ASSESSMENT OF THE RELATIONSHIP BETWEEN EXPENDITURE ON EDUCATION AND STUDENTS´ PERFORMANCE IN THE PISA STUDY

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Abstract

Under the conditions of global competition, education is one of the most important factors of sustained economic growth. It influences the quality of human capital, which determines the development of a knowledge-based economy. The European Union recognises the significance and importance of the education system, which is reflected in the Community's strategic documents. The policy of the European Union and the Organisation for Economic Co-operation and Development focuses on levelling out opportunities between the Member States. The aim of the paper is to measure and assess the relationship between expenditure on education and students' performance in the PISA study. A comparative cross-country statistical analysis has been based on secondary data collected from different sources, mainly the OECD and Eurostat. Students' performance is analysed in terms of skills in the following areas: science, reading and mathematics. The empirical part compares the inputs and outputs of education systems in the EU and OECD member countries. In order to find an explanation for cause-and-effect relations, regression models have been used. It is concluded that there is a close positive correlation between students' performance in science, reading and mathematics (PISA results 2015) and the amount of money spent per primary student.

Key words: education, education expenditure, PISA results, measures of dependence, regression models

JEL Code: C20, I21

Introduction

In the era of knowledge-based economy, according to many economists, human capital should be considered as the most important factor determining sustainable economic growth since its quality determines the effective use of existing fixed assets and the ability of the economy to generate technical progress (Lucas, 1988; Redding, 1996; Bucci, 2003). Human capital is a category defined in various ways. Human capital is broadly understood as the psycho-physical characteristics of an individual (innate abilities, knowledge resources, the level of education, skills and professional experience, health status, the level of culture, socio-economic activity, etc.) that affect work efficiency. Understood more narrowly, human capital is identified with the level of education. In theory, it is assumed that the impact of human capital on socio-economic development exists and is unquestionable. Empirical research (e.g.: Hanushek & Kimko 2000; Asteriou & Agiomirgianakis 2001) indicates that the main direction of dependence runs from human capital to economic growth, which obviously does not exclude the impact of economic growth on multiplication of human capital. A qualified labour force is a key determinant of economic growth (Xu & Liu, 2017). In the long run, efficiency gains in education spending will have large effects on GDP (Kirui, Changeiywo & Sang, 2015, Gonand, 2007; Grosskopf, Hayes & Taylor 2014). Gonand (2007) highlighted that in most OECD countries a 10% increase in educational output might raise GDP by an estimated 3-6%. The analysis of efficiency and effectiveness focuses on the search for the relationship between expenditures (inputs) and outputs along with their outcomes. Farrell (1957, p. 11) highlighted that: “It is important to know how far a given industry can be expected to increase its output by simply increasing its efficiency, without absorbing further resources” (Farrell, 1957). He also dealt with the issue of measuring efficiency. Its measurement and assessment are important from the point of view of creating such a policy of a given country that corresponds to its current social and economic needs (Mandl, Dier & Ilzkovitz, 2008,). Effectiveness relates the input or the output to the final objectives to be achieved, i.e. the outcome. The outcome is usually linked to growth or welfare objectives and therefore may be influenced by multiple factors. Effectiveness is a measure of success. It shows whether the resources used enabled the achievement of the objectives set. Effectiveness, however, should not be confused with efficiency. The latter is normally used when the input-output ratio is considered. Efficiency should be considered from the perspective of cost and/or resources required to produce a given output. Education spending (input) affects educational attainment rates (output). The input-output ratio is the most basic measure of efficiency. It is a study of effects that different sectors have on the economy as a whole. For example, the outputs of an education system are often measured in terms of performance or attainment rates of students of a certain age. The final outcome, however, could be the educational qualifications of the working-age population as a whole. In this context, the authors of the article limited the results of empirical research to showing the dependence between the input (expenditure on education) and the output (students' performance in the international PISA test) of education systems in the EU and OECD member countries. The paper presents an assessment of the impact of variables describing expenditure on education on students' results achieved in the PISA test.

