Estudios de Economía Aplicada
ISSN: 1133-3197
secretaria.tecnica@revista-eea.net
Asociación Internacional de Economía Aplicada
España

ALBÆK, KARSTEN

A Test of the 'Use it or Lose It' Hypothesis in Labour Markets around the World

Estudios de Economía Aplicada, vol. 34, núm. 2, 2016, pp. 323-352
Asociación Internacional de Economía Aplicada
Valladolid, España

ESTUDIOS DE ECONOMÍA APLICADA VOL. 34-2 2016 PÁGS. 323–352

A Test of the 'Use it or Lose It' Hypothesis in Labour Markets around the World*

KARSTEN ALBÆK

SFI - The Danish National Centre for Social Research, Herluf Trolles Gade 11, 1052 København K, Denmark. E-mail: kal@sfi.dk

ABSTRACT

This paper investigates skills and the use of skills at work in 21 OECD countries. The skills included in the analysis are literacy, numeracy and problem-solving. The paper investigates the conjecture that the deterioration of skills with age might be more pronounced in occupations with a limited use of skills than in occupations with more intensive use of these skills - an implication of the 'use it or lose it' hypothesis. The paper examines the development over age of both measured skills and the use of skills at work in two aggregate categories of occupations: a group of high-skilled workers (ISCO major occupations from 0 to 4) and a group of low-skilled workers (ISCO major occupations from 5 to 9). High-skilled workers have higher measured skills than low-skilled workers and high-skilled workers use skills more at work than low-skilled workers. Measured skills decline from the age of 35 both for high- and low-skilled workers at about the same pace. The use of skills at work also declines from the age of 35 for both high-skilled workers and low-skilled workers at about the same pace, and at about the same rate as measured skills. The evidence does not support the 'use it or lose it' hypothesis.

Keywords: Skills, Occupations, Ageing.

Una prueba de la hipótesis "usarlo o perderlo" en los mercados de trabajo del mundo

RESUMEN

Este artículo investiga las habilidades y el uso de habilidades en el trabajo en 21 países de la OCDE. Las habilidades incluidas en el análisis son la escritura, el cálculo y la resolución de problemas. El trabajo investiga la hipótesis de que el deterioro de las habilidades con la edad podría ser más pronunciado en ocupaciones con un uso limitado de las competencias que en ocupaciones con un uso más intensivo de estas habilidades - una implicación de la hipótesis de "usarlo o perderlo". El documento analiza la evolución con la edad del nivel de las habilidades consideradas y el uso de las mismas en el trabajo en dos categorías agregadas de ocupaciones: un grupo de trabajadores altamente cualificados (ISCO principales ocupaciones de 0 a 4) y un grupo de trabajadores de baja calificación (ISCO principales ocupaciones de 5 a 9). Los trabajadores altamente cualificados tienen un nivel de habilidades más alto que los trabajadores poco cualificados y los trabajadores altamente cualificados utilizan más habilidades en el trabajo que los trabajadores poco cualificados. El nivel de habilidades disminuye a partir de los 35 años tanto para los trabajadores de alta y de baja cualificación al mismo ritmo. El uso de las habilidades en el trabajo también se reduce desde la edad de 35 años tanto para los trabajadores altamente cualificados y los trabajadores poco cualificados al mismo ritmo, y más o menos al mismo ritmo que el nivel de las mismas. La evidencia no apoya la hipótesis de "usarlo o perderlo".

Palabras clave: Habilidades, ocupaciones, envejecimiento.

JEL Classification: J14

* *This paper is an outcome of the joint Nordic project 'Skill acquisition, skill loss, and age - A comparative study of Cognitive Foundation Skills (CFS) in Denmark, Finland, Norway, and Sweden'. Financial support from NordForsk, Research Project #54861, is gratefully acknowledged. The views and opinions expressed are those of the author alone and do not necessarily reflect those of the funder. I thank Jan-Erik Gustafsson, Erik Mellander, Anders Rosdahl, the participants in the SFI Advisory Board Conference, June 2015, and the Workshop on economics of education: Competences' acquisition, skills & the labour market, University of Barcelona, September 2015, for constructive comments.*

Artículo recibido en febrero de 2016 y aceptado en abril de 2016
Artículo disponible en versión electrónica en la página www.revista-eea.net, ref. ə-34202

ISSN 1697-5731 (online) – ISSN 1133-3197 (print)

1. INTRODUCTION

Education and training to obtain skills is generally considered a major element in skill formation. Economists measure investment in schooling as the number of years spent in educational institutions, and firms train workers with the aim of increasing the ability of their workforce and obtaining higher productivity. In physical activities such as sports, training is likewise essential for obtaining results, and skills that are not used deteriorate rapidly. The deterioration of skills might be impeded by the use of these skills, not only with respect to physical activity but also with respect to mental activity.

The hypothesis that engaging in cognitively-demanding activities can prevent or impede age-related decline in cognitive abilities is known as the ‘use it or lose it’ hypothesis. This hypothesis appears to be both intuitive and plausible, with considerable appeal. However, Salthouse (2006) makes a careful review of the psychological literature on this topic but does not find much evidence for the validity of the hypothesis. According to Salthouse (2006) much of the literature fails to distinguish between the *level* of cognitive ability and the *change* in cognitive ability. Included in his review are studies that compare the cognitive ageing of experts and amateurs (e.g. chess players), and of narrow occupational groups such as architects, physicians and university professors.[1]

This paper investigates the following conjecture: the deterioration of skills over age might be less pronounced in occupations with intensive use of cognitive skills than in occupations with more limited use of these skills. This hypothesis is tested by analysing how measured skills and the use of these skills at work vary with age in major occupational groups in the workforce of 21 developed countries.

The level and use of the cognitive abilities of the workforce is a topic of substantial interest. Cognitive skills are considered a major element in individual success in the labour market and society (e.g. Heckman *et al.* (2006)). A substantial part of skill formation takes place in formal education and a major purpose of schools and educational institutions is the formation of cognitive abilities (e.g. Hanushek (1986)).

The data for the analysis is the PIACC survey, which is collected by the OECD. The survey measures ‘information-processing’ skills in three domains (types of skills): literacy, numeracy and problem-solving (use of information technology). The respondents answer questions in tests for these three types of skills and also answer items about the intensity of their use of these skills at work.

[1] There is no agreement on Salthouse’s synthesis of the psychological literature on this topic, see the exchange between Schooler (2007) and Salthouse (2007). Desjardins & Warnke (2012) contains a broad review of the literature on ageing and skills.

The aim of the assessment of cognitive abilities in PIAAC is that the cognitive outcome measures should reflect abilities amenable to policy initiatives.[2]

The survey also contains information about occupational groups of employed workers according to the International Standard Classification of Occupations (ISCO). Although this classification contains ten major occupational groups (the 1-digit ISCO level), the number of respondents in each country is too limited to enable analysis at the 1-digit level. To gain power in the analysis, employed workers in each country are combined into two groups according to their skill-level as measured by the 1-digit ISCO classification: 'high-skilled' workers in ISCO levels 0 to 4 and 'low-skilled' workers in ISCO levels 5 to 9. These two groups of workers classified according to ISCO levels are sometimes labelled 'white-collar' and 'blue-collar' workers (e.g. Heckman *et al*. (2006), p. 428).

The variation in skill and skill use over age groups and occupations is shown for each of the 21 countries in a condensed graphical analysis that also displays the uncertainty in the form of 95 per cent confidence intervals. The combination of both averages and confidence intervals allows assessment of the extent to which significant differences exist between skills and skill use across ages, occupations, and countries. In addition to the graphical analysis, regression analysis is undertaken for those ages that exhibit a negative relation between skills and age, that is, for the respondents aged 35 to 65.

Hanushek *et al.* (2015) analyse returns to skills on the PIAAC data and confirm that there are substantial returns to measured cognitive skills in the countries in the survey. However, to the extent that the 'use it or lose it' hypothesis is valid, regressions of current wages on contemporaneous measures of cognitive ability may be affected by reverse causality: individuals who secure high-quality jobs with high earnings may tend to improve or maintain their basic skills (see Edin and Gustavsson (2008) for an elaboration of this hypothesis).

The data have several advantages as they are representative within countries and comparable across countries, and contain a relatively large number of observations and a fairly large number of countries. However, as the data are cross-sectional, estimates of the change in cognitive ability with age are potentially biased. There are (at least) two phenomena that might result in bias in the estimates of the relation between cognitive skills and age from cross-sectional data. One is cohort effects, the other is retirement. The discussion section following the empirical analysis contains a discussion of the magnitude of the potential bias of the estimates including references to the literature on this topic.

[2] According to the OECD (2013a), p. 28, the skills measured in PIAAC are '…."learnable". That is, countries can shape the level and distribution of these skills in their populations through the quality and equity of learning opportunities both in formal educational institutions and in the workplace.'

The paper is organized as follows. Section 2 presents the data. Section 3 discusses the methodology. Section 4 contains the results for reading ability and reading at work. Section 5 presents the results for numeracy, and section 6 presents the results for problem-solving. Section 7 discusses the results, including a consideration of potential bias of the estimates. Section 8 concludes.

2. THE DATA

The data for the paper stem from the Programme for the International Assessment of Adult Competencies (PIAAC) database. This survey of adult skills assesses the proficiency of adults aged 16-65 for three measures of cognitive skills - literacy, numeracy, and problem-solving in technology-rich environments. These skills are intended to measure 'key information-processing competencies' that are relevant to adults in many social contexts and work situations. While data was collected for 24 participating countries, only 21 are used in the analysis: Austria, Belgium (only Flanders), Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, Norway, Poland, the Slovak Republic, Spain, Sweden, England (England and Northern Ireland) and the United States.[3] The data was collected from August 2011 through March 2012 in most participating countries.

Representative samples of the adult population were interviewed in their homes in the language of their country. While questions were answered via computer, respondents with no computer experience could use paper and pencil. The interview included both a background questionnaire and questions for the assessment of cognitive skills.

According to the OECD (2013a), the assessment domains in PIAAC are as follows. *Literacy* is the ability to understand, evaluate, use and engage with written texts to participate in society, to achieve one's goals, and to develop one's knowledge and potential. *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. *Problem-solving* is the ability to use digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks.

This paper uses the scores for these three measures of cognitive skills and the corresponding measures of skill use at work included in questionnaire (literacy, numeracy and problem-solving). In addition, the background information on the age and occupation of the worker is used.

