DOES TECHNICAL EFFICIENCY IN SECONDARY EDUCATION VARY SIGNIFICANTLY ACROSS THE MAJORITY OF EU COUNTRIES? THE CASE OF GREECE

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ABSTRACT

This article continues the work of previous studies, exploring the efficiency of secondary education by applying a non-parametric methodology. The article review previous studies as well as some conceptual and methodological issues of a non-parametric approach. Most importantly, the Data Envelopment Analysis (DEA) technique is introduced and then applied to a range of EU countries, including Greece, to assess the technical efficiency of secondary education. Empirical results show that technical efficiency in secondary education varies considerably in the vast majority of EU countries. Greece shows a high level of technical efficiency in secondary education, ranking it in the second quartile among EU countries. Therefore, for a better picture, it is recommended that public expenditure on secondary education be streamlined with a possible redirection of certain excessive resources in the field of higher education.

JEL classification: I21

Keywords: Efficiency, Data Envelopment Analysis, Secondary Education, Economics.

INTRODUCTION

In this period of economic crisis in Europe, efficiency in the school system is subject to much attention and weighs heavily on the resources of the country. Even today the schools differ dramatically in quality Hanushek (1986).

Efficient and high-quality education is the basis of the intervention strategy for the strengthening of human resources. Only a good school system can affect students' cognitive skills, can contribute to increasing productivity, social mobility and the full enjoyment of civil rights in society. Hence the growing interest in measuring the level of efficiency of student learning acquired skills and their ability to use in everyday life and at work Hanushek and Woessmann (2010).

Education is one of the most important parts of government spending in most developed economies (European Commission, 2017). Indeed, the public sector finances and manages the Greek education system, and this is also true in most European and emerging market economies (Bank of Greece, 2019).

From 2009-2018, the proportion of GDP spent on education in the EU-28 averaged 5%. This average however hid disparities between many EU countries. Also during this period there have been significant changes in educational funding. In Croatia the proportion of GDP allocated to education increased by more than 47% between 2009 and 2018, by 3% in Sweden and by 2%

in Belgium during the same period. In contrast, in the rest of the EU, the share of GDP spent on education fell from 2% (Germany) to 36% (Lithuania) during this period. Whereas, in Greece the percentage of GDP allocated to education decreased by 2.5% between 2009 and 2018. The same picture in the overall data for the period 2009-2018 also covers expenditure disparities at different levels of education. Expenditure decreased by about 6% for pre-school and by about 12% for higher education as a percentage of GDP during the period 2009-2018. In contrast, expenditure on secondary education decreased by 15% (Eurostat, 2018). However, due to the relatively high amount and importance of this type of government expenditure, measuring its efficiency should be high on each government's policy agenda (European Commission, 2020).

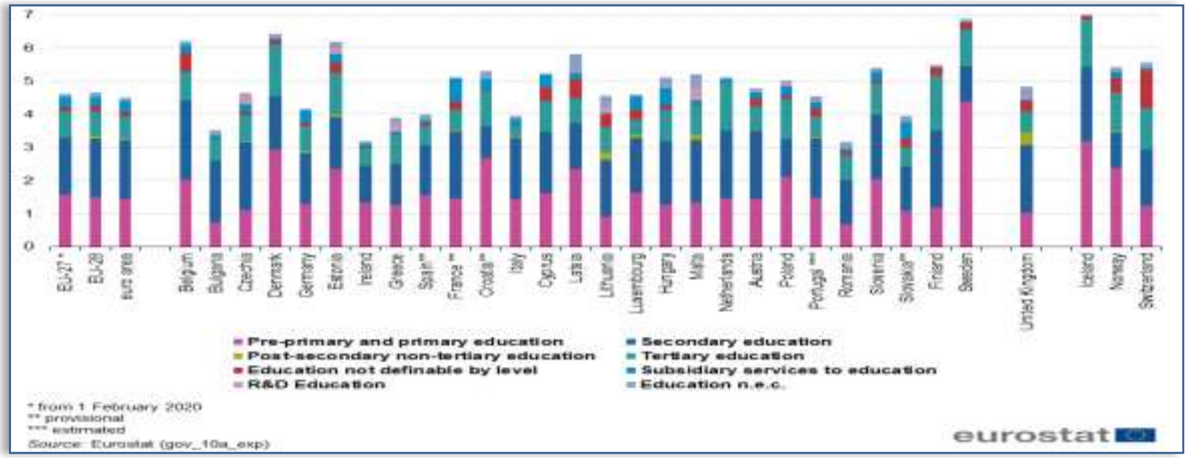
Many empirical studies on public sector performance and efficiency (at national level) that have applied non-parametric methods (DEA) find a significant efficiency gap between countries. These studies mainly concern with Gupta and Verhoeven (2001) on education and health in Africa, Clements (2002) on education in Europe, St. Aubyn (2003) on training costs in the OECD, Afonso et al. (2005, 2006) on public sector performance expenditure in the OECD, Afonso and St. Aubyn (2005, 2006 a,b) on health and education efficiency in OECD countries. Gunnarsson and Mattina (2007) evaluated the efficiency of public expenditure by comparing spending on health, education and social protection in Slovenia. In addition, Afonso et al. (2008) assessed the efficiency of public spending on income redistribution. Then, Mandl et al. (2008); Jafarov and Gunnarsson (2008) continued the work of Afonso et al. (2005). In addition, Grosskopf and Moutray (2001), Johnes (2006), Castano and Cabanda (2007), Jafarov and Gunnarsson (2008), Cherchye et al. (2010), Obadić and Aristovnik (2011), K. Chen and Chen (2011), Thieme et al. (2012), Aristovnik (2012 a,b) and Gavurova et al. (2017) have focused on measuring efficiency or quality in education, As cross-country analyzes, especially in the field of secondary education, are rarely used for policy analysis, we will apply the DEA approach to EU countries, with particular emphasis on Greece in the rest of the article. DEA is chosen here because it is the most common method for measuring technical efficiency, as it can be applied to multiple inputs and multiple outputs. The analysis includes 28 EU countries, for the period 2009-2018.

