of numeracy and literacy skills; (iii) the cohort effects identified by the model are substantially different by educational level; and (iv) while the transformation of upper secondary education into skills shows a steady level of efficiency over time (the only exceptions being the youngest age group and a 'peak' presented by the age group corresponding to those born in 1970-75), in the case of higher education the efficiency when transforming schooling into skills increases for all the age groups from 1945 to 1970, decreasing slightly thereafter for the youngest age groups.

5. Some explanatory factors of the differences in the level of skills by age group

This section aims at complementing the evidence provided in sections 3 and 4 with an additional analysis centred, in this case, in explaining aggregate differences in skills between age groups located at the extremes of the age distribution. The unit of analysis is, therefore, the age group.

Table 5 and Graph 1 show the differences in both numeracy and literacy skills as a function of age. Both skills increase from the youngest age group to the 26-30 (in the case of literacy) and 31-35 (in the case of numeracy) age groups. Subsequently, the trend decreases, the level of skills reaching a minimum in the older age groups. In this process of skill loss after the respective prime ages, two factors operate: on the one hand, ageing, defined in section 3 as a biological and behavioural process; and, on the other, levels of schooling, which, due to the progressive quantitative extension of education, are generally higher for the younger age groups. Graph 4 shows this

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[8] The null hypothesis of equality between the coefficient of the first age group and the coefficient of the last age group is also rejected, with a zero p-value.

progressive extension, including the corresponding 95% confidence interval. The maximum level of schooling is reached for those aged 30, with an average of 14 years of schooling, while for people aged 65 the average value drops to 11.9 years.

In the following analysis we select the 31-35 year age group as being representative of the prime age groups with a high probability of having finished their degree and of having entered the labour market. We compare the skills of this age group with those of the older age group (60-65) and seek to identify the contribution, in the difference found, of the two main factors (as identified above) determining this skill loss.

The following formulation is used to disentangle the two factors. The equation that explains skills is given by:

$$Y_i = X_i'\beta + u_i \tag{2}$$

This equation enables us to compute the average skills of a certain Y age group J by calculating the corresponding average values of all individuals belonging to this group:

$$\bar{Y} = \bar{X}'\beta + \bar{u} \tag{3}$$

In the same way, for age group O, it is possible to calculate:

$$\bar{\bar{Y}} = \bar{\bar{X}}'\beta + \bar{\bar{u}} \tag{4}$$

where the upper double line indicates the average values of all individuals belonging to age group O.

The difference in the average skills of cohorts J and O can then be decomposed as follows:

$$\underbrace{\left(\bar{Y} - \bar{\bar{Y}}\right)}_{\substack{\text{Observed} \\ \text{difference}}} = \underbrace{\left(\bar{X}' - \bar{\bar{X}}'\right)\beta}_{\substack{\text{Explained} \\ \text{difference}}} + \underbrace{\left(\bar{u} - \bar{\bar{u}}\right)}_{\substack{\text{Unexplained} \\ \text{difference}}} \tag{5}$$

Substituting the population parameters by the corresponding estimates, we are able to disaggregate the variation of skills for different age groups.

Table 6 shows the results of comparing the numeracy and literacy skills of the older age group (61-65 years old) with those of the prime age group (31-35 years old). In the case of numeracy skills, the observed difference between age groups is 50.27 points while the estimated difference is 48.81 points, which suggests that our model fits the actual change well (the unexplained difference representing barely 2.9%). With our model, we can disentangle the contribution of, first, age and experience in the labour market (which amounts to 24.6 points or 48.99% of the total difference); second,

schooling, including both formal initial education[9] and subsequent participation in non-formal education and training programs (which amounts to 17.6 points or 35.09% of the total difference); and, third, other factors related to the composition of the population, gender, etc. (amounting to 6.5 points or 13.02% of the total difference).

Table 6 also shows the results of our analysis for literacy skills. The contribution of age and experience in determining differences between age groups for these skills (45.74% of the total) is slightly lower than that observed for numeracy skills, while the contribution of schooling is higher (44.78% of the total).

