Total Productivity Change of Health Centers in Greece in 2016-2018: A Malmquist Index Data Envelopment Analysis Application for the Primary Health System of Greece.

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Research

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Abstract

Background: This paper attempts to evaluate Primary Health Care System by evaluating Health Centers in Greece.

Methods: Malmquist Index Data Envelopment Analysis is applied to study the total productivity of 155 Health Centers in Greece during 2016-2018. The Data were collected from the Ministry of Health and were submitted into quality tests to ensure validity and avoid bias.

Results: This paper measures the productivity of each of the 155 Health Centers in Greece and how it shifted during 2016-2018. In addition, the overall productivity change of the 155 Health Centers over time is calculated and analyzed into a change due to technical efficiency and a change due to technological efficiency. The analysis of the means values showed a decrease of 0.9% in the overall productivity factor from the year 2016 to the year 2017 and a decrease of 5.2% from the year 2017 to the year 2018. The overall decrease in the productivity of the 155 health Centers was 3.1%. From 2016 to 2018, 59 Health centers changed their productivity mainly due to technological change, 91 mainly due to technical efficiency change, while one Health Center showed regression to its total productivity due to equal regression of its technical efficiency and technology.

Conclusions: The method used is non-parametric Data Envelopment Analysis along with Malmquist Index, so as to include panel data in the analysis. Meaningful results were extracted by indicating the number of Health Centers that their productivity improved, regressed or remained constant through the period 2016-2018. This paper may contribute to improve Health Centers’ efficiency and productivity. Furthermore, valuable results can be extracted, for the National Health Care System in order to match available resources depending on each Health Center’s needs, as well as for manager planners and stakeholders in Primary Health Care.

JEL Classification: C14, C32, C52, I10

Background

Primary Health Care has received more attention recently as the World Health Organization (WHO) has pointed out its importance to the overall health of the population and its contribution to the National Health System of every country. Every country in the OECD participates in a strategy that focuses on strengthening Primary Health Care as stated by WHO at Alma-Ata in 1978. OECD countries including Greece attempted to monitor Primary Health Care to follow the strategy imposed by WHO [1].

Health Care expenditures in Greece are higher than the average expenditures of OECD Countries. This is mainly due to the inadequate primary health care system and the delivery of health care services [2]. The lack of health promotion, disease prevention and rehabilitation as well as the dissatisfaction of people receiving health services indicate distribution problems in health services, problematic administration, and low productivity. This is mainly due to the inadequacy of primary health care, which highlights the importance of its contribution to the whole Health Care System and the efforts that should be made, in order to strengthen it [3–5].

The economic crisis of the last decade in Greece was accompanied with funding cuts for the National Health System. In order to overcome the negative effects of funding cuts while strengthening National Health System, reforms were introduced. Emphasis was placed on Primary Health Care and its contribution to the overall health of the population.

Health Centers are one of the main compounds of Primary Health System and by attempting to evaluate their productivity and efficiency important information would be given for Primary Health Care in Greece. Nowadays, 207 Health Centers are in operation in Greece, out of which 155 were submitted for the analysis of this paper. The other 52 Health Centers were excluded due to lack of data, in order to avoid random estimation and possibility of bias.

Method

There are two approaches to measure the efficiency according to the relevant literature, parametric and non-parametric. Non-parametric approaches are most commonly used in healthcare studies, since they have the advantage that the functional form need not be known [6]. The most commonly used non-parametric approach is Data Envelopment Analysis (DEA) [7]. Moreover, DEA has the advantage of handling multiple inputs and outputs, as well as used with any input-output measurement. In studies measuring Healthcare efficiency, DEA is the most used method [8].

Farrell (1957), based on Debreu (1951) and Koopmans (1951), first introduced modern efficiency, and attempted to measure the efficiency of a firm by considering multiple inputs [9,10]. Farrell analyzed and decomposed the efficiency measured, into two components, technical and allocative efficiency, both of which together appraise economic efficiency [11].

Charnes, Cooper and Rhodes (CCR, 1978), based on Farrell, proposed the model of DEA. DEA is a linear programming method that constructs a non-parametric frontier containing all the firms submitted for analysis in order to measure their efficiencies. The firms are called Decision Making Units (DMUs) and their data, translated as inputs and outputs, are used to measure their efficiencies. The constructed frontier includes all efficient DMUs while below the frontier all inefficient ones are placed. Technical efficiency depends on the “input-output ratio of productivity” [12] and can be decomposed into pure technical efficiency and scale efficiency. Essentially, technical efficiency refers to the conversion of inputs into outputs according to best practice so that the DMU is as efficient as possible. “Pure technical efficiency and scale efficiency comprise technical efficiency” [2].