Inputs

In the EU, the average annual cost of secondary education (ISCED 2 to 4) is higher (1.8%) than that of primary school students (ISCED 1). The average cost in higher education in the EU was almost half of that of primary school students (0.7%). Differences between countries tend to widen with the relative educational level. The cost of primary education in public sector institutions range from 0.7% in Bulgaria and Romania to 4.4% in Sweden, while the cost in public sector higher education institutions range from 0.5% in Ireland and Luxembourg to 1.7% in Finland. . The average annual cost of secondary education (ISCED 2 to 4) in Greece in 2018 is (1.2%) which is less than 1/3 of the average annual cost in the EU (Graph 1).

In European countries, the employment status of fully trained teachers for primary, lower secondary and upper secondary education in the public sector falls into two main categories.

In more than half of the countries surveyed, teachers are usually employed on permanent contracts subject to general legislation. As public sector employees, teachers are employed at local or school level, although they are usually employed directly by the school where they teach. Teachers who are civil servants are employed by public authorities at central, regional or local level. Teachers working in public schools in Greece are civil servants according to the respective laws of the civil servants of the countries, but sign an employment contract with the head teacher since they are public schools are established as separate legal entities (Eurostat, 2018).



GRAPH 1
TOTAL GENERAL GOVERNMENT EXPENDITURE ON EDUCATION, 2018 (% OF GDP)

Outputs and Outcomes

In 2009, across Europe, the average teacher-student ratio in high schools was 1:12. Since 2000, the teacher-student ratio has fallen to two-thirds of countries with an average of two students per teacher in primary education and one student in secondary education. In lower secondary education, the largest increase (9.4) is found in Finland, Slovenia (5.2) and Sweden (4.9). In contrast, there was a decrease in Cyprus (-2) and Malta (-1.3). In Greece, the increase was on average 1.4 students per teacher, during the period 2009-2018 (The World Bank).

After studying the PISA results, Greek students compared to students from some countries with some useful features: France, whose education system is similar to ours, Portugal, which is a country and an economy of similar size with ours and small Estonia, which is the EU country that performs best of all, we note that the students of Greece lag behind the students in these countries in the 2018 research, in all three subjects (OECD, 2018).

Behind this, the results published by the OECD, is a wealth of data that reflects not only students' performance and skills, but also valuable information about how they live, the influences they have from home and their school environment, as well as school conditions and infrastructure.

Ninety-one percent of young people in Europe aged 20-24 have successfully completed upper secondary education (ISCED 3) in 2018. This confirms the positive trend observed across Europe since 2000. In fact, the vast majority of countries report an increase in the number of young people holding at least a upper secondary education degree in the last ten years. Several countries report rates well above the European average: in Belgium, Spain, Estonia, Finland, the UK, Ireland, Latvia, Norway and Sweden, around nine out of ten people between the ages of 20 and 24 have at least one higher secondary education degree. The highest level is in Finland, where the number is over 99% for this age group. For Greece, there is a decrease of about 2% [The World Bank].

The purpose of the work is twofold

First, the measurement of the input-oriented relative efficiency by using DEA method under variable returns to scale (VRSTE) during the period 2009-18. The DEA, despite its flexibility, does not allow statistical interference.
Secondly, the identification of EU countries where efficiency in secondary education is higher than average. These EU countries can be used as benchmarks to improve the efficiency of other countries in secondary education. Measuring the efficiency of EU countries in secondary education identifies the inefficient EU countries and analyzing results, provides useful conclusions to decision makers.

The rest of the work is organized as follows: In Section 1, a brief reference to the Greek secondary education system is presented. Section 2 provides a brief theoretical methodology, and review of the empirical literature. In Section 3, the data are presented and the results are discussed. Finally, Section 4 presents the final remarks and policy proposals (implications).

A Brief Review of Greek Secondary Education[1]

Secondary education includes two cycles of study: Gymnasio.

The first one is compulsory and corresponds to gymnasio (lower secondary school).

1. It lasts 3 years
2. It provides general education
3. It covers ages 12-15
4. It is a prerequisite for enrolling at general or vocational upper secondary schools
5. Parallel to imerisio (day) gymnasio, esperino (evening) gymnasio operates. Attendance starts at the age of 14.

Lykeio (Upper Secondary schools)

The second one is the optional geniko or epangelmatiko lykeio (general or vocational upper secondary school).

1. It lasts 3 years
2. Pupils enrol at the age of 15
3. There are two different types:

A. Geniko (general) lykeio. It lasts 3 years and includes both common core subjects and optional subjects of specialisation
B. Epangelmatiko (vocational) lykeio. It offers two cycles of studies:
   I. The secondary cycle
   II. The optional post-secondary cycle, the so-called “apprenticeship class”.

Parallel to day lykeia, there are also:

A. Esperina genika (evening general) lykeia
B. Esperina epangelmatika (evening vocational) lykeia.

REVIEW OF LITERATURE

Variables' Sampling, Sources and Data

We use five variables: Expenditure per student, secondary (% of GDP per capita) (X_1),Teacher- pupil ratio, secondary (X_2), School enrolment, secondary (% gross) (X_3), PISA average (2015) (X_4), School enrolment, tertiary (% gross) (X_5). The data provided by the OECD, UNESCO and the World Bank's Development Indicators database.

Methodology and Models

In this study we have used four models to study the relative efficiency in secondary education of EU member countries during the periods 2009-12 (Table A.1), 2012-15 (Table A.1) and 2015-19 (Table A.3). Existing studies show that DEA is an effective research tool for evaluating the efficiency of the education sector, given the diverse combination of inputs and types and number of outcomes. As a result, different inputs and outputs/outcomes were tested on four DEA analysis models. The four models are structured as follows:

MODEL	INPUTS	OUTPUTS
I	X_1	X_2, X_3
II	X_1, X_2	X_3, X_4
III	X_2	X_4, X_5
IV	X_3	X_4, X_5

In the majority of studies using DEA the data are analyzed cross-sectionally, with each decision-making unit (DMU)-in this case the country - being observed only once. Nevertheless, data on DMUs are often available over multiple time periods. In such cases, it is possible to perform DEA over time where each DMU in each time period is treated as if it were a distinct DMU. For the data analysis we use the DEAP Version 2.1 software package and Frontier Version 4.1 software package (Coelli, 1996)[2].