[3] Although Australia and Cyprus are included in the survey, the data are not present as public use files. The Russian Federation is omitted because, according to OECD (2013a), the data are only preliminary.

The three skills in PIAAC are measured on a 500-point scale. The scores are normalised by subtracting the country-specific means and dividing by the country-specific standard deviations.

I investigate how both cognitive skills and the use of skills vary between occupations. The PIAAC database contains variables that indicate the occupations of the respondents according to the categories of the International Standard Classification of Occupations (ISCO). The ISCO numbers occupational categories so that the first digit indicates the major occupational category to which each occupation belongs. The 10 major occupational categories are as follows: (0) armed forces occupations, (1) managers, (2) professionals, (3) technicians and associate professionals, (4) clerical support workers, (5) service and sales workers, (6) skilled agricultural, forestry and fishery workers, (7) craft and related trades workers, (8) plant and machine operators and assemblers, and (9) elementary occupations.

The number of observations per country is too small to trace a statistically development over age for each of the major occupations. Hence, the major occupations in two aggregate categories are combined: (a) 'ISCO 0-4' containing major occupations from '0 army' to '4 clerical support workers' and (b) 'ISCO 5-9' containing major occupations from '5 service and sales workers' to '9 elementary occupations'. The first group, 'ISCO 0-4', thus contains the first five major occupations, while the second group, 'ISCO 5-9', contains the last five. In the rest of the paper, the group of workers in the 'ISCO 0-4' category are denoted as 'high-skilled' workers, and workers in the 'ISCO 5-9' category are denoted as 'low-skilled' workers.

For most countries the data contains age as a continuous variable, but for four countries age is reported only for age brackets (Austria, Canada, Germany and the US). For these four countries I construct a continuous variable by applying the midpoint of the age brackets as data points. The procedure is replicated for the countries where the continuous measure is available and no large differences in the results are found.

Drawing on the answers on the use of literacy, numeracy, and problem-solving at work, indices for the use of these three skills are constructed. These indices are applied in place of those indices for reading, writing, numeracy and problem-solving at work included in the PIAAC database and constructed by the OECD. However, my indices are very close to those included in the PIAAC database for those workers for which the OECD has constructed indices (the correlation coefficients are 0.92 for reading, 0.95 for numeracy and 0.90 for problem-solving). A main reason for applying my own indices is that the indices in the PIAAC database omit the category 'never' in the calculations, with the implication that a non-negligible share of the respondents has missing values.[4]

Looking first look at the use of reading or literacy at work, the questionnaire contains eight items on this topic. The participants were asked to state the intensity of the following activities at the workplace by answering how often they usually: (a) read directions or instructions, (b) read letters, memos or e-mails, (c) read articles in newspapers, magazines or newsletters, (d) read articles in professional journals or scholarly publications, (e) read books, (f) read manuals or reference materials, (g) read bills, invoices, bank statements or other financial statements, and (h) read diagrams, maps or schematics.

The items have the same answer categories, and a score value is assigned to each of the categories. The answer categories are as follows (the parentheses contain the score values): 'never' (value 1), 'less than once a month' (value 2), 'less than once a week but at least once a month' (value 3), 'at least once a week but not every day' (value 4), and 'every day' (value 5). The mean value of the score for the eight items is then calculted. These mean values form the basis for calculating the average use of literacy at work for age categories and occupational groups.

Next, the use of numeracy at work is assessed from the answers on the following six items about how often the respondents usually: (a) calculate prices, costs or budgets, (b) use or calculate fractions, decimals or percentages, (c) use a calculator - either hand-held or computer based, (d) prepare charts, graphs or tables, (e) use simple algebra or formulas, and (f) use more advanced math or statistics such as calculus, complex algebra, trigonometry or use of regression techniques. From the answers to these items, the mean score for use of numeracy at work is calculated in the same way as the mean scores for reading at work.

Finally the intensity of problem-solving with information and computer technology (ICT) at work is assessed from the answers to the following seven items about how often respondents usually: (a) use email, (b) use the internet in order to better understand issues related to work, (c) conduct transactions on the internet, for example buying or selling products or services, or banking, (d) use spreadsheet software, for example Excel, (e) use a word processor, for example Word, (f) use a programming language to program or write computer code, and (g) participate in real-time discussions on the internet, for example online conferences, or group chats. For each respondent, the index of problem-solving at work is calculated in the same way as the mean scores for reading and numeracy at work.

[4] Anders Rosdahl constructed these alternative measures for the use of skills and applied them in Rosdahl (2013).

Table A1 in the appendix presents statistics for the sample of employed workers in the 21 countries. Sample sizes range from 2,841 in Italy to 5,791 in England, with Canada as an upper outlier with 19,168. In most countries the group of high-skilled workers contains slightly more than half of the observations, while the group of low-skilled workers contains slightly less than half (exceptions are Korea, Poland, the Slovak Republic and Spain). The average share of employed workers increases from 43 per cent at age 16-24 to about 80 per cent at age 25-54, after which age a decrease sets in and results in an employment ratio of 51 per cent at age 55-65. The average number of years of schooling decreases from 13.5 years in age category 25-34 to 11.8 years in age category 55-65.

3. METHODOLOGY

This section presents the methodology applied in the paper. First, the empirical model that is applied in the paper is presented, followed by the statistical modelling behind the calculation of the standard errors presented in the paper.

The point of departure in the empirical analysis is the following model

$$y_{ij} = a_j + b_j OCC_{ij} + c_j AGE_{ij} + d_j OCC_{ij} AGE_{ij} + e_j S_{ij} + \epsilon_{ij},$$

where y_{ij} is an outcome variable of worker i in country j (either the level of skill or the use of skill), OCC_{ij} is a dummy variable that takes the value one if worker i in country j is high-skilled and zero if the worker is low-skilled, AGE_{ij} is the age of worker i in country j, S_{ij} is the number of years of schooling of worker i in country j, and ϵ_{ij} is the error term of worker i in country j.

Parameter b_j measures the difference in the skill level between high- and low-skilled workers in country j, parameter c_j measures the decline in skill level for low-skilled workers in country j, parameter d_j measures the difference in the decline over age in the skill level between high and low-skilled workers in country j, and parameter e_j measures the impact of schooling on skills in country j. When y_{ij} is a measure of the skill level of the worker, the 'use it or lose it' hypothesis implies that the expected sign of parameter d_j is positive, see Salthouse (2006).

In addition to parameter estimates for each country in the sample, the arithmetic average of the parameter estimates for the countries in the sample is reported. The standard error of this average is calculated from the standard errors of the parameter estimates for the countries.[5]

The countries use different sampling schemes for drawing samples of the

[5] The variance of the arithmetic average of the country parameters is the sum of the variances of the country parameter estimates divided by the square of the number of countries.

adult populations and have different response rates of different groups of the adult populations. The data contains weights to align the respondents with the population, and these sampling weights are applied in all the analyses.

The respondents do not answer all items in the questionnaire. Estimates of individual cognitive abilities are based on both item response theory and statistical modelling including latent regressions. These estimates of individual cognitive abilities are given in the data as ten ‘plausible values’ for each individual for each of the three measures of cognitive skills (literacy, numeracy and problem-solving). As the plausible values for each individual are correlated, valid estimates of variance estimators take this correlation into account.[6] Throughout the paper I use the 10 plausible values for each individual for the three measures of cognitive skills, and present standard errors that take into account both the sampling variability and the imputation variance associated with the plausible values.

4. LITERACY AND AGE

This section displays results for literacy skills and use of literacy in major occupational categories over age for each of the 21 countries. Graphs for the literacy skills and use in different age categories are displayed, and regression results for the development of literacy skills and use with age are presented.

Figure 1 shows how the literacy score varies over ages and occupations in the different countries (listed alphabetically). I start with Germany, which is representative for most countries.

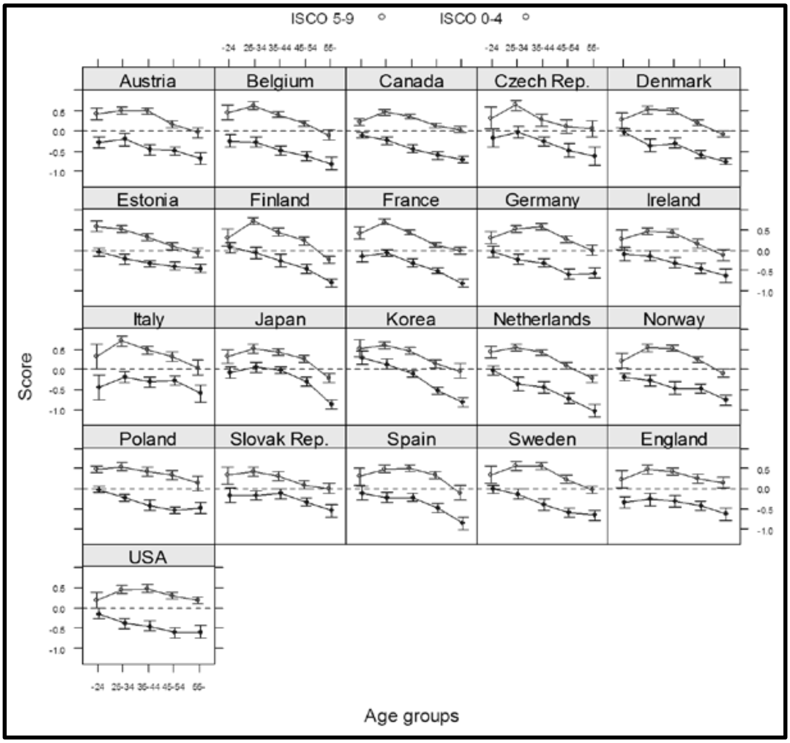
For the high-skilled workers in occupational categories ISCO 0-4, the literacy score in age category 16-24 is slightly above zero, which is the mean score for all workers in the sample for Germany. As previously mentioned, the scores for each country are normalized by subtracting the average score and dividing by the dispersion for each country. The score increases to about 0.5 in age category 25-34 and slightly more up to age category 35-44. However, the score decreases to a level of about 0.5 in age category 45-54 and even further to a level of about zero in age category 55-64. For the low-skilled workers in occupational categories ISCO 5-9, the literacy score in age category 16-24 is zero. The score decreases to about -0.5 in age categories 25-34 and 35-44, followed by a further decrease to a level slightly below -0.5 in age categories 45-54 and 55-64.