Our results point to the combined action of the two factors under consideration, with a contribution of age and experience that accounts for almost half of the total difference. The ageing factor, driving skills downwards, threatens the growth potential of our economies, especially if we take into account the long-term trend of ageing suffered by most developed societies. Moreover, it is a factor that is, to a large extent, beyond the control of public policies. However, the expansion of schooling partially offsets this decline in skills with ageing, with the participation of individuals in the educational system being a factor that can be modified by policy measures. Specifically, schooling –in the sense we give it – can be increased by means of educational policy, either through the straightforward quantitative expansion of formal education or by improvements in its quality. Moreover, an intensification of non-formal education and training programs might also be useful to partially offset the negative effect of ageing on skills. Additional interventions, aimed at reshaping learning so as to avoid the rapid skill loss we detect in the years immediately after leaving formal education, might also be envisaged. To sum up, there are several options available for seeking to compensate the decay in skills associated with ageing.

6. Conclusions

This article has aimed to analyse how adult skills change across age groups, disentangling two factors of change: on the one hand, an ageing effect and, on the other, a cohort effect related to changes over time in the quality of schooling. Adult skills have been examined in terms of cognitive competencies as assessed in the OECD's PIAAC.

This aim is of some relevance, especially if we take into account the profile of the relation between age and skills: an individual's numeracy and literacy skills increase

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[9] Possible changes in the efficiency of the transformation of schooling into skills through successive cohorts, as described in sections 3 and 4 herein, are included in this factor.

up to the age of about 25-30 years and, after this, tend to decrease continuously. Our research question has been centred on the factors associated with that trend.

We have drawn on data for sixteen countries participating in the first edition of the PIAAC (2012). We estimated a model in which numeracy and literacy skills are related to a set of variables, among which we included our two variables of interest. The first is a functional form of schooling which combines education level with age, indicating the efficiency of the educational system in transforming schooling into skills. The model allows this efficiency to vary both between age groups and education levels. The second variable is a functional form of age, which captures the direct ageing effect (caused by processes related simultaneously to biological and behavioural maturation). Additionally, the model included other variables aimed at capturing and controlling a range of different sources of skill acquisition, namely family background, participation in the labour market and participation in non-formal education programs.

Taking our two variables of interest into consideration, the estimation of the model yielded the following main results. First, the direct ageing effect decreased monotonically for all the age groups considered. Second, we found very similar cohort effects, in relation to the efficiency in the transformation of schooling into skills for numeracy and literacy skills. Third, the cohort effect varied substantially between upper secondary education and higher education. And fourth, the cohort effect for upper secondary education showed a steady level of efficiency over time, while, in the case of higher education, efficiency increased for all the age groups between 1945 and 1970, decreasing slightly thereafter for the youngest age groups.

The evidence provided by the article is complemented, in section 5, by an additional analysis in which we seek to explain aggregate differences in skills between the age groups located at the extremes of the age distribution (31-35 years vs. 60-65 years), the unit of analysis being the age group. These differences were split into two components with opposite effects: ageing, which tends to decrease skills, and levels of schooling, which, in recent decades, have shown a persistent quantitative extension of skills. Our results indicate that age accounts for almost half of the total difference in skills between the two selected age groups, while changes in schooling, including quantitative and possible qualitative changes, account for 35.09% (in the case of numeracy) and 44.78% (literacy) of the difference.

All in all, the results provided by this article show that ageing, a factor of increasing significance in most developed societies, drives skills downwards, all else

being constant, and also that quantitative expansions and qualitative improvements of schooling can be used by public policy as a means to partially compensate for this trend.