EMPIRICAL ANALYSIS

Methodology and Data

Efficiency analysis is a well-known problem in economics (Farrell, 1957). In education empirical research the most popular technique is Data Envelopment Analysis. Education is the application that attracts the most attention in the early days of DEA development. Frontier efficiency measurement techniques have been applied to many different types of education institutions. These include primary and secondary schools. (Bessent et al., 1982); Deller and Rudnicki (1993); Chalos and Cherian (1995) Data Envelopment Analysis has its origins in the seminal work by Charnes et al. (1978) who reformulated Farrell's (1957) work. It is non–parametric linear programming techniques that estimate the relative efficiency of homogeneous Decision Making Units (DMUs). Data Envelopment Analysis provides an analytical tool for determining effective and ineffective performance as the starting point for inducing theories about best-practice behavior (Charnes et al., 1994). This method defines a non-parametric frontier and measures the efficiency of each DMU (here upper secondary school) relative to that frontier. This method evaluates DMUs based on efficiency ratings (≤ 1 or ≤ 100%). A score of 1 means that the DMU is efficient. A DMU with efficiency score less than 100% is regarded to be inefficient relative to other units. DMUs face the same efficiency frontier, independently of their relative size.

The model could be input-oriented, which refers to the determination of minimum inputs for producing a given level of output. Also, the model could be output-oriented, by focusing on the maximization of outputs with given levels of inputs. This study employs an input-oriented model as we can assume that Upper Secondary schools aim to minimize their inputs for a given level of outputs. Moreover, the input-oriented is selected because we suspect at least from a longer-term perspective, that outputs are less upper secondary school choice variables than inputs for our upper secondary schools, so input choices are assumed to predominate. In undertaking previous work comparisons of input-oriented and output-oriented Data Envelopment Analysis analyses suggested that the results were not sensitive (Millan and Chan, 2006). Formally, under an input-oriented perspective we have to deal with the following Data Envelopment Analysis model in envelopment form (Charnes et al., 1978):

CRS

$$\min_{\theta,\lambda}\theta, \quad Y\lambda \geq Y_i \qquad (1)$$

$$\text{s.t.} \quad X\lambda \leq \theta X_i, \quad \lambda \geq 0$$

VRS

$$\min_{\theta,\lambda}\theta, \quad Y\lambda \geq Y_i \qquad (2)$$

$$\text{s.t.} \quad X\lambda \leq \theta X_i, \quad N1'\lambda = 1, \quad \lambda \geq 0$$

where λ is the vector of relative weights ($N\times 1$) given to each unit and N is the number of unit. Assuming that there data on I inputs and O outputs: X represents the matrix of inputs ($I \times N$) and Y is the matrix of outputs ($O\times N$). For the i^{th} unit these are represented by the column vectors Xi for the inputs and Yi for the outputs. This refers to constant returns to scale (Constant Returns to Scale) model.

The Constant Returns to Scale assumption is avoided in the Variable Returns to Scale model (Banker et al., 1984) by the introduction of an additional constraint on the λ, allowing returns to scale, i.e., $N1'\lambda=1$, where $N1'$ is a vector of ones. This restriction imposes convexity of the frontier. Finally, the efficiency score (θ) is a scalar and estimate the technical efficiency by assuming values between 0 and 1, with a value of 1 indicating a point on the frontier and hence a technical efficient unit (Farell, 1957).

In this study we employ the non-parametric output-oriented DEA in order to measure the relative T.E. Scale Efficiency and the SFA of 64 public upper secondary schools.

RESULTS AND DISCUSSION

Table 1
DESCRIPTIVE STATISTICS DEA, FOR THE PERIOD 2009-12(A)

Descriptive Statistics	Model I	Model II	Model III	Model IV
	VRSTE			
Mean	0.933	0.924	0.909	0.928
Median	0.938	0.934	0.932	0.954
Mode	1	1	1	1
S.D[3].	0.054	0.078	0.123	0.114
C.V[4].	5.8	8.4	13.5	12.3
Min	0.759	0.630	0.358	0.397

Max	1	1	1	1
Range	0.241	0.370	0.642	0.603
Skewness	-1.367	-2.208	-3.615	-4.064
Kurtosis	3.196	6.727	15.752	19.008

Source: Author's calculation

Table 1 gives us useful and interesting data on this study. In particular during the AD period (2009-12) and for four examination models, there is only one country that is fully efficient in secondary education, Finland. The Ranking of this country is interesting, where it does not change significantly. While, the countries with low efficiency, show a greater difference in the change of the Ranking, such as the countries Malta, Cyprus, Bulgaria, Sweden (Table A.4 in Appendix). For model I, the mean efficiency is high with a value of 0.933 and a small standard deviation with a value of 0.054 and relative variability with a value of 5.8, i.e. the sample is not homogeneous, while the slope has a value -1.367<0, i.e. the distribution shows a negative asymmetry, so its vertex is shifted to the right and the kurtosis is 3.196>3, i.e. the distribution is finely convex. The same picture with small differences is presented in the next three models II, III and IV, i.e. we have a very large deviation in efficiency, which is can be seen from the range from 0.241 to 0.603.

Finland is one of the countries on the efficiency frontier and Malta is a tail. Greece holds a position close to the average of the EU countries in this study, during the period 2009-12.
Table 2 presents the descriptive statistics DEA, for the period 2012-15.

