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Evaluation of Upper Secondary Schools on Efficiency and Productivity Change in 2016-2019: Empirical evidence from schools in the region in Central Greece

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Abstract

The study investigates the relative efficiency and productivity change of Upper Secondary Schools in the region of Central Greece during the period 2016–2019. It measures the technical and scale efficiencies and productivity change by using DEA output-oriented and Malmquist analysis. Empirical analysis reveals that few are efficient and most are inefficient. The efficiency under constant returns to scale varies in interval [0.666–1.000] and under variable returns to scale in interval [0.759–1.000], with average efficiency score being 0.875 and 0.923 respectively. This means that given the quantities of inputs, Upper Secondary Schools could produce, on average, more quantities of outputs by 12.5% or 7.7% respectively. The scale efficiency varies in the interval [0.745–1.000] and the mean is 0.948. The findings suggest that schools on average refrain 5.2% from the optimal scale. The results show that average values of efficiency are moving around the average performance of Upper Secondary Schools of other countries in the world and the European Union. The total factor productivity change of production factors has risen by an annual average of 5.2% relative to the base year 2016.

JEL Classifications: C14, J48, P41.
Keywords: Upper Secondary Schools; Efficiency; Productivity; Data Envelopment Analysis; Malmquist analysis.

1. Introduction

Like any production unit secondary schools use inputs (i.e. limited economic resources) that are competitively acquired. Outputs emerge from the educational units after the educational process. The aim is to either minimize inputs for a given level of output (input-oriented DEA) or where a unit is made more efficient through the proportional increase of its outputs while the inputs proportions remain unchanged (output-oriented DEA). In this context, the performance of secondary schools is estimated by the extent of the efficiency (technical and scale) and productivity change.

The methods-techniques commonly used to measure the efficiency of educational units are the Data Envelopment Analysis and the Stochastic Frontier Analysis. Productivity change is measured by the Malmquist Analysis. In this paper you use the DEA with output-oriented. We utilize the non-parametric methodology of data envelopment analysis (DEA) (Charnes et al., 1978). DEA, a state-of-the-art non-parametric methodology, can be used to assess performance of homogeneous units utilizing multiple inputs to produce multiple outputs. DEA enjoys a number of advantages over other traditional parametric methods, and has been used extensively to assess school performance (Norman and Stocker, 1991; Sammons et al., 1993; Thanassoulis and Dunstan, 1994).In recent years, as inputs have remained relatively stable, research interest has shifted to maximizing output. After all, the international empirical literature shows that output-orientated DEA is increasingly favored.

The work concerns the 64 public homogeneous Upper Secondary Schools (USSs) operating in this region during the period under review. The Region of Central Greece is a representative region of the 13 Regions of the country since the main economic, social and educational characteristics that most of them have, are about on average (Karatheodoros et. al. (2016, 2019) ; ELSTAT (2014, 2018, 2019)).

The Upper Secondary Education in Greece is an optional level of education, it lasts 3 years and the students who complete their studies, with pan-Hellenic examinations, claim a place in the Universities of the country. Secondary education (SE) is an important form of investment in human capital. It has historically included economic growth as part of its core mission. It is a well-established fact that the quality of education matters more than quantity. The SE has contributed positively to the growth rate of the Greek economy (Tsamadias and Prontzas, 2009) and to the economies of its 13 regions (Karatheodoros et al., 2016).

The purpose of the paper is threefold:

First, to measure the relative efficiency and productivity change of the USSs in Central Greece over the period 2016-19. It is the most recent period of time which coincides with the beginning of the abnormal period, of the pandemic Covid 19, with the country taking steps towards normalcy, from the previous economic crisis. Also, to identify the USSs which perform higher than the average efficiency as well as the average overall productivity. These USSs can be used as benchmarks to improve the performance of other USSs.

Second, to compare the performance of the USSs of the Region in connection with the countries of the world, in particular the ones in the European Union.

Third, to investigate if the environmental variables (the number of students in the USS (Z_1), the school unit seat (Z_2), the year the school started operating (Z_3), pupil-teacher ratio (Z_4), GDP per capita, per Regional Unit (Z_5), VRSTE (Z_6) have effects on USS performance.

The contribution of this work is that it evaluates school units by sharing the sizes of technical efficiency and productivity change, as well as investigates the effect of environmental variables on the technical efficiency of units. Educational output, at its most basic level, can be measured by "quantity" indicators such as course enrolment and completion rates, study duration, the level of education reached, or even equated with the quantity of inputs. It contributes to the literature, since for the first time the change in productivity is measured and it is one of the few tasks that measure efficiency.

In the empirical economic literature, a few studies have examined the efficiency and productivity change of secondary education schools.

The problem of defining productivity in education has been studied by several authors: Callahan(1962), Hanushek(2003), Baird et al.(2010), Boser(2011), Guthrie and

Ettema(2012), Hanuskek and Ettema(2017) is an indicative set of papers and books published along this line of research.

Education policy has traditionally ignored any consideration of productivity. Indeed, considering productivity has generally been viewed as something bad, something that can only have bad implications for educational quality and for school policy (Callahan, 1962).

There has been extensive research into ways to improve school outcomes and also ways that have not proven to be generally successful. In particular, specifying inputs to the process—including spending, class size reduction, or the like—do not seem to raise outcomes consistently when they are not linked to outcomes and to incentives for the people in schools (Hanushek, 2003).

When presenting their data on education productivity, the U.K. Office for National Statistics points out that “it is unlikely that a single measure of productivity change will ever capture all the costs and benefits of education” (Baird et al., 2010).

Boser (2011) constructs three measures of education productivity and applies them to more than 9,000 school districts in 46 states. Finally, the Predicted Efficiency Rating uses spending and demographic information to predict student achievement and measures how much better or worse districts do than expected.

In today’s world of fiscal imbalances and budgetary pressures, it seems impossible to continue ignoring productivity. Given the disconnect between inputs and outputs and the fact that inputs are unlikely to continue to increase as quickly as they have in the past (Guthrie & Ettema, 2012), a close examination of the current practices that undermine productivity increases in education and a thoughtful exploration of alternative practices that might reverse this trend is in order.

Private sector productivity in the United States has increased in recent years while productivity in education has declined. Although there are many ways that education productivity could be defined and measured, it is unlikely that any reasonable measure would show a great productivity increase, given a major escalation of inputs with most output measures remaining relatively unchanged(Hanuskek and Ettema, 2017).

To the best of our knowledge, this paper is the third to investigate the efficiency of upper secondary schools (Maragos and Despotis (2016); Sotiriadis et al. (2015)) and the second to study productivity change for upper secondary education in Greece (Margaritis et al., 2020). Also, there are a few studies (Tsamadias and Kyratzi (2014); Kyratzi et.al (2015)) for higher education institutions in Greece. Measuring the efficiency of upper secondary schools identifies inefficient schools and enables the competent authorities to reduce their wastage.

The remainder of the paper is organized as follows: Section 1, presents a brief reference to the Greek secondary school system. Section 2, provides a review of the empirical literature. Section 3, provides a short theoretical methodology and models. Section 4, present Empirical Analysis, Section 5, presents data and discusses our results. Finally, Section 6 presents the concluding remarks and policy implications.

2. Review of Empirical Literature

In the Empirical literature, the following works have been recorded.

