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Measuring Technical Efficiency of Health Centers in Greece: A Data Envelopment Analysis Application for the Primary Health System of Greece

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Abstract:

Purpose: *In this paper Data Envelopment Analysis will be applied to investigate the technical efficiency of 196 Heath Centers in Greece. The analysis is referred at their efficiency in the year 2018.*
Design/Methodology/Approach: *Data were collected by the Ministry of Health and were analyzed by performing quality tests to ensure validity and avoid bias. The method used is the non-parametric Data Envelopment Analysis and more specifically the input-oriented, one-stage VRS model. Tobit regression analysis was performed to analyze the effect of the Health Region in the efficiency of the Health Centers.*
Findings: *The results of the paper indicate the efficient Health Centers in Greece, which construct the efficient frontier. The inefficient Health Centers in Greece lie beneath the efficient frontier. Moreover, the 196 Health Centers included in the research were classified depending on the Health Region they belong to, to investigate the effect of the Health Regions in the efficiency measured.*
Practical Implications: *This study highlights the importance of measuring the efficiency of Primary Health Care. Taking into consideration the contribution of Health Centers to the National Health System, the results may be used as a guide for improvements for the efficiency of the Health Centers.*
Originality/Value: *The research focus on the underestimated field of Primary Health Care and its importance. The application of Data Envelopment Analysis combined with the Tobit Regression Model reveals a new approach for measuring the efficiency.*

Keywords: *Health Care's Efficiency, Data Envelopment Analysis, Tobit Regression Model, Primary Health Care*
JEL codes: *C14, C32, C52, I10.*
Paper Type*: Research Paper*

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1. Introduction

Primary Health Care is an essential compound of the National Health System of every country. The World Health Organization is constantly highlighting the importance of Primary Health and its contribution to the overall health of the population in every country. Moreover, a strategy focusing on the reinforcement of primary health care was declared in Alma-Ata in 1978. Attempts have been made since then to monitor primary health care in every country and Greece was included (World Health Organization, 2017). Health Centers are one of the major compounds of Primary Health System and by attempting to evaluate their efficiency important information would be given for Primary Health Care in Greece. Nowadays, Greece has 207 Health Centers 196 of which were submitted for the analysis of this paper. The other 11 Health Centers were excluded owing to the lack of data to avoid random estimation and possibility of bias.

Considering the case of Greece, health care expenditures are higher than the average expenditures of OECD countries. This is mostly due to the insufficient primary health care system and the delivery of health care services (Androutsou, Geitona, and Yfantopoulos, 2011).

The above is amplified by the dissatisfaction of people receiving the health services, which combined with the lack of health promotion, disease prevention and rehabilitation, indicates problematic administration, low productivity, and distribution problems on health services. One of the main factors is the inadequacy of primary health care, highlighting the importance of its contribution to the overall Health Care System and the efforts that should have been made, to strengthen it (Tountas, Karnaki, and Pavi, 2002; Economou and Giorno, 2009; Lionis *et al.,* 2009).

2. Data Envelopment Analysis

Efficiency can be measured by using parametric and non-parametric approaches. The advantage of the non-parametric approach is that the functional form need not be known. The most used non-parametric approach is Data Envelopment Analysis (Dimas, Goula, and Soulis, 2012). Moreover, through Data Envelopment Analysis multiple inputs and outputs can be handled as well as used with any input-output measurement. In healthcare efficiency measurement studies, DEA is the dominant method to apply (Worthington, 2004).

Modern efficiency was first introduced by Farrell (1957), who based on Debreu (1951) and Koopmans (1951) and attempted to measure efficiency of a firm considering multiple inputs. Farrell analyzed that efficiency consists of two components, technical efficiency, and allocative efficiency, and these two combined give the measure of economic efficiency (Farrell, 1957). The method applied in this paper is Data Envelopment Analysis (DEA), first introduced by Charnes, Cooper, and Rhodes, (1978). Data Envelopment Analysis is a method using liner programming to construct a non-parametric frontier involving all the Decision-Making Units (DMU's) and their data translated as inputs and outputs, measuring their efficiencies. The frontier includes all the efficient DMU's while beneath the frontier are placed all the inefficient ones.

Technical efficiency measured by DEA, refers to the maximum production of outputs by the DMU's given a certain number of inputs used or to the minimum quantities of inputs used by the DMU's to obtain a certain level of outputs (Charnes, Cooper, and Rhodes, 1978). Regarding the above, technical efficiency depends on the input-output ratio of productivity (Hollingsworth, Dawson, and Maniadakis, 1999) and can be decomposed into pure technical efficiency and scale efficiency. In order to achieve the decomposition of the efficiency two methods of DEA have to be implemented, the first one based on the assumption of constant return to scale (CRS) and the second one based on the assumption of variable return to scale (VRS) (Banker, Charnes, and Cooper, 1984). CRS method is applied when all DMU's are operating at an optimal level while, when there is imperfect competition, VRS method is applied considering that not all DMU's are operating at an optimal level, assuming that there are scale efficiencies (SE).