Table 2
DESCRIPTIVE STATISTICS DEA, FOR THE PERIOD 2012-15(B)

Descriptive Statistics	**Model I**	**Model II**	**Model III**	**Model IV**
	VRSTE			
Mean	0.806	0.933	0.923	0.953
Median	0.780	0.934	0.933	0.950
Mode	1	1	1	1
S.D.	0.986	0.525	0.516	0.036
C.V.	122.3	56.3	55.9	3.8
Min	0.661	0.822	0.813	0.883
Max	1	1	1	1
Range	0.339	0.178	0.187	0.117
Skewness	0.711	-0.532	-0.499	-0.216
Kurtosis	-0.411	-0.292	-0.022	-0.622

Source: Author's calculation

Table 2 gives us useful and interesting data on this study. In particular, during the B′ period (2012-15) and for four examination models, there are no countries that are fully efficient in secondary education. While, low-efficiency countries, show a greater difference in the change of the Ranking, such as the countries Malta, Cyprus, Czech (Table A.5 in Appendix). For model I, the mean efficiency is relatively low with a value of 0.806 and standard deviation of 0.986 and relative variability having a value of 122.3, i.e. the sample is not homogeneous, the skewness is 0.711>0, i.e. the distribution has a positive asymmetry, so its vertex is shifted to the right and the kurtosis has a value of -0.411<3, i.e. the distribution is wide. In the next three following models II, III and IV the average value ranges from 0.933 to 0.953 and the standard deviation ranges from 0.036 to 0.525. Finland is one of the countries with high efficiency, while whereas Malta (Model I), Cyprus (Model II, III & IV), Romania (Model III & IV) are high on the scale of efficiency in secondary education, during this period. Greece continues to be around the average in the list of EU countries in the period 2012-15. Table 3 presents the descriptive statistics DEA, for the period 2015-18.

Table 3
DESCRIPTIVE STATISTICS DEA, FOR THE PERIOD 2015-18 (C)

Descriptive Statistics	Model I	Model II	Model III	Model IV
	VRSTE			
Mean	0.762	0.931	0.935	0.960
Median	0.716	0.937	0.950	0.961
Mode	1	1	1	1
S.D.	0.127	0.054	0.055	0.035
C.V.	16.7	5.8	5.9	3.6
Min	0.603	0.809	0.804	0.863
Max	1	1	1	1
Range	0.397	0.191	0.196	0.137
Skewness	0.941	-0.507	-0.931	-0.951
Kurtosis	-0.431	-0.537	0.313	1.180

Source: Author's calculation

Table 3 again gives us useful and interesting data on this study. More specifically, during the C΄ period (2015-18) and for four examination models, there is only one country that is fully efficient in secondary education, Finland. Another interesting feature is the Ranking in Greece, where it does not change significantly. While, countries with low efficiency in secondary education, differ more widely in the change of the Ranking, such as the countries Croatia and France (Table A.6 in Appendix). For model I, the mean efficiency is low with a value of 0.762 and a small standard deviation with a value of 0.127 and relative variability with a value of 16.7, i.e. the sample is not homogeneous, the skewness has a value of 0.941> 0, i.e. the distribution has a positive asymmetry, so its vertex is shifted to the right and the kurtosis has a value of -0.431<3, i.e. the distribution is wide. In the next three models II, III and IV the average value ranges from 0.931 to 0.960 and the standard deviation ranges from 0.035 to 0.055. Finland is one of the countries with high efficiency, while on the contrary Croatia (Model I), Romania (Model II & III), Bulgaria (Model III & IV) are still high on the scale of efficiency in secondary education, during this period. Finland is one of the countries on the border of efficiency and Croatia (Model I), Romania (Model II & III), Bulgaria (Model III & IV) are tails in terms of the size of efficiency in secondary education, over that period. Greece shows a decline in the position of the list of EU countries, during the last period 2015-18.

From Table A.7 in Appendix, we find that in all four study models, Finland is fully efficient in secondary education. This country is the country of benchmarks. The results of which must be adopted by the rest. While Estonia is perfectly efficient only during periods II & IV, Greece is perfectly efficient only during periods I, III & IV, Slovakia is perfectly efficient only during periods IV, Ireland is perfectly efficient during periods II and III and finally Belgium is perfectly efficient only in period I. All other EU countries are less efficient in secondary education. At a very good level of efficiency in the four study models, during all three periods, are the UK, Netherlands, Ireland, Greece, Estonia, Denmark, Belgium and of course Finland. On the other hand, Bulgaria, Croatia, Cyprus, Hungary, Latvia, Lithuania, Luxembourg, Malta, Romania and Slovakia are at a very poor level of efficiency. Malta in particular at the last place, followed by Cyprus, Romania, Lithuania and Luxembourg. So Malta, in order to achieve optimal efficiency, should increase the output of the study by 26.3% (output-oriented). Greece, as can be seen from the table below 5, is around the average, i.e. it is in a relatively good position compared to other EU countries, during the period 2009-2018. We can classify EU countries in terms of relative efficiency in secondary education into four quarters. Table 4 below shows this classification.

Table 4
QUARTERS OF EU COUNTRIES IN TERMS OF EFFICIENCY IN SECONDARY

Quarter I	Quarter II	Quarter III	Quarter IV
Finland	Germany	Czech.R	Luxemburg
Belgium	Slovenia	Austria	Lithuania
Netherlands	Spain	Portugal	Slovakia
UK	Poland	Latvia	Bulgaria
Estonia	Greece	Italy	Romania
Denmark	France	Croatia	Cyprus
Ireland	Sweden	Hungary	Malta

Source: Author's calculation

The countries that need to significantly improve their efficiency are the countries in the IV quadrant, while the countries in the II and III quadrants, can make appropriate corrective actions in inputs(reduction) and outputs(increase) so as to improve their efficiency and reach the desired optimal position of the I quadrant .

CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

In almost all European countries Secondary Education receives proportionately more Government funding than any other level of education. Therefore, measuring the efficiency of secondary education is particularly important. However, the analysis of the measurement of efficiency in secondary education in policy-making is not common. Existing literature show that DEA is an effective tool for evaluating the efficiency of the education sector, given the varying combination of inputs, outputs and number of outcomes. As a result, different inputs and outputs were tested on four DEA analysis models.