Technical efficiency measured by DEA has two orientations according to the relevant literature. The output orientation refers “to the maximum amount of outputs that can be produced by the DMUs for a given amount of inputs used” [6,13], while the input orientation refers “to the minimum amounts of inputs
used by DMU's in order to obtain a certain level of outputs” [6,13]. The input orientation of DEA binds the outputs produced in order to solve a linear programming equation that minimizes the inputs used, while the output orientation of DEA binds the inputs used to solve a linear programming equation that maximizes the outputs produced.

In addition, two methods of DEA have been proposed, the first one is based on the assumption of constant return to scale (CRS) as was introduced by Charnes, Cooper and Rhodes (CCR, 1978), while the other one is based on the assumption of variable return to scale (VRS) as later introduced by Banker, Charnes and Cooper at 1984. "The CRS method is applied when all DMU's are operating at an optimal level while, under imperfect competition, the VRS method is applied considering that not all DMU's are operating at an optimal level, assuming that there are scale efficiencies” [14, 42].

Either CRS or VRS DEA is able to measure the technical efficiencies of the DMU's included in the analysis but without the availability to include panel data, taking into consideration the impact of time upon the efficiencies. To overcome this limitation, the Malmquist Productivity Index (MPI) can be used along with the DEA. The MPI measures productivity change over time and decomposes it into change due to technology and technical efficiency [15].

Productivity change was initially explained as technology change but later it was accepted that in productivity change are included both, technology and technical efficiency change. MPI was first introduced by Caves et al. (1982), who relied on Shephard’s (1970) distance function, in order to measure the productivity change [15].

The MPI DEA is essentially a non-parametric mathematical programming approach, which according to the literature is the most widely used method to include panel data in the analysis and calculate the indices of total factor productivity, technical efficiency and its components (pure technical efficiency and scale efficiency) and technological change, over time [2].

Productivity is defined as the ratio of an index of outputs over an index of inputs used to produce them [16-18]. Increasing productivity means that more outputs are obtained from the same amount of inputs or less inputs are required to produce the same amount of outputs. The change of productivity over time is called productivity change and shifts over time due to technical efficiency and technical/technological change [2,11,19-21].

In this paper the input-oriented MPI DEA is used. First input-oriented because in the health sector it is impossible to predefine the outputs, but instead the inputs can be predefined and controlled. Secondly, MPI DEA, because panel data are included in the paper [22-24].

**Model Specification - Data Envelopment Analysis and Malmquist Productivity Index**

The mathematical concepts of DEA and MPI are briefly analyzed below, since the aim of this paper is to evaluate the productivity and efficiency of the 155 Health Centers in Greece during 2016-2018. Extended mathematical analysis of the methods of DEA and MPI and how they are used is presented in the relevant literature.

Before presenting the mathematical background of MPI, DEA will be analyzed. The mathematical analysis refers to an input-oriented DEA under CRS and VRS assumption, since both are needed to estimate MPI.

In the input-oriented mathematical model of CRS, it is assumed that there are "N DMU's that use K inputs to produce M outputs. Under this assumption there are two matrices, K*N input matrix, referred as X, and M*N output matrix, referred as Y, which both represent the data of all N DMU's” [25]. In order to measure the efficiency of the DMU's the literature considers the calculation of the ratio of all outputs over all inputs. T.J. Coelli presented the following mathematical linear programming problem in 1996:

\[
\text{max}_{u,v} (u'y/v'x),
\]

s.t.

\[
u'y/v'x \leq 1, \ j=1,2,\ldots,N,
\]

\[u,v \geq 0,\]

Where \(u\) is an M*1 vector of output weights and \(v\) is a K*1 vector of input weights“ [25]. The problem aims to compute the values of \(u\) and \(v\), maximizing the efficiency of the DMU's. As it can be observed there is a constraint indicating that all efficiency measures must lie within the closed interval of (0,1).