For European Countries: Kirjavainen and Loikkanen (1998). This paper analyzes the efficiency differences among Finnish senior secondary schools by Data Envelopment Analysis (DEA). Average efficiencies in the most extensive models were 82-84 per cent.;

Stupnytskyy (1998). The paper estimates efficiency of secondary schools in the Czech Republic using Data Envelopment Analysis. The estimated efficiency is then related to school and teacher characteristics using Tobit model. It was found that schools differ significantly in their efficiency, which ranges from 0.6 to 1. The total efficiency of secondary schools was estimated to be 0.83 (CCR model) and 0.87 (BCC model). ; Soteriou et al. (2000). One of the major findings was that in the case of Cyprus, room for school efficiency improvement exists, even though not great. Despite the low rankings schools in Cyprus obtained during the TIMSS, most of the schools find themselves very close to the efficient frontier. These results emphasize the existing homogeneity between schools as far as efficiency is concerned, and underline the importance of future international efficiency studies.; Oliveira and Santos (2006). The study concludes that the unemployment rate, access to health care services, adult education and living infrastructures are determinants of school efficiency. The differences between the coast and the interior of Portugal seem to be more relevant, as far as school efficiency is concerned, than whether or not the school belongs to one of the major coast metropolitan areas.; Manceb and Bandrés (2006). The most inefficient centres, according to the DEA, are held in low esteem by their own pupils. The centres located in urban areas are more efficient than those located in rural areas.The educational reform of 1990 does not appear to have resulted in greater efficiency at secondary-school level, although this result must be treated cautiously given the reduce number of centres that were affected by this reform when the estimation was made.; Agasisti (2014). The results show that at least one indicator of competition is statistically associated with higher performances of schools, suggesting that there is a potential role for improving schools' results by increasing the number of schools competing each other. These findings are consistent with a previous analysis conducted on the same dataset by estimating an Educational Production Function.; Aparicio et al. (2018). This paper analyzes the drivers causing productivity changes of especially vulnerable public schools during the crisis. . The results reveal that during the crisis schools improved their total factor productivity by raising academic achievement despite cutbacks in resources. We also found that there was a strong convergence pattern during the financial crisis, driven by the catch-up process of some schools.

For non-European countries: Adkins and Moomaw (2005). Our results indicate that additional instructional and noninstruction expenditures improve student performance, but only by a small amount. In addition, we find that school district size, teacher education and experience, and teacher salary affect the technical efficiency of schools; Demir et al. (2010). As a result of the study, it was found that 7 of the 48 schools (%14.56) were efficient. Also, it was found that the most efficient region in Turkey was Istanbul and the most efficient school types were science high schools and police colleges.; Ramzi et al. (2013). Our results show the absence of significant relationship between school resources and student performance. The output variable, non-doubling rate in the 9th year is the only factor able to influence the efficiency level of governorates in terms of 2nd cycle of basic education and secondary education. By regressing efficiency scores on non-discretionary variables, we find that inefficiency in education is strongly related to poverty within governorates.; Nghiem et al. (2014). Our results show that the average technical efficiency of Australian schools is 59 per cent and congestion exists for all of the available inputs.; Afonso et al. (2018). Our results show that there is a positive relationship between school resources and student achievement and performance. Moreover, there was an increase in output efficiency scores in most governorates through the period from 1999 to 2008.; Dufrechou (2018). Results show a minor role of inefficiency since 1990 and different efficiency profiles depending on the country's education outlays. Besides, globalization and democracy show up as important conditions affecting the efficiency path of the Latin American sub-sample.; Nauzer et al. (2018). The analysis results indicate that efficiency of colleges ranged between 0 and 1 with an average of 0.872(CRS) and 0.909(VRS) using Tobit model. The second stage analysis found that the location, zone, types of colleges, teacher-student ratio, student-class ratio, college status and canteen have significant effect on school's performance,

For European countries & non-European countries: Afonso and St.Aubyn (2006). Results from the first-stage imply that inefficiencies may be quite high. On average and as a conservative estimate, countries could have increased their results by 11.6 percent using the same resources23, with a country like Indonesia displaying a waste of 44.7 percent.; Nahar and Arshad (2007). Malaysia's secondary education remains technically inefficient, where the CRS efficiency was 64% and the VRS efficiency was 94%; Nahar and Arshad (2014). The CRS-technical efficiency is 71%. The average technical efficiency under the VRS assumption, on the other hand, is 86% with a standard deviation of 0.12. The minimum technical efficiency score under the CRS assumption is 33% while under the VRS assumption, it is 55%.

3. Methodology and Models

The output-oriented DEA models are very similar to their input-oriented counterparts.
Consider the example of the following output-orientated VRS model:

$$\max_{\phi,\lambda} \phi,$$

$$\text{st} \quad -\phi q_i + Q\lambda \geq 0,$$

$$x_i - X\lambda \geq 0,$$

$$I1'\lambda = 1$$

$$\lambda \geq 0,$$

where $1 \leq \phi < \infty$, and $\phi - 1$ is the proportional increase in outputs that could be achieved by the i-th firm, with input quantities held constant. Note that $1/\phi$ defines a TE score that varies between zero and one (and that this is the output-oriented TE score reported by DEAP) (Coelli, 1996).

In addition, technological changes might occur that could affect and shift the frontier. These two effects could determine the total productivity change. For panel data, the MI (Malmquist, 1953) could be employed so as to measure the productivity change and decompose it into its two separate components. The first and the most commonly-considered, source of productivity growth is technical change (TC), which results from a shift in the production technology. The second source of productivity growth of a firm could be due to improved efficiency in the firm's ability to use the available technology, which is efficiency change (EC) (Coelli, 1996). The Malmquist productivity index (MPI) is introduced as a theoretical index by Caves et al. (1982) and became more popular as an empirical index by Fare et al. (1994). In order to measure the change in the efficiency score, the latter should be split into two components: 1) one related to the real change in productivity (efficiency), 2) one related to the change in production frontier. This index is composed by distance functions, and it is therefore superior to alternative indexes of productivity growth. MPI is the product of technical efficiency and technology change. More specifically, the MI of productivity growth (M) evaluates the productivity change of a unit between two time periods (Fare et al., 1994) defined the IO MI between year t and t + 1 as the ratio of the distance function for each year relative to a common technology, as follows:

$$\mathrm{M}_1^t(x^t, y^t, x^{t+1}, y^{t+1}) = [\frac{D_1^t(x^{t+1}, y^{t+1})}{D_1^t(x^t, y^t)}] \quad (3)$$

If the base year is the t + 1, then the MI for the t + 1 period is as follows:

$$\mathrm{M}_1^{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = [\frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_1^{t+1}(x^t, y^t)}] \quad (4)$$

where the subscript I indicates an input-oriented, M is the productivity of the most recent production point (x^{t+1}, y^{t+1}) (using period t + 1 technology) relative to the earlier production point (x^t, y^t) (using period t technology), D are input distance functions, x is the inputs, y is the outputs, and t is the current period. Following Fare et al. (1994) the MI can be expressed as a geometric mean of the two indices, evaluated with respect to period t and period t + 1 technologies as follows:

$$\mathrm{M}_I(x^{t+1}, y^{t+1}, x^t, y^t) = [\frac{D_1^t(x^{t+1}, y^{t+1})}{D_1^t(x^t, y^t)} x \frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_1^{t+1}(x^t, y^t)}]^{1/2} \quad (5)$$

Fare et al. (1994) further suggested that this index can be decomposed further into two components: one describing the technical efficiency change (improvements in efficiency relative to the frontier) and another reflecting on the technological change (shifts in the frontier) of the different units under study, as follows:

$$\mathrm{M}_1(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_1^t(x^t, y^t)} \cdot [\frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_1^{t+1}(x^{t+1}, y^{t+1})} x \frac{D_1^t(x^t, y^t)}{D_1^{t+1}(x^t, y^t)}]^{1/2} \quad (6)$$

↕ ↕

Efficiency change *Technological change*

The appropriate required distance functions can be estimated via DEA technologies, as described above (Charnes et al., 2008; Fare et al., 1994; Coelli et al., 2005). Note that MI > 1 denotes progress in the Total Factor Productivity (TFP) change (net effect is positive). MI = 1 denotes no change in TFP, while MI < 1 denotes productivity decline from period t to t+1 (see also Chen et al., 2014; Assaf, 2011; Worthington, 2000). The same applies for the other components.

4. Empirical Analysis

This study employ the non-parametric output-oriented D.E.A. and M.A. in order to measure the relative TE, Scale Efficiency (SE) and the TFP change of 64 public USSs.