According to the empirical results, Greece has a relatively high technical efficiency in secondary education, as it is ranked in the second quarter among the twenty-eight EU countries. Greece's is near to the EU in terms of efficiency in secondary education. Inefficiency is particularly low in Malta, Cyprus, Romania, Bulgaria, Slovakia, Lithuania, and Luxembourg, where poor scores come mainly from low enrollment rates (secondary and tertiary) and low PISA scores. Indeed, public expenditure on secondary education is relatively high for Greece.

Therefore, in order to retain a good level of efficiency in secondary education or to improve its position relative to other EU countries, Greece must continue a number of initiatives to enhance the efficiency in secondary education sector.

Suggested

Firstly, set up an Observatory body, especially in the low-efficiency countries, to monitor annual performance in secondary education. Data would naturally be made available to policymakers.

Secondly, it is advisable that for Greece the considerable potential for rationalizing public secondary education expenditure that is being exploited without sacrificing the results and the redirection of resources in the field of higher education is also recommended.

Thirdly, the secondary education system in Greece needs to be modernized to reduce operating costs by merging and closing selected schools that serve very few students, while taking into account other socio-economic issues (remote mountainous areas and small islands). The teaching surplus should be rationalized without completely replacing those who retire. Indeed, a reduction in the number of secondary school teachers due to retirement and the implementation of a selective reduction in the recruitment of new teachers is required in the future.

However, at least three considerations need to be taken into account when measuring the efficiency of the secondary education sector and they should be taken into account when interpreting the results presented.

First, the applications of the techniques presented are hampered by the lack of adequate data to support these techniques. Quality data are required because available efficiency measurement techniques are sensitive to extreme points and may be influenced by external factors. Indeed, the substantial inefficiency found may merely reflect environmental factors (such as climate, socio-economic background, etc.). This also suggests the need to apply a combination of techniques to measure efficiency and effectiveness.

Second, the exact definition used for inputs, outputs, and outcomes can significantly affect results.

Finally, it is vital importance to know that when using a non-parametric approach and although DEA is an established and valid methodology, differences between countries are not statistically evaluated, which can be considered as a further limitation of such a methodology.

ENDNOTES

1. https://eacea.ec.europa.eu/national-policies/eurydice
2. Coelli, T.J. (1996). A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation. CEPA Working Paper No. 7/96, Department of Econometrics, University of New England, Armidale. http://www.uq.edu.au/economics/cepa/frontier.php
3. S.D.: Standard Deviation
4. C.V.: Coefficient of Variability

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APPENDIX

Table A.1
VARIABLES (PRICES) OF EU COUNTRIES, FOR THE PERIOD 2009-12(A)

No.	Country	Variables				
		X_1	X_2	X_3	X_4	X_5
1	Austria	29.048	9.978	98.861	506	74.101
2	Belgium	0.01	0.01	156.711	505	67.646
3	Bulgaria	21.944	12.123	90.888	446	57.023
4	Czech R.	23.459	9.799	94.771	508	63.532
5	Cyprus	37.343	8.16	94.218	438	48.952
6	Denmark	31.206	0.01	120.056	498	74.879
7	Estonia	27.331	8.992	105.15	541	68.407
8	Finland	34.656	9.766	107.72	545	93.221
9	France	27.997	12.623	106.425	499	54.427
10	Germany	23.527	13.008	103.517	524	0.01
11	Greece	0.01	0.01	100.839	467	104.417
12	Hungary	21.277	10.185	96.702	494	63.64
13	Ireland	27.798	0.01	116.108	522	62.476
14	Italy	23.924	0.01	101.672	494	66.26
15	Latvia	26.941	8.783	102.603	502	86.627
16	Lithuania	21.71	8.558	105.277	496	18.275
17	Luxembourg	18.801	8.646	101.183	491	70.02
18	Malta	48.954	8.314	98.674	0.01	37.336
19	Netherlands	0.01	13.568	123.621	522	66.92
20	Poland	23.716	9.995	96.079	526	73.948
21	Portugal	34.876	7.384	105.877	489	65.167
22	Romania	13.804	12.609	96.642	439	64.816
23	Slovakia	17.653	12.026	92.182	471	56.455
24	Slovenia	30.332	9.073	98.573	514	87.162
25	Spain	26.52	10.802	123.508	496	78.407
26	Sweden	30.835	9.612	98.195	485	72.413
27	UK	29.837	0.01	99.089	514	58.91
Mean		23.204	7.928	105	478.96	64.276
S.D.		11.097	4.592	13.555	99.507	21.09

*** CROATIA is missing, for this period.*

Table A.2
VARIABLES(PRICES) OF EU COUNTRIES, FOR THE PERIOD 2012-15(B)

No.	Country	Variables				
		X_1	X_2	X_3	X_4	X_5
1	Austria	27.121	9.608	98.742	495	79.124
2	Belgium	24.534	9.436	160.342	502	72.103
3	Bulgaria	20.19	12.864	100.081	446	64.366
4	Croatia	0.01	11.37	99.138	475	64.394
5	Czech R.	23.811	9.644	101.792	493	65.437
6	Cyprus	37.789	7.841	97.676	433	48.831
7	Denmark	28.91	11.29	127.363	502	80.359
8	Estonia	21.622	8.237	107.984	534	73.101
9	Finland	26.071	11.577	132.993	531	90.926
10	France	26.764	12.886	104.77	495	59.844
11	Germany	23.158	12.502	101.596	509	62.322
12	Greece	0.01	8.011	100.668	455	113.249

13	Hungary	19.292	10.474	102.293	477	56.834
14	Ireland	23.681	0.01	117.246	503	71.237
15	Italy	22.555	11.375	102.293	481	64.02
16	Latvia	31.528	8.164	111.61	490	74.562
17	Lithuania	17.05	8.318	107.784	475	19.407
18	Luxembourg	20.656	8.148	101.645	483	68.873
19	Malta	38.122	8.164	93.981	465	43.834
20	Netherlands	0.01	14.24	130.118	509	76.61
21	Poland	22.235	9.218	103.048	501	71.377
22	Portugal	29.087	9.277	114.214	501	66.347
23	Romania	14.233	12.612	94.677	435	48.606
24	Slovakia	18.756	11.229	91.353	461	54.388
25	Slovenia	25.147	9.679	106.176	513	84.706
26	Spain	19.247	11.758	130.455	493	87.032
27	Sweden	24.673	11.481	119.884	493	64.741
28	UK	22.86	15.848	114.599	509	58.239
Mean		21.754	10.188	109.804	487.82	67.317
S.D.		9.349	2.868	15.184	25.475	17.122