The mathematical conception of DEA is analyzed briefly below, since the aim of this paper is to evaluate the efficiency of the Health Centers in Greece. Extended Mathematical analysis of DEA method and how it is employed is presented in the relevant literature. In the mathematical model of CRS, it is assumed that there are N DMU's, using K inputs to produce M outputs. Considering the above there are two matrixes, K*N input matrix and M*N output matrix, representing the data of all DMU's. In order to measure the efficiency of the DMU's the literature considers the calculation of the ratio of all outputs over all inputs. The mathematical linear programming problem is represented:

$\max_{u,v} (u'y_i/v'x_i)$,

subject to:
$u'y_j/v'x_j \leq 1$, $j=1,2,\ldots\ldots,N$,
$u,v \geq 0$,

Where u is an M*1 vector of output weights and v is a K*1 vector of input weights. The aim is to calculate the values for u and v, maximizing the efficiency of the DMU's. As it is observed there is a constraint indicating that all efficiency measures must be placed inside the closed interval of (0,1).

In order to avoid the infinite solutions of the above mathematical formula a new constraint, $v'x_i=1$, was imposed:

$\mathrm{Max}_{\mu,\nu} (\mu'y_i)$,
subject to:

$v'x_i=1$,
$\mu'y_j-v'x_j\leq 0$, $j=1,2,\ldots,N$,
μ, $\nu\geq 0$.

It is obtained that a notation change from u,v to μ,ν transforms the first mathematical linear programming problem to a multiplier form.

By applying the duality in linear programming, an equivalent form is presented:

$\text{Min}_{\theta,\lambda}\ \theta$,

subject to:
$-y_i+Y\lambda\geq 0$,
$\theta x_i-X\lambda\geq 0$,
$\lambda\geq 0$.

Symbol θ is a scalar and λ is a N*1 vector of constants. The above model has fewer constraints, and it can be applied more easily. Symbol θ represents the efficiency of the DMU's and their values are inside the closed interval of (0,1). Values of 1 impose that the DMU's are operating at the optimum efficiency level while values less than 1 impose inefficiencies. The mathematical function above must be solved N times for every DMU (Coelli, 1996).

As already mentioned, the CRS model assumes constant return to scale based that all DMU's are operating at an optimal scale. On the contrary, VRS model overpasses this assumption considering that there might be efficiencies of scale. By adding one more constraint to the CRS model SE effects is calculated and technical efficiency is decomposed to pure technical efficiency and scale efficiency for each DMU. The mathematical function transform as follows:

$\text{min}_{\theta,\lambda}\ \theta$,

subject to:
$-y_i+Y\lambda\geq 0$,
$\theta x_i-X\lambda\geq 0$,
$N1'\lambda=1$
$\lambda\geq 0$.

N1 representing an N*1 vector of one's (Coelli, 1996).

3. Input and Output Orientations

There are two orientations in the literature for the DEA method, input orientation and output orientation. Input orientation describes the minimum number of inputs required to achieve the level of outputs produced, while output orientation describes the maximum amount of outputs that can be achieved through the combination of various quantities of inputs (Seiford and Thrall, 1990). In input orientation outputs produced remain constant (minimize inputs used) while in output orientation inputs used remain constant (maximize outputs produced), in an attempt to perform the linear programming approach of DEA to estimate the frontier and the efficiencies of the Heath Centers.

4. Data

Attempt has been made in this paper to include all Health Centers of Greece although some of them were facing lack of data, so they were excluded to avoid random estimation and possibility of bias. Therefore, 196 Health Centers were submitted to conduct the DEA analysis and measure their efficiency.

The Heath Centers contributing the sample are homogenous, since they represent the majority of the Health Centers of Greece (94,68% of the total), distributed across the seven Health Regions of Greece. Moreover, they use the same categories of inputs producing the same categories of outputs, differencing each other only through the amounts been used. This makes them comparable and validates this paper to measure their relative efficiencies. Also, there must be noted that according to the literature, the requirements to perform DEA were satisfied, ensuring meaningful results. These requirements include that at least one DMU of the sample consumes and produces every input and output and also that each DMU of the sample consumes at least one input and produces at least one output (Grosskopf, 2002; Färe and Grosskopf, 2004). Including the majority of the Health Centers in Greece discriminatory power between the efficient and inefficient units is also succeeded (Sarkis and Talluri, 2002; Sarkis, 2007).

There were 13 outputs included in the analysis of this paper to measure the efficiency and they represent the total health services provided by the Health Centers. More specifically, the outputs used by each Health Center were:

1. Total number of “Chronic disease cases” faced – Output1;
2. Total number of “Emergencies” faced – Output2;
3. Total number of “Nursing Operations” employed – Output3;
4. Total Number of “Microsurgeries” employed – Output4;
5. Total Number of “Dental Procedures” employed – Output5;
6. Total Number of “Regular Incidents” faced – Output6;
7. Total Number of “Urgent Incidents” faced – Output7;
8. Total Number of “Transcriptions” given – Output8;
9. Total Number of “Bio pathological and Laboratory exams” applied – Output9;
10. Total Number of “Other exams” applied, which are not included in the categories above – Output10;
11. Total Number of “Test Mantoux” applied – Output11;

12. Total Number of “Vaccinations for kids and teenagers” applied – Output12;
13. Total Number of “Vaccinations for adults” applied – Output13.

In contrast, there were 4 inputs used and they represent the total personnel employed and occupied at the Health Centers:

1. Total “Number of Doctors” employed – Input1;
2. Total “Number of Managers” employed – Input2;
3. Total “Number of non-medical staff” employed – Input3;
4. Total “Number of Nursing Staff” employed – Input4;

All inputs and outputs used in order to conduct this paper are referred in the year 2018. Table 1 shows the descriptive statistics of all inputs and outputs used to evaluate the efficiencies of the 196 Health Centers. In Table 1, descriptive statistics shows the minimum and the maximum values of inputs and outputs observed. Also, the Mean and the Standard Deviation of every input and output is presented.