4.1 Variables' Sampling, Sources and Data

The study use six input variables: Number of students (X_1), number of teachers (X_2), public expenditures (X_3), ($X_3 = X_{31} + X_{32} + X_{33}$, where X_{31} = teachers' wages, X_{32}= USS operating costs and X_{33} = school transport costs), courtyard land surface (X_4), buildings and civil engineering structures (X_5), number of computers (X_6) and four output variables: number of USSs graduates (Y_1), number of excellent students in the 3rd grade of USSs (school performance) graduating (Y_2), number of students who have graduated, have first passed a National exam and succeeded in the University (Y_3), number of excellent students(they achieved over 18,000 marks for their entry into higher education) of the 3rd Grade USS (Y_4). Data for variables X_1, X_2, X_4, X_5, X_6,Y_1,Y_2,Y_3,Y_4 are derived from USSs of the region of Central Greece, from the secondary education address and from the regional education directorate of the region of Central Greece. For variable X_3 the study obtain the data from the secondary education address and from the services of the Municipality of the region of Central Greece. For the data analysis the study use the DEAP Version 2.1 software package (Coelli, 1996).

4. 2 Results and Discussion

Table 1 presents the summary statistics of inputs and outputs.

Table 1. Descriptive statistics of input and output variables by year.

Variables / Statistics	Inputs						Outputs			
	X1	X2	X3	X4	X5	X6	Y1	Y2	Y3	Y4
2016-17										
AVG	165	15.74	420,566	2,314.5	1,651	21.63	51.47	13.38	39.77	4.89
S.D.	101	7.46	218,251	1,741	834.6	9.31	30.87	8.97	28.2	4.92
Max	442	36	932,105	9,000	3,162	44	151	32	117	17
Min	34	5	110,629	203	350	5	11	1	5	0.01
2017-18										
AVG	165.3	15.78	408,349	2,314.5	1,651	21.63	54.51	17	40.23	4.91
S.D.	103.3	7.62	197,665	1,741	834.6	9.31	34.16	14.34	29.11	5.07
Max	436	37	882,873	9,000	3,162	44	151	89	136	17
Min	35	5	117,223	203	350	5	8	0.01	5	0.01
2018-19										
AVG	160.4	15.49	417,327	2314.5	1,651	21.63	53.79	14.64	44.13	6.02
S.D.	100.5	7.22	198,832	1741	834.6	9.31	35.40	9.60	32.59	5.87
Max	426	37	914,644	9,000	3,162	44	155	41	129	34
Min	34	4	113,336	203	350	5	12	0.01	7	0.01

Source: Author calculation Notes: 1. Standard Deviation (S.D.), 2. Average (AVG)

The average number of students per USS is about 160-165. The average number of students per teacher is about 16. The average total expenditures per USS is about 413,600. The average number of excellent students per USS in the 3rd grade graduating is about 14. The average number of excellent students (they achieved over 18,000 marks for their entry into higher education) of the 3rd Grade per USS is about only 5. The average number of students who have graduated, have first passed a national exam and succeeded in the University per USS is about 39. Also, the study conclude that there is a large courtyard land surface and large building per student, while a large number of students per computer. Moreover, the student – teacher ratio is 9.967 for the region of Central Greece in 2018, while for OECD countries it was 13, for the EU23 countries it was 12 and the end for G20 countries was 15 and last but not least, for Greece in 2013 was 8. Expenditure per student in upper secondary education was 2,774 € for Greece in 2018, while for OECD countries it was 9,119 € and for the EU22 countries it was 9,445€. Private expenditure per student in upper secondary education was 2,525 €. For Greece in 2015, the total annual cost per student of upper secondary education was 4,390 € (Margaritis, 2019; OECD, 2013; OECD, 2018). Public education expenditure as a share of GDP was 3.9% in 2017 (EU average: 4.6%). Since 2010, Greece has managed to lower early school leaving in rural areas by 12 pps, putting it among the best performers in the EU for that category. (European Commission, Education and Training Monitor 2019, Greece)[1]

The study measures the relative TE with CRS and VRS as well as the SE. The efficiency scores are relative scores which suggests that USSs can improve their performance even when efficiency score is high.

The Appendix A (Table I) presents the Technical (TE) and Scale Efficiencies (SE) of upper secondary schools data on the inputs and outputs of all upper secondary Schools in the Region of Central Greece for the years 2016-17, 2017-18 and 2018-19.

The next Table 2, presents the mean of technical, scale efficiency and productivity change of upper secondary schools of the region of Central Greece, for the period 2016-19.

Table 2. Mean of technical, scale efficiencies and productivity change of upper secondary schools of the region of Central Greece(2016–2019)

Region	**Output-oriented**										
	Technical Efficiency-Scale Efficiency							Productivity Change			
	DMU	Mean						2016-19			
		CRS	R	VRS	R	SE	R	EC	TC	TFPC	R
Voiotia	1	0.952	17	0.965	27	0.987	28	0.945	1.050	0.992	43
	2	0.843	37	0.849	50	0.993	19	1.102	1.098	1.211	6
	3	0.808	48	0.833	54	0.970	39	0.967	1.058	1.023	37
	4	1.000	1	1.000	1	1.000	1	1.000	1.014	1.014	38
	5	0.999	11	1.000	2	0.999	11	0.999	1.105	1.104	21
	6	0.879	31	0.924	35	0.949	42	1.004	0.996	1.000	41
	7	0.816	45	0.849	51	0.961	40	1.229	1.013	1.245	5
	8	0.747	59	0.806	59	0.928	47	0.993	0.997	0.931	55
	9	0.809	47	0.814	56	0.994	17	0.932	1.028	0.958	51
	10	0.829	40	1.000	3	0.829	61	0.918	1.081	0.993	42
	11	0.775	55	0.831	55	0.926	48	0.830	1.010	0.838	64
	12	0.771	57	0.878	45	0.877	53	0.978	1.082	1.058	30
	13	1.000	2	1.000	4	1.000	2	1.000	0.901	0.901	59
	14	0.973	15	1.000	5	0.973	36	0.959	0.907	0.869	63
	AVG	**0.872**	-	**0.911**	-	**0.956**	-	**0.990**	**1.024**	**1.010**	-
Evia	15	0.971	16	0.971	25	0.999	12	1.000	1.077	1.077	24
	16	0.947	19	0.961	28	0.985	29	1.090	1.082	1.179	9

[1]https://ec.europa.eu/education/sites/education/files/document-library-docs/et-monitor-report-2019-greece_en.pdf

	17	0.763	58	0.776	62	0.983	31	0.919	1.078	0.990	45
	18	0.666	64	0.780	61	0.850	57	1.042	1.073	1.118	17
	Table2: (continue)										
	Table2: (continue)										
	19	0.814	46	0.837	53	0.972	37	1.052	1.001	1.053	31
	20	0.946	20	1.000	6	0.946	43	1.027	1.032	1.060	28
	21	0.943	22	1.000	7	0.943	44	1.099	1.002	1.101	22
	22	0.832	39	0.845	52	0.983	32	0.909	1.045	0.950	52
	23	0.988	12	0.989	22	0.999	13	0.982	0.976	0.959	49
	24	0.915	24	0.920	36	0.994	16	0.986	1.041	1.026	36
	25	0.881	30	0.889	42	0.991	21	0.963	1.030	0.992	44
	26	0.794	52	0.800	60	0.991	22	0.914	0.992	0.907	57
	27	0.898	27	0.902	39	0.996	15	1.102	0.973	1.073	25
	28	0.868	34	0.877	46	0.989	26	1.161	0.993	1.153	11
	29	0.878	32	0.886	43	0.990	23	0.882	0.990	0.873	62
	30	0.796	51	0.814	57	0.977	35	0.952	1.013	0.964	48
	31	1.000	3	1.000	8	1.000	3	1.000	0.945	0.945	53
	32	0.805	49	0.813	58	0.989	26	1.017	1.034	1.051	33
	33	0.898	27	0.942	32	0.954	41	1.049	0.997	1.045	34
	34	0.882	29	0.978	24	0.902	49	1.000	1.052	1.053	32
	35	0.776	54	0.874	48	0.880	52	0.831	1.089	0.905	58
	36	0.826	41	1.000	9	0.826	62	0.928	0.970	0.900	60
	AVG	**0.868**	-	**0.902**	-	**0.961**	-	**0.996**	**1.022**	**1.017**	-
Evrytania	37	1.000	4	1.000	10	1.000	4	1.000	1.415	1.415	1
	AVG	**1.000**	-	**1.000**	-	**1.000**	-	**1.000**	**1.415**	**1.415**	-
Fthiotida	38	1.000	5	1.000	11	1.000	5	1.000	1.308	1.308	3
	39	1.000	6	1.000	12	1.000	6	1.000	1.194	1.194	7
	40	0.949	18	0.951	30	0.998	14	0.921	1.040	0.958	50
	41	1.000	7	1.000	13	1.000	7	1.000	1.193	1.193	8
	42	0.978	13	0.988	23	0.990	23	1.035	1.121	1.160	10
	43	1.000	8	1.000	14	1.000	8	1.000	1.068	1.068	27
	44	0.775	55	1.000	15	0.775	63	1.165	1.126	1.312	2
	45	0.797	50	0.902	39	0.885	51	1.050	1.008	1.059	29
	46	0.853	36	0.950	31	0.896	50	1.037	1.065	1.105	20
	47	1.000	9	1.000	16	1.000	9	1.000	0.969	0.969	47
	48	0.946	20	0.953	29	0.993	19	1.092	1.038	1.134	14
	49	0.823	43	0.876	47	0.938	46	0.993	1.147	1.139	13
	50	0.782	53	0.932	34	0.834	60	1.217	1.027	1.250	4
	51	0.826	41	0.968	26	0.854	56	1.087	1.036	1.127	16
	52	0.940	23	1.000	17	0.940	45	0.939	0.942	0.884	61
	53	0.887	28	0.904	38	0.980	33	1.079	1.046	1.128	15
	54	0.853	35	0.863	49	0.988	27	1.119	0.990	1.108	19
	55	0.904	25	0.911	37	0.992	20	1.165	0.985	1.147	12

