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# EFFICIENCY IN THE TRANSFORMATION OF SCHOOLING INTO COMPETENCES: A CROSS-COUNTRY ANALYSIS USING PIAAC DATA

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Human Capital

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# EFFICIENCY IN THE TRANSFORMATION OF SCHOOLING INTO COMPETENCES: A CROSS-COUNTRY ANALYSIS USING PIAAC DATA

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ABSTRACT: This study (i) compares the competence levels of the adult population in a set of OECD countries; (ii) assesses the comparative efficiency with which the education system in each country transforms schooling into competences, distinguishing by educational level, and (iii) tracks the evolution of this efficiency by birth cohorts. Using PIAAC data, the paper applies standard parametric frontier techniques under two alternative specifications. The results obtained under both specifications are similar and identify Finland, Sweden, Denmark and Japan as being the most efficient and Spain, the United Kingdom, Italy, Ireland and Poland as the least efficient. The evolution of the efficiency levels by age cohorts shows that higher education is more efficient for younger cohorts, while lower and upper secondary education present a stable trend over cohorts.

JEL Codes: I21, C13

Keywords: Adult population competences, efficiency, PIAAC, parametric frontier techniques

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## 1. Introduction

The consideration of human capital as a key factor both in the economic growth of countries and in the labor outcomes of individuals represents a long-standing tradition in the literature. Similarly, the limitations researchers face as they seek to measure this human capital – typically by resorting to the number of years of schooling (or, alternatively, the level of education attained) on the basis of Mincer's (1970; 1974) proposal – have been well documented. More recently, various studies have recommended considering the cognitive skills or competences acquired by individuals – as well as the number of years of schooling – when measuring human capital. Borghans et al. (2001) discuss the advantages of such an approach, stressing that the level of education achieved by an individual is an imperfect indicator of their human capital at any one point in time. Indeed, several studies provide empirical support for such arguments and show that cognitive competences can account for a large part of a country's growth in productivity (Hanushek and Kimko 2000; Barro 2001; Hanushek and Woessmann 2008) and for a part of an individual's labor achievements that cannot be explained by their educational attainments (McIntosh and Vignoles 2001; Green, and Riddell 2003).

If, therefore, we assume that an individual's skills are defined not only by the quantity of education they have received (measured in terms of the number of years of schooling), but also by the quality of that education (measured in terms of the cognitive competences acquired), it is of great interest to researchers to (i) determine which factors account for the acquisition of competences throughout an individual's life cycle and (ii) identify the greater performance that some individuals derive from their schooling in terms of competences than is obtained by others. The first of these issues has been broadly analyzed by estimating education production functions (Hanushek 1979; 1997). It has been concluded that not only the number of years of formal education received but other relevant variables, including an individual's personal characteristics and his/her socio-economic environment, can determine the acquisition of cognitive competences (Björklund and Salvanes 2011; Mazzona 2014). When estimating education production functions, however, it is assumed that all the units included in the sample obtain the same benefit from each of the explanatory variables considered. In international comparisons, this means, for example, assuming that an additional year of schooling in two countries with different institutional environments – and, more specifically, with different education systems – is equally effective, on average, in translating higher levels of schooling into competences for their populations. In order to refine this assumption, we need to determine whether the efficiency in the transformation of the number of years of schooling received into competences varies by country. The estimation of production frontiers is useful for this purpose since it indicates, for a given reference unit, the distance from that unit to the frontier, estimated using the most efficient units in the sample. For a given set of countries, this technique would provide a sorting of countries as a function of their distance from the frontier, or what is the same, as a function of the efficiency with which their education systems transform an additional year of schooling into competences[1].

[1] A review of papers using parametric boundary techniques to analyze various issues related to education can be found in Worthington (2001).

The importance attached to the analysis of efficiency in education has grown notably in recent years (see De Witte and López-Torres 2015, for an exhaustive review of the literature). The bulk of the work in this regard has focused on estimating the efficiency of different units (districts, schools or students) operating within the same country, with far fewer studies comparing the efficiency of education systems across countries. However, among the latter, the most relevant draw on information provided by the OECD's PISA program as they compare from different perspectives the efficiency with which the education systems of different countries operate. For example, Afonso and Aubyn (2005; 2006) and Sutherland et al. (2009) analyze the efficiency of public spending on education for a group of OECD countries, and emphasize the role played by the institutions of each country in accounting for the disparity in the results reported. The influential role played by a country's institutions is similarly stressed by De Jorge and Santín (2010), who, like Deutsch et al. (2013), consider an analysis of efficiency at the student level as the best approach to optimize the use of available information. Agasisti and Zoido (2015) assess efficiency at both the national and school level for a broad set of OECD countries. They document a notable heterogeneity both between and within countries in terms of the degree of efficiency achieved by their respective education systems and schools. Giambona et al. (2011), in contrast, focus on the role played by the students' socio-economic characteristics in the determination of their competences. The authors assess the efficiency of the education systems of several EU countries with particular regard to their ability to help students from a poor family background achieve optimal development of their cognitive competences. The importance of the socio-economic environment is similarly stressed in Thieme et al. (2012). The authors compare the efficiency of a broad set of countries taking into account not only the results obtained by the students but also the degree of dispersion in the distribution of those results as an indicator of the equity of the system. Other studies use several waves of cross-sectional data in order to evaluate the evolution of a given output over time. This is the case of Agasisti (2014) when comparing the efficiency of public expenditure on education in twenty European countries between 2006 and 2009. In a similar vein, Giménez et al. (2017) examine student progress in terms of competences between 2003 and 2009, as they assess the extent to which their progress can be accounted for by the availability of better resources and/or the enhanced efficiency of their respective education systems. Other databases that have been used to evaluate the efficiency of education systems in an international setting include the Third International Mathematics and Science Study (TIMSS) – see Clements (2002) and Giménez et al. (2007); and the Progress in International Reading Literacy Study (PIRLS) – see Cordero et al. (2017).

The aforementioned papers adopt different methodologies (mainly non-parametric, but also semi-parametric and parametric) to calculate the efficiency with which different inputs are combined (at the country, school and/or student levels) in the production of various outputs related to student competences. However, despite this multiplicity of tools and results, they share a common limitation derived from their use of cross-sectional data that refer to individuals belonging to the same birth cohort. This means that we can only evaluate the efficiency of the education system for a given academic year (as in the case of TIMSS or PIRLS) or for a specific age (as in the case of PISA). In contrast, to the best of our knowledge, this paper is among the first that seeks to undertake an efficiency analysis for the education

system as a whole, distinguishing by country and by level of education[2]. This is possible as we draw on data from the Program for the International Assessment of Adult Competencies (PIAAC), a survey conducted by the OECD among individuals aged 16-65 that have received a varied number of years of schooling. By estimating standard stochastic frontier functions, our objectives are as follows: (i) to compare the competence levels of the adult population in a set of OECD countries; (ii) to assess the comparative efficiency with which the education system in each country transforms schooling into competences, distinguishing by educational level, and (iii) to track the evolution of this efficiency by birth cohorts.

The rest of the paper is structured in four sections: sections 2 and 3 outline the methodology and the database used, section 4 reviews the main results obtained and, finally, section 5 presents the study's main conclusions.

## 2. Methodology

Here we propose an education production function and employ standard stochastic frontier techniques to calculate the distance from each country to the frontier. In this way, a classification of the countries is obtained as a function of the (in)efficiency with which they transform schooling into competences.

The education production function can be expressed as follows:

$$\begin{aligned} Y_{iJ} &= \beta' X_{iJ} + w_{iJ} = \beta' X_{iJ} + \left(v_{iJ} - u_{iJ}\right) \\ E\left[u_{iJ} / w_{iJ}\right] &= \delta_{iJ} = h_i + \theta_J \end{aligned} \tag{1}$$

in which the competences of individual "i" living in country "J" are accounted for by the variables included in "$X_{iJ}$" plus a term of inefficiency or of distance with respect to the frontier, "$u_{iJ}$". The expected value of this distance from the frontier, for individual "i", is given by "$\delta_{iJ}$", which is the result of the standard calculation of frontier distances when using stochastic frontiers.