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Table 1. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Numeracy	542.0646	96.1126	49.6917	888.2642
Literacy	549.3120	88.3885	47.1337	831.2783
Schooling	12.7323	3.0259	3.0000	22.0000
Age	39.9555	14.4749	16.0000	65.0000
Experience	18.2143	13.1439	0.0000	55.0000
Gender: male	0.4783	0.4995	0.0000	1.0000
Immigrant1	0.0796	0.2707	0.0000	1.0000
Immigrant2	0.0173	0.1304	0.0000	1.0000
Nativespeaker	0.9233	0.2660	0.0000	1.0000
Pared2	0.3815	0.4858	0.0000	1.0000
Pared3	0.2232	0.4164	0.0000	1.0000
Skilled occupation	0.6122	0.4873	0.0000	1.0000
Non formal education	0.3919	0.4882	0.0000	1.0000

Table 2. Sample distribution by age and by education level

Variable		Percentage
Education level	Basic	26.83
	Intermediate	43.38
	Higher education	29.79
Age group	16-20	8.79
	21-25	8.29
	26-30	9.98
	31-35	10.73
	36-40	11.59
	41-45	11.12
	46-50	10.58
	51-55	10.08
	56-60	9.12
	61-65	9.72

Table 3. Returns to schooling by education level

Education level	Coefficient		Average years of schooling	Returns by additional years of schooling	
	Numeracy	Literacy		Numeracy	Literacy
Intermediate	43.85813	37.48626	12.32281	-	-
Higher education	79.90233	71.25528	16.13928	9.44438185	8.8482341

Table 4. Determinants of numeracy and literacy by education level and age cohorts

VARIABLES	Numeracy	Literacy
Education: see graph 3		
Age: see graph 2		
Sex: male	20.88***	3.607***
	37.84	7.101
Immigrant1	-29.82***	-34.14***
	-18.08	-22.09
Immigrant2	-11.68***	-13.16***
	-5.316	-6.331
Nativespeaker	31.44***	29.34***
	17.92	17.89
Pared2	16.08***	15.41***
	23.16	24.03
Pared3	35.96***	33.99***
	43.89	44.90
Experience	1.437***	1.102***
	10.67	8.860
$Experiencie^2$	-0.0197***	-0.0186***
	-7.110	-7.264
Skilled occupation	31.09***	26.08***
	48.48	43.98
Non formal education	11.95***	11.83***
	20.15	21.62
Czech Republic	-10.76***	-4.452***
	-6.918	-3.043

Denmark	-3.229**	-9.624***
	-2.105	-6.820
Estonia	33.78***	42.78***
	19.31	25.80
Finland	6.128***	26.93***
	3.881	18.20
Ireland	-32.93***	-4.316***
	-20.09	-2.893
Italy	-24.83***	-15.89***
	-13.62	-9.576
Japan	4.248***	29.11***
	2.674	20.08
Korea	-34.47***	-9.235***
	-22.36	-6.517
Netherlands	9.589***	25.97***
	6.064	17.59
Norway	-5.049***	3.600**
	-2.973	2.350
Poland	-37.46***	-15.95***
	-23.89	-10.91
Slovak Republic	-0.915	0.680
	-0.565	0.461
Spain	-43.04***	-25.19***
	-25.93	-16.00
Sweden	7.444***	16.45***
	4.270	10.38
United Kingdom	-30.45***	-1.470
	-19.95	-1.043
Constant	470.4***	489.5***
	124.3	136.9
Observations	78,825	78,825
R-squared	0.341	0.348

Note: t-statistics below coefficients. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5. Numeracy and literacy skills by cohort

| Age	Cohort	Value	Lower limit	Upper limit
Numeracy skills				
16-20	1	539.8514	538.0194	541.6835
21-25	2	554.9839	553.2221	556.7457
26-30	3	559.1966	557.2661	561.1272
31-35	4	559.3848	557.4617	561.3078
36-40	5	556.5519	554.7032	558.4006
41-45	6	550.0798	548.191	551.9685
46-50	7	541.4388	539.5518	543.3258
51-55	8	527.7028	525.7611	529.6445
56-60	9	518.4784	516.5403	520.4165
61-65	10	509.1117	507.1988	511.0247
Literacy skills				
16-20	1	557.5503	555.8869	559.2137
21-25	2	569.469	567.8694	571.0686
26-30	3	570.3308	568.5779	572.0836
31-35	4	567.1315	565.3854	568.8775
36-40	5	564.8601	563.1816	566.5387
41-45	6	554.5522	552.8373	556.2671
46-50	7	544.3747	542.6614	546.088
51-55	8	529.6294	527.8665	531.3924
56-60	9	518.9467	517.187	520.7064
61-65	10	510.0311	508.2942	511.768