	56	1.000	10	1.000	18	1.000	10	1.000	1.096	1.096	23
	57	0.743	62	0.883	44	0.845	58	0.971	1.103	1.071	26
	58	0.746	60	0.759	64	0.983	31	0.954	1.024	0.977	46
	AVG	**0.900**	-	**0.947**	-	**0.950**	-	**1.039**	**1.073**	**1.114**	-
Fokida	59	0.873	33	0.902	40	0.970	39	0.925	1.085	1.003	40
	60	0.745	61	1.000	19	0.745	64	0.912	0.996	0.909	56
	61	0.818	44	0.939	33	0.870	55	0.945	0.992	0.937	54
	62	0.978	14	1.000	20	0.978	34	1.035	1.006	1.041	35
	63	0.682	63	0.766	63	0.877	54	1.055	1.053	1.110	18
	64	0.836	38	1.000	21	0.836	59	1.023	0.990	1.013	39
	AVG	**0.895**	-	**0.945**	-	**0.947**	-	**0.983**	**1.020**	**1.002**	-
	AVG	**0.875**	-	**0.923**	-	**0.948**	-	**1.007**	**1.045**	**1.052**	-
	S.D.	0.092	-	0.076	-	0.641	-	0.082	0.082	0.118	-
	Max	1	-	1	-	1	-	1.229	1.415	1.415	-
	Min	0.666	-	0.759	-	0.745	-	0.830	0.901	0.838	-

Source: Author calculation Note: 1. Ranging (R)

From the Table 2, the study conclude that:

The Constant Returns to Scale TE, nine upper secondary schools (14%) (U4, U13, U37, U38, U39, U41, U43, U47, U56) of the 64 were efficient. The scores range from 0.666 to 1.000. The average efficiency score is 0.875. This means that given the quantities of inputs, USSs could produce, on average, more quantities of outputs by 0.125 (or 12.5%).

The Variable Returns to Scale TE (most realistic), twenty one upper secondary schools (32.8%) (U4, U5, U10, U13, U14, U20, U21, U31, U36, U37, U38, U39, U41, U43, U44, U47, U52, U56, U6, U62, U64) of the 64 were efficient. The scores range from 0.759 to 1.000. The average efficiency score is 0.923. This means that given the quantities of inputs, USSs could produce, on average, more quantities of outputs by 0.077 (or 7.7%).

The findings in Table 2 show that in overall efficiency scores under Constant Returns to Scale TE are lower than those estimated under Variable Returns to Scale TE as expected. The SE, ten upper secondary schools (15,6%) (U4, U13, U31, U37, U38, U39, U41, U43, U47, U56) of the 64 were efficient. TE scores range from 0.745 to 1.000. The average efficiency score is 0.948. The findings suggest that schools on average refrain 5.2% from the optimal scale.

The results indicate that, on average, TFP increases at the rate of 5.2% annually, during the investigated period. On examining the components of this productivity change, it becomes evident that this is due to the combination of both positive annual average EC (0.7%) and TC (4.5%) respectively. The findings suggest also that forty two (65.6%) of USSs (U2, U3, U4, U5, U6, U7, U12, U15, U16, U18, U19, U20, U21, U24, U27, U28, U32, U33, U34, U37, U38, U39, U41, U42, U43, U44, U45,U46, U48, U49, U50, U51, U53, U54, U55, U56, U57, U59, U61, U62, U63, U64) have an increase in average TFP (i.e., TFP >1) during the period 2016–19, ranging between 1.3% and 41.5%. On the other hand, the remaining twenty two (34.4%) of USSs (U1, U8, U9, U10, U11, U13, U14, U17, U22, U23, U25, U26, U29, U30, U31, U35, U36, U39, U47, U52, U58, U60) have registered regression in terms of TFP (i.e., TFP < 1) during the same period, ranging between –0.7% and –16.2%.

This finding suggests that it was the poor technology, which needed to be updated, or that best-practice technology has not been used in the management. The worst deterioration in the average TFP occurred in U11 (–16.2%). This productivity loss was due to the technological regression, despite the no alteration in the efficiency change. For example, in U37 there was an average positive increase in TFP over the period 2016–2019 of 41.5% (first-ranked). This was composed of a 0% improvement in efficiency (moving towards the efficient frontier), which is EC and a slight increase of 41.5% due to technological progress (movement in the frontier), which is TC.

The study investigate the performance of USSs by size criterion, dividing them into two groups: USSs, we characterize them as relatively large (28 or 43.8%), if are larger than the average value of 163 students, and USSs, we characterize them as relatively small (36 or 56.2%), if are smaller than the average value of 163 students. The findings of large in size USSs (CRSTE=0.916, VRSTE=0.938, SE=0.976, TFP=1.077) they are higher than small (CRSTE=0.810, VRSTE=0.932, SE=0.869, TFP=1.040).