To avoid the infinite solutions of the above mathematical formula, “a new constraint, \(v'x=1\)” [25], has been introduced:

\[
\text{max}_{\mu,v} (\mu'y),
\]

s.t.

\[v'x=1,
\]

\[\mu'y/v'x \leq 0, \ j=1,2,\ldots,N,
\]

\[\mu, v \geq 0.
\]

A notation change from \(u,v\) to \(\mu,v\) converts the first mathematical linear programming problem into a multiplier form” [25].
By applying duality in linear programming, an equivalent form is developed:

\[ \min_{\theta, \lambda} \theta, \]
\[ \text{s.t.} \]
\[ -y_i + \lambda \geq 0, \]
\[ \theta x_i - X \lambda \geq 0, \]
\[ \lambda \geq 0. \]

The symbol \( \theta \) is a scalar and \( \lambda \) is an \( N \times 1 \) vector of constants\(^{[25]} \). The above model has fewer constraints and is easier to apply. The symbol \( \theta \) represents the efficiency of the DMUs and their values are within closed interval of \((0,1)\). Values of 1 mean that the DMUs operate at an optimal level of efficiency, while values less than 1 mean inefficiencies. The mathematical function has to be solved \( N \) times for each DMU\(^{[25]} \).

The CRS model is based on the assumption that all DMUs are operating at an optimal scale. In contrast, VRS model overpasses this assumption considering that there might be scale efficiencies. By adding one more constraint to the CRS model, scale efficiency effects are calculated and technical efficiency is decomposed into pure technical efficiency and scale efficiency for each DMU\(^{[42]} \). The mathematical function transforms as follows:

\[ \min_{\theta, \lambda} \theta, \]
\[ \text{s.t.} \]
\[ -y_i + \lambda \geq 0, \]
\[ \theta x_i - X \lambda \geq 0, \]
\[ N^1 \lambda = 1 \]
\[ \lambda \geq 0. \]

\( N^1 \) represents an \( N \times 1 \) vector of ones\(^{[25]} \).

The MPI is an extended application of DEA, to measure productivity change over time for each DMU, and analyze it into change owing to technical efficiency and change owing to technology\(^{[25]} \).

MPI DEA is used for panel data and there is no need to choose between CRS or VRS approach, since they give the same results. This is because in estimating the MPI DEA, both the CRS and the VRS approaches are used to calculate the various distances that construct the Malmquist Indices\(^{[26]} \). The distances mentioned are essentially the technical efficiencies of each DMU for each period included in the analysis (from \( t \) to \( t + 1 \)). Assuming that the MPI is measured at a given period \( (t) \), the distances calculated are:

1. "previous period (t-1) CRS DEA frontier"
2. "currents period (t) CRS DEA frontier"
3. "next periods (t+1) CRS DEA frontier"
4. "currents period (t) VRS frontier"

\( ^{[25,27]} \)

There are two orientations for the MPI DEA method, input and output orientations. In input orientation the production is described by calculating the minimal proportional decrease of the input vector, given the output vector, while in the output orientation the production is described by calculating the maximal proportion increase of the output vector, given the input vector\(^{[27]} \).

In this paper, panel data for three years (2016-2017-2018) are considered, forming two periods (2016-2017 and 2017-2018). The calculation of MPI involves the estimation of four distances for each of the two periods. DEA analysis by CRS and VRS assumption is performed for each of the three years (2016, 2017 and 2018) measuring the efficiencies of the DMUs.

By applying the MPI DEA method (DEAP program) "five indices are calculated for each DMU for the two periods:

1. Technical efficiency change (relative to CRS technology) - effch
2. Technological change - techch
3. Pure technical efficiency change (relative to VRS technology) - pech
4. Scale efficiency change - sech
5. Total factor productivity change – tfpch"
All the indices are relative to the previous year, which explains the fact that although data are available for the years 2016, Malmquist Indices cannot be estimated as no data are available for the year 2015.

The Malmquist Index was first introduced in 1970 with Shephard’s distance function and has since been widely used in many areas where efficiency needed to be measured with panel data. Färe specified an output-oriented MPI in 1994 [28]. In this paper, the input-oriented MPI is used. Essentially the MPI index of one period, is the geometric mean of two Malmquist Indices calculated for year t and year t+1.

\[
M^t(y_{t+1}, x_{t+1}, y_t, x_t) = d^t(x_{t+1}, y_{t+1}) / d^t(x_t, y_t), M^{t+1}(x_{t+1}, y_{t+1}) / d^{t+1}(x_t, y_t)
\]

[25,28,29].