1 Research data

The European Union in terms of the functioning of education systems is definitely not a homogenous creation. The education system is subject to internal national regulations, which in many cases may lead to inequality and deepening of disparities. From the point of view of the analysed variables, the greatest differences occur in the number of students from abroad studying in a given country as a percentage of the total tertiary enrolment in that country. The confirmation of this fact is the very high value of the coefficient of variation (V_s = 104.7%). Among other factors that significantly differentiate the EU countries, the following ones should be mentioned: the share of people aged 15-29 in informal education (Vs = 85.2%) and the proportion of people aged 25-64 participating in lifelong learning (Vs = 75.7%). The Danes are undisputed leaders in the area of educational and training activity, with the value of the latter indicator amounting to 31.9%. In general, the strength of the Scandinavian countries lies in their openness to participation in various forms of education and training. This is confirmed by the highest registered percentage of people taking advantage of the informal education offer in the 15-29 age group (30.1%). The threat of exclusion from the education system still remains a critical area. In this area, the greatest problems both in relation to early leavers from education and training and to the NEET group are encountered in Italy, Bulgaria, Spain, Romania, but also in Portugal, Malta, Croatia and Greece. Both these factors are also the justification for the occurrence of large discrepancies between the Member States in the field of education. Area 1 that describes the financial situation in education is also an area characterised by significant differences. The strongest dispersion within Area 1 is recorded for total government expenditure on R&D. R&D spending accounts for the largest share of total expenditure in Germany, Estonia, Denmark, Portugal, Luxembourg and Finland. The Latvian, Maltese, Hungarian, Bulgarian and Romanian governments spend the least on R&D. Estonians and Finns spend a large proportion of public finances on education. However, the largest percentage of total expenditure is allocated to education in Lithuania, Latvia and Cyprus.

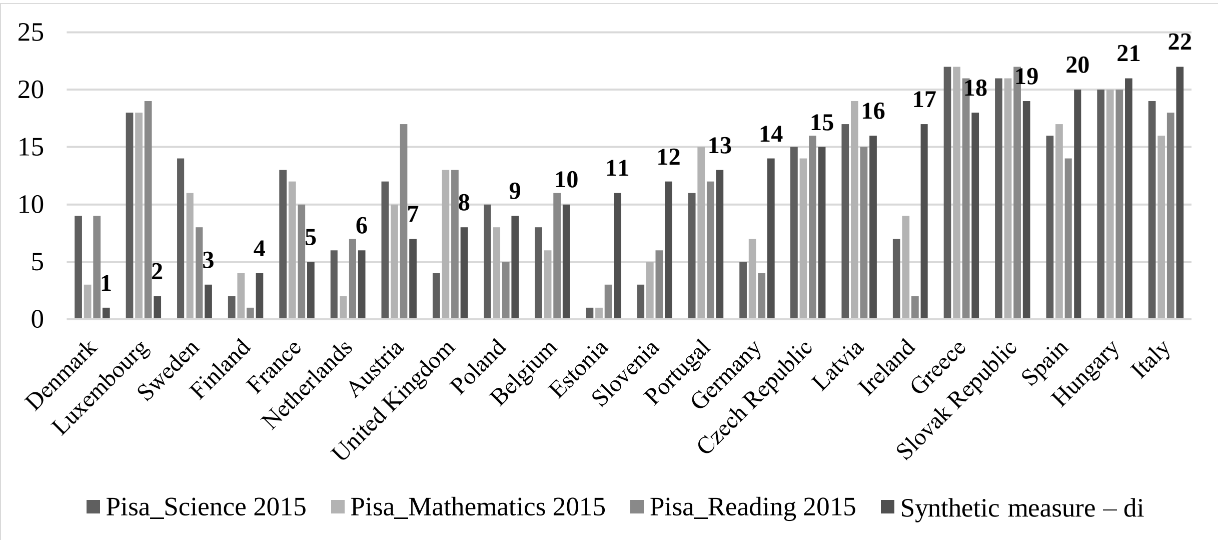
Tab. 1: Diagnostic variables selected for multidimensional assessment of education systems in the EU

Area 1. Financial situation	Total government expenditure on education (% of total expenditure) – S
	Total government expenditure on R&D (% of total expenditure) – S
	Share of persons employed in the education sector in total employment (%) – S
Area 2. Participation in education or training	Participation in early childhood education (% of the age group between 4-years-old and the starting age of compulsory primary education) – S
	Participation rate in education and training (last 4 weeks) – % of the total population in this age group – S
	Duration of compulsory education (in years) – S
	Participation rate in informal education and training (last 4 weeks) – % of the total population in this age group – S
Area 3. Compulsory education	Pupil-teacher ratio in primary education – ISCED1 – D
	Foreign languages learnt per pupil in lower secondary education (average) – ISCED2 – S
	Gross enrolment ratio in primary education (%) – S
Area 4. Higher education	Young people aged 20-24 with at least upper secondary educational attainment level (% of the total population in this age group) – S
	Population aged 30-34 with tertiary educational attainment level (% of the total population in this age group) – S
	Graduates in tertiary education. in science, math, computing, engineering, manufacturing, and construction per 1000 of population aged 20-29 – S
	Inbound mobility rate (% of total student population in a given country) – S
Area 5. Threat of exclusion from participation in education	Early leavers from education and training – age group 18-24 – D
	Youth neither in employment nor in education and training (NEET) rate – % of the total population in this age group – D
	Households with Internet access (% of total households) – S

Source: own elaboration based on Eurostat Database.