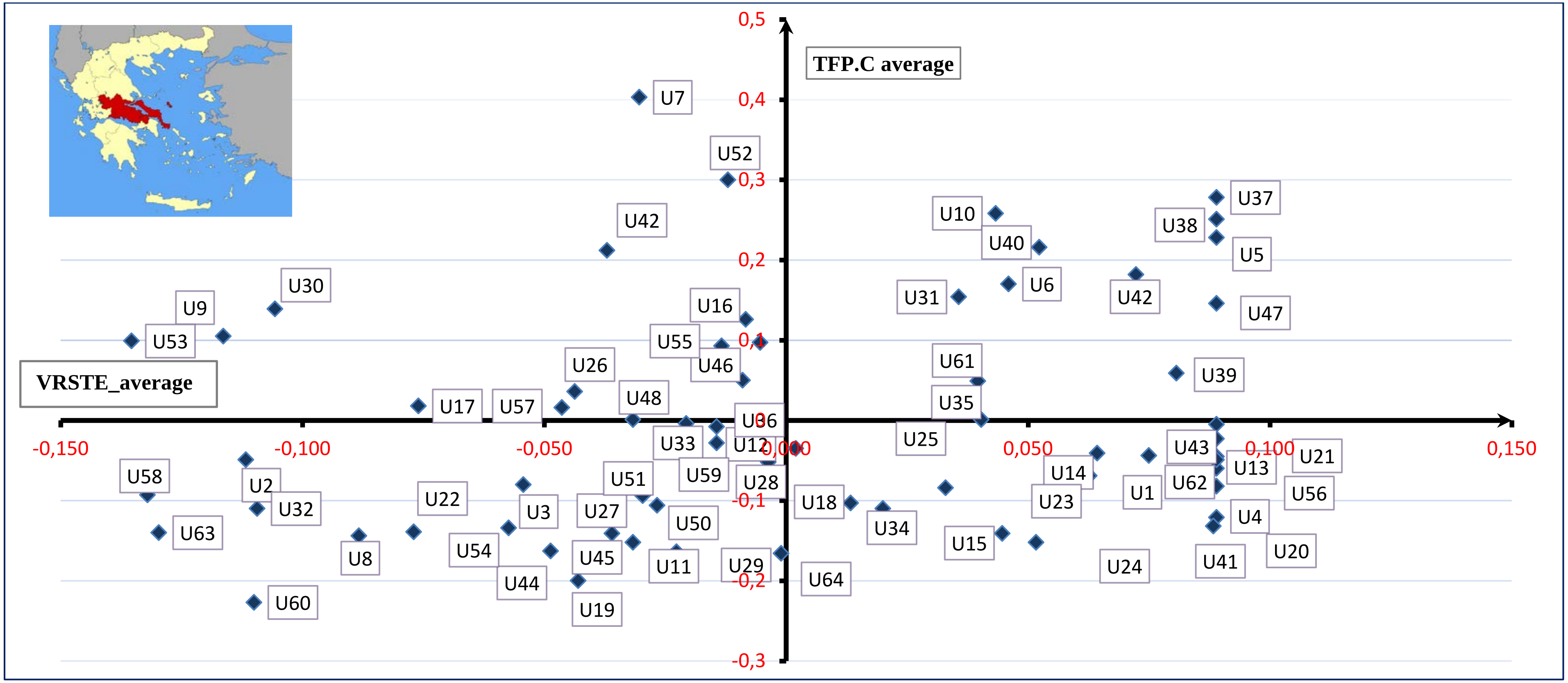
The study investigate the performance of USSs by the year of operation criterion, dividing them into two groups: USSs we characterize them as relatively old (51 or 79.7%), if that operated before 2000, and USSs we characterize them as relatively new (13 or 20.3%), if that operated after 2000.The findings of USSs that were established and started operating before 2000 (CRSTE=0.854, VRSTE=0.939, SE=0.910, TFP=1.052) perform higher than USSs that started after 2000 (CRSTE=0.861, VRSTE=0.927, SE=0.926, TFP=1.044).

The study investigate the performance of USSs by the seat of operation criterion, dividing them into two groups: USSs we characterize them as schools with a Provincial City seat (14 or 21.9%), and USSs we characterize them as schools with a Rural City seat (50 or 78.1%). The findings of USSs that were characterized them as schools with a Provincial City seat (CRSTE=0.947, VRSTE=0.962, SE=0.984, TFP=1.112) perform higher than USSs that characterized them as schools with a Rural City seat (CRSTE=0.854, VRSTE=0.911, SE=0.938, TFP=1.035).

The findings are in line with the efficiency of other tasks for the USSs of other European and non-European countries (Marcebon et al. (2017); Aparicio et al.(2018); Afonso et al.(2018); Dufrechou (2018); Nauzer et al.(2018)).

As a next step, the study classify USSs based on their TE in the year 2016 and the results of the TFP change in the period 2016–19 (see Figure 1). In this figure, the study choose a threshold of about 95% for good TE and we consider that below this value, USSs have scope for improving efficiency.

Figure 1. VRSTE efficiency _average and TFP Change (2016–19)



Source: Author calculation

Figure 1 shows the results image in the four quadrants. If the inputs and outputs change, the arrangement of the USSs in the four quarters will also change. The average of VRSTE of USSs in the region of Central Greece, in the period 2016–19 is 0.923 and the average of TFP change is 1.052, where the beginning of the axes is the point (0.923, 1.052).

- **Quadrant A**: average efficiency value greater than 0.923 and average productivity change value greater than 1.052.The twelve USSs of this category (18.8%) (U5, U6, U10, U31, U35, U37, U38, U39, U40, U42, U47, U61) have improved their efficiency and they represent the benchmarks to be completed by inefficient USSs. This suggests that they should maintain their position by continuing to implement good strategies for their mission. Most of them are schools with above average size and in the capitals of the regional units.

- **Quadrant B**: average efficiency value lower than 0.849 and average productivity change value greater than 1.052. The USS (U7) located in the 'upper-left quadrant' still maintains a good efficiency in managing their resources, in spite of their productivity decline. They have not made an increase in their efficiency during the 2016–19 period. Moreover, if they do not want to lose their current position they have to maintain a rapid growth in the future by maintaining positive technological change.

- **Quadrant C**: average efficiency value lower than 0.923 and average productivity change value lower than 1.052. Problematic USSs (U2, U3, U8, U11, U12, U19, U22, U27, U28, U29, U32, U33, U38, U44, U45, U50, U51, U54, U58, U59, U60, U63) in the bottom-left quadrant are those that have medium-low efficiency in managing their resources in 2018 and then register a decline in productivity from 2016 to 2019. Special attention should be given to those USSs and action is needed to diagnose their problems and improve their efficiency. Lastly, there is scope for improvement in the efficiency (by managing better their resources) and hence the productivity of these USSs. It should be mentioned that the present ranking of USSs concerning their efficiency and productivity, is valid for the specific inputs and outputs, data and time period.

- **Quadrant D**: average efficiency value greater than 0.923 and average productivity change value lower than 1.052. It is interesting to note that eighteen USSs (28.1%) (U1, U4, U13, U14, U15, U18, U20, U21, U23, U24, U25, U34, U41, U43, U56, U59, U62, U64). Special consideration should be given to these USSs and there should be ways of improving their efficiency. These USSs are possible candidates to move to category A if they continue their current strategies of productivity improvement.

On the other hand, the spearman's rho correlation between CRSTE and VRSTE gives a value of 0.803 for 64 USSs with p-value=0.000 indicating that we have a moderately positive correlation (R^2=0.660).

5. Environmental Impact of DMUs on their Efficiency (Tobit analysis)

In recent years the impact of environmental variables on USSs on efficiency has been investigated. In Table 3 presents Empirical Studies.

Table 3: Empirical Studies

No	Authors	Countries reference	Years reference	Number of USSs	Methodology	Environmental Variables
	European countries					
1	Kirjavainen and Loikkanen (1998)	Finland	1997	291	DEA: OO, CRS and VRS, SFA, Tobit boostrap	Z_1, Z_2, Z_3, Z_4
2	Stupnytskyy (1998)	Czech Republic	1997-98	98	DEA.: OO, C.C.R. και B.C.C., Tobit boostrap	Z_2, Z_5, Z_7, Z_8, Z_9, Z_{10}, Z_{11}, Z_{13}
3	Afonso and St.Aubyn (2005)	European Central Bank	2001	25 countries	DEA: OO & IO, Tobit,boostrap	Z_{16}

Source: Author calculation

The environmental variables for the study of VRSTE are presented below.

The number of students in the school (Z_1), the school unit seat, a pseudo variable that receives the value 1 if it is in urban and 0 if it is in semi-rural (Z_2), the year the school started operating, a pseudo variable that receives the value 1 if established after 2000 and 0 if established before 2000 (Z_3), student-teacher ratio (Z_4), GDP per capita, per Regional Unit (Z_5), VRSTE (Z_6), ui: the disturbing term.

The estimation of this variable is achieved using a function of the following form:

$$T.E._i = \alpha + b_1 Z_1 + b_2 Z_2 + b_3 Z_3 + b_4 Z_4 + b_5 Z_5 + ui \quad (7)$$

In Table 4 we present, the results of the OLS (7), and in Table 5 we present, the results of the Tobit Analysis for the average values of environmental variables for the period 2016-19.

For DEA VRS (OO), the values of $R^2 = 0.222$ and Adj.R^2 are satisfactory, since the data are layered and show a satisfactory interpretive capacity of the equation. The findings of Table 4 show that only the unit seat of USSs has had positive and statistically significant effect on VRSTE.