By computing the geometric mean of the above individual Malmquist Indices, the MPI for one period (from t to t+1) takes the following form:

\[
M(y_{t+1}, x_{t+1}, y_t, x_t) = \left( \left[ \left[ d^t(x_{t+1}, y_{t+1}) / d^t(x_t, y_t) \right] * \left[ d^{t+1}(x_{t+1}, y_{t+1}) / d^{t+1}(x_t, y_t) \right] \right]^{1/2} \right)
\]

[25,28,29].

The MPI for a period (t to t+1), represents the productivity at the production point \((x_{t+1}, y_{t+1})\) relative to the production point \((x_t, y_t)\) for each DMU.

In addition, reshaping the index can the changes due to technical efficiency and technology be explained:

\[
M(y_{t+1}, x_{t+1}, y_t, x_t) = \left[ \left( d^{t+1}(x_{t+1}, y_{t+1}) / d^t(x_t, y_t) \right) * \left( d^t(x_{t+1}, y_{t+1}) / d^{t+1}(x_{t+1}, y_{t+1}) \right) \right]^{1/2}
\]

[25,28,29].

The first fraction of the equation represents technical efficiency change, while the second one technology change, for the period (t to t+1). Moreover, technical efficiency change can be further analyzed into change due to pure technical efficiency and scale inefficiency. Positive total productivity growth from time t to time t+1 means a value greater than one for the index [19,25,28,29].

In order to calculate the MPI equation, the four distances must be calculated by linear programming methods as presented below:

1. \[d^t(x_t, y_t)^1 = \min_{\theta, \lambda} \theta, \]
   \[\text{s.t. } y_t + Y_t \lambda \geq 0, \theta x_t - X_t \lambda \geq 0, \lambda \geq 0\]
2. \[d^{t+1}(x_{t+1}, y_{t+1})^1 = \min_{\theta, \lambda} \theta, \]
   \[\text{s.t. } y_{t+1} + Y_{t+1} \lambda \geq 0, \theta x_{t+1} - X_{t+1} \lambda \geq 0, \lambda \geq 0\]
3. \[d^t(x_{t+1}, y_{t+1})^1 = \min_{\theta, \lambda} \theta, \]
   \[\text{s.t. } y_{t+1} + Y_{t+1} \lambda \geq 0, \theta x_{t+1} - X_{t+1} \lambda \geq 0, \lambda \geq 0\]
4. \[d^{t+1}(x_t, y_t)^1 = \min_{\theta, \lambda} \theta, \]
   \[\text{s.t. } y_t + Y_t \lambda \geq 0, \theta x_t - X_t \lambda \geq 0, \lambda \geq 0\]

Note that in this paper there must be calculated \(N(3T-2)\) linear programming equations [25,29]. Taking into consideration the 155 Health Centers and the 2 time periods that were included into the analysis, 620 Linear Programming equations need to be calculated.

Data

Efforts were made to include all Health Centers of Greece in the analysis of this paper, but due to lack of data, only 155 Health Centers were finally included. Therefore, 52 Health Centers were excluded to avoid random estimation and possibility of bias.

The sample used for the analysis of this paper is homogenous, as it includes the majority of Health Centers of Greece (74,87% of the total), distributed across the seven Health Regions of Greece. The 155 Health Centers use the same categories of inputs generating the same categories of outputs, differing only in the quantities been used. This ensures comparability and validates this paper to measure their productivities and efficiencies for the years 2016, 2017, 2018 with DEA. Furthermore, according to the literature, the requirements for conducting MPI DEA are satisfied, ensuring meaningful results. These requirements include that at least one DMU in the sample consumes and produces each input and output and that each DMU in the sample consumes at least one input and produces at least one output [30,31]. By including the majority of Health Centers in Greece discriminatory power between the efficient and inefficient units is also achieved [32,33].