Table 6. Explanatory factor of the improvement in numeracy skills when passing from the old cohort (aged between 61 and 65 years) to prime age cohort (aged between 31 and 35 years)

	Value		Percentage	
	Numeracy	Literacy	Numeracy	Literacy
Contribution of age and experience	24.63	26.12	48.99	45.74
Contribution of schooling	17.64	25.57	35.09	44.78
Remaining factors	6.54	4.67	13.02	8.17
Explained variation	48.81	56.35	97.10	98.69
Non explained variation	1.46	0.75	2.90	1.31
Observed variation	50.27	57.10	100.00	100.00

Graph 1. Numeracy and literacy skills by age
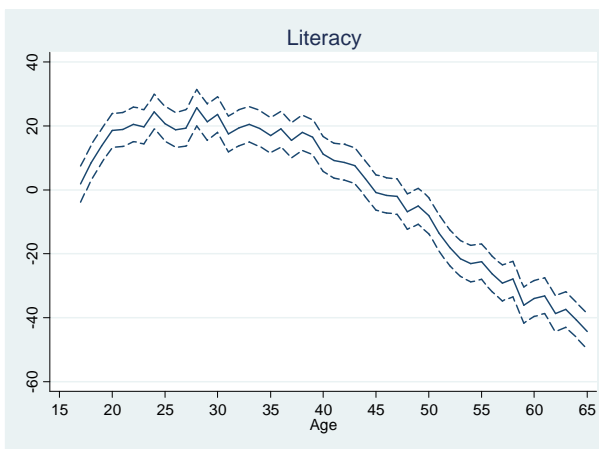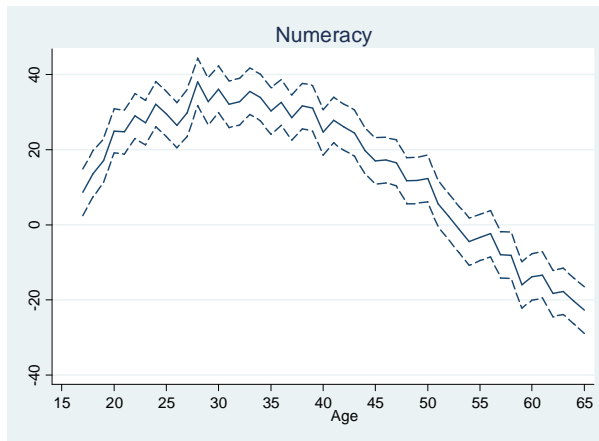
Numeracy

Literacy

Graph 2. Effects of ageing on numeracy and literacy skills
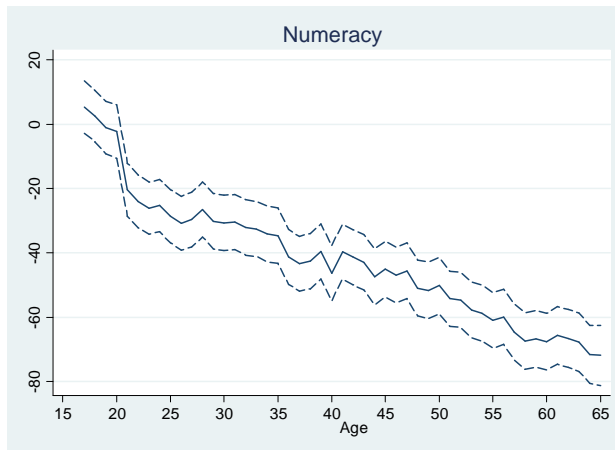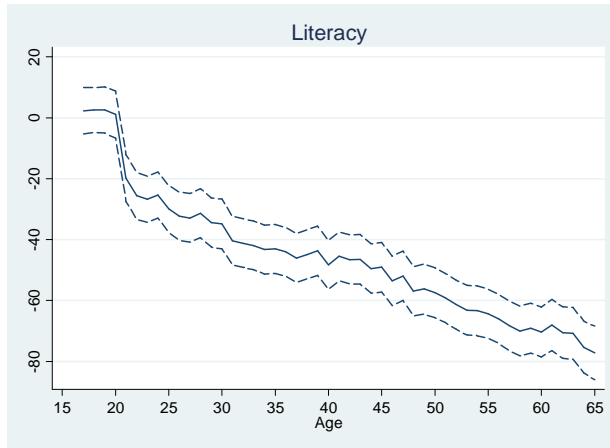
Numeracy