The vertical bars in the diagram illustrate the 95 per cent confidence intervals of the means. For example the upper limit of the confidence interval for high-skilled workers in age category 55-64 is below the lower limit of the

[6] See OECD (2013b) and von Davier, *et al.* (2009) for the construction and use of plausible values. The technique is an example of ‘multiple imputation’.

confidence interval for high-skilled workers in age category 45-54. The decrease in literacy score is thus statistically significant. The same holds for the decrease in the score for high-skilled workers from age category 35-44 to age category 45-54. For low-skilled workers, there is a significant decrease in the literacy score from age categories 25-34 and 35-44 to age categories 45-54 and 55-64.

Figure 1
Literacy scores in main occupations and ages



Source: PIACC.

The lower limit of the confidence intervals for high-skilled workers is above the upper limit of the confidence interval for low-skilled workers for all age categories. Thus, the differences in literacy skills between the two groups are statistically significant. A considerable difference exists between the curves for the literacy scores for high- and low-skilled workers. For several of the age categories the difference is around one, which is the standard deviation of the (normalised) literacy score. This observation underscores the importance of including occupational categories in analyses of literacy skills of employed workers.

Several of the literacy score patterns for Germany over age for both high- and low-skilled workers are also found for other countries. The highest literacy score for high-skilled workers is obtained in either age category 25-34 or age category 35-44, while older age categories exhibit lower scores (the only exception is Estonia, where age category 15-24 has the highest score). The literacy scores for high-skilled workers are always above the average except for age category 55-64, where the score is close to the average. Significant differences from zero for this age category appear in Finland, Japan and the Netherlands, with scores slightly below the average, and in the US, with a score slightly above the average.

The highest literacy score for low-skilled workers is obtained in either age category 15-24 or age category 25-34 while older age categories exhibit lower scores. In most countries, all of the literacy scores for low-skilled workers are significantly below the country averages except for age category 15-24, which often has a score close to the average. In all countries, low-skilled workers in the two oldest age categories have literacy scores significantly below the country average. The difference is large, about 0.5 or more. For age categories 25-34 and above, high-skilled workers have significantly higher literacy scores than low-skilled workers in all countries. Again, the difference is substantial.

At the beginning of the age distribution, all countries (except Estonia) exhibit an increase in the literacy score for high-skilled workers from age category 15-24 to age category 25-34. Many of these increases are either statistically significant or close to significant. In contrast, for all other age categories the literacy score is either at the same level or lower than that at the previous and younger age category - in many cases statistically significantly lower.

The likely reason for the increases in the literacy score for high-skilled workers from age category 15-24 to age category 25-34 is a composition effect. The high-skilled workers in age category 25-34 differ from the high-skilled workers in category 15-24. For example, many employees in major occupational category two (ISCO 2), professionals, have a tertiary education and often leave higher educational institutions after the age of 24 (according to Table A1, age group 16-24 has a low employment rate of 43 per cent at age 16-24 compared to 77 per cent at age 25-34). This group, which scores high on literacy ability, is thus typically included in the group of high-skilled workers (ISCO 0-4), at ages 25-34, but not at ages 15-24. The number of persons belonging to the group of high-skilled workers at age 15-24 is limited, a finding that is reflected in the comparatively large confidence intervals for this group.

The test of the ‘use it or lose it’ hypothesis appears in Table 1, which contains the coefficients from a regression of the literacy score on the dummy for belonging to the group of high-skilled workers, age divided by ten, the interaction between the dummy and age, and the number of years of schooling.[7] As I focus on the decline in cognitive ability, the analysis is confined to workers aged 35-65. According to the graphical analysis, the decline in cognitive abilities in both the high- and the low-skilled groups begins by age category 35 to 44 in most countries, while the decline in some countries sets in at age category 25-34.

Table 1
Regression coefficients for literacy skills and use of literacy at work for workers of age 35 to 65 in 21 OECD

	Literacy skills								Use of literacy at work					
	Occupation		Age/10		Interaction		Education		Occupation		Age/10		Interaction	
	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.
Austria	**0.793**	**0.089**	-0.078	0.046	**-0.187**	**0.056**	**0.104**	**0.008**	**0.893**	**0.076**	**-0.096**	**0.042**	**0.103**	**0.050**
Belgium	**0.626**	**0.084**	-0.057	0.052	**-0.167**	**0.060**	**0.146**	**0.008**	**0.982**	**0.078**	-0.068	0.053	0.043	0.056
Canada	**0.579**	**0.079**	-0.064	0.034	-0.061	0.044	**0.130**	**0.007**	**0.712**	**0.060**	**-0.116**	**0.035**	**0.082**	**0.041**
Czech Rep.	**0.243**	**0.119**	**-0.156**	**0.059**	0.018	0.095	**0.125**	**0.016**	**0.926**	**0.084**	**-0.104**	**0.044**	**0.137**	**0.049**
Denmark	**0.527**	**0.075**	**-0.191**	**0.037**	-0.059	0.042	**0.122**	**0.008**	**0.661**	**0.072**	**-0.064**	**0.029**	**0.089**	**0.036**
Estonia	**0.397**	**0.067**	**-0.076**	**0.028**	**-0.138**	**0.042**	**0.109**	**0.008**	**1.215**	**0.048**	**-0.128**	**0.024**	0.026	0.032
Finland	**0.520**	**0.093**	**-0.204**	**0.049**	**-0.115**	**0.054**	**0.089**	**0.009**	**0.750**	**0.065**	**-0.097**	**0.036**	**0.097**	**0.042**
France	**0.342**	**0.064**	**-0.156**	**0.029**	-0.002	0.043	**0.119**	**0.005**	**0.751**	**0.053**	**-0.126**	**0.033**	**0.108**	**0.038**
Germany									**0.939**	**0.087**	**-0.114**	**0.041**	0.084	0.056
Ireland	**0.542**	**0.095**	0.001	0.048	**-0.168**	**0.058**	**0.114**	**0.009**	**0.754**	**0.071**	**-0.174**	**0.043**	0.070	0.051
Italy	**0.498**	**0.095**	-0.016	0.054	**-0.172**	**0.066**	**0.080**	**0.008**	**1.241**	**0.071**	-0.024	0.034	-0.056	0.054
Japan	0.149	0.079	**-0.340**	**0.034**	0.068	0.046	**0.151**	**0.010**	**0.719**	**0.071**	**-0.136**	**0.032**	**0.140**	**0.045**
Korea	**0.368**	**0.065**	**-0.142**	**0.032**	**-0.102**	**0.047**	**0.122**	**0.007**	**0.619**	**0.055**	**-0.368**	**0.023**	**0.320**	**0.039**
Netherlands	**0.547**	**0.091**	**-0.239**	**0.051**	-0.046	0.057	**0.145**	**0.008**	**0.878**	**0.076**	**-0.169**	**0.040**	**0.104**	**0.050**
Norway	**0.793**	**0.086**	**-0.123**	**0.044**	**-0.150**	**0.049**	**0.098**	**0.009**	**0.727**	**0.084**	**-0.106**	**0.047**	0.026	0.059
Poland	**0.398**	**0.100**	-0.020	0.044	-0.058	0.066	**0.119**	**0.011**	**1.301**	**0.079**	-0.033	0.042	-0.051	0.056
Slovak Rep.	0.117	0.095	**-0.204**	**0.047**	0.018	0.059	**0.105**	**0.011**	**1.096**	**0.075**	**-0.121**	**0.031**	0.081	0.049
Spain	**0.314**	**0.080**	**-0.229**	**0.042**	0.007	0.057	**0.113**	**0.006**	**1.135**	**0.063**	**-0.070**	**0.033**	-0.014	0.048
Sweden	**0.733**	**0.100**	-0.079	0.044	**-0.167**	**0.056**	**0.128**	**0.011**	**0.975**	**0.074**	-0.013	0.039	-0.040	0.045
England	**0.461**	**0.109**	**-0.103**	**0.052**	-0.003	0.066	**0.103**	**0.011**	**0.667**	**0.060**	**-0.137**	**0.041**	0.084	0.049
USA	**0.425**	**0.106**	-0.094	0.050	-0.036	0.060	**0.168**	**0.010**	**0.783**	**0.078**	0.015	0.046	0.034	0.053
Average	**0.468**	**0.020**	**-0.128**	**0.010**	**-0.076**	**0.013**	**0.119**	**0.002**	**0.892**	**0.016**	**-0.107**	**0.008**	**0.070**	**0.010**
Std.dev.	0.188		0.087		0.079		0.022		0.206		0.078		0.082	

Notes: Figures in bold denote significance at the 5 percent level. Occupation is a dummy variable taking the value one if the worker belongs to major occupational groups 0-4 and zero for major occupational groups 5-9. Interaction is the interaction between occupation and age divided by 10. The indices for skills and use of skills are normalized by dividing by the country specific standard deviations. Education is the number of years of schooling.

Source: PIACC.

The first column of Table 1 contains the coefficient of the skill dummy. It

[7] The German data unfortunately do not contain information about the number of years of education. Thus Table 1 contains no regression results for Germany.

shows that high-skilled workers in 18 out of 20 countries have significantly higher scores than low-skilled workers. The average difference for all countries is 0.468 standard deviations (calculated as the unweighted averages of the coefficients for the 20 countries). Norway and Austria are the countries that have the highest difference (0.80 standard deviations), while the Slovak Republic and Japan have the lowest (0.12 and 0.15 standard deviations, respectively).

Education has a significant impact on literacy skills in all countries and the impact is substantial, as one more year of education implies increases in the literacy score of 0.12 standard deviations according to the country average. The impact of schooling on literacy is highest in the US, where the coefficient is 0.17 standard deviations.

The column containing the coefficient of age shows that literacy skills decline with age in all but one of the 20 countries (Ireland) and that the decline is significant in 12 countries. The decline in three countries (Canada, Sweden and the US) is borderline significant. The average decline is 0.128 standard deviations per decade, and according to this estimate, the average decline in literacy skills from age 35 to 65 is thus 0.398 standard deviations. Most countries exhibit declines that are not significantly different from the average for all countries. However, the decline in Japan of 0.340 standard deviations per decade shows a reduction that is substantially larger than that in most other countries.