In the analysis of this paper, 12 outputs were included to measure the productivity change and the change in technical efficiency and technology of each Health Center. The outputs represent the total Health Care services provided by each Health Center:

1. Total number of “Nursing Operations” applied – Output1
2. Total Number of “Microsurgeries” applied – Output2
3. Total Number of "Dental Procedures" applied – Output3
4. Total number of "Chronic disease cases" faced – Output4
5. Total number of "Emergencies" faced – 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 "Test Mantoux" applied – Output10
11. Total Number of "Vaccinations for adults" applied – Output11
12. Total Number of "Vaccinations for kids and teenagers" applied – Output12

In contrast, 4 inputs were used, representing the total staff employed and occupied in the Health Centers:

13. Total "Number of Managers" employed – Input1
14. Total "Number of Doctors" employed – Input2
15. Total "Number of Nursing Staff" employed – Input3
16. Total "Number of non-medical staff" employed – Input4

All inputs and outputs used for this paper are for the years 2016, 2017 and 2018. In Additional File 1 a table is presented, which shows the descriptive statistics of all inputs and outputs used to evaluate the total productivity and efficiency of each of the 155 Health Centers included in the analysis of this paper. The descriptive statistics show the minimum, maximum and mean values, as well as the standard deviation of each input and output included in the analysis.

Results

Productivity

The productivity and the efficiency of each of the 155 Health Centers were measured by performing input-oriented MPI DEA using DEAP ver2.1 program.

The summary table with the results of technical efficiencies under CRS and VRS assumption for 2016, 2017, 2018 of all DMU's included in the analysis are presented below.

Table 1 – Descriptive Statistics, Mean, Maximum, Minimum and Standard deviation of the efficiencies in each year, under CRS and VRS assumption for the 155 DMU's

| N       | YEAR1-crs | YEAR1-vrs | YEAR2-crs | YEAR2-vrs | YEAR3-crs | YEAR3-vrs |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| Valid   | 155       | 155       | 155       | 155       | 155       | 155       |
| Missing | 0         | 0         | 0         | 0         | 0         | 0         |
| Mean    | .85419    | .94366    | .85128    | .92827    | .85074    | .93104    |
| Std. Deviation | .203580 | .134536   | .210957   | .145666   | .197387   | .139425   |
| Minimum | .195      | .318      | .274      | .307      | .317      | .333      |
| Maximum | 1,000     | 1,000     | 1,000     | 1,000     | 1,000     | 1,000     |
| Percentiles | 25      | 72600     | 98800     | 68600     | 98400     | 71400     |
|          | 50        | 1,00000   | 1,00000   | 1,00000   | 1,00000   | 1,00000   |
|          | 75        | 1,00000   | 1,00000   | 1,00000   | 1,00000   | 1,00000   |

By performing the Spearman-rank correlation between efficiencies calculated under the CRS and VRS assumption, the correlation coefficient is calculated for each year.

Table 2 – Spearman-rank correlations between input oriented crste and vrste models

Year 2016
For the years 2016, 2017, and 2018, the correlation coefficients are 0.571, 0.698, and 0.665, respectively. The statistically significant coefficients show a high degree of correlation between the CRS and VRS methods for each year [34].

Malmquist Productivity Index

The results for the 2016-2017 and 2017-2018 periods, as well as the overall results for the period 2016-2018, are presented in Additional File 2, for all the firms included in the analysis. Effch, techch, petch, sech and tfpch columns represent the indices related to efficiency change, technological change, pure technical efficiency change, scale efficiency change and total factor productivity change, respectively. Indices that take values greater than one indicate progress for the Health Center, values less than one indicate decline, while when equal to one they indicate no change from t to t+1 [27].

In Table 3 Summary Statistics with Mean, Minimum and Maximum values, and the Standard Deviation of effch, techch, tfpch under each of the two periods, as well as the overall results for both periods, over all DMU's are presented.

Table 3 – Mean, Minimum, Maximum and St. Deviation of effch, techch, tfpch of each period over all DMU’s
In the first period (2016-2017), 73 Health Centers achieved progress in their total productivity, while 82 had lower productivity levels. In the second period, 72 Health Centers achieved progress in their total productivity, while 83 had lower productivity levels. Overall productivity for both periods showed an increase for 61 Health Centers and a decrease for 94 Health Centers.

After monitoring the productivity change of each Health Center, the factor that contributed mainly to the change shall be explained.
The first period (2016-2017), 48 Health Centers showed improvement in their technical efficiency, 43 showed decline in their technical efficiency, while 64 achieved the same levels of technical efficiency. In addition, 74 Health Centers achieved improvement in their technology, while 81 showed decline in their technology. The second period (2017-2018), 43 Health Centers showed improvement in their technical efficiency, 44 showed decline in their technical efficiency, while 68 achieved the same levels of technical efficiency. In addition, 62 Health Centers showed technology improvement, while 93 technology decline for the second period.