Table 1. *Descriptive Statistics for inputs and outputs*

	N	Minimum	Maximum	Mean	Std. Deviation
Chronic Disease cases	196	0	47697	4794,07	8186,230
Emergencies	196	0	20131	1708,84	2054,894
Nursing operations	196	0	28457	4285,74	4291,017
Microsurgeries	196	0	2968	354,13	500,518
Dental Procedures	196	0	11022	1122,47	1736,334
Regular incidents	196	0	69195	12969,63	9889,944
Urgent incidents	196	0	46759	9122,02	8306,569
Transcriptions	196	0	56313	11061,94	9079,243
Bio pathological and laboratory exams	196	0	160149	15181,26	23239,509
Other exams	196	0	26984	4016,07	4421,843
Test Mantoux	196	0	640	42,37	86,752
Vaccinations applied for kids and teenagers	196	0	2754	530,15	651,199
Vaccinations applied for adults	196	0	3948	545,35	641,971
Number of Doctors	196	1	37	10,11	7,359
Number of Managers	196	1	12	2,59	1,905
Number of Non-medical staff	196	1	30	7,72	4,673
Number of Nursing Staff	196	1	48	16,04	9,599
Valid N (listwise)	196				

Source: *Own elaboration.*

5. Model Specifications

In this paper the VRS, input-oriented, one-stage model is used. Firstly, input-oriented because in the health sector it is impossible to predefine the outputs but instead inputs may be predefined and controlled. Secondly, one-stage DEA because it performs better than two-stage and multistage DEA both in deterministic and stochastic scenarios (Daouia and Simar, 2007; Johnson, Ostfeld, and Keesing, 2015; Simar and Wilson, 2018). Finally, the VRS model is used because it would be a mistake to assume that all DMU's operate at an optimum level, since they operate in district areas with differences and peculiarities in many aspects such as concentration of people in their Region, environmental factor which may affect the health of the overall population, availability to employ specialized workforce and hospitals nearby that may affect the efficiencies calculated. After the DEA is performed, a second stage analysis will be implemented to investigate if the Health Regions where Health Centers are located has an impact in the efficiencies. Moreover, internal validity of the model will be tested.

6. Sampling – Results

The efficiencies were measured by performing DEA by the DEAP ver2.1 program. The analysis was performed assuming variable return to scale, input-oriented, one-stage DEA. The efficiencies of the firms are presented in the following Table 2.

Table 2. *Data Envelopment Analysis Results*

Firms	*CRSTE*	*VRSTE*	*SLACKS*	*RTS*
1	1.000	1.000	1.000	-
2	1.000	1.000	1.000	-
3	1.000	1.000	1.000	-
4	0.633	0.748	0.846	drs
5	0.935	0.983	0.951	drs
6	1.000	1.000	1.000	-
7	1.000	1.000	1.000	-
8	1.000	1.000	1.000	-
9	0.991	1.000	0.991	drs
10	0.591	0.612	0.965	irs
11	1.000	1.000	1.000	-
12	0.807	0.948	0.852	irs
13	1.000	1.000	1.000	-
14	1.000	1.000	1.000	-
15	0.563	0.670	0.840	irs
16	1.000	1.000	1.000	-
17	0.362	1.000	0.362	irs
18	0.593	0.796	0.745	irs
19	0.758	1.000	0.758	irs
20	0.778	0.971	0.802	drs
21	1.000	1.000	1.000	-
22	1.000	1.000	1.000	-
23	1.000	1.000	1.000	-
24	1.000	1.000	1.000	-
25	1.000	1.000	1.000	-
26	0.960	1.000	0.960	drs
27	0.234	0.500	0.469	irs

28	1.000	1.000	1.000	-
29	0.458	0.466	0.983	irs
30	1.000	1.000	1.000	-
31	0.490	0.620	0.789	irs
32	0.862	1.000	0.862	drs
33	0.718	0.738	0.973	irs
34	0.350	0.628	0.558	irs
35	1.000	1.000	1.000	-
36	1.000	1.000	1.000	-
37	1.000	1.000	1.000	-
38	1.000	1.000	1.000	-
39	0.869	0.927	0.937	drs
40	1.000	1.000	1.000	-
41	1.000	1.000	1.000	-
42	1.000	1.000	1.000	-
43	1.000	1.000	1.000	-
44	1.000	1.000	1.000	-
45	0.781	0.987	0.792	drs
46	1.000	1.000	1.000	-
47	0.276	0.281	0.983	irs
48	0.401	0.401	0.999	-
49	1.000	1.000	1.000	-
50	0.686	0.714	0.960	irs
51	0.871	1.000	0.871	irs
52	1.000	1.000	1.000	-
53	1.000	1.000	1.000	-
54	0.316	1.000	0.316	irs
55	0.771	0.921	0.837	irs
56	0.471	1.000	0.471	irs
57	1.000	1.000	1.000	-
58	0.860	0.861	0.999	drs
59	0.771	1.000	0.771	drs
60	0.889	0.895	0.993	irs
61	1.000	1.000	1.000	-
62	0.772	1.000	0.772	irs
63	0.351	0.500	0.702	irs
64	1.000	1.000	1.000	-
65	1.000	1.000	1.000	-
66	1.000	1.000	1.000	-
67	0.794	0.794	1.000	-
68	1.000	1.000	1.000	-
69	1.000	1.000	1.000	-
70	1.000	1.000	1.000	-
71	1.000	1.000	1.000	-
72	1.000	1.000	1.000	-
73	1.000	1.000	1.000	-
74	1.000	1.000	1.000	-
75	1.000	1.000	1.000	-
76	0.956	1.000	0.956	irs
77	0.628	0.729	0.862	irs