In the area of education, one-dimensional/univariate assessment has limited cognitive capabilities. Especially due to the fact that the presented statistics allow one to make some general conclusions regarding the sphere of education. Thus, the indication of one undisputed leader among the EU Member States is virtually impossible. Therefore, the authors have considered it necessary to apply the methods of multidimensional comparative analysis and to construct a synthetic measure that would allow to compare the elements of a set (the EU countries) described simultaneously by many variables (features). Linear ordering methods are used in social and economic studies to determine the order or classification of objects due to one aggregate feature which is a synthetic representative of many features describing ordered objects. The article uses the Hellwig's linear ordering method, which is an example of a model method, i.e. in this method the reference point for objects in a multidimensional space is a model. The basic stages in a linear ordering procedure are: determining the nature of variables (stimulants, nominants, destimulants), determining variable weights, normalising variables, determining model coordinates in the case of modelling aggregation, model-based or non-model-based aggregation (Bąk, 2016). After the verification of the formal assumptions regarding the degree of correlation of variables and the level of their variation, 14 out of 17 initially determined variables were used for the construction of the synthetic measure, of which 2 were destimulants, and the remaining 12 were stimulants. Due to the dispersion in the sample lower than 10%, the following variables were eliminated from the further statistical procedure: (1) Participation in early childhood education, (2) Young people aged 20-24 with at least upper secondary educational attainment level, and (3) Gross enrolment ratio in primary education. In the presented study, the critical value of Pearson's linear correlation coefficient was set at 0.9. The value of none of the partial coefficients of correlation included in the *R* matrix exceeded the adopted level. The ranking, developed on the basis of the synthetic measure, allowed a multidimensional assessment of the functioning of education systems. The results of our own analysis were compared with the results obtained by students in individual countries as part of the PISA test 2015.

Fig. 1: Rankings of EU countries based on the synthetic assessment of their education systems and the performance of students in the PISA test 2015



Source: own elaboration

The comparison of four different rankings (Figure 1) confirms the existence of significant differences in the area of education between the individual countries. The comparative analysis has been limited to the EU Member States that are also members of the OECD. Additionally, the presented data show that favourable conditions in the area of education do not necessarily translate directly into the results achieved by students. For example, a summary assessment of the education system showed the best results for Denmark, Luxembourg and Sweden. And although Danish pupils performed well in the PISA 2015 test, especially with regard to the assessment of skills in the *Mathematics* part, in the case of the other two previously mentioned countries, a direct relationship between the synthetic measure and students' performance is not so obvious. It seems that the well-functioning system of education in Sweden or Luxembourg does not translate directly into the achievements of students assessed in the framework of the international PISA test. The Swedish education system is regarded as one of the most effective in Europe, characterised by the highest percentage of people employed in the education sector in the entire EU. At the same time, the level of skills measured in the framework of PISA Science and Pisa Mathematics places Swedish students out of the top ten.

2 Methods

This section presents the results of research aimed at the quantitative assessment of the impact of factors describing socio-economic development, including expenditure on education (input), on educational attainment rates (output) in 35 OECD countries. Statistical data for 2015 from the international PISA (Programme for International Student Assessment) study were used in the analyses. The PISA is carried out by an international consortium overseen by the OECD (Organisation for Economic Cooperation and Development) and representatives of its member countries. It is the largest international test of students' skills in the world. It has been conducted every 3 years since 2000 in all the OECD countries as well as in several dozen partner countries. In each edition of the survey, one of the areas: reading, mathematics or science – is a leading field. The latest PISA assessment, in 2015, focused on science. The OECD PISA is a study of 15-year-olds – students who were 15 years of age in the year preceding the test; in 2015, they were students born in the year 1999. Over 500,000 students from 72 countries and regions participated in PISA 2015. The PISA study is conducted on a representative random sample. The design for selecting the sample of students in the PISA survey comprises a two-stage stratified selection applying a systematic sampling procedure in which the selection of school is the first step and the second is the sampling of students from the previously drawn schools (also in the systematic stratified sampling mode).