One reason for the decline in cognitive scores is that younger cohorts tend to have higher levels of education than older cohorts. Indeed, Table A1 in the appendix shows that the number of years of schooling declines with age from age 35 in all the countries in the sample. However, as schooling enters as an explanatory variable in the regressions for literacy skills, the coefficients of age are the associations between literacy skills and age after accounting for the level of education.

The contention is that high-skilled workers have a higher use of literacy at work than low-skilled workers (we will see shortly that this contention is correct). If the ‘use it or lose it’ hypothesis is valid, high-skilled workers should thus exhibit a lower decline in literacy scores than low-skilled workers, implying a positive coefficient of the interaction term between age and the occupation dummy.

The coefficient of the interaction term estimates differences in the change in cognitive abilities over age between the group of high-skilled and the group of low-skilled workers. The analysis in this paper thus distinguishes between the level of cognitive ability and the change in cognitive ability, which is in contrast to much of the literature according to Salthouse (2006).

According to the evidence from the coefficients of the interaction term in Table 1, the hypothesis of positive coefficients of the interaction term is rejected. Out of the 20 countries, 16 have negative coefficients and 9 of these coefficients are significantly different from zero. Only four countries have positive interaction terms, and none of these are significantly different from zero. The average interaction term for the 21 countries is -0.076 standard deviations. According to this estimate, the literacy scores for high-skilled workers thus decline by 0.205 standards deviations per decade (0.128+0.076) or 0.634 standard deviations from age 35 to 65. As the estimate is 0.398 standard deviations for low-skilled workers, high-skilled workers thus experience a higher loss of literacy skills.

The appropriateness of specifying the decline in reading scores as a linear function in age is tested by including age squared as an explanatory variable for the sample of workers used for Table 1, that is, workers of age 35 and older. A faster decline in scores at later ages will yield a negative coefficient to age squared. The result of the specification test is that the coefficient of age squared is significantly different from zero for four out of 20 countries, where all four coefficients are negative (results not reported). Thus, I conclude that the linear specification for the age variable is valid for most countries. As a further specification test, the logarithm of the test score is entered on the left-hand side of the regression instead of the level of the test score. This specification entails that the decline in scores with age is described as a relative decline instead of the absolute decline displayed in Figure 1. The result is no difference in the significance of the coefficients: all significant coefficients in Table 1 are also significantly different from zero when the test scores enter in log form, and all insignificant coefficients are also insignificant under the alternative specification.

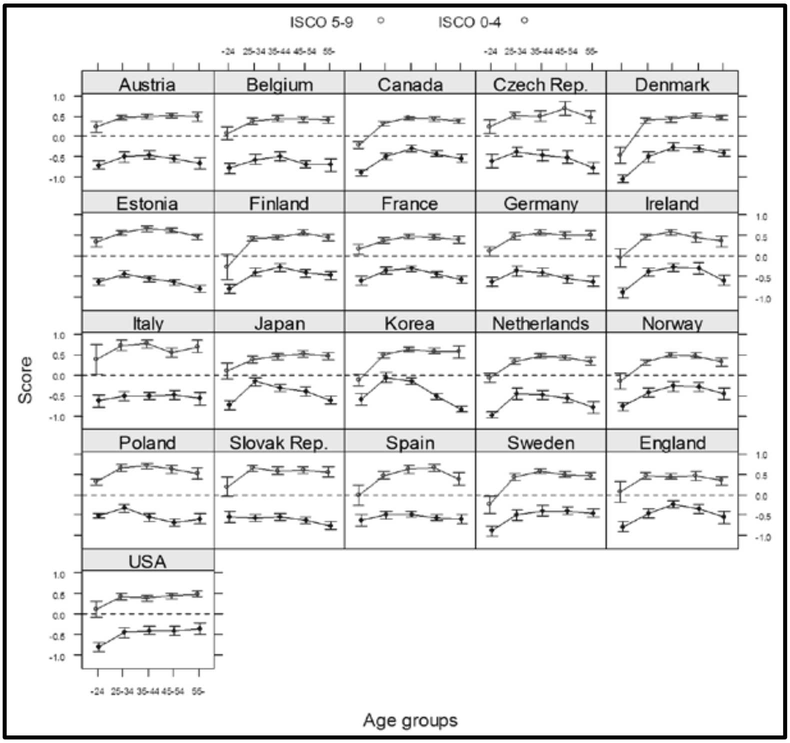
Next, looking at the use of reading at work (Figure 2), high-skilled workers in all countries exhibit a steep increase in the use of reading at work from age category 15-24 to age category 25-34 and in nearly all countries this increase is significant. However, afterwards the variation in the use of literacy at work over ages for high-skilled workers appears to be limited - several of the curves are essentially flat and there are few examples of significant differences in scores between age categories.

Low-skilled workers in all countries also exhibit an increase in the use of reading at work from age category 15-24 to age category 25-34 that in many countries is significant. In some countries (e.g. the Nordic countries) the increase continues to age category 35-44. From age category 35-44, the curves for low-skilled workers decrease in several countries. The decrease is especially pronounced in Japan and Korea, which both exhibit sharp, significant decreases in the use of reading at work for low-skilled workers. In the other countries the curves are flat, except for the US, which exhibits a slight (albeit insignificant) increase.

The level of use of reading for high-skilled workers is higher than the average in all countries except for those in age category 15-24. Conversely, the level of use of reading for low-skilled workers is lower than the average in all countries for all age categories.

Figure 2

Use of reading at work in main occupations and ages



Source: PIACC.

Table 1 summarises the difference in the use of reading skills between high-skilled and low-skilled workers and how this difference develops with age. The first column below the heading 'Use of literacy at work' containing the coefficient of the dummy for high-skilled occupations shows that, in all countries, the use of reading skills among high-skilled workers is significantly larger than that among low-skilled workers. The average difference is 0.892 standard deviations. Countries with significantly smaller differences between high- and low-skilled workers in the use of reading at work include Japan, Korea and two of the Nordic countries (Denmark, Finland while Norway is borderline significant).

The column containing the coefficients of age shows that the use of reading for all workers declines with age in all countries (except the US), and 16 countries have coefficients that are significantly below zero. The average decline is 0.107 standard deviations per decade, and only two countries (Korea and the US) deviate significantly from the average. The average decline in the use of reading for low-skilled workers is thus 0.321 standard deviations from age 35 to age 65.

The column for the interaction term for literacy at work in Table 1 shows the coefficients of the interaction term between age and the dummy for high-skilled workers, which are positive for 17 countries, and nine of these coefficients are significantly different from zero. The average coefficient is 0.070 standard deviations, implying that the use of reading at work among high-skilled workers declines by the moderate amount of 0.037 (0.107-0.070) standard deviations per decade, that is 0.111 standard deviations from age 35 to age 65. The decline in the use of reading at work thus takes place primarily among low-skilled workers.

The average decline in the use of literacy at work is smaller than the average decline in literacy scores. For low-skilled workers the decline in the use of literacy constitutes 83 per cent of the decline in the literacy score (0.107/ 0.128), while the decline in the use of literacy for high-skilled workers constitutes 18 per cent of the decline in literacy skills (0.037/ 0.204). The decline in literacy skills over age is substantially stronger than the decline in the use of literacy.

Thus, the analysis of literacy skills and the use of skills at work shows very little evidence for the 'use it or lose it' hypothesis. There is a pronounced decline in the use of literacy at work from age 35 for low-skilled workers and a smaller decline for high-skilled workers. However, literacy skills declines substantially for both groups, and in most countries the decline for high-skilled workers is larger than that for low-skilled workers. In many countries, high-skilled workers thus show a lower decline in the use of literacy, but a larger decline in ability than low-skilled workers, a finding that is at variance with the 'use it or lose it' hypothesis.

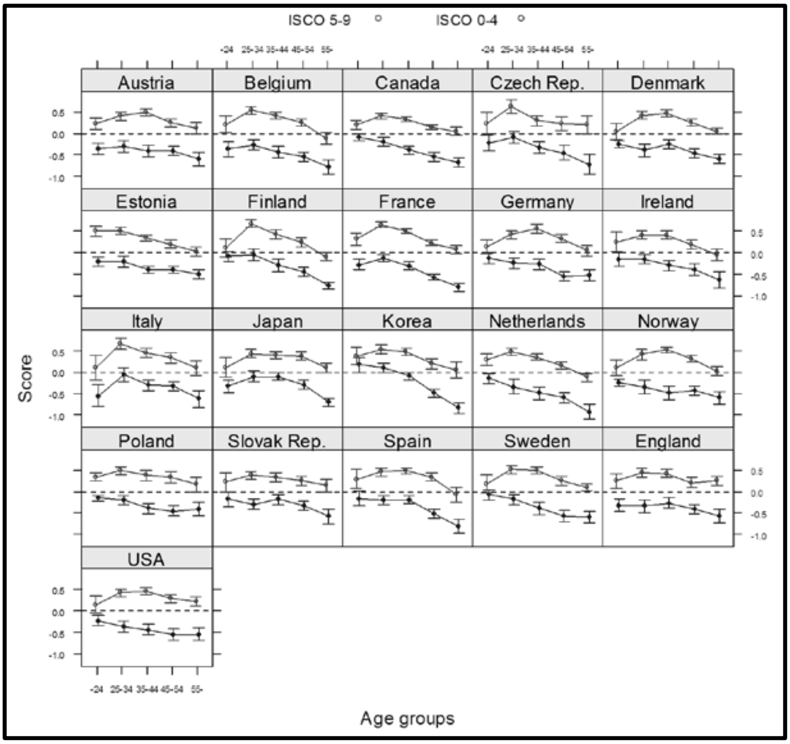
5. NUMERACY AND AGE

Next numeracy, with respect to both ability and use at work, is examined. As in the previous section, graphs for the scores for each country and the results of the regression analysis are presented.

The scores for numeracy appear in Figure 3, which, in many respects, looks similar to Figure 1. In all countries, numeracy increases among high-skilled workers from age category 15-24 to age category 25-34, and in all countries the decline in numeracy sets in at either age category 25-34 or age category 35-44. The numeracy score of low-skilled workers decreases from age category 35-44 in all countries, and in many countries the decrease begins before this age level.

The numeracy score for high-skilled workers is above the country average in all countries except for age category 55-65, which is close the average. With one exception (Korea, where the scores for the two youngest age categories are above the average), low-skilled workers have numeracy scores below the country averages in all countries for all age categories. Most of the scores are significantly lower than the averages, and above age 45 all scores are significantly lower than the average for all countries.