A "Tobit estimation is inappropriate, but the OLS regression is a consistent estimator because the efficiency scores generated by DEA models are not generated via a censoring process, but are instead fractional data" (McDonald , 2009), as quoted in Guan and Chen (2012).

The results are further interpreted using the Tobit model and the results are given in Table 5 shows that only the unit seat of USSs has had positive and statistically significant effect on VRSTE. For the data analysis we use the STATA® Statistics / Data Analysis 14.2 SE software package (1985-2015 Stata Corp LLC, USA).

Table 4. OLS model

Variables	**Coefficient**	**t**	**95% C.I.**
Z1	-0.00014	-0.91	[-0.00048, 0.000178]
	(0.367)		
	n.s.		
Z2	0.0737	**2.87**	[0.02235, 0.125]
	(0.006)		
	*		
Z3	-0.0395	-1.82	[-0.0832, 0.004]
	(0.075)		
	n.s.		
Z4	0.00797	1.38	[-0.00362, 0.01957]
	(0.174)		
	n.s.		
Z5	-1.37e-06	-0.48	[-7.11e-06, 4.36e-06]
	(0.663)		
	n.s.		
cons	0.8687	12.76 1.005]	[0.7324,
	(0.000)		
	*		
R^2	**0.222**		
Adj. R^2	0.154		
F(6,57)	3.30		

Table 5. Tobit model

Variables	**Coefficient**	**t**	**95% C.I.**
Z1	-0.000159	-1.01	[-0.0004757, 0.0001569]
	(0.317)		
	n.s.		
Z2	0.07578	**3.05**	[0.0261245, 0.1254455]
	(0.003)		
	*		
Z3	-0.04224	-2.00	[-0.0845846, 0.0000962]
	(0.051)		
	n.s.		
Z4	0.008242	1.47	[-0.0029502, 0.0194345]
	(0.146)		
	n.s.		
Z5	-1.28e-06	-0.46	[-6.82e-06, 4.25e-06]
	(0.644)		
	n.s.		
cons	0.86596	13.18	[0.7344433, 0997471]
	(0.000)		
	*		
LR chi2(6)	16.29		
Pseudo R^2	-0.1131		
Log likelihood	80.1278		
/sigma	0.066537		[0.05462, 0.078445]

Source: Author's calculation

Notes: 1. * level of statistical significance 5 %, n. s.: non-significant,

2. Numbers in parentheses show the p- value(P>|t|),

3. 95% Conf. Interval (95% C.I.)

6. Concluding Remarks and Policy Recommendation

The results from empirical analysis and discussion reveal that:

First, the efficiency CRSTE varies in interval [0.666 –1.000], the average efficiency is estimated at 0.875. This means that given the quantities of inputs, Upper Secondary Schools could produce, on average, more quantities of outputs by 0.125 (or 12.5%). The efficiency VRSTE varies in interval [0.759 –1.000], the average efficiency is estimated at 0.923. This means that given the quantities of inputs, Upper Secondary Schools could produce, on average, more quantities of outputs by 0.077 (or 7.7%).The SE varies in the interval [0.745 – 1.000] and the average is 0.948 (94.8%).The findings suggest that schools on average refrain 5.2% from the optimal scale. There is a waste of resources if there is a difference between the actual values and the potential values in the outputs.

The findings are in line with the efficiency of other tasks for the USSs of other European and non-European countries. Second, the TFP change has risen by an annual average of 5.2% relative to the base year 2016. This is due to a 0.7% improvement in efficiency (EC) and a 4.5% increase in technological progress (TC).

Third, the findings of large in size USSs (CRSTE=0.916, VRSTE=0.938, SE=0.976, TFP=1.077) they are higher than small (CRSTE=0.810, VRSTE=0.932, SE=0.869, TFP=1.040).The findings of USSs that were established and started operating before 2000 (CRSTE=0.854, VRSTE=0.939, SE=0.910, TFP=1.052) perform higher than USSs that started after 2000 (CRSTE=0.861, VRSTE=0.927, SE=0.926, TFP=1.044). The findings of USSs that were characterized them as schools with a Provincial City seat (CRSTE=0.947, VRSTE=0.962, SE=0.984, TFP=1.112) perform higher than USSs that characterized them as schools with a Rural City seat (CRSTE=0.854, VRSTE=0.911, SE=0.938, TFP=1.035).This finding suggests that it was the poor technology, which needed to be updated, or that best-practice technology has not been used in the management. The rate of TFP change is satisfactory and the higher of the two components is EC.

Fourth, the best performances are the comments, as shown in Figure 1 in the 1st quarter. The twelve USSs (U5, U6, U10, U31, U35, U37, U38, U39, U40, U42, U47, U61) of this category have improved their efficiency and they represent benchmarks to be completed by inefficient USSs. This suggests that they should maintain their position by continuing to implement good strategies for their mission.

Fifth, from the environmental variables that were examined, it was found only the unit seat of USSs has had positive and statistically significant (5%) effect on VRSTE.

Proposal:

First, planning and implementing a policy of unifying school units, and especially of small schools, in the capitals of the Regions, despite the reactions of local communities and teachers they may encounter.

Second, the establishment of an observatory in the Region and throughout the country to monitor the performance of upper secondary schools annually and whenever they deem it necessary to intervene to make improvements. Observatory data must be made available to policy makers. Further, merging some upper secondary schools to improve results over the coming years is another possible solution. As the secondary school-age population is expected to decline in the medium term, schools should also consider pooling their resources by jointly hiring and sharing new teachers. Therefore, the implication of efficiency scale can serve as an indicator for all upper secondary schools on a national level and hence the set up of a benchmark is necessary. Moreover, the suitable reallocation of resources would increase the efficiency scores of inefficient schools.

References

Adkins, L.C. and Moomaw, R.L.(2005). On the Determinants of Technical Efficiency in Oklahoma Schools: A Stochastic Frontier Approach, *Oklahoma State University*. https://business.okstate.edu/site-files/docs/economy/school3.pdf

Afonso, A., & Aubyn, M. S. (2006). Cross-country efficiency of secondary education provision: A semi-parametric analysis with non-discretionary inputs, *Economic Modelling*, 23(3), 476– 491. https://www.sciencedirect.com/science/article/pii/S0264999306000149

Afonso, A.†, Ayadi, M., Ramzi S.(2018). Assessment of efficiency in basic and secondary education in Tunisia: a regional analysis, *School of Economics and Management Technical University of Lisbon*, WP 06/2013/DE/UECE.

https://www.sciencedirect.com/science/article/pii/S0738059316302048

Agasisti, T. (2014), "The efficiency of public spending on education: An empirical comparison of EU countries", *European Journal of Education*, 49(4), 543- 557.

https://mpra.ub.uni-muenchen.de/85152/1/MPRA_paper_85152.pdf

Aparicio, J., Cordero, M.J., Gonzalez, M., Lopez-Espin, J.J. (2018). Using non-radial DEA to access school efficiency in a cross-country perspective: An empirical analysis of OECD countries, *Omega*,79, 9-20. http://dspace.umh.es/bitstream/11000/5279/1/14-Aparicio_etal_Omega2018.pdf

Assaf, A. (2011). A fresh look at the productivity and efficiency changes of UK airlines,

Applied Economics, 43(17), 2165-2175.

https://www.tandfonline.com/doi/pdf/10.1080/00036840903085071?needAccess=true

Baird, A., Haynes, J., Massey, F., & Wild, R. (2010). Public service output, input and productivity: Education. Newport: UK Centre for the Measurement of Government Activity.

https://link.springer.com/article/10.1057/elmr.2011.18.pdf

Boser, U. (2011). Return on educational investment: A district-by-district evaluation of U.S. educational productivity. Washington, DC: Center for American Progress.

https://eric.ed.gov/?id=ED535853.pdf

Callahan, R. (1962). Education and the cult of efficiency. Chicago, IL: The University of Chicago Press.