78	1.000	1.000	1.000	-
79	0.703	1.000	0.703	irs
80	0.428	1.000	0.428	irs
81	0.700	0.703	0.995	irs
82	1.000	1.000	1.000	-
83	0.236	0.262	0.902	irs
84	0.479	0.632	0.758	irs
85	0.512	1.000	0.512	irs
86	1.000	1.000	1.000	-
87	0.832	0.878	0.948	drs
88	1.000	1.000	1.000	-
89	1.000	1.000	1.000	-
90	0.498	0.623	0.798	irs
91	0.798	0.809	0.987	irs
92	0.467	0.479	0.975	irs
93	0.434	0.508	0.855	irs
94	0.903	0.943	0.958	irs
95	1.000	1.000	1.000	-
96	0.583	0.584	0.999	-
97	0.785	0.787	0.998	drs
98	0.724	1.000	0.724	irs
99	0.750	0.770	0.975	drs
100	0.266	1.000	0.266	irs
101	1.000	1.000	1.000	-
102	0.453	1.000	0.453	irs
103	1.000	1.000	1.000	-
104	1.000	1.000	1.000	-
105	0.587	1.000	0.587	irs
106	0.427	0.456	0.936	irs
107	0.546	0.720	0.758	irs
108	0.994	1.000	0.994	irs
109	0.696	0.711	0.979	irs
110	1.000	1.000	1.000	-
111	1.000	1.000	1.000	-
112	1.000	1.000	1.000	-
113	1.000	1.000	1.000	-
114	0.830	0.832	0.997	drs
115	0.742	0.909	0.816	drs
116	0.643	0.648	0.993	irs
117	1.000	1.000	1.000	-
118	0.768	1.000	0.768	irs
119	1.000	1.000	1.000	-
120	0.284	1.000	0.284	irs
121	0.308	1.000	0.308	irs
122	0.887	0.887	1.000	-
123	0.694	0.769	0.902	irs
124	1.000	1.000	1.000	-
125	0.871	1.000	0.871	irs
126	0.248	0.526	0.472	irs
127	0.729	0.844	0.863	irs

128	0.049	1.000	0.049	irs
129	1.000	1.000	1.000	-
130	1.000	1.000	1.000	-
131	0.757	1.000	0.757	irs
132	0.852	1.000	0.852	irs
133	1.000	1.000	1.000	-
134	0.348	1.000	0.348	irs
135	0.818	1.000	0.818	irs
136	0.918	0.949	0.968	irs
137	0.352	1.000	0.352	irs
138	0.448	1.000	0.448	irs
139	1.000	1.000	1.000	-
140	0.678	1.000	0.678	irs
141	1.000	1.000	1.000	-
142	0.749	0.830	0.902	irs
143	0.604	1.000	0.604	irs
144	0.342	1.000	0.342	irs
145	1.000	1.000	1.000	-
146	1.000	1.000	1.000	-
147	1.000	1.000	1.000	-
148	0.560	0.581	0.964	irs
149	0.801	1.000	0.801	irs
150	0.404	0.630	0.641	irs
151	0.468	1.000	0.468	irs
152	0.646	1.000	0.646	irs
153	1.000	1.000	1.000	-
154	1.000	1.000	1.000	-
155	1.000	1.000	1.000	-
156	0.371	0.521	0.712	irs
157	1.000	1.000	1.000	-
158	1.000	1.000	1.000	-
159	1.000	1.000	1.000	-
160	0.506	0.588	0.860	irs
161	0.430	1.000	0.430	irs
162	0.886	1.000	0.886	irs
163	0.380	0.557	0.683	irs
164	0.955	1.000	0.955	drs
165	0.700	1.000	0.700	irs
166	0.321	1.000	0.321	irs
167	0.985	1.000	0.985	drs
168	0.968	0.996	0.972	irs
169	1.000	1.000	1.000	-
170	1.000	1.000	1.000	-
171	0.776	1.000	0.776	irs
172	0.923	0.951	0.971	irs
173	1.000	1.000	1.000	-
174	1.000	1.000	1.000	-
175	0.592	0.676	0.876	irs
176	1.000	1.000	1.000	-
177	1.000	1.000	1.000	-

178	0.667	1.000	0.667	irs
179	1.000	1.000	1.000	-
180	1.000	1.000	1.000	-
181	1.000	1.000	1.000	-
182	0.975	1.000	0.975	irs
183	0.349	0.543	0.642	irs
184	1.000	1.000	1.000	-
185	0.583	1.000	0.583	irs
186	1.000	1.000	1.000	-
187	1.000	1.000	1.000	-
188	0.777	1.000	0.777	irs
189	0.856	0.909	0.942	irs
190	1.000	1.000	1.000	-
191	1.000	1.000	1.000	-
192	1.000	1.000	1.000	-
193	0.788	0.850	0.927	irs
194	1.000	1.000	1.000	-
195	1.000	1.000	1.000	-
196	1.000	1.000	1.000	-
mean	*0.806*	*0.916*	*0.877*	

Source: *Own elaboration*

The column CRSTE represents the technical efficiency assuming constant return to scale in DEA, while the column VRSTE represents the technical efficiency assuming variable return to scale in DEA. The column presenting the SLACKS is calculated using the CRSTE/VRSTE fraction and indicates the scale efficiencies. Slacks present the extra amount by which an input can be reduced to achieve technical efficiency after all inputs have been reduced in equal proportion to reach the production frontier or the extra amount by which an output can be increased to achieve technical efficiency after all outputs have been increased to reach the production frontier. So, there are input and output slacks which are calculated by the equations $\theta x_i - X\lambda \geq 0$ and $-y_i + Y\lambda \geq 0$ respectively, represented in the VRS model. When the equations are equal to zero there are no slacks for the i-th DMU (Coelli, 1996).