The distance to the frontier for individual "i" living in country "J" has two components: the individual component "$h_i$", which gathers the innate ability of individual "i", and "$\theta_J$", a component of the country that includes the average efficiency with which the country's education system transforms schooling into competences. When calculating the average of the individuals living in country "J", we obtain:

[2] Gupta and Verhoeven (2001) use information on adult population competences to make international comparisons of efficiency indicators. However, the aim of their study is not to evaluate the efficiency with which schooling is translated into competences, as is the case in our paper, but rather to compare the efficiency with which public expenditure on education and health improve a series of social development indicators, for some thirty African countries. For the specific case of education, the outputs assessed are school attendance rates in primary and secondary education and adult population competences.

$$\frac{\sum_{i=1}^{M}\delta_{iJ}}{M} = \frac{\sum_{i=1}^{M}h_i}{M} + \theta_J \rightarrow \theta_J \quad (2)$$

In other words, for individuals from country "J", insofar as the innate ability of the individuals within the same country tends to be compensated for, the average of the individual distances to the frontier will come closest to the average distance from the component country's derived frontier, which may represent a way to approach the efficiency of that country's education system.

The functional specification for the education production function suggests that using a linear, as opposed to a semi-logarithmic model, provides the best fit for the available data. Moreover, it appears that age and experience – two of the explanatory variables included in the model – have a free effect on the competences when creating dummy specific variables for age (i.e. a dummy for each age in years) and experience (i.e. a dummy for each experience in years), compared to a more standard specification that suggests a linear effect for age and a quadratic effect for experience. We estimate both options with the available data and conclude that the latter gives the better outcomes (see Annex 1).

Standard stochastic frontier techniques are applied to Equation 1 under two different specifications. In the first, the influence of the explanatory variables is accounted for, which means the equation is estimated using the standard frontier function technique and that the estimated coefficients are common to all the countries considered. In the second, the frontier functions methodology is adapted so as to allow the coefficients (other than formal education) that affect the transformation of inputs into competences (including, for example, number of years of experience or type of occupation) to vary from country to country. This approach, which can be consulted in Annex 2, means we can isolate more precisely the (in)efficiency of the formal education system in transforming years of education received into competences. This said, both approaches in fact give very similar results.

## 3. Data

The data used in the present paper are drawn from the first wave of the PIAAC (corresponding to 2012), an OECD initiative aimed at assessing the competences of the population aged 16-65. This database follows in the wake of others that have measured the competences of the adult population (including IALS and ALL), although the number of participating countries is in this case greater and the competences evaluated refer not only to language skills, but also to mathematical skills and the use of new technologies. All these competences are measured using specific tests, the results of which are presented in terms of plausible values (ten for each skill). These plausible values indicate the performance of each individual on a scale of 0 to 500 points and are grouped into six levels. The survey, designed to facilitate a comparative analysis of the participating countries, also offers harmonized information on the use of the competences assessed in the workplace and in daily life; on the socio-demographic characteristics of the individuals surveyed (e.g. gender, age, nationality, level of education of parents); and on their training and job characteristics (e.g. education

level, work experience throughout their working life, work situation: employed, inactive, unemployed, salary and other characteristics of the job: type of contract and working day, performance of supervision tasks, and even variables that allow for the identification of eventual educational or skill mismatches).

We have excluded from the sample those countries that give rise to any kind of concern regarding the reliability of the data they provide and those which fail to provide information on some of the variables considered in our study. Our model's dependent variable is numeracy competences rescaled to 1000 so as to facilitate the interpretation of the results[3]. The explanatory variables provide information about age, number of years of schooling, work experience (in quadratic terms), gender, first or second generation immigrant status, (the absence of) coincidence between the mother tongue and the language in which the survey is carried out, the level of studies of the parents, type of occupation and possible attendance on non-regulated training courses.

Table 1 presents the descriptive statistics for the variables in the overall sample (excluding observations without information regarding any of the variables considered in the analysis, which limits the sample to around 79,000 observations). The average value of the numeracy competence is c. 542 points, with a marked standard deviation of around 96 points. The average number of years of schooling stands at 12.73 for individuals whose average age is 40 years old and who have an average work experience of 18.21 years. The proportion of first generation immigrants is 7.9% (falling to 1.7% for second generation immigrants), most individuals (92%) respond to the survey in their mother tongue and 38% (22%) have at least one ascendant with post-compulsory (higher) secondary education. Roughly two-thirds of the individuals in the sample work in a skilled occupation and, finally, around 40% reported participating on non-regulated training courses in the 12 months prior to the survey.

**Table 1. Descriptive statistics**

| Variable | Average | Standard dev. | Min | Max |
|---|---|---|---|---|
| Mathematics Comp. | 542.0646 | 96.1126 | 49.6917 | 888.2642 |
| 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 |
| Man | 0.4783 | 0.4995 | 0.0000 | 1.0000 |
| Immigrant 1st gen. | 0.0796 | 0.2707 | 0.0000 | 1.0000 |
| Immigrant 2nd gen. | 0.0173 | 0.1304 | 0.0000 | 1.0000 |
| Mother tongue | 0.9233 | 0.2660 | 0.0000 | 1.0000 |
| Parents higher secondary ed. | 0.3815 | 0.4858 | 0.0000 | 1.0000 |
| Parents higher ed. | 0.2232 | 0.4164 | 0.0000 | 1.0000 |

[3] All of the study's estimations have been replicated using literacy skills as the dependent variable. The results obtained (available upon request) are, to a large extent, quantitatively and qualitatively similar to those presented here for numeracy.

| | | | | |
|---|---|---|---|---|
| Qualified occupation | 0.6122 | 0.4873 | 0.0000 | 1.0000 |
| Non-regulated training | 0.3919 | 0.4882 | 0.0000 | 1.0000 |

Table 2 shows the average competences by country, with values ranging from 491 for Spain to 576 points for Japan. Table 3 ranks the countries by competences, with Japan and the Nordic countries heading the classification and Ireland, Spain and Italy finding themselves at the bottom of the ranking.

**Table 2. Average competences by country**

| Country | Average Competences |
|---|---|
| Belgium | 560.7724 |
| Czech. Rep | 551.4677 |
| Denmark | 556.5568 |
| Estonia | 546.239 |
| Finland | 564.4532 |
| Ireland | 511.1808 |
| Italy | 494.2578 |
| Japan | 576.3407 |
| Korea | 526.7724 |
| Holland | 560.6922 |
| Norway | 556.5957 |
| Poland | 519.5378 |
| Slovak Rep. | 551.6152 |
| Spain | 491.6435 |
| Sweden | 558.1049 |
| United Kingdom | 523.4517 |

**Table 3. Ranking of countries by competences**

| Country |
|---|
| Japan |
| Finland |
| Belgium |
| Holland |
| Sweden |
| Norway |
| Denmark |
| Slovak Rep. |
| Czech Rep. |
| Estonia |
| Korea |
| United Kingdom |
| Poland |
| Ireland |
| Italy |
| Spain |

Finally, and given that throughout this study the efficiency indices are estimated distinguishing by level of education, Graph 1 presents average numeracy scores for each level of education contemplated. Note that the rankings of countries according to their average competences per level of study (see Table 4) present considerable similarities to those obtained as a function of the efficiency indices (see Graphs 2 and 3).

**Graph 1. Average competences by country and level of studies**

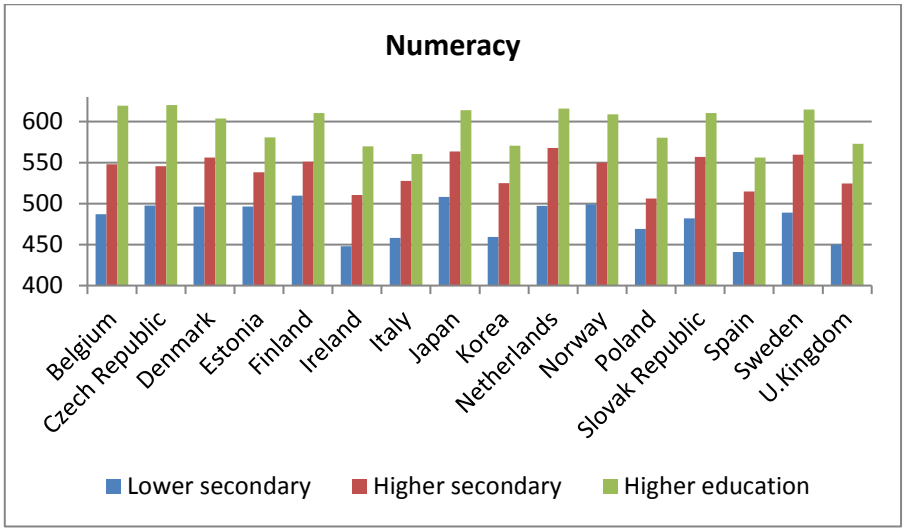



**Table 4. Classification of countries as a function of their competence level, by level of studies**

| Lower Secondary | Higher Secondary | Higher education |
|---|---|---|
| Finland | Holland | Belgium |
| Japan | Japan | Holland |
| Norway | Sweden | Sweden |
| Czech Rep. | Slovak Rep. | Japan |
| Holland | Denmark | Slovak Rep. |
| Estonia | Finland | Finland |
| Denmark | Norway | Norway |
| Sweden | Belgium | Denmark |
| Belgium | Czech Rep. | Estonia |
| Slovak Republic | Estonia | Poland |
| Poland | Italia | United Kingdom |
| Korea | Korea | Korea |
| Italia | United Kingdom | Ireland |
| United Kingdom | Spain | Italy |
| Ireland | Ireland | Spain |
| Spain | Poland | Belgium |

## 4. Results

Graph set 2 shows the results of the estimation of the efficiency indices for specification 1 (see methodology, section 2), in which the influence of the explanatory variables is taken into account. Graph set 3 corresponds to specification 2, which also incorporates a frontier function but in which the coefficients (with the exception of formal education) that affect the transformation of inputs into outputs are allowed to vary from

country to country[4]. In each case, the results are broken down into the three educational levels completed by the individuals: up to lower secondary; higher secondary, and higher education. Note that the results obtained from the two specifications are largely similar, with only minor differences.