Graph 3. Efficiency on the transformation of schooling into competencies

Numeracy

Literacy
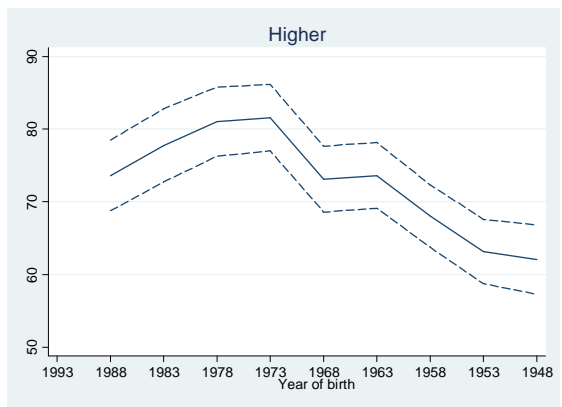
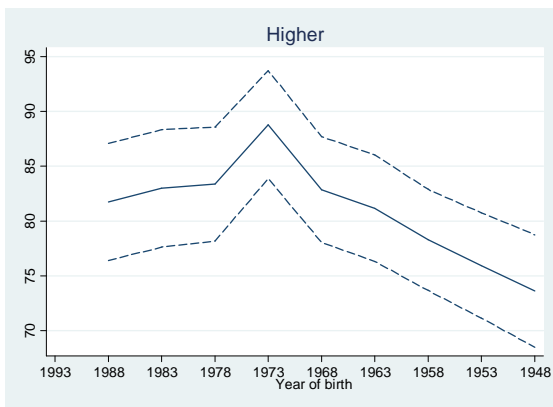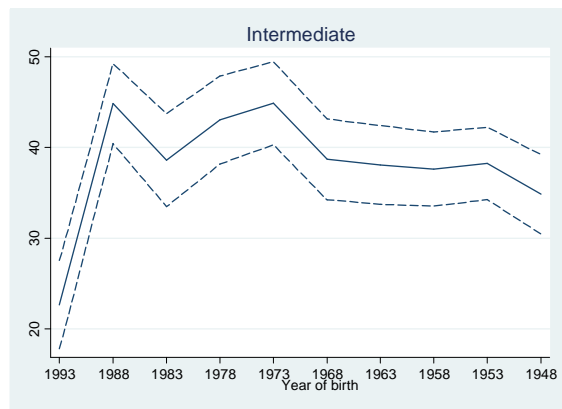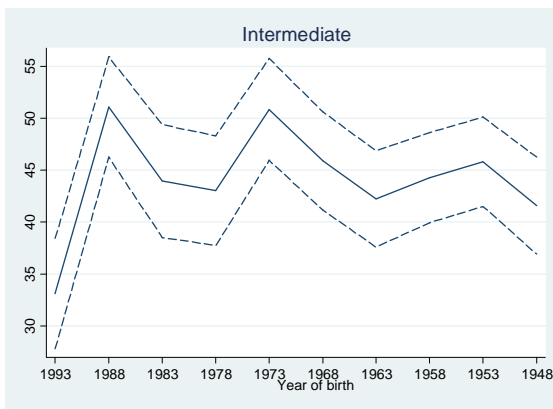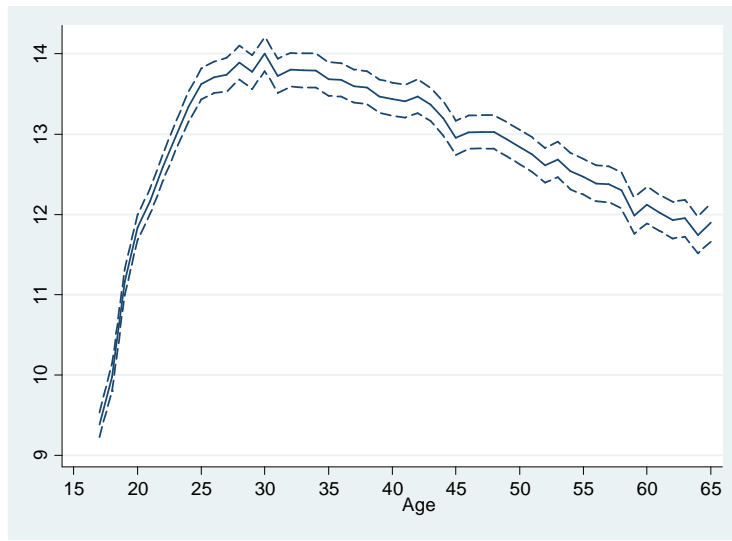**Graph 4. Average years of schooling by age**