As indicated by the Steering Committee for the Review of Commonwealth/State Service Provision in 1997, return to scale express the relationship between output and inputs and can be constant, increasing or decreasing depending on whether output increases in proportion to, more than or less than inputs, respectively.

The analysis assuming constant return to scale indicates 91 technical efficient Health Centers out of 196, which leads to a percentage of 46.6% of efficiency among the total number of Health Centers. In contrast, the analysis assuming variety return to scale indicates 138 technical efficient Health Center out of 196, leading to a percentage of 70.4% of efficiency among the total number of Health Centers. Performing the Spearman-rank correlation between CRSTE and VRSTE efficiencies, the correlation coefficient is 0.602 and it is statistically significant presenting high degree of correlation between the two methods as shown in the Table 3 (Reddy *et al.*, 2015).

Table 3. *Spearman-rank correlations between input oriented crste-vrste models*

			crste	vrste
Spearman's rho	crste	Correlation Coefficient	1,000	,602**
		Sig. (2-tailed)	.	,000
		N	196	196
	vrste	Correlation Coefficient	,602**	1,000
		Sig. (2-tailed)	,000	.
		N	196	196
**. Correlation is significant at the 0.01 level (2-tailed).				

Source: *Own elaboration.*

Table 4 presents the average efficiency score with CRSTE method being 0.806 with standard deviation 0.243 and minimum efficiency observed 0.049. The average efficiency score with VRSTE method is 0.916 with standard deviation 0.163 and minimum efficiency observed 0.262. VRS method is more accurate considering the high significant correlation between the two models and the assumption that not all DMU's are operating at an optimal level, taking into consideration the scale efficiencies in the analysis.

Table 4. *Frequencies*

		crste	vrste
N	Valid	196	196
	Missing	0	0
Mean		,80578	,91608
Std. Deviation		,243251	,163452
Minimum		,049	,262
Maximum		1,000	1,000
Percentiles	25	,64375	,92250
	50	,95550	1,00000
	75	1,00000	1,00000

Source: *Own elaboration.*

In Appendix, the summary of peers is represented. Peers are the efficient DMU's "operating" closer to the inefficient Health Center. The percentage variation from the inefficient Health Center to achieve the efficiency of its peers, are the peer weights. The number of times a Health Center is a reference to an inefficient Health Center is presented at the table as peer count (Coelli, 2011).

7. Tobit Regression Analysis

Furthermore, analysis is conducted to investigate if the Health Regions where the Health Centers belong to affects the efficiencies. Since the results of the efficiencies of the DMUs are censored between the interval (0,1), OLS (Ordinary Least Squares) cannot be used. The application that will give valuable results explaining the efficiencies is the censored regression model Tobit, which is designed to estimate the linear relationship between variables when the dependent variable is censored (Jehu-Appiah *et al.*, 2014; Xenos *et al.*, 2017). In this application of Tobit regression model, the dependent variable is the VRS technical efficiency of each Health Center censored between the interval (0,1), while the independent one is the exogenous factor Health Regions. In this second stage of the analysis, DEA efficiency scores are regressed against the 7 Health Regions of Greece. Model verification:

$Y_{i=} X_i b_0 + e_i,\ e_{i\ \sim} (0, \sigma_0^2),$
$Y_i = \max(y_i^*, 0)$

Where X_i is a row vector of observable Health Region of efficiencies, b is a column of vector of associated coefficients, ei ~ $(0, \sigma_0^2)$ and y_i is a latent variable with data that are censored at (0, 1) interval (Dimas, Goula, and Soulis, 2012)

Tobit regression analysis results are presented in Table 5 indicating that (given p-value=0.255>α) Health Regions are not statistically significant.

Table 5. *Tobit Regression Analysis results under VRS assumption*

	Coefficient	Std. Error	z Value	Sig.
(Intercept)	1,102	,108	10,211	,000
HealthRegions	,025	,022	1,138	,255
Log(scale)	-,877	,109	-8,031	,000

Note: *Lower bound: 0, Upper bound: 1; Tobit(formula=vste_tobit~HealthRegions, left = 0, right = 1, dist = "gaussian", data = dta, na.action=na.exclude). Scale: 0.4159. Residual d.f.: 193; Log likelihood: -98.741, D.f.: 3; Wald statistic: 1.296, D.f.: 1*

Source: *Own elaboration*

8. Model Validation

For the internal validity of the DEA model under VRS assumption the Spearman-rank correlation test was performed. Internal validity is to compare if there are differences in the efficiencies of Health Centers using different inputs and outputs. DEA is a non-parametric method, so it is not possible to compare the efficient scores produced by different models directly. However, the comparison of the efficiencies can be applied by non-parametric correlation tests (Ganley and Cubbin, 1992; Valdmanis, 1992; Parkin and Hollingsworth, 1997; Maniadakis *et al.*, 2008).