Focusing on Graph set 2, similar patterns are found for the three levels of education (Graphs 2a, 2b and 2c). The efficiency in the transformation of the number of years of schooling into competences is greatest in three of the Nordic countries analyzed (Finland, Sweden and Denmark), Japan and Belgium. In contrast, the lowest levels of efficiency are recorded in Spain, Italy, Ireland, Poland, Korea and the United Kingdom. This pattern is repeated with only minor differences across the three levels of education: the order of the countries is largely similar, with some notable differences, (for example, in the case of higher education Italy presents an especially low level of efficiency and Poland presents a slightly higher level of efficiency).

Graph set 3 (Graphs 3a, 3b and 3c) presents the efficiency indices using specification 2 (in which the coefficients that affect the transformation of inputs into outputs vary from country to country). As in Graph set 2, the Nordic countries present the highest rates of efficiency, these indices being slightly higher than those reported for specification 1. Japan and Belgium present very similar levels of efficiency to those obtained with specification 1, but they fall in the overall ranking of countries by rates of efficiency. The United Kingdom and Italy present the lowest levels of efficiency, while Spain, Ireland and Poland present indices that are similarly low for both specifications. Here the differences in the efficiency indices between the three levels of education (which are small in the case of specification 1) are even smaller. All in all, the positions occupied by the countries in the rankings are very similar across the three levels of education.

Graph set 4 tracks the evolution of the efficiency levels over the different age cohorts for the three levels of education considered. In the case of higher education, it can be seen that in most of the countries considered the levels of efficiency in generating competences are higher among the younger cohorts. This increase in the index is most significant in Spain and Italy, but is also appreciable in the Nordic countries (with the exception of Denmark), Belgium, Holland and Korea. In the cases of the United Kingdom and Ireland, the increase is less pronounced. However, there are hardly any changes in the levels of efficiency in the remaining countries: Japan, Denmark and the four Eastern European countries considered (i.e. Czech Republic, Estonia, Poland and the Slovak Republic).

In the case of higher secondary education, the pattern presented is one of general stability across all the cohorts. The only deviations from this trend are recorded in the cases of Italy and the United Kingdom, where there has been a fall in efficiency among the youngest cohorts, and in that of Finland, where there has been an increase in efficiency.

Likewise, in the case of lower secondary education, efficiency levels in most countries remain stable across all the cohorts. There are exceptions to this general pattern. For example,

[4] Table A.3.1 of Annex 3 gathers the numerical indices calculated according to specification 1, and Table A.3.2 the numerical indices according to specification 2.

in Spain and Korea efficiency levels have increased among younger cohorts, whereas in Italy and the United Kingdom there has been a fall in efficiency levels for these same cohorts. In the Eastern European countries, the pattern of stability is interrupted in the cohort aged between 46 and 55 (26-45 in Slovakia) with marked declines in efficiency, associated in all probability with the historic evolution of the education systems in these countries

## 5. Conclusions

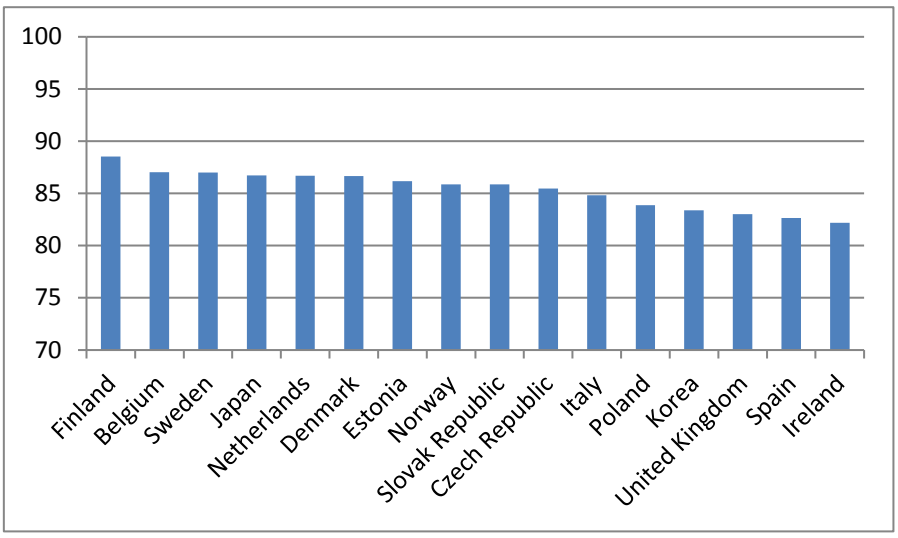
The aim of this study has been to compare the degree of efficiency with which the OECD countries produce competences from the schooling provided and from other inputs and, also, to monitor how this efficiency has evolved over different age cohorts. To do so, we have estimated standard stochastic frontier functions applied to OECD data from the PIAAC. In order to estimate this frontier we used two specifications so as to verify the robustness of our results. In the first specification, the influence of the explanatory variables has been taken into account and a function was estimated whose coefficients are common to all of the countries considered; in the second, the frontier functions methodology has been generalized to allow the coefficients (other than formal education) that affect the transformation of inputs into competences (including, years of experience and type of occupation) to vary from country to country.

The levels of efficiency reported by the analyses were similar for both specifications. Furthermore, the results by level of education show that in most cases the efficiency indices are similar for all three levels of education. However, efficiency in the transformation of schooling into competences is greatest in Finland, Sweden, Denmark, Japan and Belgium, while the lowest levels of efficiency are to be found in Spain, the United Kingdom, Italy, Ireland and Poland.

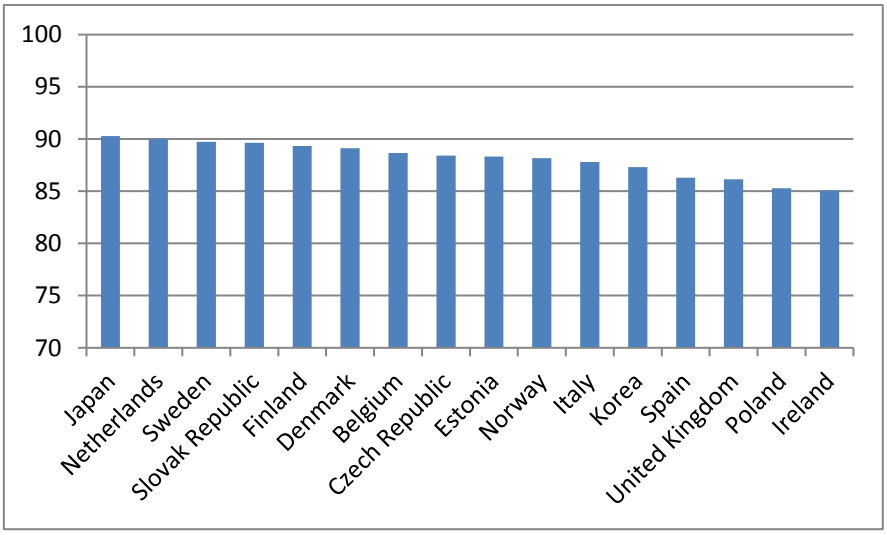
Finally, as regards the evolution in the levels of efficiency associated with different age cohorts, we found that in the case of higher education, levels are higher among younger cohorts, whereas in the cases of lower and upper secondary education, the general pattern, albeit with some exceptions, is one of stability for all the cohorts considered.