Appendix

Table A.1. Description of the variables

VARIABLE	DEFINITION
Pb1000m, Pb1000l	Dependent variables: average numeracy (PVNUM1-10) and literacy (PVLIT1-10) competencies normalized to 1000
$\beta_1 Int_{i1}$... $\beta_{10} Int_{i10}$	Dummies indicating that individuals born in the 1st … 10th cohort hold upper secondary education
$\alpha_1 Sup_{i1}$... $\alpha_{10} Sup_{i10}$	Dummies indicating that individuals born in the 1st … 10th cohort hold higher education
Age	Person resolved age: AGE_R
Experience	Years of paid work during lifetime: C_Q09
Gender	Person resolved gender: GENDER_R
Immigrant1	First generation immigrants: IMGEN=1
Immigrant2	Second generation immigrants: IMGEN=2
Nativespeaker	Respondent is native speaker: NATIVESPEAKER
Pared2	At least one parent has attained secondary or post-secondary, non-tertiary: PARED=2
Pared3	At least one parent has attained tertiary: PARED=3
Skilled occupation	Occupational classification of respondent's job (4 skill based categories), last or current (derived). ISCOSKIL4=1
Non formal education	Participated in non-formal education in 12 months preceding survey (derived). NFE12=1

Table A.2. Determinants of numeracy and literacy by education level and age cohorts

VARIABLES	Numeracy	Literacy
Intermediate1	33.13***	22.67***
	12.21	9.141
Intermediate2	51.09***	44.85***
	20.79	19.92
Intermediate 3	43.95***	38.60***
	15.85	14.78
Intermediate 4	43.04***	43.03***
	15.97	17.39
Intermediate 5	50.85***	44.88***
	20.33	19.20
Intermediate 6	45.89***	38.69***
	19.02	17.01
Intermediate 7	42.24***	38.08***
	17.82	17.20
Intermediate 8	44.28***	37.62***
	20.01	18.04
Intermediate 9	45.81***	38.25***