The VRS efficiencies were calculated by performing different models of DEA. The models are represented in Table 6, which shows the different inputs and outputs used to calculate efficiencies.

Table 6. *Models with different combinations of variables*

Models/ Variables	Out 1	Out 2	Out 3	Out 4	Out 5	Out 6	Out 7	Out 8	Out 9	Out10	Out11	Out12	Out13	Inp 1	Inp 2	Inp 3	Inp 4
M0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M1	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
M2			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M3	X	X	X	X		X	X		X			X	X	X		X	X

Source: *Own elaboration.*

The first model (MO) is the model taking into consideration all inputs and outputs, the second model (M1) excludes the input variable "Number of Managers", the third model (M2) excludes the output variables "Chronic Disease Cases" and "Emergencies", while the fourth model (M3) excludes the input variables "Other Exams" and "Number of Managers" and the output variables "Test Mantoux", "Dental Procedures" and "Transcriptions". After the efficiencies of each model were estimated under the VRS input-oriented DEA model the Spearman-rank correlation coefficients were calculated.

Table 7. *Model Validity test with Spearman Rank Correlation*

			model0	model1	model2	model3
Spearman's rho	model0	Correlation Coefficient	1,000	,578**	,955**	,481**
	model1	Correlation Coefficient	,578**	1,000	,526**	,873**
	model2	Correlation Coefficient	,955**	,526**	1,000	,422**
	model3	Correlation Coefficient	,481**	,873**	,422**	1,000

Note: ***. Correlation is significant at the 0.01 level (2-tailed).*
Source: *Own elaboration.*

The Spearman-rank correlations tests for internal validity show that there is statistically significant correlations between different model specifications.

9. Limitations

The dataset was provided by the Ministry of Health and refers to the period 2018. Attempts had been made to gather Financial Data for the Health Centers that would have been used as inputs for the purposes of this paper, contributing to the evaluation of the efficiencies. Unfortunately, there was lack of data for costs and expenditures for the Health Centers, but regarding that Health Centers are labor-intensive units the total personnel employed and occupied was used as inputs to estimate the efficiencies. It is strongly recommended that the Greek Government start collecting Financial Data in order to evaluate the efficiency of Primary Health Care given the attention that has been paid during the last decade (Xenos *et al.*, 2017). Moreover, eleven Health Centers were excluded from this paper due to lack of data.

10. Conclusion

This paper provides the relative efficiency of Primary Health Care Centers by using the non-parametric Data Envelopment Analysis method. The technical efficient Health Centers are indicated, benchmarking the overall efficiency of Health Centers in Greece. The efficient Health Centers can be used as benchmarks for the inefficient ones to improve their efficiencies. Furthermore, it was investigated if the Health Region where the Health Centers are located affects the efficiency, without significant results. Extensive research should be made to investigate other exogenous factors that may affect efficiency such as demographic, socioeconomic, community criteria, environmental factors, etc. This paper may contribute to improve Health Centers efficiencies. Also, valuable results can be extracted for National Health Care System to match available resources depending on each Health Center's needs.

The results of the analysis for the efficiencies of the Health Centers were extracted by using the DEAP version 2.1 for Windows by Coelli (1996). Also, statistics and Tobit regression analysis were applied by the IBM SPSS program and R programming add-on for SPSS.

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Appendix. *SUMMARY OF PEERS*

firm	peers	peer weights (lambda weight)	Firm peer count
1			0
2			1
3			0
4	7, 42, 89, 153, 70, 164, 184	0.097, 0.236, 0.230, 0.239, 0.049, 0.085, 0.064	0
5	184, 7, 6, 53, 41, 69, 42	0.005, 0.559, 0.064, 0.081, 0.080, 0.143, 0.067	0
6			1
7			19
8			2
9			0
10	119, 153, 41, 184, 7, 30, 78, 157, 166	0.017, 0.283, 0.189, 0.139, 0.004, 0.078, 0.052, 0.163, 0.075	0
11			0
12	157, 69, 166, 111, 24	0.159, 0.011, 0.333, 0.376, 0.121	0
13			3
14			1
15	176, 166, 41, 184, 119, 157, 88	0.034, 0.405, 0.074, 0.075, 0.311, 0.057, 0.044	0
16			0
17	174, 119, 64, 166	0.085, 0.836, 0.033, 0.046	0
18	166, 35, 69, 173	0.112, 0.125, 0.128, 0.635	0
19	184, 129, 196, 88, 169, 74	0.518, 0.000, 0.134, 0.091, 0.202, 0.054	0
20	24, 7, 14, 30, 21, 184	0.365, 0.293, 0.013, 0.158, 0.082, 0.088	0
21			1
22			5
23			2
24			4
25			0
26			0
27	111, 179, 119, 184, 174, 166, 173	0.132, 0.030, 0.254, 0.076, 0.050, 0.282, 0.176	0
28			0
29	69, 70, 170, 23, 130, 196, 78, 88, 35, 41, 179, 119	0.024, 0.009, 0.001, 0.160, 0.235, 0.024, 0.088, 0.258, 0.051, 0.025, 0.104, 0.020	0
30			14
31	130, 88, 173, 153, 78, 65, 166	0.027, 0.099, 0.390, 0.077, 0.201, 0.013, 0.193	0
32			0
33	155, 157, 184, 41, 117, 30, 78	0.168, 0.314, 0.160, 0.139, 0.007, 0.055, 0.157	0
34	173, 69, 166, 119	0.531, 0.001, 0.367, 0.101	0
35			4
36			0
37			2