**Graph set 2. Efficiency indices for competence in mathematics. Specification 1.**

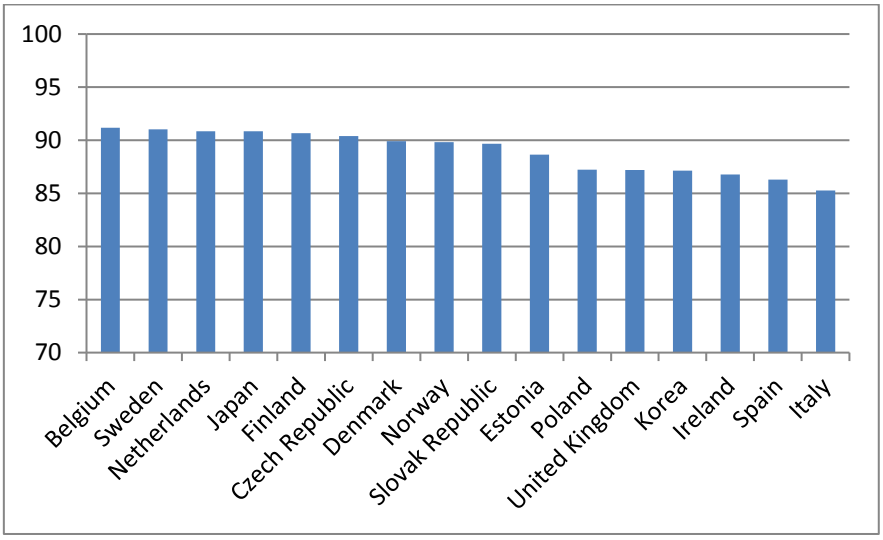
**Graph 2.a. Lower secondary**




**Graph 2.b. Higher secondary**

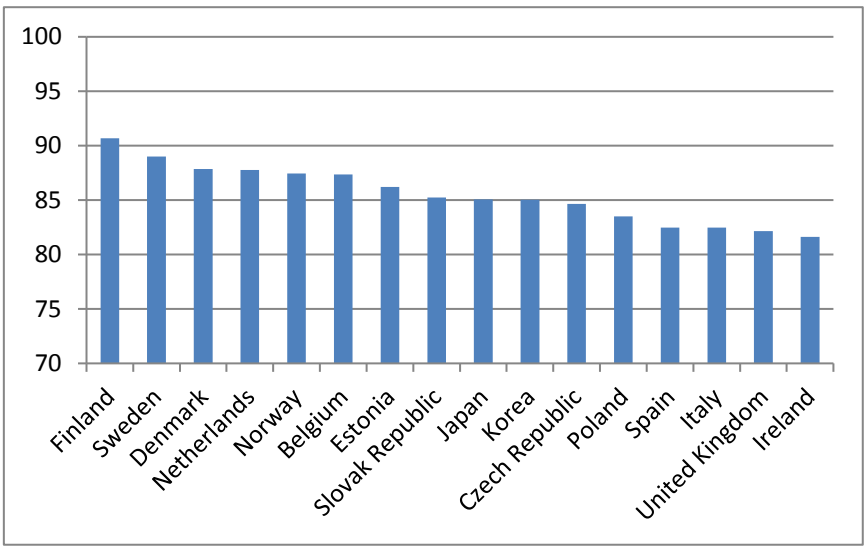



**Graph 2.c. Higher education**

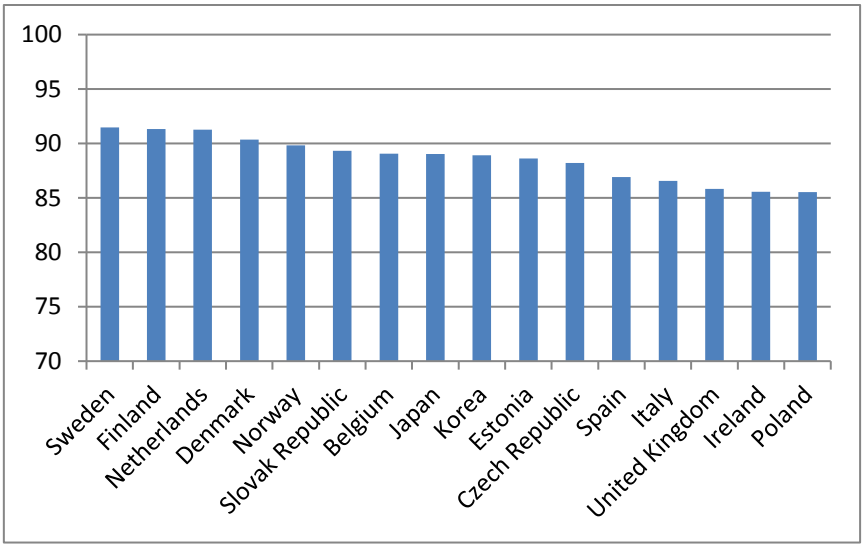


**Graph set 3. Efficiency indices for competences in mathematics. Specification 2.**

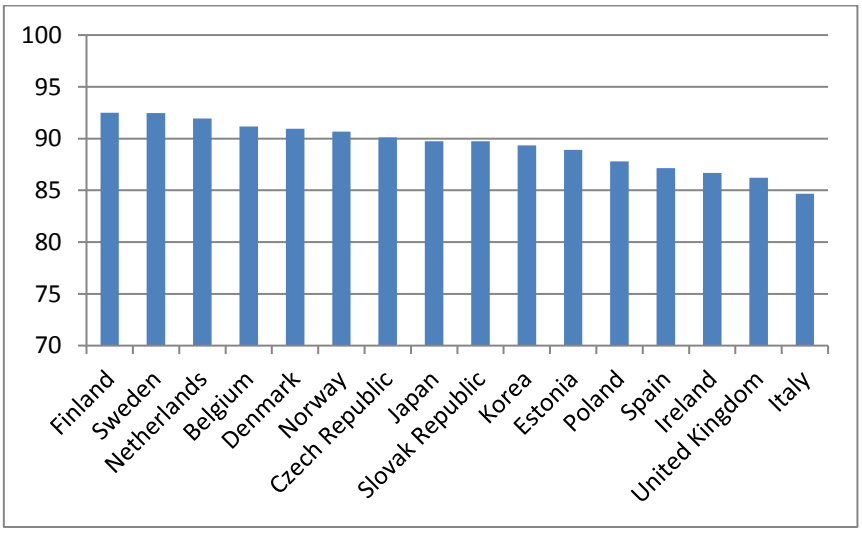
**Graph 3.a. Lower secondary**




**Graph 3.b. Higher secondary**

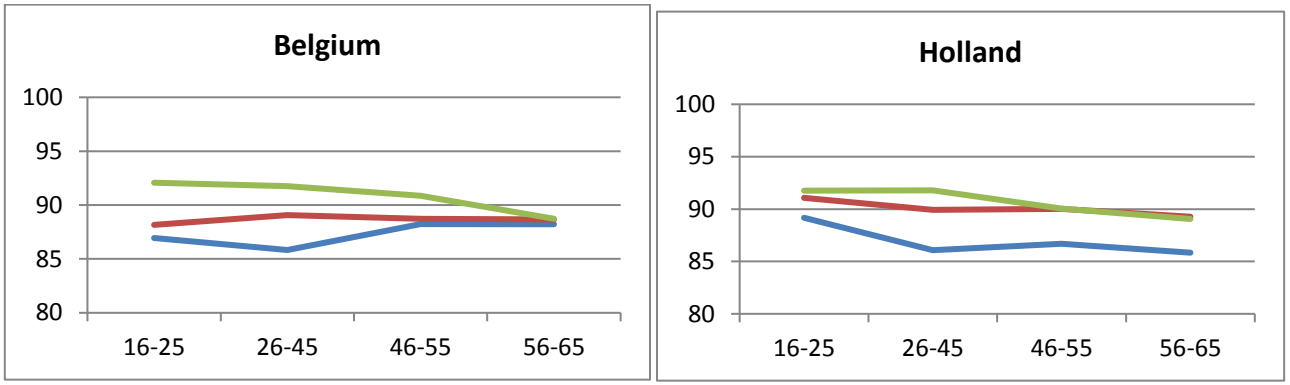



**Graph 3.c. Higher education**

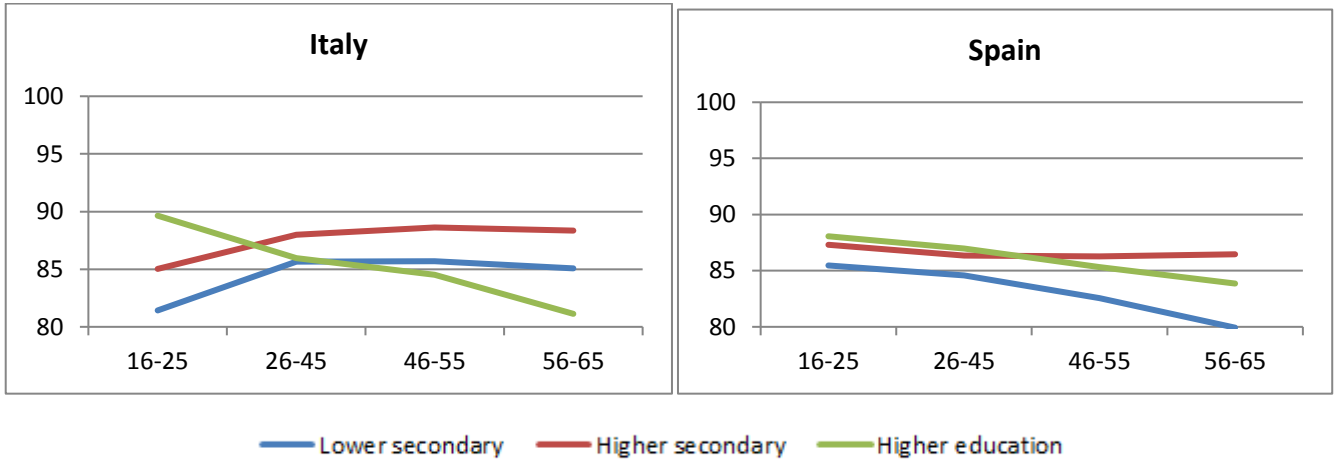