Students' achievements in the PISA test in the following areas – depending on the model – were adopted as indicators of output education effectiveness: mathematical literacy, scientific literacy and reading literacy. The input measures are selected indicators describing socio-economic development included in the PISA study.

Thus, the PISA performance function can be written as follows:

$$PISA = \alpha_0 + \alpha_1 GDP + \alpha_2 EXPEN + \alpha_3 PERCEN + \alpha_4 SHARE + \varepsilon_t, \qquad (1)$$

where:

PISA – students' performance in the PISA test (Pisa Mathematics/Pisa Reading/Pisa Science); GDP – Per capita GDP (in equivalent USD converted using PPPs); EXPEN – Cumulative expenditure per student between 6 and 15 years (in equivalent USD converted using PPPs); PERCEN – Percentage of 35-44 year-olds with tertiary education; SHARE – Share of students in their own country whose PISA index of economic, social and cultural status is below -1; $\alpha_1,...,\alpha_k$ – model parameters; ε_t – random component for which ε_t ~ N(0, σ^2).

Different variants of models were tested, including curvilinear regression. The results of the estimation of selected (according to the authors, the best ones in substantive and statistical terms) models are presented in Table 2. The multivariate linear regression models presented below were obtained using the stepwise method in SPSS.

Tab. 2: Results of estimations of model parameters: PISA Mathematics, PISA Reading, PISA Science

Variable	Estimation of parameters					
	PISA Mathematics		PISA Reading		PISA Science	
	(1)	(2)	(1)	(2)	(1)	(2)
constant	**499.35***		**486.92***		**496.53***	
GDP	**-0.001***	**-0.613***				
EXPEN	**0.001***	**0.671***				
PERCEN			**0.817***	**0.404***		
SHARE	**-1.195***	**-0.633***	**-0.886***	**-0.539***	**-1.033***	**-0.560***
R^2	0.647		0.613		0.567	
R^2 adjusted	0.598		0.559		0.508	

Specification: (1) – non-standardised coefficients, (2) – standardised coefficients, R^2– coefficient of determination, "*"statistically significant coefficients at the level of p=0.05.

Source: own elaboration.

3 Results and Discussion

All the three analysed models are statistically correct. For each regression model analysed, the parameters marked "*" proved to be statistically significant at the level p = 0.05. The models are well-fitted to empirical data. This is evidenced by significantly higher than zero values of determination coefficients (probabilities in the Anova test are less than 0.05).

The values of regression coefficients estimated using the least-squares method allow to write the equations which describe the relationship between the variable *PISA Mathematics* and the *GDP*, *EXPEN* and *SHARE* variables:

$$PISA\_Matematics = 499.35 - 0.001GDP + 0.001EXPEN - 1.195SHARE \qquad (2)$$

We observe that *Cumulative expenditure per student between 6 and 15 years* is an important factor determining the performance of students in Mathematics. The variable *Share of students in their own country whose PISA index of economic, social and cultural status is below -1* is significant, but as expected, it has a negative impact on the performance of 15-year-olds in Mathematics. The negative sign for the *Per capita GDP* variable is somewhat of a surprise, as it is inconsistent with the theory of economics. Expenditure on education has the greatest impact on students' performance in Mathematics. With the increase in education spending of USD 1, the improvement in Mathematics attainment of 0.001 points is expected. (Tab. 2).

The relationship between the *PISA Reading* variable and the statistically significant explanatory variables is described by the equation:

$$PISA\_\mathrm{Re}ading = 486.915 + 0.817PERCEN - 0.886SHARE \qquad (3)$$

The estimation of the *PISA Reading* model indicates that, apart from the constant, *Percentage of 35-44 year-olds with tertiary education* has a significant, positive, influence on Reading attainment. A 1% (percentage point) increase of this variable results in an increase of 0.817 points in Reading attainment. Similarly to the PISA Mathematics model, the *Share of students in their own country whose PISA index of economic, social and cultural status is below -1* variable also has a significant, but negative, influence on Reading attainment, as a 1 point increase results in a decrease in Reading attainment of 0.886 points.