Source: Author's calculation

Table A.3
VARIABLES(PRICES) OF EU COUNTRIES, FOR THE PERIOD 2015-18(C)

No.	Country	Variables				
		X_1	X_2	X_3	X_4	X_5
1	Austria	27.274	9.441	100.977	490	83.444
2	Belgium	0.01	9.286	162.482	499	75.224
3	Bulgaria	0.01	12.637	101.122	424	70.767
4	Croatia	0.01	0.01	97.995	472	67.24
5	Czech R.	23.668	10.353	104.838	497	64.102
6	Cyprus	39.399	6.883	99.778	439	60.101
7	Denmark	0.01	0.01	129.689	493	81.595
8	Estonia	18.108	8.783	112.937	530	71.72
9	Finland	25.847	13.241	151.088	522	87.336
10	France	26.454	0.01	103.256	493	63.607
11	Germany	23.041	12.072	101.486	503	67.302
12	Greece	22.582	8.535	99.768	452	126.383
13	Hungary	21.208	10.154	102.851	481	48.489
14	Ireland	16.467	0.01	117.009	496	77.395
15	Italy	22.897	10.669	103.004	468	62.945
16	Latvia	24.843	7.789	111.459	487	70.43
17	Lithuania	17.052	9.138	107.551	482	19.636
18	Luxembourg	19.213	8.069	102.816	477	80.987
19	Malta	29.884	7.503	95.265	457	48.129
20	Netherlands	22.92	14.433	133.117	503	80.466
21	Poland	22.108	9.258	106.843	511	66.614
22	Portugal	27.693	9.787	117.867	492	62.186
23	Romania	16.192	12.108	89.938	426	47.423
24	Slovakia	19.199	11.152	91.11	464	49.245
25	Slovenia	23.873	9.953	112.554	507	78.833
26	Spain	18.52	11.796	128.715	483	90.331
27	Sweden	23.597	12.887	142.672	499	62.916
28	UK	21.079	17.453	138.831	505	58.35
Mean		19.756	9.051	113.108	484	68.686
S.D.		9.44	4.385	18.533	26.261	18.727

Source: Author's calculation

Table A.4
DEA EFFICIENCIES AND RANKING ABOUT MODELS, FOR THE PERIOD 2009-12(A)

No.	Country	Model I		Model II		Model III		Model IV	
		VRSTE	Rank	VRSTE	Rank	VRSTE	Rank	VRSTE	Rank
1	Austria	0.938	14	0.934	14	0.928	15	0.954	14
2	Belgium	1.000	1	1.000	1	0.983	7	0.927	16
3	Bulgaria	0.893	25	0.830	24	0.818	24	1.000	1
4	Czech R.	0.944	12	0.944	12	0.932	13	1.000	2
5	Cyprus	0.817	26	0.814	26	0.809	25	0.876	25
6	Denmark	0.942	13	0.961	9	0.987	5	0.914	22
7	Estonia	1.000	2	1.000	2	0.996	4	1.000	3
8	Finland	1.000	3	1.000	3	1.000	1	1.000	4
9	France	0.952	9	0.927	16	0.916	16	0.919	19
10	Germany	0.998	5	0.973	8	0.961	10	0.973	9
11	Greece	0.895	24	0.925	18	1.000	2	1.000	5
12	Hungary	0.921	18	0.920	20	0.906	20	0.937	15
13	Ireland	0.974	7	1.000	4	1.000	3	0.958	11
14	Italy	0.918	19	0.951	10	0.962	9	0.923	17
15	Latvia	0.930	15	0.931	15	0.932	14	0.956	13
16	Lithuania	0.925	17	0.927	17	0.915	17	0.916	21
17	Luxembourg	0.918	20	0.921	19	0.905	21	0.919	20
18	Malta	0.759	27	0.630	27	0.358	27	0.397	27
19	Netherlands	1.000	4	1.000	5	0.958	11	0.958	12
20	Poland	0.977	6	0.977	7	0.965	8	1.000	6
21	Portugal	0.909	21	0.911	21	0.907	19	0.902	24
22	Romania	0.929	16	0.826	25	0.806	26	0.841	26
23	Slovakia	0.900	22	0.882	23	0.864	23	1.000	7
24	Slovenia	0.947	11	0.948	11	0.948	12	1.000	8
25	Spain	0.956	8	0.943	13	0.910	18	0.910	23
26	Sweden	0.899	23	0.895	22	0.891	22	0.920	18
27	UK	0.948	10	0.985	6	0.985	6	0.968	10

Source: Author's calculation

Table A.5
DEA EFFICIENCIES AND RANKING ABOUT MODELS, FOR THE PERIOD 2012-15(B)

No.	Country	Model I		Model II		Model III		Model IV	
		VRSTE	Rank	VRSTE	Rank	VRSTE	Rank	VRSTE	Rank
1	Austria	0.725	25	0.927	18	0.936	14	1.000	1
2	Belgium	1.000	1	1.000	1	0.941	10	0.941	18
3	Bulgaria	0.838	9	0.842	26	0.836	26	0.889	27
4	Croatia	0.798	12	0.981	7	0.890	22	0.955	11
5	Czech R.	0.739	20	0.924	19	0.923	17	0.968	10
6	Cyprus	0.669	27	0.822	28	0.813	28	0.883	28
7	Denmark	0.903	6	0.949	12	0.944	9	0.944	16
8	Estonia	0.727	24	1.000	2	1.000	1	1.000	2
9	Finland	0.937	4	1.000	3	1.000	2	1.000	3
10	France	0.857	8	0.928	17	0.927	16	0.949	15
11	Germany	0.831	10	0.953	10	0.953	7	1.000	4
12	Greece	0.774	15	1.000	4	1.000	3	1.000	5
13	Hungary	0.765	16	0.899	23	0.893	21	0.932	22
14	Ireland	0.736	21	1.000	5	1.000	4	0.943	17