Figure 3
Numeracy scores in main occupations and ages



Source: PIACC.

Table 2 shows the results of the regression analysis. High-skilled workers have a significantly higher numeracy score than low-skilled workers in all countries but one (the Slovak Republic) with an average difference of 0.430 standard deviations. The difference in numeracy scores is thus very close to the average difference for the literacy score of 0.468 standard deviations.

The numeracy score for low-skilled workers declines with age in all countries. This decline is significantly different from zero in 10 countries. The average decline in the numeracy score is 0.100 standard deviations per decade (0.309

standard deviations from age 35 to age 65), which also is close to the decline in the literacy score of 0.128 standard deviations.

Table 2
Regression coefficients for numeracy skills and use of numeracy at work for workers of age 35 to 65 in 21 OECD countries

	Numeracy skills								Use of numeracy at work					
	Occupation		Age/10		Interaction		Education		Occupation		Age/10		Interaction	
	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.
Austria	**0.682**	**0.093**	-0.057	0.046	**-0.130**	**0.056**	**0.116**	**0.009**	**0.807**	**0.080**	**-0.094**	**0.039**	-0.017	0.052
Belgium	**0.573**	**0.086**	-0.059	0.055	**-0.150**	**0.061**	**0.146**	**0.010**	**0.799**	**0.067**	**-0.162**	**0.042**	0.020	0.050
Canada	**0.460**	**0.067**	**-0.072**	**0.033**	-0.029	0.041	**0.136**	**0.007**	**0.742**	**0.058**	**-0.102**	**0.031**	0.011	0.035
Czech Rep.	**0.262**	**0.117**	**-0.116**	**0.059**	0.052	0.087	**0.147**	**0.015**	**0.745**	**0.082**	**-0.135**	**0.049**	0.086	0.052
Denmark	**0.423**	**0.079**	**-0.127**	**0.034**	-0.039	0.045	**0.126**	**0.008**	**0.583**	**0.068**	**-0.146**	**0.026**	0.024	0.037
Estonia	**0.413**	**0.062**	**-0.068**	**0.031**	**-0.102**	**0.040**	**0.124**	**0.008**	**0.951**	**0.055**	**-0.166**	**0.022**	-0.018	0.032
Finland	**0.496**	**0.094**	**-0.148**	**0.041**	-0.077	0.052	**0.093**	**0.009**	**0.475**	**0.084**	**-0.165**	**0.043**	**0.137**	**0.052**
France									**0.894**	**0.050**	**-0.118**	**0.025**	-0.048	0.032
Germany	**0.394**	**0.056**	**-0.133**	**0.030**	-0.001	0.037	**0.134**	**0.005**	**0.835**	**0.091**	**-0.115**	**0.032**	-0.001	0.050
Ireland	**0.479**	**0.087**	-0.009	0.049	**-0.123**	**0.058**	**0.112**	**0.009**	**0.728**	**0.074**	**-0.179**	**0.034**	-0.037	0.048
Italy	**0.485**	**0.093**	-0.045	0.048	-0.110	0.064	**0.073**	**0.008**	**1.067**	**0.084**	-0.013	0.039	**-0.223**	**0.063**
Japan	**0.166**	**0.075**	**-0.214**	**0.033**	**0.116**	**0.045**	**0.164**	**0.009**	**0.563**	**0.069**	**-0.222**	**0.026**	**0.154**	**0.039**
Korea	**0.306**	**0.065**	**-0.145**	**0.040**	-0.051	0.051	**0.133**	**0.007**	**0.515**	**0.065**	**-0.323**	**0.024**	**0.153**	**0.041**
Netherlands	**0.503**	**0.096**	-0.160	0.057	-0.035	0.061	**0.146**	**0.009**	**0.843**	**0.073**	**-0.175**	**0.037**	-0.022	0.046
Norway	**0.782**	**0.084**	-0.037	0.048	**-0.168**	**0.055**	**0.111**	**0.010**	**0.778**	**0.084**	**-0.093**	**0.035**	0.036	0.053
Poland	**0.297**	**0.089**	-0.002	0.043	-0.037	0.061	**0.122**	**0.012**	**0.883**	**0.085**	**-0.081**	**0.037**	0.005	0.055
Slovak Rep.	0.171	0.098	**-0.169**	**0.043**	0.038	0.058	**0.125**	**0.011**	**0.880**	**0.084**	**-0.166**	**0.033**	0.077	0.054
Spain	**0.282**	**0.081**	**-0.225**	**0.040**	0.027	0.055	**0.114**	**0.007**	**1.003**	**0.073**	-0.031	0.034	**-0.169**	**0.050**
Sweden	**0.658**	**0.107**	-0.033	0.049	**-0.115**	**0.058**	**0.128**	**0.010**	**0.898**	**0.066**	**-0.065**	**0.031**	-0.034	0.042
England	**0.402**	**0.097**	-0.090	0.048	0.021	0.063	**0.103**	**0.012**	**0.912**	**0.082**	**-0.110**	**0.032**	-0.026	0.050
USA	**0.358**	**0.107**	-0.082	0.046	-0.033	0.058	**0.176**	**0.010**	**0.603**	**0.072**	**-0.150**	**0.036**	**0.101**	**0.044**
Average	**0.430**	**0.020**	**-0.100**	**0.010**	**-0.047**	**0.013**	**0.126**	**0.002**	**0.786**	**0.016**	**-0.134**	**0.007**	0.010	0.010
Std.dev.	0.163		0.064		0.075		0.023		0.161		0.067		0.093	

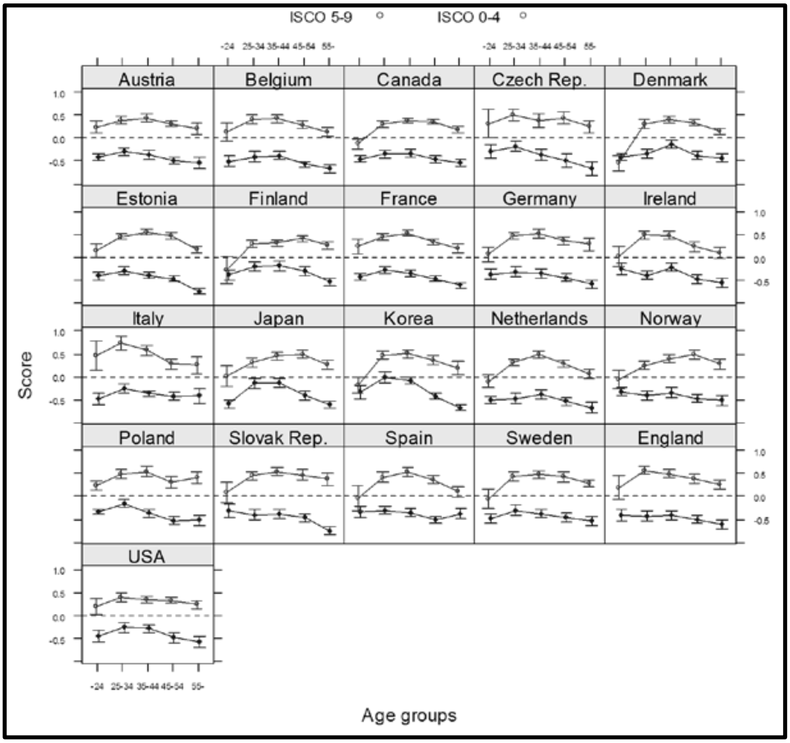
Notes: Figures in bold denote significance at the 5 percent level. Occupation is a dummy variable taking the value one if the worker belongs to major occupational groups 0-4 and zero for major occupational groups 5-9. Interaction is the interaction between occupation and age divided by 10. The indices for skills and use of skills are normalized by dividing by the country specific standard deviations. Education is the number of years of schooling.

Source: PIACC.

The interaction term between the dummy for high-skilled workers and age is negative for 15 countries and significantly different from zero for six of them. Of the five countries with positive interaction terms, only the one for Japan is significant. The average decline in numeracy skills is -0.047 standard deviations, which implies a skill loss for high-skilled workers of 0.147 standard deviations per decade (0.455 standard deviations from age 35 to age 65). Except for Japan, the evidence is that high-skilled workers lose numeracy skills at a faster pace than low-skilled workers. The test of the validity of a linear decline in numeracy scores with age yields the result that the coefficient of age squared is significantly different from zero for three countries, where all three coefficients are negative.

Figure 4 shows the use of numeracy at work for high- and low-skilled workers. The development of the use of numeracy at work for high-skilled workers is comparable to the use of reading for the younger age categories, where skills increase from age category 15-24 to either age category 25-34 or 35-44. From age category 35-44 the use of numeracy for high-skilled workers exhibits a decreasing tendency in most countries. For low-skilled workers the decrease sets in from either age category 25-34 or age category 35-44.

Figure 4
Use of numeracy at work in main occupations and ages



Source: PIACC.

Table 2 contains the regression analysis for use of numeracy at work. In all countries high-skilled workers use numeracy at work significantly more than low-skilled workers. The average difference in the use of numeracy at work is 0.786 standard deviations, which is smaller than the average difference in the use of literacy at work of 0.892 standard deviations.

For low-skilled workers the use of numeracy declines with age in all countries, and this decline is significant in all countries except Italy and Spain. The average decline is 0.134 standard deviations per decade (0.402 standard deviations from age 35 to age 65), slightly more than the decline in the use of literacy.

The interaction term between the dummy for high-skilled workers and age gives mixed evidence for differential development of the use of numeracy at work between low- and high-skilled workers. The coefficient is positive for 11 countries and significant for four of them (Finland, Japan, Korea and the US) but negative for 10 countries and significant for two of them (Italy and Spain). The average coefficient of the interaction term is a moderate 0.010 standard deviations. The decline in the use of numeracy for high-skilled workers is 0.124 standard deviations (0.134-0.010), corresponding to a decline on 0.372 standard deviations from age 35 to age 65.

The average decline in the use of numeracy at work is smaller than the average decline in numeracy scores. For low-skilled workers the average decline in the use of numeracy is higher than the average decline in the numeracy score (0.134 versus 0.100 standard deviations), while the decline in the use of numeracy for high-skilled workers constitutes 84 per cent of the decline in numeracy skills (0.124/ 0.147).