The analysis of the means values showed a decrease of 0,9% in the overall productivity factor from the year 2016 to the year 2017 and a decrease of 5,2% from the year 2017 to the year 2018. The overall decrease in the productivity of the 155 health Centers was 3,1%.

To examine the change in total productivity, an additional fraction is calculated. If the fraction effch-techch>0 is true, then the change in productivity is mainly due to change in technical efficiency, while if it is false, productivity change is mainly due to change in technology for each Health Center [35].

Moreover, since effch=pech*sech, if pech>sech is true, then the change in technical efficiency is mainly due to the pure technical efficiency progress or regress, while if it is false, then the change in technical efficiency is mainly due to the change in scale efficiency for each Health Center.

From 2016 to 2018, 59 Health centers changed their productivity mainly due to technological change, 91 mainly due to technical efficiency change, while one Health Center showed regression to its total productivity due to equal regression of its technical efficiency and technology.

It should be stated that the majority of health centers changed their productivity through time due to technical efficiency change, but also that the Health Centers with high volatility in their productivity, had high volatility in their technology, explaining the fact that Health Centers that faced the biggest changes in their productivity was mostly due to technology change. This explains the fact that in Figure 1, presenting the mean productivity change over time as well as the mean technology change over time, the change through the 2 periods has similar movement.

**Model Validation**

To test the internal and external validity of the MPI DEA input-oriented model, the Spearman-rank correlation test was performed. Internal validity compares whether there are differences in the overall productivity of Health Centers when different inputs and outputs are used, while external validity compares whether there is consistency over time based on data from different time periods. DEA is a non-parametric method, so it is not possible to directly compare productivity and efficiency by different models. However, the comparison of efficiencies and productivities can be applied through non-parametric correlation tests [36-39].

The total productivities of Health Centers were calculated using different models, with different inputs and outputs. The models are presented in Table 6, which shows the different inputs and outputs used to calculate the efficiencies and total productivities of the Health Centers by each model.

### Table 6 – Different Models for internal validity check

| Models/Variables | Out1 | Out2 | Out3 | Out4 | Out5 | Out6 | Out7 | Out8 | Out9 | Out10 | Out11 | Out12 | Inp1 | Inp2 | Inp3 | Inp4 |
|------------------|------|------|------|------|------|------|------|------|------|-------|-------|-------|------|------|------|------|
| M0               | X    | X    | X    |      |      |      |      |      |      |       |       |       |      |      |      |      |
| M1               |      | X    | X    |      |      |      |      |      |      |       |       |       |      |      |      |      |
| M2               | X    | X    |      |      |      |      |      |      |      |       |       |       |      |      |      |      |
| M3               |      | X    | X    |      |      |      |      |      |      |       |       |       |      |      |      |      |

The first period (2016-2017), 48 Health Centers showed improvement in their technical efficiency, 43 showed decline in their technical efficiency, while 64 achieved the same levels of technical efficiency. In addition, 74 Health Centers achieved improvement in their technology, while 81 showed decline in their technology. The second period (2017-2018), 43 Health Centers showed improvement in their technical efficiency, 44 showed decline in their technical efficiency, while 68 achieved the same levels of technical efficiency. In addition, 62 Health Centers showed technology improvement, while 93 technology decline for the second period.

The analysis of the means values showed a decrease of 0,9% in the overall productivity factor from the year 2016 to the year 2017 and a decrease of 5,2% from the year 2017 to the year 2018. The overall decrease in the productivity of the 155 health Centers was 3,1%.

To examine the change in total productivity, an additional fraction is calculated. If the fraction effch-techch>0 is true, then the change in productivity is mainly due to change in technical efficiency, while if it is false, productivity change is mainly due to change in technology for each Health Center [35].

Moreover, since effch=pech*sech, if pech>sech is true, then the change in technical efficiency is mainly due to the pure technical efficiency progress or regress, while if it is false, then the change in technical efficiency is mainly due to the change in scale efficiency for each Health Center.