15	Italy	0.793	13	0.902	22	0.901	20	0.941	19
16	Latvia	0.742	19	0.929	15	0.929	15	0.931	23
17	Lithuania	0.729	23	0.912	20	0.890	22	0.891	26
18	Luxembourg	0.696	26	0.912	21	0.909	19	0.951	14
19	Malta	0.661	28	0.871	24	0.871	24	0.982	8
20	Netherlands	1.000	2	1.000	6	0.955	6	0.955	12
21	Poland	0.733	22	0.939	14	0.939	12	0.975	9
22	Portugal	0.786	14	0.945	13	0.938	13	0.938	21
23	Romania	0.827	11	0.828	27	0.815	27	0.913	25
24	Slovakia	0.746	18	0.869	25	0.863	25	1.000	6
25	Slovenia	0.760	17	0.961	8	0.973	5	1.000	7
26	Spain	0.931	5	0.949	12	0.939	12	0.939	20
27	Sweden	0.874	7	0.929	16	0.923	18	0.923	24
28	UK	1.000	3	0.957	9	0.953	8	0.953	13

Source: Author's calculation

Table A.6
DEA EFFICIENCIES AND RANKING ABOUT MODELS, FOR THE PERIOD 2015-18(C)

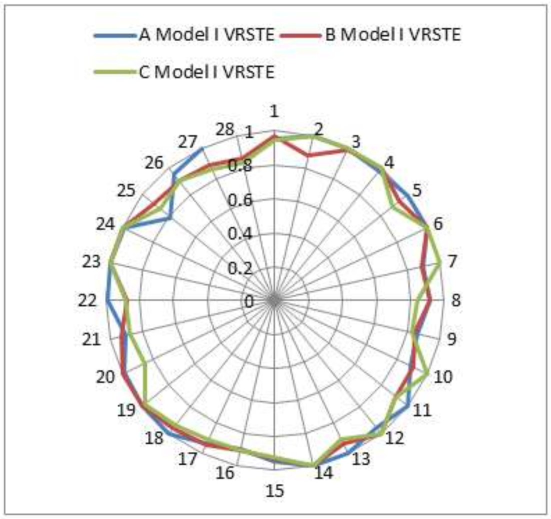
No.	Country	Model I		Model II		Model III		Model IV	
		VRSTE	Rank	VRSTE	Rank	VRSTE	Rank	VRSTE	Rank
1	Austria	0.677	21	0.925	18	0.958	10	1.000	1
2	Belgium	1.000	1	1.000	1	0.955	11	0.948	21
3	Bulgaria	1.000	2	0.850	26	0.814	27	0.863	28
4	Croatia	0.603	28	0.957	12	0.952	14	0.974	10
5	Czech R.	0.712	15	0.938	14	0.938	17	0.973	11
6	Cyprus	0.632	26	0.843	27	0.840	26	0.888	27
7	Denmark	0.798	8	1.000	2	1.000	1	0.953	18
8	Estonia	0.730	12	1.000	3	1.000	2	1.000	2
9	Finland	1.000	3	1.000	4	1.000	3	1.000	3
10	France	0.636	25	0.994	6	0.994	6	0.972	12
11	Germany	0.720	14	0.949	13	0.949	15	1.000	4
12	Greece	0.657	24	0.857	25	1.000	4	1.000	5
13	Hungary	0.698	20	0.908	20	0.908	22	0.950	20
14	Ireland	0.720	13	1.000	5	1.000	5	0.956	16
15	Italy	0.707	18	0.884	22	0.883	23	0.924	26
16	Latvia	0.708	16	0.931	16	0.932	19	0.931	24
17	Lithuania	0.708	17	0.914	19	0.909	21	0.932	23
18	Luxembourg	0.666	22	0.905	21	0.938	18	0.965	13
19	Malta	0.618	27	0.870	24	0.870	25	0.953	19
20	Netherlands	0.924	6	0.959	9	0.960	9	0.965	14
21	Poland	0.706	19	0.964	8	0.964	8	0.991	8
22	Portugal	0.772	9	0.936	15	0.928	20	0.928	25
23	Romania	0.741	11	0.809	28	0.804	28	1.000	6
24	Slovakia	0.660	23	0.875	23	0.875	24	1.000	7
25	Slovenia	0.746	10	0.958	10	0.973	7	0.979	9
26	Spain	0.860	7	0.927	17	0.953	12	0.957	15
27	Sweden	0.950	5	0.958	11	0.942	16	0.942	22
28	UK	1.000	4	0.969	7	0.953	13	0.953	17