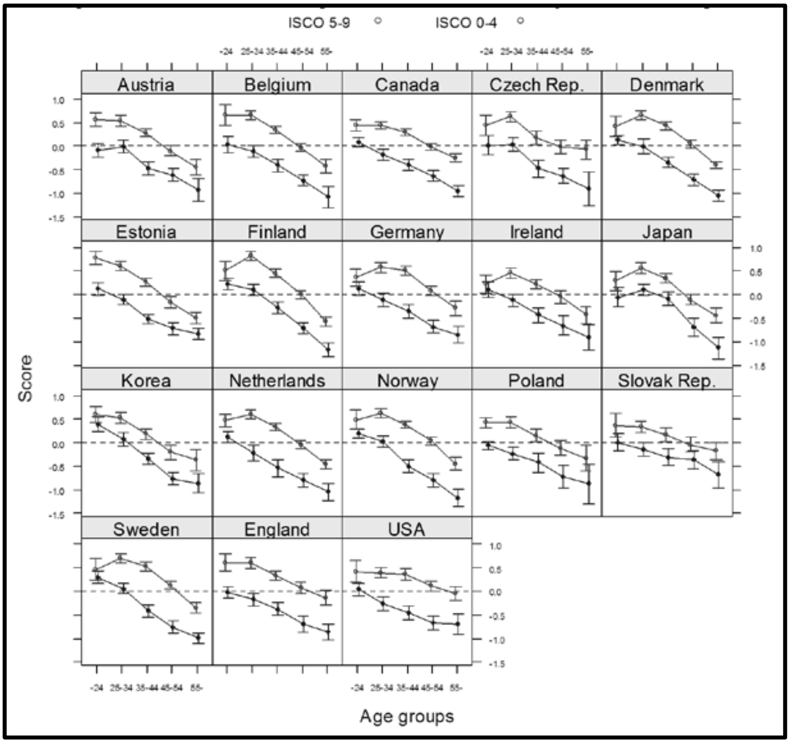
The 'use it or lose it' hypothesis gains little support from the analysis of numeracy skills and the use of numeracy at work. In most countries the use of numeracy at work declines at about the same rate for both high- and low-skilled workers from age 35. However, numeracy skills also decline for both groups at approximately the same pace in many countries. Even though high-skilled workers use numeracy skills at work substantially more than low-skilled workers, for most countries there is no indication that high-skilled workers retain their numeracy skills to a higher degree than low-skilled workers. The only exception is Japan, where high-skilled workers lose numeracy abilities at a significantly slower pace than low-skilled workers.

6. PROBLEM-SOLVING AND AGE

I next look at problem-solving, both the problem-solving score and the use of problem-solving at work. The problem-solving score for high- and low-skilled workers by age categories appears in Figure 5. As three countries (France, Italy and Spain) decided not to participate in this part of the PIAAC survey, the assessment of problem-solving is done for 18 countries.

The problem-solving score is higher for high-skilled workers than for low-skilled workers in all age categories and in most cases it is significantly higher. The main exception is age group 15-24, where the difference is not significant in 10 countries.

Figure 5
Problem solving scores in main occupations and ages



Source: PIACC.

In all countries the problem-solving score for high-skilled workers is higher than the average problem-solving score in the younger age categories and lower than the average in the older age categories. Low-skilled workers have problem-solving scores below the average in all countries from age category 35-44, while younger age categories typically have scores on or above the average. For high-skilled workers the decline begins in age category 25-34, with five exceptions where the decline sets in from age category 15-24. For low-skilled workers the decline begins from age category 15-24, with three exceptions where the decline begins in age category 25-34.

Table 3 shows the results of the regression analysis of the problem-solving score. High-skilled workers have a significantly higher score than low-skilled workers in all but two countries. The average difference is 0.500 standard deviations, which is close to the difference for both the literacy and the numeracy scores. Norway and Sweden are the two countries with the highest difference in problem-solving scores between high- and low-skilled workers.

Table 3
Regression coefficients for problem solving skills and use of problem solving at work for workers of age 35 to 65 in 18 OECD countries

	Problem solving skills								Use of problem solving at work					
	Occupation		Age/10		Interaction		Education		Occupation		Age/10		Interaction	
	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.	Coeff.	Std.err.
Austria	**0.669**	**0.104**	**-0.211**	**0.071**	-0.152	0.078	**0.071**	**0.012**	**1.312**	**0.073**	**-0.092**	**0.035**	-0.050	0.050
Belgium	**0.599**	**0.093**	**-0.254**	**0.056**	**-0.139**	**0.065**	**0.116**	**0.008**	**1.306**	**0.073**	**-0.125**	**0.044**	0.001	0.050
Canada	**0.501**	**0.083**	**-0.246**	**0.044**	-0.004	0.050	**0.095**	**0.007**	**1.203**	**0.055**	**-0.155**	**0.029**	0.018	0.032
Czech Rep.	**0.462**	**0.157**	-0.164	0.098	-0.010	0.116	**0.089**	**0.016**	**1.368**	**0.084**	**-0.078**	**0.038**	-0.006	0.047
Denmark	**0.573**	**0.084**	**-0.337**	**0.041**	-0.057	0.048	**0.098**	**0.010**	**1.085**	**0.064**	**-0.112**	**0.027**	0.020	0.036
Estonia	**0.641**	**0.072**	**-0.214**	**0.038**	**-0.200**	**0.044**	**0.082**	**0.010**	**1.563**	**0.039**	**-0.101**	**0.018**	**-0.114**	**0.024**
Finland	**0.572**	**0.096**	**-0.403**	**0.045**	-0.087	0.051	**0.077**	**0.011**	**1.179**	**0.065**	**-0.157**	**0.036**	0.050	0.039
Germany									**1.260**	**0.070**	**-0.121**	**0.030**	-0.008	0.042
Ireland	**0.399**	**0.102**	**-0.170**	**0.081**	-0.085	0.079	**0.136**	**0.013**	**1.240**	**0.066**	**-0.216**	**0.025**	-0.058	0.041
Japan	**0.229**	**0.106**	**-0.507**	**0.061**	0.088	0.072	**0.115**	**0.013**	**1.086**	**0.054**	**-0.172**	**0.024**	0.010	0.036
Korea	**0.358**	**0.088**	**-0.303**	**0.057**	-0.061	0.073	**0.097**	**0.013**	**1.060**	**0.050**	**-0.321**	**0.020**	0.037	0.038
Netherlands	**0.653**	**0.103**	**-0.244**	**0.056**	-0.114	0.065	**0.124**	**0.009**	**1.254**	**0.069**	**-0.139**	**0.040**	-0.012	0.044
Norway	**0.677**	**0.078**	**-0.333**	**0.046**	-0.055	0.049	**0.105**	**0.012**	**1.196**	**0.065**	**-0.105**	**0.039**	0.014	0.044
Poland	0.258	0.157	**-0.270**	**0.097**	0.036	0.128	**0.085**	**0.021**	**1.528**	**0.065**	**-0.046**	**0.023**	**-0.173**	**0.043**
Slovak Rep.	0.209	0.131	**-0.179**	**0.076**	-0.032	0.093	**0.096**	**0.016**	**1.393**	**0.062**	**-0.096**	**0.025**	-0.070	0.042
Sweden	**0.763**	**0.107**	**-0.265**	**0.046**	**-0.136**	**0.059**	**0.113**	**0.012**	**1.357**	**0.065**	**-0.094**	**0.034**	-0.041	0.038
England	**0.504**	**0.108**	**-0.227**	**0.054**	0.009	0.065	**0.096**	**0.011**	**1.277**	**0.060**	**-0.135**	**0.034**	-0.010	0.038
USA	**0.432**	**0.148**	**-0.191**	**0.077**	-0.009	0.092	**0.134**	**0.014**	**1.238**	**0.065**	**-0.082**	**0.036**	0.004	0.039
Average	**0.500**	**0.027**	**-0.266**	**0.016**	**-0.059**	**0.018**	**0.102**	**0.003**	**1.272**	**0.015**	**-0.130**	**0.007**	**-0.022**	**0.010**
Std.dev.	0.167		0.090		0.075		0.019		0.137		0.062		0.055	

Notes: Figures in bold denote significance at the 5 percent level. Occupation is a dummy variable taking the value one if the worker belongs to major occupational groups 0-4 and zero for major occupational groups 5-9. Interaction is the interaction between occupation and age divided by 10. The indices for skills and use of skills are normalized by dividing by the country specific standard deviations. Education is the number of years of schooling.

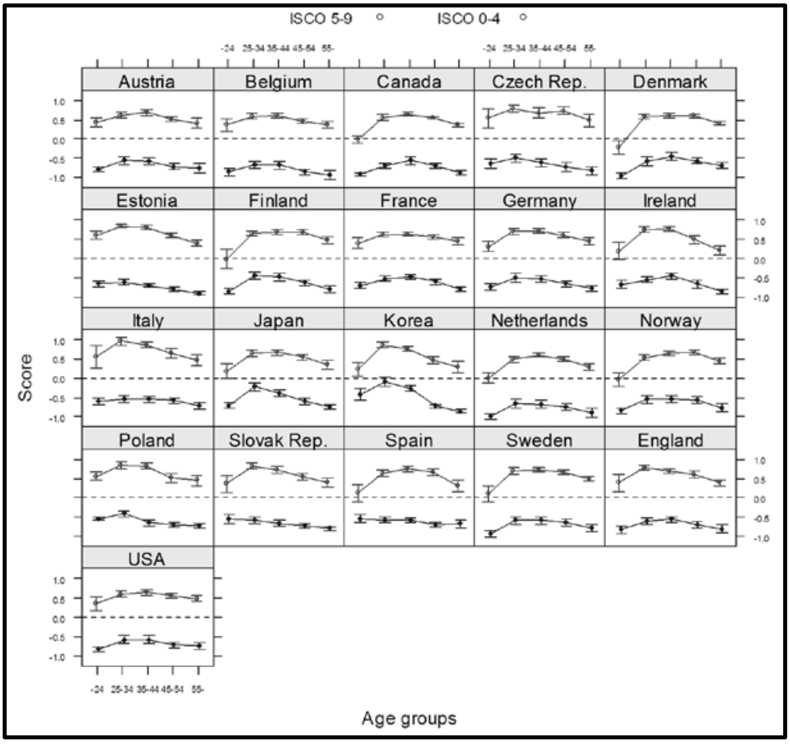
Source: PIACC.