Caves, D., Christensen, L. and Diewert, E. (1982). The economic theory of index numbers and the measurement of input, output and productivity, *Econometrica*, 50(6), 1393–1414.

https://www.jstor.org/stable/1913388?seq=1.pdf

Charnes, A., Cooper, W.W. and Rhodes, E. (1978). "Measuring the efficiency of decision making units", *European Journal of Operational Research*, 2, 429-44.

https://www.sciencedirect.com/science/article/abs/pii/0377221778901388.pdf

Chen, F., Liu, Z. and Kwch, Q. (2014). Intellectual capital and productivity of Malaysian general insurers, *Economic Modelling*, 36(1), 413–420.

https://www.sciencedirect.com/science/article/pii/S0264999313004343

Coelli, T. (1996). A Guide to DEP Version 2-1: A Data Envelopment Analysis A Computer Program, CEPA, Australia. http://www.owlnet.rice.edu/~econ380/DEAP.PDF

ELSTAT, (2014, 2018, 2019) www.statistics.gr

Fare, R., Grosskopf, S. Norris, M. and Zhang, Z.(1994). Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries, *American Economic Review*, 84(1), 66-83.

https://ideas.repec.org/a/aea/aecrev/v84y1994i1p66-83.html.pdf

Guthrie, J., & Ettema, E. (2012). Public schools and money: Strategies for improving productivity in times of austerity. Education Next, 12(4), 18-23.

https://go.gale.com/ps/i.do?id=GALE%7CA303757982&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=15399664&p=AONE&sw=w&userGroupName=anon%7Ed4064140.pdf

Hanushek, E. (2003). The failure of input-based schooling policies. Economic Journal, 113(485), F64-F98.
http://hanushek.stanford.edu/sites/default/files/publications/Hanushek%202003%20EJ%20113%28485%29.pdf
Hanushek, E and Ettema, E.(2017). Defining Productivity in Education: Issues and Illustrations, The American Economist, 62(2), 165–183.
http://hanushek.stanford.edu/sites/default/files/publications/Hanushek%2BEttema%202017%20AmericanEconomist%2062%282%29.pdf
Karatheodoros, A., Staikouras, C. & Tsamadias, C. (2016).The effect of R&D Expenditure on Innovationin the Regions of Greece, Education, Lifelong Learning, Research and Technological Development, Innovation and Economics, Greece, 2, 701-712.
https://www.researchgate.net/publication/337011884_The_Effect_of_RD_Expenditure_on_Innovation_in_the_Regions_of_Greece
Karatheodoros, A., Tsamadias, C.& Pegkas, P. (2019).The effects of formal educations' levels on regional economic growth in Greece over the period 1995–2012, *Review of Regional Research* , 39, 91–111. https://link.springer.com/article/10.1007/s10037-018-0128-0
Kirjavainen, T., & Loikkanen, H. A. (1998). Efficiency Differences of Finnish Senior Secondary Schools: An Application of DEA and Tobit Analysis. Economics of Education Review, 17(4), Than Public Schools? Evidence from Tanzania, *Education Economics*, 9(2), 145-172.
https://www.sciencedirect.com/science/article/pii/S0272775797000484
Kyratzi, P., Tsamadias, C., & Giokas, D. (2015). Measuring the efficiency and productivity change of Greek universities over the time period 2005-2009, *International Journal of Education Economics and Development*, 6(2), 111-129.
https://ideas.repec.org/a/ids/ijeded/v6y2015i2p111-129.html
Malmquist, S. (1953). Index numbers and indifference surfaces, Trabajos de Estatistica, 4, 209–242. https://link.springer.com/article/10.1007/BF03006863
Manceb, M-J. & Bandrés, E. (2006). Efficiency Evaluation in Secondary Schools: the key role of model specification and of ex post analysis of results, *Education Economics*, Ml, 7(2), 131-152. https://www.tandfonline.com/doi/pdf/10.1080/09645299900000012?needAccess=true
Maragos,E.K. and Despotis, D.K. (2016). Evaluation of High School Performance: A Data Envelopment Analysis Approach, *University of Piraeus*, Piraeus, Greece.
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.650.3298&rep=rep1&type=pdf
Margaritis, S., Tsamadias, P., Argyropoulos, E.(2020). Investigating the Relative Efficiency and Productivity Change of Upper Secondary Schools: The case of Schools in the region of Central Greece, *Journal of the Knowledge Economy* (in press(2020)).
Margaritis, S., Pallas, D. (2019), "Annual Expenditures per Student of General Secondary Education: The Case of the Regional Unit of Central Greece, in the Year 2017 2, Proceedings of the 2nd Panhellenic Scientific Conference International Participation "*Greece - Europe 2020: Education, Lifelong Learning, Research, New Technologies, Innovation and Economics*", Lamia, September 28,29,30, 2018, INOEK, ECB, 2 , 279-292.
Nahar, M. & Arshad, M. (2007). How Efficient is Malaysia's Secondary Education?, Bagaimanakah Keberkesanan Pendidikan Menengah di Malaysia.
http://www.ukm.my/jurfpend/jurnal38/3MOHDNAHARMOHDARSHAD.pdf
Nahar, M. & Arshad, M. (2014). Efficiency of Secondary Education in Selected OIC Countries, *Global Education Review*, 1(4), 53-75. https://files.eric.ed.gov/fulltext/EJ1055159.pdf
Nauzeer, S., Jaunky, V.C., Ramesh, V.(2018). Efficiency Assessment of Secondary Schools in Mauritius: A DEA Approach, *International Journal of Enviromental & Science Education* e-ISSN: 1306-3065 2018, 13(10), 865-880.
https://pdfs.semanticscholar.org/99c4/33c4872ab4454d3ab6047002fd921550d408.pdf?_ga=2.214586711.1319718135.1572264708-1162147583.1572264708
Nghiem, S., Nguyen, H. and Connelly, L. (2014). The Efficiency of Australian Schools: Evidence from the NAPLAN Data 2009-2011, MPRA Paper, no. 56231.
https://mpra.ub.uni-muenchen.de/56231/1/MPRA_paper_56231.pdf
Norman, M. and Stocker, B. (1991). Data Envelopment Analysis: the Assessment of Performance, Wiley, Chichester.

http://deazone.com/en/norman-m-and-b-stoker-1991-data-envelopment-analysis-the-assessment-of-performance-new-york-usa-wiley.pdf

OECD (2013). Education at a Glance 2013: OECD Indicators, OECD Publishing.
http://www.oecd.org/education/eag2013%20(eng)--FINAL%2020%20June%202013.pdf

OECD (2018). Education at a Glance 2018: OECD Indicators, OECD Publishing, Paris.
https://www.oecd-ilibrary.org/docserver/eag-2018-en.pdf?expires=1572288880&id=id&accname=guest&checksum=BC3C2A33B95AC8989DD7C5C7F3590B5B

Oliveira, M. and C. Santos (2006). Assessing school efficiency in Portugal using FDH and bootstrapping, *Journal Applied Economics*, 37(8), 957-968.
https://www.tandfonline.com/doi/full/10.1080/00036840500061095

Sammons, P., Nuttall, D. and Cuttance, D. (1993). "Differential school effectiveness: results from a reanalysis of the Inner London Authority's junior school project data", *British Educational Research Journal*, 19, 381-405.
https://www.tandfonline.com/doi/abs/10.1080/0141192930190407.pdf

Soteriou, A. C., Karahanna, E., Papanastasiou, C., & Diakourakis, M. S. (1998). Using DEA to evaluate the efficiency of secondary schools: the case of Cyprus, *International Journal of Educational Management*, 12(2), 65–73.
https://pdfs.semanticscholar.org/6661/f93e48f8cd21faa0d333d04c9fdbee23fa6e.pdf

Sotiriadis, D., Menexes, G., Tsamadias, C. (2015). Investigating the Efficiency of Senior Secondary Schools:Evidence from Schools in the Greek region of Central Macedonia, *International Journal of Business and Economic Sciences Applied Research*, 11(2), 36-43.
https://www.researchgate.net/publication/328343643_Investigating_the_Efficiency_of_Senior_SEcondarySchools_Evidence_from_Schools_in_the_Greek_region_of_Central_Macedonia_International_Journal_of_Businessand_Economic_Sciences_Applied_Research_Vol_11_