**Graph set 4. Efficiency indices for competence in mathematics according to level of education and cohort**

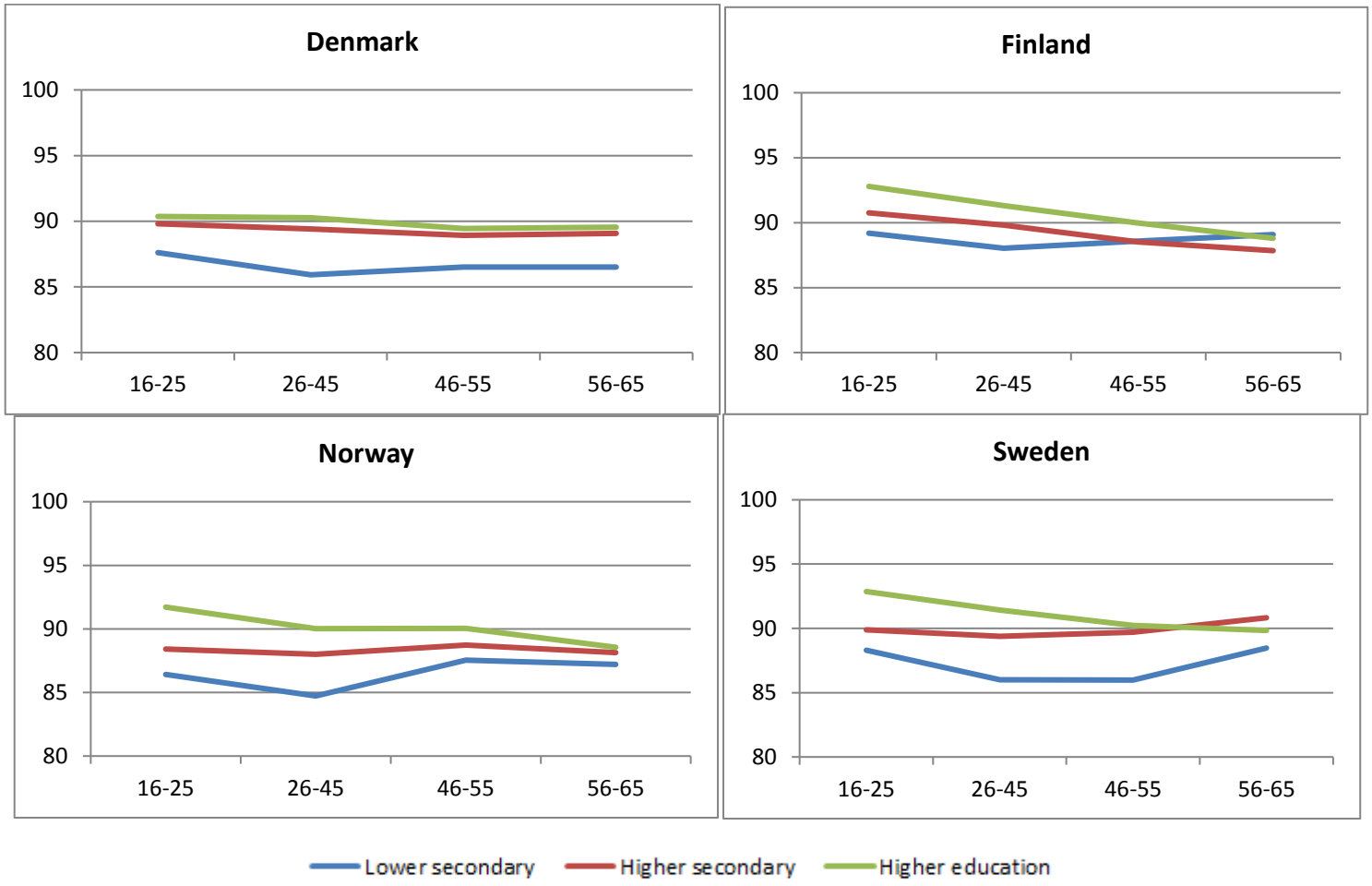
**Continental countries**



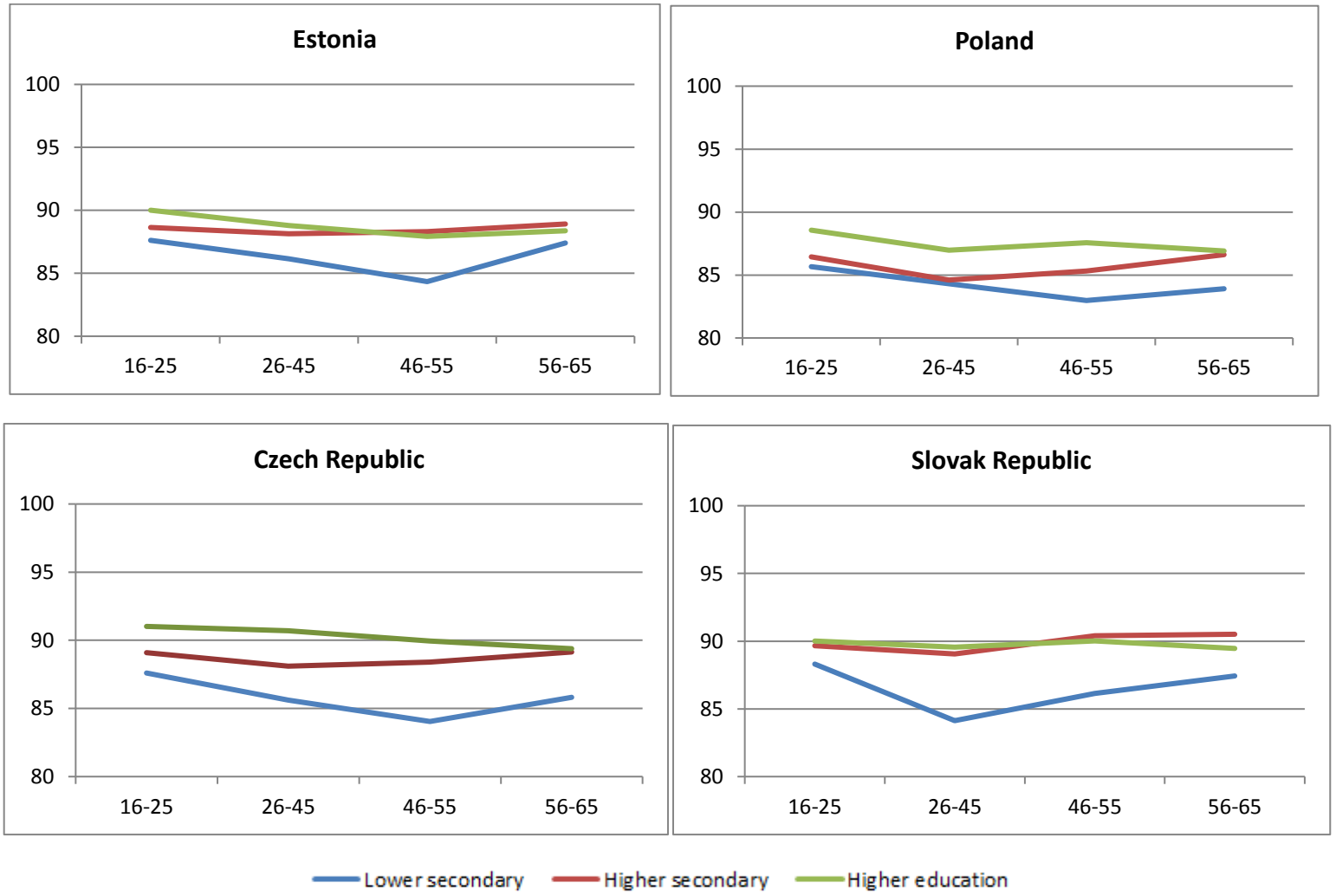

**Mediterranean countries**



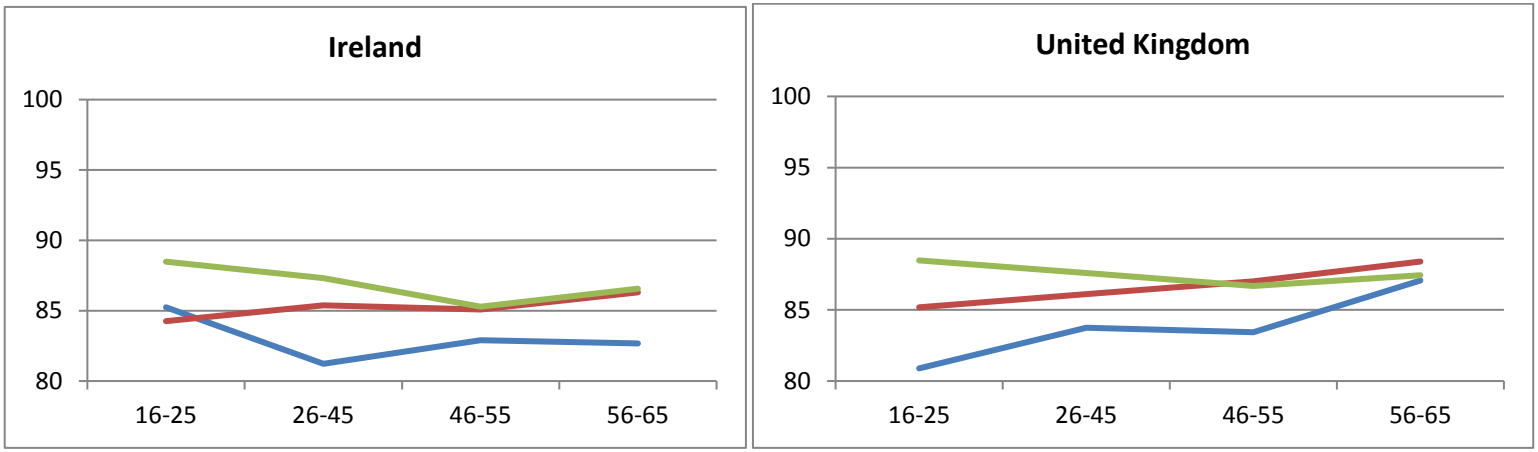
**Nordic countries**



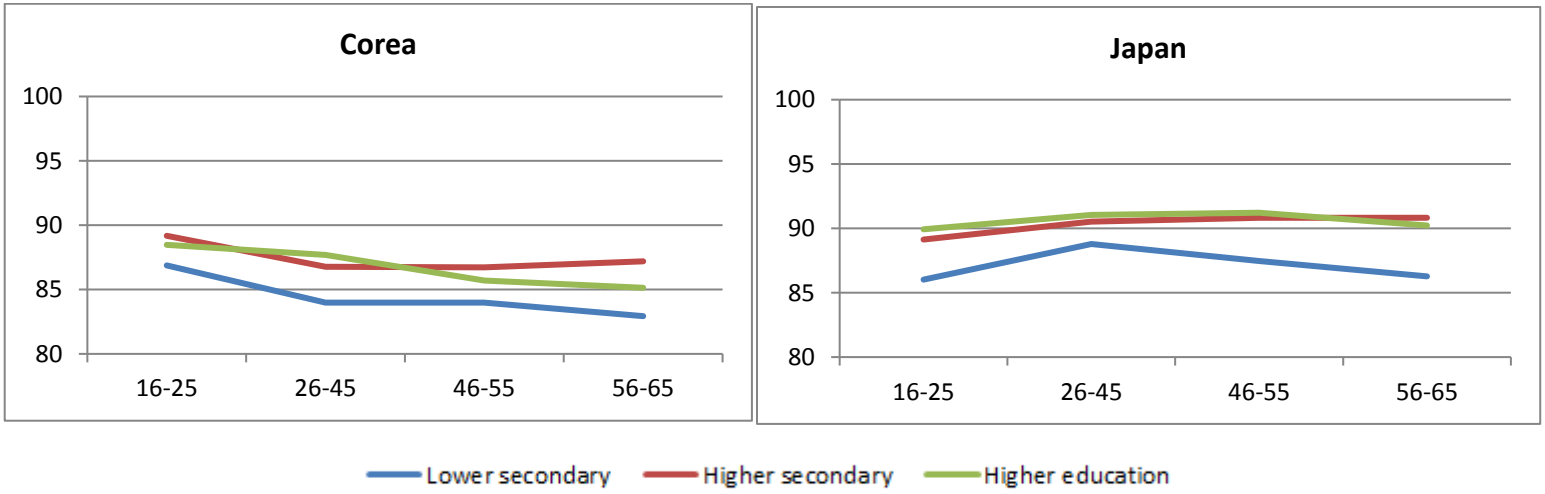
**Eastern European countries**



**Anglo-Saxon countries**




**Asian countries**



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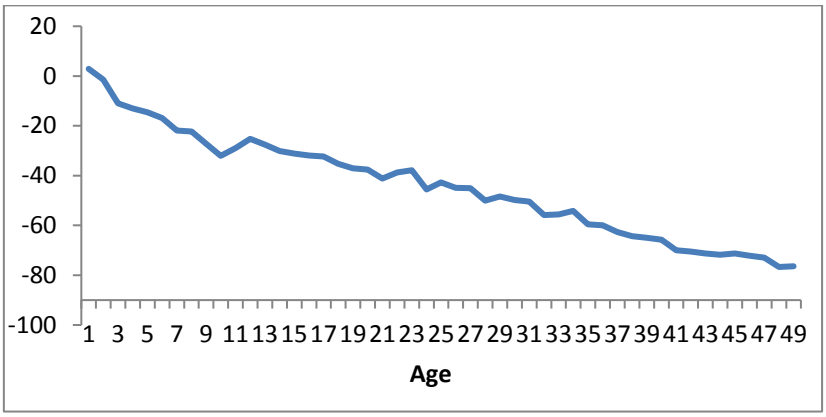
## ANNEX 1. Selection of the functional form of age and experience in education production

**Table A.1.1. Free Effect of age and experience**

| Variables | Estimated coefficients |
|---|---|
| Schooling | 9.93*** |
| | 87.65 |
| Age dummies: see Graph 1.A | |
| Experience dummies: see Graph 2.A | |
| Woman | -21.31*** |
| | -39.57 |
| Immigrant 1st gen. | -33.73*** |
| | -23.93 |
| Immigrant 2nd gen. | -7.42*** |
| | -3.65 |
| Mother tongue | -19.92*** |
| | -13.64 |
| Parents basic ed. | -30.98*** |
| | -40.98 |
| Parents secondary ed. | -15.13*** |
| | -22.42 |
| Unqualified occupation | -27.94*** |
| | -43.79 |
| Without non-regulated training | -12.84*** |
| | -22.56 |
| Constant | 585.52*** |
| | 155.09 |
| Schwarz Statistic | 907087.7 |
| Observations | 78,825 |