38			10
39	117, 42, 157, 192, 7, 147, 184	0.146, 0.121, 0.026, 0.316, 0.235, 0.116, 0.041	0
40			0
41			19
42			12
43			2
44			0
45	181, 7, 164, 119, 8, 42	0.000, 0.123, 0.332, 0.203, 0.233, 0.108	0
46			2
47	78, 184, 157, 117, 41, 69, 119, 7, 88	0.224, 0.049, 0.470, 0.013, 0.006, 0.103, 0.077, 0.026, 0.031	0
48	130, 195, 196, 157, 42, 153, 177, 194, 69	0.039, 0.149, 0.371, 0.119, 0.060, 0.055, 0.016, 0.109, 0.082	0
49			0
50	78, 157, 71, 166, 153, 119, 24, 41	0.167, 0.039, 0.031, 0.142, 0.224, 0.254, 0.029, 0.114	0
51	88, 184, 119, 64, 22, 179	0.026, 0.037, 0.060, 0.119, 0.244, 0.513	0
52			3
53			6
54	38, 119, 37, 153	0.093, 0.179, 0.102, 0.626	0
55	173, 195, 177, 78, 69, 146, 166, 141	0.112, 0.116, 0.060, 0.108, 0.184, 0.159, 0.242, 0.020	0
56	153, 88, 166, 140, 196, 141, 174	0.119, 0.093, 0.194, 0.212, 0.036, 0.008, 0.338	0
57			2
58	13, 157, 184, 103, 141	0.590, 0.132, 0.057, 0.046, 0.175	0
59			0
60	173, 157, 117, 66, 78, 72, 71, 41, 184, 88	0.002, 0.031, 0.048, 0.044, 0.502, 0.015, 0.147, 0.074, 0.037, 0.099	0
61			0
62	112, 64, 38, 98, 196, 141	0.012, 0.353, 0.126, 0.220, 0.040, 0.249	0
63	184, 195, 88, 129, 166, 140, 196, 181	0.085, 0.214, 0.090, 0.021, 0.061, 0.373, 0.103, 0.053	0
64			10
65			6
66			5
67	111, 119, 7, 30, 184, 177, 42, 157, 130	0.307, 0.136, 0.018, 0.085, 0.140, 0.088, 0.154, 0.068, 0.004	0
68			0
69			15
70			4
71			6
72			3
73			0
74			1
75			0
76			0
77	88, 78, 166, 119, 157, 41, 179, 184, 146	0.079, 0.315, 0.232, 0.005, 0.064, 0.039, 0.073, 0.061, 0.132	0
78			19
79	173, 64, 86, 53, 179, 184	0.031, 0.186, 0.051, 0.259, 0.458, 0.016	0
80	53, 174, 30	0.212, 0.651, 0.137	0
81	110, 43, 42, 153, 69, 119, 111, 184	0.065, 0.182, 0.024, 0.106, 0.122, 0.385, 0.053, 0.062	0
82			0
83	153, 78, 141, 69, 64, 177, 195, 119	0.075, 0.014, 0.154, 0.073, 0.100, 0.097, 0.017, 0.470	0

84	141, 191, 184, 43, 111, 166, 41, 179, 195, 129, 103	0.091, 0.116, 0.010, 0.053, 0.073, 0.379, 0.048, 0.116, 0.038, 0.006, 0.070	0
85	184, 174, 129, 128, 30	0.015, 0.065, 0.278, 0.164, 0.478	0
86			4
87	42, 2, 70, 196, 7	0.164, 0.086, 0.422, 0.286, 0.043	0
88			18
89			2
90	195, 166, 159, 41, 88, 119, 130, 23, 129, 196	0.011, 0.230, 0.036, 0.012, 0.085, 0.103, 0.190, 0.016, 0.270, 0.046	0
91	7, 184, 41, 42, 157, 111	0.018, 0.238, 0.061, 0.074, 0.354, 0.254	0
92	196, 69, 130, 7, 111, 140, 153	0.212, 0.014, 0.367, 0.165, 0.072, 0.117, 0.054	0
93	30, 173, 166, 184, 155, 130	0.021, 0.702, 0.041, 0.137, 0.069, 0.030	0
94	130, 113, 66, 173, 177, 71	0.148, 0.260, 0.007, 0.205, 0.224, 0.156	0
95			0
96	7, 130, 117, 157, 184, 66	0.001, 0.453, 0.121, 0.273, 0.115, 0.037	0
97	195, 117, 78, 7, 30, 184, 101, 196	0.566, 0.001, 0.241, 0.077, 0.008, 0.019, 0.005, 0.083	0
98	179, 103, 153, 178, 37, 38	0.241, 0.063, 0.419, 0.014, 0.122, 0.141	1
99	41, 7, 78, 130, 153, 101, 196	0.115, 0.182, 0.055, 0.178, 0.451, 0.004, 0.014	0
100	86, 119, 153, 169, 140	0.090, 0.011, 0.291, 0.343, 0.264	0
101			2
102	179, 184, 166, 88, 173	0.299, 0.253, 0.180, 0.004, 0.264	0
103			4
104			1
105			0
106	119, 184, 153, 71, 173, 78	0.150, 0.042, 0.094, 0.023, 0.437, 0.254	0
107	184, 157, 166, 173	0.168, 0.166, 0.210, 0.456	0
108			0
109	157, 78, 173, 41, 184, 153, 71	0.108, 0.161, 0.264, 0.088, 0.212, 0.030, 0.138	0
110			1
111			9
112			2
113			1
114	196, 155, 30, 7, 181, 69, 42	0.533, 0.129, 0.136, 0.034, 0.037, 0.096, 0.036	0
115	8, 42, 89, 196, 119, 7, 70	0.074, 0.066, 0.141, 0.050, 0.278, 0.126, 0.265	0
116	196, 119, 153, 13, 7, 141, 69	0.396, 0.027, 0.058, 0.080, 0.038, 0.376, 0.025	0
117			7
118	184, 153, 177, 174, 141, 169	0.109, 0.205, 0.055, 0.445, 0.008, 0.179	0
119			37
120	196, 86, 166, 133	0.009, 0.062, 0.628, 0.301	0
121	184, 153, 166, 129	0.150, 0.461, 0.356, 0.033	0
122	184, 130, 13, 41	0.393, 0.284, 0.161, 0.162	0
123	35, 41, 176, 88, 119, 130, 46	0.032, 0.012, 0.213, 0.173, 0.179, 0.386, 0.003	0
124			0
125			1
126	173, 119, 196, 166, 184, 57, 179	0.534, 0.046, 0.020, 0.323, 0.021, 0.026, 0.030	0
127	65, 196, 166, 30, 119, 130, 155, 157	0.354, 0.043, 0.188, 0.022, 0.058, 0.119, 0.000, 0.216	0
128	119, 140, 166	0.222, 0.556, 0.222	1
129			10
130			18