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The total productivities of Health Centers were calculated using different models, with different inputs and outputs. The models are presented in Table 6, which shows the different inputs and outputs used to calculate the efficiencies and total productivities of the Health Centers by each model.
The first model (M0) is the model that considers 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 "Number of Managers" and "Number of non-medical staff" and the output variables "Test Mantoux", "Dental Procedures" and "Transcriptions".

After estimating the total productivities of the 155 Health Centers, under the input-oriented MPI DEA, for the four different models, Spearman-rank correlation coefficients were calculated.

Table 7 – Model Internal Validity test with Spearman Rank Correlation (Total Productivity)

| Spearman's rho | tfpch (M0) | tfpch (M1) | tfpch (M2) | tfpch (M3) |
|---------------|------------|------------|------------|------------|
| Correlation Coefficient | 1,000 | .896** | .951** | .766** |
| Sig. (2-tailed) | . | .000 | .000 | .000 |
| N | 155 | 155 | 155 | 155 |

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

To subject the analysis to an external validity test, the spearman-rank correlation test between the calculated total productivities over the two periods was performed.

Table 8 – Model External Validity test with Spearman Rank Correlation (Productivity of each period)

| Spearman's rho | tfpch (period1) | tfpch (period2) |
|---------------|----------------|----------------|
| Correlation Coefficient | 1,000 | -250** |
| Sig. (2-tailed) | . | .002 |
| N | 155 | 155 |

The Spearman-rank correlation tests for external validity show that there is low, but statistically significant correlation between time periods.

The spearman-rank coefficients re-ensure strong external and internal validity for the model.

Discussion

The dataset was provided by the Ministry of Health and refers to the years 2016, 2017 and 2018. Attempts were made to collect Data for all 207 Health Centers of Greece, as well as Financial Data for the Health Centers, which would have been used as inputs for the purposes of this paper and would have contributed to the evaluation of the total productivities and efficiencies of the Health Centers. Unfortunately, data on costs and expenditures for the Health Centers were missing, but since that Health Centers are labor-intensive units, the total staff employed and occupied was used as inputs for the estimation of the total productivities and efficiencies. It is recommended that the Greek Government start gathering Financial Data to estimate the total productivity and efficiency of Primary Health Care [40]. In addition, 52 Health Centers were excluded from this paper due to lack of data, mainly due to the change in the system the data were collected in 2016.
Conclusion

In this paper the non-parametric DEA method along with the MPI was used, so as to estimate the productivity change during the period 2016–2018. Moreover, after the estimation of productivity of each Health Center for the years 2016, 2017 and 2018, as well as the change of productivity of each Health Center over time, the factors that contributed the most were estimated, indicating the changes to technical efficiency and technology for the Health Centers during the period 2016–2018.

Meaningful results were extracted by indicating the number of Health Centers that their productivity improved, regressed or remained constant through the period 2016–2018. Also, the productivity evaluation is critical, since it provides important information about the viability and efficiency of each Health Center, as well as it shows the overall growth and progress of Primary Health Care [7].

In addition, Health Centers could have been submitted into a second-regression analysis, showing if there is correlation between their productivity levels and the Health Region they belong to, “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 Health Centers that it may affect” [8,41]. In a previous paper for Health Centers in Greece for 2018, a Tobit regression analysis was employed to investigate if the above assumption was accurate. Since the study showed that the efficiency of the Health Centers was not affected by the Health Region they belong to, there was no reason to conduct further analysis [42]. Extensive research should be made in order 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' efficiency and productivity. Furthermore, valuable results can be extracted, for the National Health Care System in order to match available resources depending on each Health Center's needs, as well as for manager planners and stakeholders in Primary Health Care.

The estimation of total productivities and efficiencies of Health Centers were calculated using DEAP version 2.1 for Windows by Coelli (1996). Statistics were performed by using the IBM SPSS program.

Abbreviations

WHO: World Health Organization; OECD: Organization for Economic Co-operation and Development; DEA: Data Envelopment Analysis; DMU: Decision Making Unit; CRS: Constant Return to Scale; VRS: Variable Return to Scale; MPI: Malmquist Productivity Index; Effch: Efficiency Change; Techch: Technology Change; Pech: Pure Efficiency Change; Sech: Scale Efficiency Change; Tfpch: Total Factor Productivity Change

Declarations

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Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from Bi-health (Ministry of Health) but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Ministry of Health.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

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Figures

![Figure 1](image_url)

Figure 1

Tfpch, techch and effch over time (Mean Values)

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