**Graph 1.A. Effect of age**




**Graph 2.A. Effect of experience**

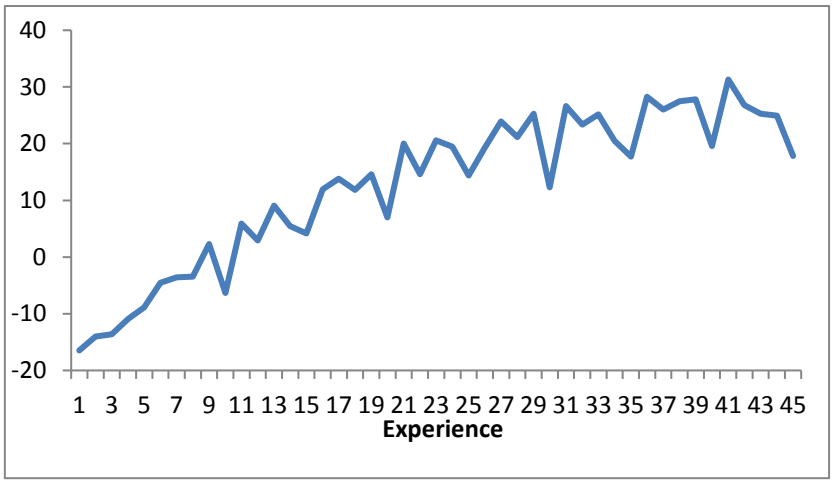



**Table A.1.2. Linear effect of age and quadratic effect of experience**

| Variables | Estimated coefficients |
|---|---|
| Schooling | 9.70*** |
| | 87.39 |
| Age | -1.50*** |
| | -31.94 |
| Experience | 1.85*** |
| | 20.42 |
| Squared experience | -0.02*** |
| | -11.88 |
| Woman | -21.23*** |
| | -39.38 |
| Immigrant 1st gen. | -34.24*** |
| | -24.25 |
| Immigrant 2nd gen. | -7.51*** |
| | -3.68 |
| Mother tongue | -20.05*** |
| | -13.69 |

| | |
|---|---|
| Parents basic ed. | -31.87*** |
| | -42.28 |
| Parents secondary ed. | -15.82*** |
| | -23.44 |
| Unqualified occupation | -28.31*** |
| | -44.37 |
| Without non-regulated training | -12.33*** |
| | -21.78 |
| Constant | 590.32*** |
| | 275.42 |
| Schwarz Statistic | 906532.7 |
| Observations | 78,825 |

**ANNEX 2. A proposal to generalize the frontier production function (Approach 2)**

The starting point is the competence production functions at the country level:

(1) $Y_{iJ} = \mu_J + \beta'_J X_{iJ} + \alpha_J S_{iJ} + w_{iJ}$

where "i" is the individual and "J" the country. $X_{iJ}$ are the characteristics of the individual and $S_{iJ}$ are the number of years of education. From this, we obtain:

(2) $Y_{iJ} - \beta'_J X_{iJ} = \mu_J + \alpha_J S_{iJ} + w_{iJ}$

(3) $Y_{iJ}^{*} = \mu_J + \alpha_J S_{iJ} + w_{iJ}$

If "$Y_{ij}^{*}$" of equation (3) were directly observable, this equation could be estimated using the standard frontier function technique and assuming a common $\alpha_J$. As this is not the case, the proposal is:

a) Estimate (1) by OLS for the different countries. This enables us to obtain a consistent estimation of the "$\beta$" coefficients.
b) From this consistent estimation of "$\beta$", we obtain an estimation of $\hat{Y}_{ij}^{*} = Y_{ij} - \hat{\beta}'_j X_{ij}$. This variable "$\hat{Y}_{ij}^{*}$" is an estimation of the competences of individual "i" living in country "J" after excluding the effects of experience, age, sex, and all the other variables on the competences acquired.
c) Given that "$\hat{Y}_{iJ}^{*}$" is the net of the contribution of the remaining variables of education, a frontier function can be estimated for this variable using the number of years of schooling as the only explanatory variable. Following this approach, the efficiency term estimated from this frontier will also refer uniquely to the years of schooling.

## ANNEX 3. Efficiency indices calculated according to specifications 1 and 2

**Table A.3.1. Efficiency indices by levels of study. Specification 1**

| | Lower Secondary | Higher Secondary | Higher education |
|---|---|---|---|
| Belgium | 87.02281 | 88.66001 | 91.17441 |
| Czech Republic | 85.46297 | 88.39928 | 90.40039 |
| Denmark | 86.66442 | 89.10681 | 89.91032 |
| Estonia | 86.17697 | 88.31044 | 88.65252 |
| Finland | 88.54883 | 89.32155 | 90.65049 |
| Ireland | 82.19496 | 85.06034 | 86.77006 |
| Italy | 84.83895 | 87.80328 | 85.25765 |
| Japan | 86.71206 | 90.28149 | 90.83987 |
| Korea | 83.38552 | 87.29479 | 87.14777 |
| Netherlands | 86.68916 | 90.00864 | 90.84135 |
| Norway | 85.86949 | 88.17571 | 89.82951 |
| Poland | 83.86766 | 85.2742 | 87.23417 |
| Slovak Republic | 85.85493 | 89.64773 | 89.68038 |
| Spain | 82.65196 | 86.29001 | 86.30075 |
| Sweden | 86.9926 | 89.72025 | 91.01138 |
| United Kingdom | 83.01533 | 86.13918 | 87.20603 |

**Table A.3.2. Efficiency indices by levels of study. Specification 2**

| | Lower Secondary | Higher Secondary | Higher education |
|---|---|---|---|
| Belgium | 87.359 | 89.06649 | 91.17212 |
| Czech Republic | 84.65757 | 88.20512 | 90.12897 |
| Denmark | 87.862 | 90.36086 | 90.93721 |
| Estonia | 86.20949 | 88.62979 | 88.8939 |
| Finland | 90.68295 | 91.31189 | 92.48883 |
| Ireland | 81.61584 | 85.55253 | 86.69101 |
| Italy | 82.47282 | 86.56282 | 84.66655 |
| Japan | 85.05509 | 89.02824 | 89.74224 |
| Korea | 85.04414 | 88.91232 | 89.33719 |
| Netherlands | 87.77496 | 91.26699 | 91.95099 |
| Norway | 87.44143 | 89.83485 | 90.65718 |
| Poland | 83.49704 | 85.52269 | 87.78531 |
| Slovak Republic | 85.24813 | 89.32839 | 89.73741 |
| Spain | 82.47431 | 86.91864 | 87.1491 |
| Sweden | 88.99646 | 91.47664 | 92.45048 |
| United Kingdom | 82.14009 | 85.82652 | 86.2135 |

**2013**

**2013/1, Sánchez-Vidal, M.; González-Val, R.; Viladecans-Marsal, E.:** "Sequential city growth in the US: does age matter?"
**2013/2, Hortas Rico, M.:** "Sprawl, blight and the role of urban containment policies. Evidence from US cities"
**2013/3, Lampón, J.F.; Cabanelas-Lorenzo, P-; Lago-Peñas, S.:** "Why firms relocate their production overseas? The answer lies inside: corporate, logistic and technological determinants"
**2013/4, Montolio, D.; Planells, S.:** "Does tourism boost criminal activity? Evidence from a top touristic country"
**2013/5, Garcia-López, M.A.; Holl, A.; Viladecans-Marsal, E.:** "Suburbanization and highways: when the Romans, the Bourbons and the first cars still shape Spanish cities"
**2013/6, Bosch, N.; Espasa, M.; Montolio, D.:** "Should large Spanish municipalities be financially compensated? Costs and benefits of being a capital/central municipality"
**2013/7, Escardíbul, J.O.; Mora, T.:** "Teacher gender and student performance in mathematics. Evidence from Catalonia"
**2013/8, Arqué-Castells, P.; Viladecans-Marsal, E.:** "Banking towards development: evidence from the Spanish banking expansion plan"
**2013/9, Asensio, J.; Gómez-Lobo, A.; Matas, A.:** "How effective are policies to reduce gasoline consumption? Evaluating a quasi-natural experiment in Spain"
**2013/10, Jofre-Monseny, J.:** "The effects of unemployment benefits on migration in lagging regions"
**2013/11, Segarra, A.; García-Quevedo, J.; Teruel, M.:** "Financial constraints and the failure of innovation projects"
**2013/12, Jerrim, J.; Choi, A.:** "The mathematics skills of school children: How does England compare to the high performing East Asian jurisdictions?"
**2013/13, González-Val, R.; Tirado-Fabregat, D.A.; Viladecans-Marsal, E.:** "Market potential and city growth: Spain 1860-1960"
**2013/14, Lundqvist, H.:** "Is it worth it? On the returns to holding political office"
**2013/15, Ahlfeldt, G.M.; Maennig, W.:** "Homevoters vs. leasevoters: a spatial analysis of airport effects"
**2013/16, Lampón, J.F.; Lago-Peñas, S.:** "Factors behind international relocation and changes in production geography in the European automobile components industry"
**2013/17, Guío, J.M.; Choi, A.:** "Evolution of the school failure risk during the 2000 decade in Spain: analysis of Pisa results with a two-level logistic mode"
**2013/18, Dahlby, B.; Rodden, J.:** "A political economy model of the vertical fiscal gap and vertical fiscal imbalances in a federation"
**2013/19, Acacia, F.; Cubel, M.:** "Strategic voting and happiness"
**2013/20, Hellerstein, J.K.; Kutzbach, M.J.; Neumark, D.:** "Do labor market networks have an important spatial dimension?"
**2013/21, Pellegrino, G.; Savona, M.:** "Is money all? Financing versus knowledge and demand constraints to innovation"
**2013/22, Lin, J.:** "Regional resilience"
**2013/23, Costa-Campi, M.T.; Duch-Brown, N.; García-Quevedo, J.:** "R&D drivers and obstacles to innovation in the energy industry"
**2013/24, Huisman, R.; Stradnic, V.; Westgaard, S.:** "Renewable energy and electricity prices: indirect empirical evidence from hydro power"
**2013/25, Dargaud, E.; Mantovani, A.; Reggiani, C.:** "The fight against cartels: a transatlantic perspective"
**2013/26, Lambertini, L.; Mantovani, A.:** "Feedback equilibria in a dynamic renewable resource oligopoly: pre-emption, voracity and exhaustion"
**2013/27, Feld, L.P.; Kalb, A.; Moessinger, M.D.; Osterloh, S.:** "Sovereign bond market reactions to fiscal rules and no-bailout clauses – the Swiss experience"
**2013/28, Hilber, C.A.L.; Vermeulen, W.:** "The impact of supply constraints on house prices in England"
**2013/29, Revelli, F.:** "Tax limits and local democracy"
**2013/30, Wang, R.; Wang, W.:** "Dress-up contest: a dark side of fiscal decentralization"
**2013/31, Dargaud, E.; Mantovani, A.; Reggiani, C.:** "The fight against cartels: a transatlantic perspective"
**2013/32, Saarimaa, T.; Tukiainen, J.:** "Local representation and strategic voting: evidence from electoral boundary reforms"
**2013/33, Agasisti, T.; Murtinu, S.:** "Are we wasting public money? No! The effects of grants on Italian university students' performances"
**2013/34, Flacher, D.; Harari-Kermadec, H.; Moulin, L.:** "Financing higher education: a contributory scheme"
**2013/35, Carozzi, F.; Repetto, L.:** "Sending the pork home: birth town bias in transfers to Italian municipalities"
**2013/36, Coad, A.; Frankish, J.S.; Roberts, R.G.; Storey, D.J.:** "New venture survival and growth: Does the fog lift?"
**2013/37, Giulietti, M.; Grossi, L.; Waterson, M.:** "Revenues from storage in a competitive electricity market: Empirical evidence from Great Britain"