In the *PISA Science* model, a significant (statistically) impact of only the *SHARE* variable and the constant was indicated:

$$PISA\_Science = 496.53 - 1.033SHARE \qquad (4)$$

The *Share of students in their own country whose PISA index of economic, social and cultural status is below -1* variable is an important characteristic determining the students' performance in Science. Therefore, unfavourable environmental conditions cause a decrease in the students' mental fitness level.

4 Conclusion

In an attempt to summarise the quantitative assessment of the impact of explanatory variables on students' performance in the specific PISA knowledge fields, it is worth using standardised coefficients. Standardisation means that regression coefficients change within the range [- 1, + 1] and can be compared between each other for different variables. The higher the absolute value of the standardised regression coefficient, the stronger the influence of this variable on the dependent variable.

Changes in performance in Mathematics are determined to the largest extent by *Cumulative expenditure per student between 6 and 15 years (in equivalent USD converted using PPPs).* The value of the standardised coefficient for this variable is 0.671 (Tab. 2). It is followed by the SHARE variable (0.633). The SHARE variable has the greatest impact on reading literacy and scientific literacy. The standardised coefficients are 0.539 and 0.560, respectively.

The presented assessment of the relationship between the input (expenditure on education) and the output (students performance in the framework of the international PISA test) does not exhaust the complexity of the issue. It is well known that students' school attainments are determined by economic, social, cultural, psychological and pedagogical factors, and students' progress in learning depends mainly on their own commitment and diligence. In the PISA study, only the first three factors are represented (the SHARE variable). Difficult living conditions of students in their social environment cause deterioration of educational attainments, which is confirmed by the PISA models – the SHARE regression coefficients are statistically significant and negative. The analysis of the relationship between the inputs and the outputs encounters some limitations, among others, some important input information that could improve the substantive and prognostic properties of the PISA models is missing. Attention should also be paid to the difficulty of measuring many variables and the level of their aggregation. The assumption of the PISA study, since its first edition in 2000, has been to provide a number of comparable results: internationally comparable, but also, in subsequent editions, comparable over time. On the other hand, the study itself must move with the times: taking into account new technologies and the progress of the educational measurement theory itself.

The conducted study and its conclusions provide a basis for further research allowing the identification and solving of many methodological problems in assessing the education system effectiveness.

References

Asteriou, D. & Agiomirgianakis, C.M. (2001). Human Capital ad Economic Growth. Time Series Evidence from Greece. Journal of Policy Modeling, 23, 481-489.

Bąk, A. (2016). Linear ordering of objects using the Hellwig-Topsis method – comparative analysis. Scientific Works of the Wrocław University of Economics, 426, 22-31. DOI: 10.15611 / September 2016.426.02.: 10.15611/pn.2016.426.02.

Bucci, A. (2003). R&D, Imperfect Competition and Growth with Human Capital Accumulation. *Scottish Journal of Political Economy*, 50(4), 417-439. DOI: 10.1111/1467-9485.5004004.

Farrell, J. (1957). The Measurement of productive efficiency. *Journal of the Royal Statistical Society*. 120, 253-290.

Gonand, F. (2007). *The impact on Growth of higher efficiency of public spending on schools*, OECD Economic Department Working Paper 547.

Grosskopf, S., Hayes K.J., & Taylor L.L. (2014). Efficiency in Education: Research and Implications. *Applied Economic Perspectives and Policy, 36*(2), 175–210. DOI: 10.1093/aepp/ppu007.

Hanushek, E.A. & Kimko, D.D. (2000). Schooling, Labour Force Quality, and the Growth of Nations. *American Economic Review*, 90(5), 1184-1208. DOI: 10.1257/aer.90.5.1184.

Kirui, P.K., Changeiywo, J.M., & Sang, A.K.. (2015). Headteachers' Perceptions of the Relationship between Parental Support and Learners' Retention in Public Secondary Schools in Bureti District, Kenya. *Journal of Education and Practice*, 6(30), 33-40.

Lucas, R.E. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22(1), 3-42.

Mandl, U., Dierx, A. & Ilzkovitz, F. (2008). *The effectiveness and efficiency of public spending*. Economic Papers 301, Brussels: Directorate-General for Economic and Financial Affairs.

Redding, S. (1996). The Low-Skill, Low-Quality Trap: Strategic Complementaries between Human Capital and R&D. *The Economic Journal*, 106(435), 458-470. DOI: 10.2307/2235260.

Xu, H. & Fangtao, L. (2017). Measuring the Efficiency of Education and Technology via DEA Approach: Implications on National Development. *Social Sciences, 6*(4), 136, DOI:10.3390/socsci6040136.

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