	20.85	18.74
Intermediate 10	41.60***	34.85***
	17.50	15.61
Higher1	1.218	-4.199
	0.147	-0.477
Higher2	81.73***	73.63***
	29.99	29.64
Higher3	82.97***	77.78***
	30.40	30.24
Higher4	83.36***	81.05***
	31.42	33.38
Higher5	88.79***	81.57***
	35.40	34.97
Higher6	82.87***	73.13***
	33.70	31.60
Higher7	81.16***	73.63***
	32.72	31.92
Higher8	78.27***	68.04***
	33.30	31.02
Higher9	75.95***	63.17***
	30.97	27.93
Higher10	73.62***	62.04***
	28.12	25.48
Age		
17	5.321	2.352
	1.277	0.605
18	2.493	2.595
	0.613	0.686
19	-1.092	2.534
	-0.263	0.656
20	-2.263	1.073
	-0.532	0.272
21	-20.34***	-19.74***
	-4.838	-5.043
22	-24.02***	-25.64***
	-5.726	-6.520
23	-26.09***	-26.67***
	-6.327	-6.929
24	-25.24***	-25.39***
	-6.101	-6.588
25	-28.58***	-29.91***
	-6.785	-7.642
26	-30.76***	-32.23***
	-7.182	-7.977
27	-29.60***	-32.84***
	-6.809	-8.018

28		-26.52***	-31.32***
		-6.088	-7.603
29		-30.17***	-34.39***
		-6.886	-8.392
30		-30.66***	-34.80***
		-6.954	-8.336
31		-30.40***	-40.38***
		-6.967	-9.927
32		-32.06***	-41.13***
		-7.290	-10.07
33		-32.56***	-41.86***
		-7.457	-10.29
34		-34.11***	-43.22***
		-7.734	-10.52
35		-34.62***	-43.03***
		-7.839	-10.48
36		-41.23***	-44.04***
		-9.484	-10.79
37		-43.40***	-46.03***
		-10.02	-11.31
38		-42.55***	-44.82***
		-9.690	-10.89
39		-39.57***	-43.64***
		-9.053	-10.66
40		-46.32***	-48.25***
		-10.59	-11.78
41		-39.66***	-45.48***
		-9.140	-11.11
42		-41.34***	-46.49***
		-9.454	-11.31
43		-42.94***	-46.44***
		-9.760	-11.20
44		-47.41***	-49.45***
		-10.71	-11.95
45		-45.02***	-49.04***
		-10.20	-11.78
46		-46.86***	-53.49***
		-10.64	-12.96
47		-45.58***	-51.87***
		-10.29	-12.53
48		-50.94***	-56.94***
		-11.50	-13.76
49		-51.67***	-56.19***
		-11.53	-13.37
50		-50.11***	-57.40***
		-11.22	-13.76

51	-54.25***	-59.14***
	-12.41	-14.42
52	-54.65***	-61.35***
	-12.48	-14.94
53	-57.69***	-63.14***
	-13.02	-15.17
54	-58.71***	-63.31***
	-13.15	-15.20
55	-60.95***	-64.32***
	-13.88	-15.58
56	-59.87***	-66.00***
	-13.67	-16.15
57	-64.60***	-68.30***
	-14.60	-16.51
58	-67.36***	-69.98***
	-15.00	-16.80
59	-66.70***	-69.06***
	-14.91	-16.49
60	-67.56***	-70.31***
	-15.12	-16.82
61	-65.67***	-67.97***
	-14.33	-15.88
62	-66.59***	-70.54***
	-14.51	-16.35
63	-67.73***	-70.73***
	-14.63	-16.33
64	-71.54***	-75.27***
	-15.58	-17.50
65	-71.86***	-77.17***
	-15.01	-17.30
Sex: male	20.88***	3.607***
	37.84	7.101
Immigrant1	-29.82***	-34.14***
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Non formal education	11.95***	11.83***
	20.15	21.62
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	-6.918	-3.043
Denmark	-3.229**	-9.624***
	-2.105	-6.820
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Italy	-24.83***	-15.89***
	-13.62	-9.576
Japan	4.248***	29.11***
	2.674	20.08
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	-22.36	-6.517
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Constant	470.4***	489.5***
	124.3	136.9
Observations	78,825	78,825
R-squared	0.341	0.348

Note: t-statistics below coefficients. *** $p<0.01$, ** $p<0.05$, * $p<0.1$