**2014**

**2014/1, Montolio, D.; Planells-Struse, S.:** "When police patrols matter. The effect of police proximity on citizens' crime risk perception"
**2014/2, Garcia-López, M.A.; Solé-Ollé, A.; Viladecans-Marsal, E.:** "Do land use policies follow road construction?"
**2014/3, Piolatto, A.; Rablen, M.D.:** "Prospect theory and tax evasion: a reconsideration of the Yitzhaki puzzle"
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**2014/5, Durán-Cabré, J.M.; Esteller-Moré, E.:** "Tax professionals' view of the Spanish tax system: efficiency, equity and tax planning"
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**2014/7, Del Rey, E.; Racionero, M.:** "Choosing the type of income-contingent loan: risk-sharing versus risk-pooling"
**2014/8, Torregrosa Hetland, S.:** "A fiscal revolution? Progressivity in the Spanish tax system, 1960-1990"
**2014/9, Piolatto, A.:** "Itemised deductions: a device to reduce tax evasion"
**2014/10, Costa, M.T.; García-Quevedo, J.; Segarra, A.:** "Energy efficiency determinants: an empirical analysis of Spanish innovative firms"
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**2014/14, Piolatto, A.; Schuett, F.:** "Media competition and electoral politics"
**2014/15, Montolio, D.; Trillas, F.; Trujillo-Baute, E.:** "Regulatory environment and firm performance in EU telecommunications services"
**2014/16, Lopez-Rodriguez, J.; Martinez, D.:** "Beyond the R&D effects on innovation: the contribution of non-R&D activities to TFP growth in the EU"
**2014/17, González-Val, R.:** "Cross-sectional growth in US cities from 1990 to 2000"
**2014/18, Vona, F.; Nicolli, F.:** "Energy market liberalization and renewable energy policies in OECD countries"
**2014/19, Curto-Grau, M.:** "Voters' responsiveness to public employment policies"
**2014/20, Duro, J.A.; Teixidó-Figueras, J.; Padilla, E.:** "The causal factors of international inequality in co2 emissions per capita: a regression-based inequality decomposition analysis"
**2014/21, Fleten, S.E.; Huisman, R.; Kilic, M.; Pennings, E.; Westgaard, S.:** "Electricity futures prices: time varying sensitivity to fundamentals"
**2014/22, Afcha, S.; García-Quevedo, J,:** "The impact of R&D subsidies on R&D employment composition"
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**2014/24, Romero-Jordán, D.; del Río, P.; Peñasco, C.:** "Household electricity demand in Spanish regions. Public policy implications"
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**2014/29, Teresa Costa, M.T.; Trujillo-Baute, E.:** "Retail price effects of feed-in tariff regulation"
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**2014/33, Backus, P.; Esteller-Moré, A.:** "Is income redistribution a form of insurance, a public good or both?"
**2014/34, Huisman, R.; Trujillo-Baute, E.:** "Costs of power supply flexibility: the indirect impact of a Spanish policy change"
**2014/35, Jerrim, J.; Choi, A.; Simancas Rodríguez, R.:** "Two-sample two-stage least squares (TSTSLS) estimates of earnings mobility: how consistent are they?"
**2014/36, Mantovani, A.; Tarola, O.; Vergari, C.:** "Hedonic quality, social norms, and environmental campaigns"
**2014/37, Ferraresi, M.; Galmarini, U.; Rizzo, L.:** "Local infrastructures and externalities: Does the size matter?"
**2014/38, Ferraresi, M.; Rizzo, L.; Zanardi, A.:** "Policy outcomes of single and double-ballot elections"

**2015**

**2015/1, Foremny, D.; Freier, R.; Moessinger, M-D.; Yeter, M.:** "Overlapping political budget cycles in the legislative and the executive"
**2015/2, Colombo, L.; Galmarini, U.:** "Optimality and distortionary lobbying: regulating tobacco consumption"
**2015/3, Pellegrino, G.:** "Barriers to innovation: Can firm age help lower them?"
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**2015/5, Cubel, M.; Sanchez-Pages, S.:** "An axiomatization of difference-form contest success functions"
**2015/6, Choi, A.; Jerrim, J.:** "The use (and misuse) of Pisa in guiding policy reform: the case of Spain"
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**2015/8, Batalla-Bejerano, J.; Trujillo-Baute, E.:** "Analysing the sensitivity of electricity system operational costs to deviations in supply and demand"
**2015/9, Salvadori, L.:** "Does tax enforcement counteract the negative effects of terrorism? A case study of the Basque Country"
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**2015/11, Piolatto, A.:** "Online booking and information: competition and welfare consequences of review aggregators"
**2015/12, Boffa, F.; Pingali, V.; Sala, F.:** "Strategic investment in merchant transmission: the impact of capacity utilization rules"
**2015/13, Slemrod, J.:** "Tax administration and tax systems"
**2015/14, Arqué-Castells, P.; Cartaxo, R.M.; García-Quevedo, J.; Mira Godinho, M.:** "How inventor royalty shares affect patenting and income in Portugal and Spain"
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**2015/17, Batalla-Bejerano, J.; Trujillo-Baute, E.:** "Impacts of intermittent renewable generation on electricity system costs"
**2015/18, Costa-Campi, M.T.; Paniagua, J.; Trujillo-Baute, E.:** "Are energy market integrations a green light for FDI?"
**2015/19, Jofre-Monseny, J.; Sánchez-Vidal, M.; Viladecans-Marsal, E.:** "Big plant closures and agglomeration economies"
**2015/20, Garcia-López, M.A.; Hémet, C.; Viladecans-Marsal, E.:** "How does transportation shape intrametropolitan growth? An answer from the regional express rail"
**2015/21, Esteller-Moré, A.; Galmarini, U.; Rizzo, L.:** "Fiscal equalization under political pressures"
**2015/22, Escardíbul, J.O.; Afcha, S.:** "Determinants of doctorate holders' job satisfaction. An analysis by employment sector and type of satisfaction in Spain"
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**2015/33, Escardíbul, J.O.; Helmy, N.:** "Decentralisation and school autonomy impact on the quality of education: the case of two MENA countries"
**2015/34, González-Val, R.; Marcén, M.:** "Divorce and the business cycle: a cross-country analysis"

**2015/35, Calero, J.; Choi, A.:** "The distribution of skills among the European adult population and unemployment: a comparative approach"
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