131			0
132			2
133			1
134	38, 52, 64, 141, 166	0.142, 0.316, 0.012, 0.282, 0.248	0
135			0
136	65, 153, 78, 173, 41, 119, 166	0.490, 0.035, 0.007, 0.029, 0.200, 0.227, 0.012	0
137	173, 184, 52, 38	0.530, 0.026, 0.415, 0.030	0
138	153, 146, 132, 177, 173, 166	0.039, 0.162, 0.436, 0.010, 0.215, 0.139	0
139			0
140			6
141			10
142	71, 78, 157, 65, 72, 153, 173, 30	0.013, 0.146, 0.027, 0.098, 0.161, 0.022, 0.454, 0.078	0
143			0
144	184, 173, 38, 153, 52	0.134, 0.016, 0.016, 0.618, 0.216	0
145			0
146			3
147			2
148	72, 170, 179, 57, 130, 173, 119, 78	0.023, 0.068, 0.325, 0.083, 0.205, 0.009, 0.166, 0.121	0
149	177, 88, 119, 86, 173, 53	0.076, 0.143, 0.091, 0.052, 0.196, 0.443	0
150	157, 41, 184, 166, 119, 22, 88	0.222, 0.019, 0.005, 0.666, 0.030, 0.030, 0.028	0
151	119, 184, 125, 166	0.220, 0.136, 0.356, 0.288	0
152	182, 38, 169, 119, 179, 112, 64	0.056, 0.245, 0.092, 0.330, 0.176, 0.000, 0.101	0
153			27
154			0
155			5
156	64, 173, 153, 181, 184, 166, 157, 53	0.055, 0.344, 0.049, 0.056, 0.197, 0.192, 0.042, 0.065	0
157			24
158			1
159			1
160	119, 153, 179, 166, 184, 65, 88, 78	0.113, 0.073, 0.137, 0.282, 0.093, 0.126, 0.126, 0.050	0
161	196, 130, 65	0.143, 0.842, 0.016	0
162	22, 129, 141, 196, 30, 88, 132, 53, 38	0.075, 0.209, 0.030, 0.050, 0.225, 0.174, 0.011, 0.102, 0.124	0
163	129, 119, 166, 7, 184, 64, 130, 173	0.044, 0.106, 0.422, 0.016, 0.019, 0.137, 0.067, 0.190	0
164			2
165	38, 88, 166, 195, 179, 64, 22, 181	0.246, 0.021, 0.187, 0.114, 0.227, 0.032, 0.089, 0.084	0
166			34
167			0
168	119, 66, 46, 177, 130, 78, 157, 69, 196	0.200, 0.000, 0.088, 0.089, 0.016, 0.194, 0.373, 0.036, 0.005	0
169			4
170			2
171			0
172	117, 173, 157, 66, 24, 147, 119, 155	0.268, 0.201, 0.213, 0.122, 0.017, 0.047, 0.086, 0.045	0
173			26
174			6
175	173, 130, 153, 30, 35, 69	0.079, 0.558, 0.083, 0.136, 0.037, 0.106	0
176			2

177			10
178			1
179			15
180			0
181			6
182			1
183	119, 41, 30, 166, 179, 153, 184, 173	0.029, 0.043, 0.023, 0.607, 0.057, 0.077, 0.056, 0.108	0
184			42
185	119, 166, 184, 111, 179	0.041, 0.220, 0.300, 0.258, 0.181	0
186			0
187			0
188	22, 184, 177, 104, 38, 196, 190, 129	0.099, 0.170, 0.099, 0.066, 0.119, 0.301, 0.146, 0.000	0
189	103, 157, 129, 158, 191	0.090, 0.086, 0.093, 0.147, 0.584	0
190			1
191			2
192			1
193	42, 140, 119, 181, 195, 196, 111, 7, 157, 153	0.172, 0.195, 0.089, 0.190, 0.172, 0.029, 0.003, 0.054, 0.022, 0.073	0
194			1
195			9
196			22

Source: *Own elaboration*