The problem-solving score for low-skilled workers decreases with age in all countries and the decrease is significant in all countries except the Czech Republic. The average decrease is 0.266 standard deviations per decade, amounting to a reduction in problem-solving ability of 0.824 standard deviations from age 35 to age 65. The decrease in the problem-solving score over age is thus substantially larger than the reduction in either the literacy or the numeracy score.

The interaction term between the dummy for high-skilled workers and age is negative in all but two countries and significantly different from zero in three, while none of the two positive coefficients are significant. The average of -0.059 implies that high-skilled workers lose problem-solving abilities in an amount of 0.325 standard deviations (0.266+0.059) per decade or 1.008 standard deviations from age 35 to age 65. This amount of skills loss is thus substantially larger than the loss of literacy ability or numeracy ability.

The use of problem-solving at work appears in Figure 6. High-skilled workers use problem-solving significantly more at work than the average worker in all age categories except category 15-24, where the use of problem-solving is close to the average in some countries (including all the Nordic countries). Low-skilled workers use problem-solving significantly less than the average worker in all age categories in all countries. A decline in the use of problem-solving at work typically begins in age category 35-44 for both high-skilled and low-skilled workers.

Figure 6
Use of problem solving in main occupations and ages



Source: PIACC.

The regression results for the use of problem-solving at work appears in Table 3. In all countries high-skilled workers use significantly more problem-solving at work than low-skilled workers. The average difference is 1.272 standard deviations, which is substantially more than the difference in the use of literacy and numeracy at work. The use of problem-solving for low-skilled workers declines with age in all countries and is significant in all cases. The average decline is 0.130 standard deviations per decade, amounting to 0.390 standard deviations from age 35 to age 65. The interaction term is insignificantly different from zero in most countries. The average is a decline of 0.029 standard deviations per decade, implying a reduction of 0.155 standard deviations per decade in the use of problem-solving at work for high-skilled workers, or 0.465 standard deviations, from age 35 to 65. The test for the validity of a linear decline in numeracy scores with age results in coefficients of age squared that are significantly different from zero for only one country.

A considerable difference exists between the problem-solving scores and the use of problem-solving compared to the scores and the use of literacy and numeracy. The difference between high-skilled and low-skilled workers in both problem-solving scores and problem-solving use at work is substantially larger than those for literacy and numeracy. Furthermore, the decline with age in both scores and the use of problem-solving is substantially larger than the decline in scores and use for literacy and numeracy.

The average decline in the use of problem-solving at work is smaller than the average decline in problem-solving scores. For low-skilled workers the decline in the use of problem-solving constitutes 49 per cent of the decline in the problem-solving score (0.130/ 0.266), while the decline in the use of problem-solving for high-skilled workers constitutes 47 per cent of the decline in problem-solving skills (0.152/ 0.325). The decline in problem-solving skills over age is stronger than the decline in the use of problem-solving.

One reason for the differences in decline with age between problem-solving on the one hand and literacy and numeracy on the other, might be cohort effects. As younger cohorts have grown up with ICT, they might thus be better at problem solving in relation to this technology. Furthermore, younger cohorts might be more ready to use this type of technology at work.

Once again, the results for problem-solving are not favourable to the 'use it or lose it' hypothesis. In most countries no significant difference appears in the decline in the use of problem-solving at work between high-skilled and low-skilled workers. However, high-skilled workers lose their problem-solving ability at about the same pace as low-skilled workers or even higher. In no country are high-skilled workers significantly better able to retain their problem-solving abilities than low-skilled workers. Despite a substantially more intensive use of problem-solving at work among high-skilled workers, they are not better able to retain their problem-solving abilities than low-skilled workers.

7. DISCUSSION

This section first discusses two phenomena that might result in bias in the estimates of the relation between cognitive skills and age from cross-sectional data such as that used in this paper. One is cohort effects, and the other is retirement. Second, the decline in the use of skills over age and the relation between age-earnings profiles and skill development over age are discussed.

The analyses have shown a more or less parallel decline in cognitive abilities for both high-skilled and low-skilled workers. High-skilled workers do not retain more of their cognitive abilities than low-skilled workers, despite their more intensive use of cognitive skills - a finding that is at variance with the ‘use it or lose it’ hypothesis. Two issues are pertinent in relation to potential bias. One is the possibility that despite the correlations that are present in the cross-sectional data, the decline in cognitive ability over age is an artefact. The other issue is whether high-skilled workers might have a slower decline in cognitive abilities over age than low-skilled workers despite the estimates to the contrary obtained by means of the cross-sectional data.

The cohort effect arises when cohorts have different levels of cognitive skills at the same age. The decline in cognitive ability over age, as shown through the cross-sectional data used in this paper, could arise if younger cohorts have higher abilities than older cohorts.

Many studies actually show an increase in cognitive ability for younger cohorts, a phenomenon named the ‘Flynn effect’ after the seminal contributions by Flynn (1984) and Flynn (1987). A typical estimate of the magnitude of the Flynn effect is an increase in cognitive abilities of 0.20 standard deviations per decade (Flynn (2000)). This figure is higher than the estimates of the decline in cognitive abilities over age in this paper.[8] Given the magnitude of the estimated Flynn effect is valid for the countries analysed in this paper, I conclude that the higher measured cognitive abilities in the younger ages are due to cohort effects, that the apparent decline in cognitive abilities over age is an artefact, and that cognitive abilities consequently do not decrease with age.

However, no consensus exists about the magnitude of the Flynn effect. A few recent studies indicate a cognitive stagnation or reversal of the Flynn effect, as younger cohorts born after 1970 do not perform as well in tests as older cohorts (see Sundet *et al.* (2004) for Norway and Teasdale and Owen (2005) for Denmark).

Furthermore, in the context of surveys of skills, Green and Riddell (2013) analyse data from the International Adult Literacy Survey (IALS) and the International Adult Literacy and Life Skills Survey (IALSS), which were carried out in 1994 and 2003, respectively, for Canada, the US and Norway. Approximately 45 per cent of the items were identical across the surveys,

[8] The regressions in this paper include education as an explanatory variable, and rising levels of education are a standard explanation of the Flynn effect. Without education, the country averages of the coefficients of age are 0.19 for literacy and 0.16 for numeracy.

implying that identifying both age and cohort effects is possible. Green and Riddell (2013) first estimate the decline in skills on the two cross-sections and then on the pooled data. As the younger cohorts have lower levels of cognitive ability than the older ones, this result is at variance with the existence of a Flynn effect. The estimates on the cross-sectional IALSS data underestimate the decline in cognitive ability over age.

The other phenomenon that might result in bias in the estimates of the relation between cognitive abilities and age is retirement. In this paper I analyse employed workers in age categories both before and after the typical retirement age. Retirement can lead to either a downward or an upward bias in the cross-sectional estimates of the effect of age on cognitive ability for employed workers. An upward bias occurs if retirees have lower cognitive ability than workers who continue in employment, because e.g. low-ability workers have more difficulty staying employed than high-ability workers. A downward bias occurs if retirees have higher cognitive ability than workers who continue in employment, because e.g. retirement is contingent on a desired level of pension and high-ability workers attain such a goal at a younger age than low-ability workers.

In principle, the decline in cognitive abilities with age for both high- and low-skilled workers, as obtained from the cross-sectional data in this paper, could be entirely due to retirement. Such would be true if workers with high cognitive ability retire earlier than those with low cognitive ability within both the group of high-skilled workers and that of low-skilled workers.

The 'use it or lose it' hypothesis could be valid despite the evidence in this paper. The hypothesis could be valid if workers with high cognitive ability within the group of high-skilled workers retire earlier than high-skilled workers with low cognitive ability, while there is no differential in retirement behaviour between high- and low-ability workers within the group of low-skilled workers.

However, while the decline in cognitive ability for the two main occupational groups analysed in this paper begins at about age 35, a significant amount of transition to retirement first begins after age 55. According to the sample statistics in Table A1, the average employment share in the sample is 80 per cent for age category 35-44 and 79 per cent for age category 45-54. The substantial decline in cognitive ability between ages 35 and 54 thus cannot be due to differential retirement patterns among workers with high and low cognitive abilities. According to Table A1 a large number of workers leave employment between age category 45-54 and age category 55-65. The employment share decreases from 79 per cent to 51 per cent, corresponding to the retirement of about one third of the employed. Measured cognitive abilities among the two thirds of the workers who remain employed from age 45-54 to age 55-65 will thus be affected to the extent that the propensity to retire differs between workers with different cognitive abilities.

The conclusion with respect to retirement and cognitive ability among employed workers is thus that the substantial decline in cognitive abilities between age category 35-44 and age category 45-54 cannot be explained by retirement, as the employment ratio is the same in both age categories. In contrast, measured cognitive ability among workers of 55-65 years of age may be influenced by the considerable amount of retirement in this age category. However, I have reported specification tests, which show that a linear decline in cognitive abilities with age cannot be rejected for most countries. The decrease in scores for employed workers during the period of retirement from age category 45-54 to age category 55-65 is thus of the same magnitude as the decrease in cognitive abilities from age category 35-44 to age category 45-54, where retirement is limited.

This paper shows a considerable decline with age in the use of cognitive skills at work. There are (at least) two possible explanations for this phenomenon. One is that older workers choose tasks at work that do not have the same content of cognitive skills as younger workers. Employed workers have reduced incentives for retaining skills as retirement approaches and may thus invest less in activities that maintain cognitive abilities, which is a hyphothesis put forward by Rohwedder and Willis (2010). Another explanation is that employers have a decreased propensity towards assigning older workers tasks calling for the intensive use of cognitive skills, for example, because older workers have fewer cognitive skills than younger workers.

This paper also shows that cognitive abilities of workers decline from about age 30 in most countries. However, wages are low at the beginning of the working life and continue to grow beyond age 30. Earnings profiles reach a maximum at an age (or labour market experience) much later than that when cognitive skills reach a maximum. Age-earnings profiles typically show that a maximum is reached after 25 years of experience in the labour market (e.g. Murphy and Welch (1990)). However, returns to cognitive skills in the PIAAC data applied in this paper increase during the twenties but are essentially constant from age 35 (Hanushek *et al.* (2015)). These observations raise the question of why earnings continue to grow after the decline in cognitive abilities has begun, while returns to these skills remain unchanged. One possible explanation is that other types of skills than those measured in the PIAAC data are valued by employers.