Stupnytskyy, O. (1998). Secondary schools efficiency in the Czech Republic, *Center for Economic Research and Graduate Education*, Prague, Czech Republic. http://praha.vupsv.cz/fulltext/ul_420.pdf

Sutherland, D., Price, R. & Gonand, F. (2010). Improving Public Spending Efficiency in Primary and Secondary Education, *Economic Studies*.
https://www.researchgate.net/publication/227347385_Improving_public_spending_efficiency_in_primary_and_secondary_education

Thanassoulis, E. and Dunstan, P. (1994). "Guiding schools to improved performance using data envelopment analysis: an illustration with data from a local educational authority", *Journal of the Operational Research Society*, 45, 1247-62.
https://link.springer.com/article/10.1057/jors.1994.198.pdf

Tsamadias, C. and Kyratzi, P.(2014). Efficiency and productivity of Greek higher technological educational institutions:an assessment over the period 2005–2009, *Int. J. Education Economics and Development, 5(3).* https://ideas.repec.org/e/pts145.html

Tsamadias, C. & Prontzas, P. (2012). The effect of education on economic growth in Greece over the 1960–2000 period, *Education Economics*, 20(5), 522-537.
https://www.tandfonline.com/doi/pdf/10.1080/09645292.2011.557906?needAccess=true

Worthington, A. (2000).Technical efficiency and technological change in Australian building societies, Abacus, 36(2), 180–197. https://core.ac.uk/download/pdf/10874489.pdf

Appendix A

Table I. Technical and Scale Efficiencies of USSs(2016–2019)

Region	**Output-oriented**									
	Technical Efficiency-Scale Efficiency									
	DMU	2016-17			2017-18			2018-19		
		CRS	VRS	SE	CRS	VRS	SE	CRS	VRS	SE
Voiotia	1	1	1	1	0.964	0.996	0.968	0.893	0.9	0.992
	2	0.808	0.822	0.983	0.739	0.739	1	0.981	0.985	0.996
	3	0.827	0.858	0.964	0.824	0.835	0.988	0.773	0.807	0.958
	4	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	0.997	1	0.997
	6	0.815	0.87	0.936	1	1	1	0.822	0.901	0.912
	7	0.577	0.604	0.956	1	1	1	0.872	0.942	0.926
	8	0.798	0.804	0.993	0.749	0.863	0.868	0.695	0.752	0.924
	9	0.835	0.84	0.994	0.868	0.872	0.996	0.725	0.731	0.991
	10	0.872	1	0.872	0.879	1	0,879	0.735	1	0.735
	11	1	1	1	0.638	0.708	0.901	0.688	0.785	0.877
	12	0.746	0.857	0.87	0.852	0.912	0.934	0.715	0.864	0.828
	13	1	1	1	1	1	1	1	1	1
	14	1	1	1	1	1	1	0.919	1	0.919
	AVG	**0.877**	**0.904**	**0.969**	**0.894**	**0.923**	**0.967**	**0.844**	**0.905**	**0.933**
Evia	15	1	1	1	0.912	0.914	0.998	1	1	1
	16	0.842	0.883	0.954	1	1	1	1	1	1
	17	0.711	0.711	1	0.927	0.945	0.98	0.652	0.672	0.969
	18	0.563	0.775	0.726	0.823	0.864	0.953	0.611	0.702	0.871
	19	0.764	0.81	0.944	0.833	0.833	0.999	0.845	0.868	0.974
	20	0.895	1	0.895	1	1	1	0.944	1	0.944
	21	0.828	1	0.828	1	1	1	1	1	1
	22	0.951	0.951	0.999	0.759	0.767	0.99	0.785	0.818	0.96
	23	1	1	1	1	1	1	0.965	0.968	0.996
	24	0.885	0896	0.987	1	1	1	0.86	0.865	0.995
	25	0.853	0.855	0.998	1	1	1	0.791	0.812	0.974
	26	0.753	0.766	0.983	1	1	1	0.629	0.635	0.991
	27	0.823	0.829	0.993	0.872	0.877	0.995	1	1	1
	28	0.683	0.688	0.993	1	1	1	0.92	0.944	0.974
	29	1	1	1	0.856	0.867	0.988	0.778	0.791	0.983
	30	0.788	0.797	0.989	0.886	0.888	0.998	0.714	0.756	0.945
	31	1	1	1	1	1	1	1	1	1
	32	0.796	0.816	0.975	0.796	0.8	0.995	0.822	0.824	0.998
	33	0.858	0.912	0.94	0.893	0.913	0.978	0.943	1	0.943
	34	0.903	1	0.903	0.84	0.934	0.9	0.904	1	0.904
	35	0.826	0.914	0.903	0.931	1	0.931	0.571	0.708	0.805

	36	0.952	1	0.952	0.706	1	0.706	0.82	1	0.82
	AVG	**0.849**	**0.891**	**0.953**	**0.911**	**0.936**	**0.973**	**0.843**	**0.880**	**0.957**
Evry tania	37	1	1	1	1	1	1	1	1	1
	AVG	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Fthiotida	38	1	1	1	1	1	1	1	1	1
	39	1	1	1	1	1	1	1	1	1
	40	1	1	1	1	1	1	0.848	0.852	0.995
	41	1	1	1	1	1	1	1	1	1
	42	0.934	0.964	0.969	1	1	1	1	1	1
	43	1	1	1	1	1	1	1	1	1
	44	0.737	1	0.737	0.587	1	0.587	1	1	1
	45	0.777	0.841	0.923	0.758	0.918	0.826	0.857	0.947	0.905
	46	0.751	0.88	0.853	1	1	1	0.808	0.97	0.834
	47	1	1	1	1	1	1	1	1	1
	48	0,839	0,858	0,978	1	1	1	1	1	1
	49	0.743	0.763	0.974	0.994	1	0.994	0.733	0.866	0.846
	50	0.656	0.872	0.752	0.719	0.923	0.779	0.972	1	0.972
	51	0.773	0.904	0.855	0.792	1	0.792	0.914	1	0.914
	52	1	1	1	0.939	1	0.939	0.881	1	0.881
	53	0.859	0.88	0.976	0.801	0.832	0.963	1	1	1
	54	0.798	0.814	0.98	0.762	0.774	0.985	1	1	1
	Table I:(continue)									
	Table I:(continue)									
	55	0.727	0.734	0.99	1	1	1	0.986	1	0.986
	56	1	1	1	1	1	1	1	1	1
	57	0.711	0.775	0.918	0.849	0.968	0.878	0.67	0.907	0.739
	58	0.776	0.802	0.968	0.755	0.767	0.984	0.707	0.708	0.998
	AVG	**0.867**	**0.913**	**0.949**	**0.907**	**0.963**	**0.942**	**0.926**	**0.966**	**0.958**
Fokida	59	0.921	0.95	0.97	0.911	0.96	0.949	0.787	0.795	0.99
	60	1	1	1	0.403	1	0.403	0.832	1	0.832
	61	0.768	1	0.768	1	1	1	0.686	0.816	0.842
	62	0.934	1	0.934	1	1	1	1	1	1
	63	0.655	0.72	0.91	0.662	0.749	0.844	0.729	0.83	0.878
	64	0,74	1	0.74	0.992	1	0.992	0.775	1	0.775
	AVG	**0.836**	**0.945**	**0.887**	**0.828**	**0.952**	**0.865**	**0.802**	**0.907**	**0.886**
	AVG	**0.860**	**0.906**	**0.949**	**0.898**	**0.944**	**0.951**	**0.868**	**0.918**	**0.945**
	S.D.	0.121	0.103	0.074	0.129	0.839	0.105	0.128	0.107	0.072
	Max	1	1	1	1	1	1	1	1	1
	Min	0.563	0.074	0.726	0.403	0.708	0.403	0.571	0.635	0.735

Source: Author calculation (Appendix) Note: 1. Ranging (R)

Note: Tables with the prices of the inputs and outputs of the upper secondary schools are available.