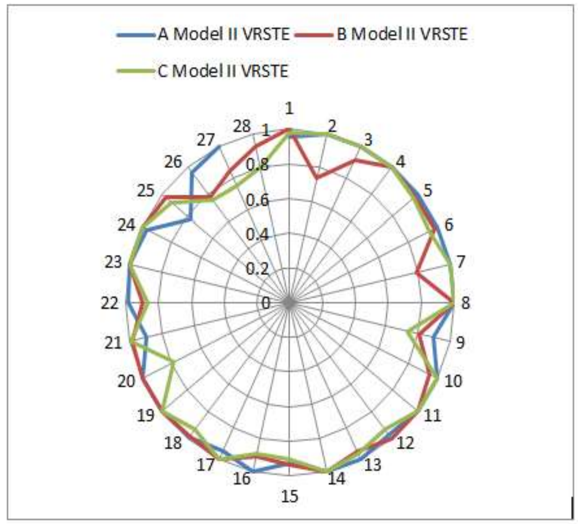
Source: Author's calculation

Table A.7
RESULTS OF DEA VRSTE (OO) PER MODEL AND PERIOD, WITH DESCRIPTIVE STATISTICS

MODEL		I			II			III			IV		
PERIOD		2009-12	2012-15	2015-18	2009-12	2012-15	2015-18	2009-12	2012-15	2015-18	2009-12	2012-15	2015-18
DEA		VRSTE											
1	Austria	0.938	0.725	0.677	0.934	0.927	0.925	0.928	0.936	0.958	0.954	1.000	1.000
2	Belgium	1.000	1.000	1.000	1.000	1.000	1.000	0.983	0.941	0.955	0.927	0.941	0.948
3	Bulgaria	0.893	0.838	1.000	0.830	0.842	0.850	0.818	0.836	0.814	1.000	0.889	0.863
4	Croatia	*	0.798	0.603	*	0.981	0.957	*	0.890	0.952	*	0.955	0.974
5	Czech R.	0.944	0.739	0.712	0.944	0.924	0.938	0.932	0.923	0.938	1.000	0.968	0.973
6	Cyprus	0.817	0.669	0.632	0.814	0.822	0.843	0.809	0.813	0.840	0.876	0.883	0.888
7	Denmark	0.942	0.903	0.798	0.961	0.949	1.000	0.987	0.944	1.000	0.914	0.944	0.953
8	Estonia	1.000	0.727	0.730	1.000	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000
9	Finland	1.000	0.937	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	France	0.952	0.857	0.636	0.927	0.928	0.994	0.916	0.927	0.994	0.919	0.949	0.972
11	Germany	0.998	0.831	0.720	0.973	0.953	0.949	0.961	0.953	0.949	0.973	1.000	1.000
12	Greece	0.895	0.774	0.657	0.925	1.000	0.857	1.000	1.000	1.000	1.000	1.000	1.000
13	Hungary	0.921	0.765	0.698	0.920	0.899	0.908	0.906	0.893	0.908	0.937	0.932	0.950
14	Ireland	0.974	0.736	0.720	1.000	1.000	1.000	1.000	1.000	1.000	0.958	0.943	0.956
15	Italy	0.918	0.793	0.707	0.951	0.902	0.884	0.962	0.901	0.883	0.923	0.941	0.924
16	Latvia	0.930	0.742	0.708	0.931	0.929	0.931	0.932	0.929	0.932	0.956	0.931	0.931
17	Lithuania	0.925	0.729	0.708	0.927	0.912	0.914	0.915	0.890	0.909	0.916	0.891	0.932
18	Luxembourg	0.918	0.696	0.666	0.921	0.912	0.905	0.905	0.909	0.938	0.919	0.951	0.965
19	Malta	0.759	0.661	0.618	0.630	0.871	0.870	0.358	0.871	0.870	0.397	0.982	0.953
20	Netherlands	1.000	1.000	0.924	1.000	1.000	0.959	0.958	0.955	0.960	0.958	0.955	0.965
21	Poland	0.977	0.733	0.706	0.977	0.939	0.964	0.965	0.939	0.964	1.000	0.975	0.991
22	Portugal	0.909	0.786	0.772	0.911	0.945	0.936	0.907	0.938	0.928	0.902	0.938	0.928
23	Romania	0.929	0.827	0.741	0.826	0.828	0.809	0.806	0.815	0.804	0.841	0.913	1.000
24	Slovakia	0.900	0.746	0.660	0.882	0.869	0.875	0.864	0.863	0.875	1.000	1.000	1.000
25	Slovenia	0.947	0.760	0.746	0.948	0.961	0.958	0.948	0.973	0.973	1.000	1.000	0.979
26	Spain	0.956	0.931	0.860	0.943	0.949	0.927	0.910	0.939	0.953	0.910	0.939	0.957
27	Sweden	0.899	0.874	0.950	0.895	0.929	0.958	0.891	0.923	0.942	0.920	0.923	0.942
28	UK	0.948	1.000	1.000	0.985	0.957	0.969	0.985	0.953	0.953	0.968	0.953	0.953

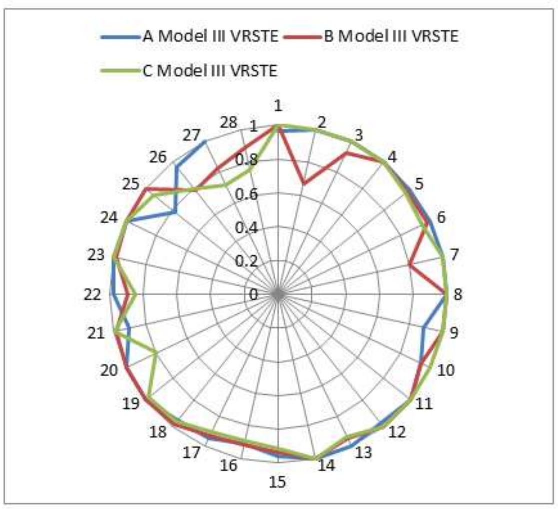
Source: Author's calculation

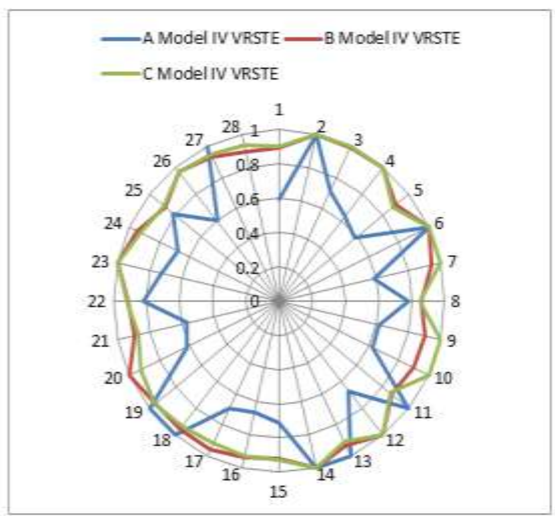




GRAPH 1
A, B, C MODEL I - DEA(VRSTE

GRAPH 2
A, B, C MODEL II - DEA(VRSTE)





GRAPH 3
A, B, C MODEL III - DEA(VRSTE)

GRAPH 4
A, B, C MODEL IV - DEA(VRSTE)