The literature on cognitive abilities includes various categorizations, including the distinction between 'fluid intelligence', which is involved in abstract reasoning and problem-solving, and particularly so with new content, and 'crystallized intelligence', which reflects conceptual and verbal knowledge primarily acquired through education and other systematic learning opportunities. While the level of fluid intelligence increases up to about 25 years of age, and declines thereafter, the level of crystallized intelligence grows, or remains stable, during most of the life-time.[9] The age profile of the PIAAC cognitive scores is similar to the age profile of fluid intelligence but not to the age profile of crystallized intelligence, which is closer to age-earnings profiles. In addition to cognitive skills, other types of skills may be valued by employers and contribute to the growth of earnings over age (see e.g. Bowles *et al.* (2001) and Heckman *et al*. (2006) for a discussion of the importance of non-cognitive skills for labour market outcome).

8. CONCLUSION

This paper analyses measured skills and the use of skills at work in 21 OECD countries. The skills contained in the analyses are literacy, numeracy, and problem-solving. The paper looks at how both measured skills and the use of skills at work develop from age 35 to age 65 in two aggregate categories of occupations: a group of high-skilled workers (ISCO major occupations from 0 to 4) and a group of low-skilled workers (ISCO major occupations from 5 to 9).

When the level of education is taken into account, high-skilled workers have about 0.5 standard deviations higher scores for both literacy and numerical skills than low-skilled workers. Both types of skills decline with age by about 0.1 standard deviations per decade for both groups. The difference in the use of literacy and numeracy at work is about 0.8 standard deviations, and the decline in the use of skills at work is also about 0.1 standard deviations per decade. These findings are remarkably robust for the countries included in the analysis.

The paper investigates the conjecture that the deterioration of skills over age might be more pronounced in occupations with a limited use of skills relative to occupations with more intensive use of these skills - an implication of the 'use it or lose it' hypothesis. The analysis shows that skills for both high- and low-skilled workers deteriorate at approximately the same pace over age. The evidence in the present paper does not support the 'use it or lose it' hypothesis.

That investment in formal schooling at younger ages increases measured cognitive skills is well established. However, this paper shows that more intensive use of cognitive skills at work does not prevent a decline in cognitive skills with age.

[9] See, e.g., Gabrielsen *et al.* (2014) and the review of the literature on ageing and skills in Desjardins & Warnke (2012) for a treatment of these and other concepts of intelligence measurement in relation to ageing.

REFERENCES

BOWLES, S., GINTIS, H., and OSBORNE, M. (2001). “The determinants of earnings: A behavioral approach”. *Journal of Economic Literature, 39,* 1137-1176.

DESJARDINS, R. and WARNKE, A. J. (2012). “Ageing and skills. A review and analysis of skill gain and skill loss over the lifespan and over time”. Paris. OECD Education Working Papers No.72.

EDIN, P. A. and GUSTAVSSON, M. (2008). “Time out of work and skill depreciation”. *Industrial and Labor Relations Review, 61,* 163-180.

FLYNN, J. R. (1984). “The Mean Iq of Americans - Massive Gains 1932 to 1978”. *Psychological Bulletin, 95,* 29-51.

FLYNN, J. R. (1987). “Massive Iq Gains in 14 Nations - What Iq Tests Really Measure”. *Psychological Bulletin, 101,* 171-191.

FLYNN, J. R. (2000). “IQ Trends over Time: Intelligence, Race, and Meritocracy”. In K.Arrow, S. Bowles, and S. Durlauf (Eds.), *Meritocracy and Economic Inequality* (pp. 35-60).

GABRIELSEN, E., LUNDETRÆ, K., GUSSTAFSSON, J.-E., and MYRBERG, M. (2014). “Background”. In A.Malin (Ed.), *Associations between age and cognitive foundation skills in the Nordic countries: A closer look at the data* (pp. 9-24). Jyväskylä: Finnish Institute for Educational Research, University of Jyväskylä.

GREEN, D. A. and RIDDELL, W. C. (2013). “Ageing and literacy skills: Evidence from Canada, Norway and the United States”. *Labour Economics, 22,* 16-29.

HANUSHEK, E. A. (1986). “The Economics of Schooling - Production and Efficiency in Public-Schools”. *Journal of Economic Literature, 24,* 1141-1177.

HANUSHEK, E. A., SCHWERDT, G., WIEDERHOLD, S., and WOESSMANN, L. (2015). “Returns to Skills around the World: Evidence from PIAAC”. *European Economics Review, 73,* 103-130.

HECKMAN, J. J., STIXRUD, J., and URZUA, S. (2006). “The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior”. *Journal of Labor Economics, 24,* 411-482.

MURPHY, K. M. and WELCH, F. (1990). “Empirical Age-Earnings Profiles”. *Journal of Labor Economics, 8,* 202-229.

OECD (2013a). *OECD Skills Outlook 2013: First Results from the Survey of Adult Skills.* Paris: OECD.

OECD (2013b). *Technical Report of the Survey of Adult Skills (PIAAC)*. Paris: OECD.

ROHWEDDER, S. and WILLIS, R. J. (2010). “Mental Retirement”. *Journal of Economic Perspectives, 24,* 119-138.

ROSDAHL, A. (2013). “De beskæftigedes arbejdsopgaver og færdigheder”. In A.Rosdahl, T. Fridberg, V. Jakobsen, and M. Jørgensen (Eds.), *Færdigheder i læsning, regning og problemløsning med IT i Danmark* (pp. 199-228). Copenhagen: SFI.

SALTHOUSE, T. A. (2006). “Mental Exercise and Mental Aging Evaluating the Validity of the "Use It or Lose It" Hypothesis”. *Perspectives on Psychological Science, 1,* 68-87.

SALTHOUSE, T. A. (2007). “Reply to Schooler Consistent Is Not Conclusive”. *Perspectives on Psychological Science, 2,* 30-32.

SCHOOLER, C. (2007). "Use It-and Keep It, Longer, Probably. A Reply to Salthouse" (2006). *Perspectives on Psychological Science, 2,* 24-29.

SUNDET, J. M., BARLAUG, D. G., and TORJUSSEN, T. M. (2004). "The end of the Flynn effect? A study of secular trends in mean intelligence test scores of Norwegian conscripts during half a century". *Intelligence, 32,* 349-362.

TEASDALE, T. W. and OWEN, D. R. (2005). "A long-term rise and recent decline in intelligence test performance: The Flynn Effect in reverse". *Personality and Individual Differences, 39,* 837-843.

VON DAVIER, M., GONZALES, E., and MISLEVY, R. (2009). "What are plausible values and why are they useful?" [Vol.2]. IERI Monograph Series: Issues and Methodologies in Large Scale Assessments.

APPENDIX

Table A1
Sample statistics

	Number of observations	Occupation group, Share		Employment share, Age category					Years of education, Age category				
		ISCO 0-4	ISCO 5-9	16-24	25-34	35-44	45-54	55-65	16-24	25-34	35-44	45-54	55-65
Austria	3,667	0.573	0.427	0.597	0.813	0.852	0.823	0.379	10.5	12.5	12.4	12.0	11.4
Belgium	3,311	0.597	0.403	0.295	0.838	0.838	0.814	0.408	11.1	13.4	13.2	12.6	11.4
Canada	19,168	0.593	0.407	0.608	0.820	0.847	0.830	0.612	11.5	13.9	14.0	13.4	13.0
Czech Rep.	3,622	0.520	0.480	0.305	0.770	0.860	0.854	0.404	11.3	13.8	13.4	13.1	12.8
Denmark	5,298	0.586	0.414	0.549	0.778	0.853	0.840	0.575	10.3	13.5	13.3	12.6	12.4
Estonia	5,331	0.514	0.486	0.440	0.833	0.852	0.811	0.570	11.0	12.6	12.3	12.4	11.9
Finland	3,869	0.534	0.467	0.407	0.798	0.874	0.842	0.567	10.5	13.3	13.4	12.7	11.4
France	4,471	0.538	0.462	0.318	0.762	0.794	0.795	0.428	11.0	12.5	12.0	10.9	9.7
Germany	4,015	0.539	0.461	0.530	0.794	0.810	0.853	0.611					
Ireland	3,638	0.552	0.448	0.373	0.721	0.671	0.672	0.494	13.9	15.8	15.1	14.1	12.7
Italy	2,841	0.513	0.487	0.215	0.674	0.729	0.677	0.334	9.9	12.6	11.1	10.1	8.7
Japan	3,844	0.509	0.491	0.496	0.762	0.783	0.825	0.625	11.5	13.7	13.5	13.4	12.4
Korea	4,354	0.447	0.553	0.302	0.721	0.793	0.792	0.574	11.4	14.5	13.9	12.3	10.1
Netherlands	3,899	0.646	0.354	0.657	0.836	0.841	0.815	0.528	11.7	14.1	13.7	13.3	12.7
Norway	3,491	0.568	0.432	0.564	0.741	0.786	0.720	0.579	12.0	14.7	14.8	14.2	13.9
Poland	5,052	0.419	0.581	0.343	0.767	0.797	0.706	0.377	11.2	14.0	13.1	12.4	11.3
Slovak Rep.	3,285	0.487	0.513	0.257	0.706	0.785	0.778	0.426	11.6	13.8	13.5	13.1	12.5
Spain	3,312	0.477	0.523	0.259	0.678	0.696	0.650	0.386	10.8	12.4	12.0	11.2	9.7
Sweden	3,312	0.572	0.428	0.425	0.785	0.867	0.872	0.665	10.6	12.7	12.7	12.4	11.7
England	5,791	0.565	0.435	0.495	0.771	0.794	0.797	0.534	12.4	13.5	13.3	12.9	12.8
USA	3,525	0.571	0.429	0.547	0.773	0.765	0.765	0.610	11.3	13.8	13.8	13.5	13.6
Average	99,096	0.546	0.454	0.428	0.769	0.804	0.787	0.509	11.3	13.5	13.2	12.6	11.8

Notes: The number of observations is the number of employed workers with registered occupational status. ISCO 1-4 and ISCO 5-9 are the major occupational groups 1 to 4 and 5 to 9, respectively. Education is the number of years of schooling. Sample weights are applied to calculate the shares and the number of years of education. Source: PIAAC.

Source: PIACC.