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MEASURING THE EFFICIENCY AND PRODUCTIVITY CHANGE OF MUNICIPALITIES WITH AN OUTPUT ORIENTED MODEL: EMPIRICAL EVIDENCE ACROSS GREEK MUNICIPALITIES OVER THE TIME PERIOD 2012-2016

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Abstract

This paper investigates the relative efficiency and productivity change of municipalities (regions of Thessaly and Central Greece), during the period 2012–2016. This period is rather special, because Greece had to meet the commitments imposed by the very tight fiscal consolidation program and, secondly, a major structural reform had preceded in Greek Local Government. It implements Data Envelopment Analysis (DEA) with output orientation and Malmquist analysis. Additionally, it estimates the effects of the environmental factors on the efficiency using Regression Analysis. The findings suggest that municipalities could produce on average the same quantity of inputs with 23.7% or 10.40% more quantity of outputs and on average refrain 14.90% from the optimal scale. The total factor productivity change has risen by an annual average of 0.6% relatively to the base year 2012. Moreover, the evaluation of municipalities on the basis of efficiency and productivity criteria and the identification of municipalities constituting benchmarks, contribute to policy formulation and region-based approaches.

Keywords: Greek municipalities, efficiency, productivity, DEA, Malmquist analysis
JEL: C14, J48, P41, P43

1. Introduction

Municipalities are units of great importance, with multiple inputs and outputs, since many public functions have been transferred from national to local authorities. Over time, municipalities are facing an increasing pressure to provide more and better quality services to citizens with limited resources, which are even more limited in times of economic crises and restrictive policies.

Greece is a member state of the European Union (1981) and of the Eurozone (2001). The basic administrative division of Greece was formed in 2011. The country is divided into 325 Municipalities (1st Grade Local Authorities), 13 Regions (2st Grade Local Authorities) and 7 Decentralized Government Administrations. The regions of Central Greece (25 municipalities) and Thessaly (25 municipalities) are located in the central zone of Greece and have similar characteristics (area 15.549 and 14.037 Km2, population 546.870 and 730.730, population density 35,17 and 52,06 citizens/ Km2 and GDP 10.537 and 11.608 million euros, respectively.

The purpose of this paper is manifold:

1) To measure the relative efficiency and productivity change of municipalities in the two representative regions (Thessaly and Central Greece) over the period 2012-2016 and to identify which perform higher than the average efficiency. This period is rather special in the Greek case, for two reasons: firstly, Greece had to meet the commitments imposed by the very tight fiscal consolidation program that had been agreed between European Commission, European Central Bank, International Monetary Fund and Greek government, and secondly, a major structural reform had preceded in Greek Local Government.

2) To compare the performance of Greek municipalities with the average level of the performance of other countries and especially those of the European Union.

3) To answer to the questions below:

i. Does the evaluation of municipalities on the basis of efficiency and productivity criteria and the identification of municipalities constituting benchmarks, contribute to policy formulation?

ii. Are the efficiency and productivity change of the relatively large municipalities comparatively higher than those of the relatively small municipalities? Is the policy of municipal mergers verified?

iii. Are there environmental variables that affect performance?

iv. Did the municipalities΄ performance improve over the period 2012-2016?

To the best of our knowledge, this is the first study which answers these questions.

The remainder of the paper is organized as follows: Section 2, provides a review of empirical literature; Section 3 presents a short theoretical framework; Section 4 specifies the empirical analysis; Section 5 issues the Second Stage Analysis and Section 6 concludes summarizing the main findings and policy recommendations.

2. Literature Review

Over the last 30 years, there have been many empirical studies that have focused on the measurement of efficiency and productivity and it is possible to identify two categories of empirical research (De Borger and Kerstens, 1996a). Some studies concentrate on the evaluation of a particular service, such as refuse collection and street cleaning (Benito, Bastida and Garcia, 2010; Worthington and Dollery, 2000), water services and street lighting. On the other hand, other studies evaluate local performance considering that municipalities supply a wide variety of services and facilities. In the studies which measure the efficiency in terms of technical, economical and appropriation, parametric and non-parametric methods are used. DEA is one of the most popular today's methods, which is a very suitable nonparametric analysis method especially for determining the efficiency of municipalities. The empirical studies (Pougkakioti and Tsamadias, 2020; Narbón-Perpiñá and De Witte, 2017) use inputs and outputs from the following:

Inputs: X1: total expenditures; X2: current expenditures; X3: personnel expenditures; X4: capital expenditures; X5: other financial expenditures; X6: local revenues; X7: current transfers; X8: public health services; X9: area.

Outputs: Y1: global output indicator; Y2: population; Y3: area; Y4: administrative services; Y5: infrastructures (Y5.1: street lighting, Y5.2: municipal roads); Y6: services (Y6.1: waste collection, Y6.2: sewerage system, Y6.3: water supply, Y6.4: electricity); Y7: sports, parks, culture facilities, etc. (Y7.1: sport, Y7.2: cultural, Y7.3: libraries, Y7.4: parks, Y7.5 : recreational); Y8 : health; Y9 : education (Y9.1 : kindergartens/nurseries, Y9.2 : primary/secondary education); Y10 : social services (Y10.1 : beneficiaries of grants, Y10.2 : care for elderly, Y10.3 : care for children, Y10.4 : social organizations); Y11 : public safety; Y12 : market; Y13 : public transport; Y14 : environmental protection; Y15 : business development; Y16 : quality index; Y17 : others.

In the study of Portuguese municipalities (Afonso and Fernandes, 2006) relative efficiency of selected 278 municipalities in 5 different regions was determined by using DEA. Also, a set of descriptive variables and their effects on inefficiency were determined by using Tobit analysis.

In the study of Benito et al. (2010) DEA was used by using the service and cost as inputs in terms of the service types of municipalities. After that, determinants of efficiency according to the different administration types like sub-structures of municipalities, directly self-governance, autonomous public agency, 100% public company checked by self-governance, 51% public company, and private company were determined comparatively.

In the study in which cost efficiency of Australian local administrations is determined, analysis of mathematical programming and econometric approaches are made comparatively (Worthington, 2000). As a result of analysis, it is indicated that DEA and stochastic methods have to be thought as supplementary tools in the analysis of local public sector.

Effects of efficiency of public services and budget and political settlement and fiscal capacity and democratic applications on efficiency were determined by using an econometric analysis method (Borge et al., 2008). The study was carried out by benefiting from global efficiency measurement criterions in Norway local administrations. It turned out that high fiscal capacity and multi-party political settlements have negative effects on the efficiency of local administrations. In addition to this, central bureaucratic budgeting method also causes efficiency to be low.

Loikkanen and Susiluoto (2006) examined in their study the cost efficiency of social aid service supply in Finland’s municipalities between 1994 and 2002. As a method, DEA was used to calculate efficiency. 6 of 10 inputs used in health, education and social services are evaluated and production costs of these services are used as outputs. As a result of the study, it has resulted that there are important differences between municipalities in cost efficiency. It shows that small municipalities in South Finland are the most efficient municipalities; however, the efficiency of the bigger municipalities in North is low.

Municipalities face different environmental conditions in social, demographic, economic, political, financial, geographical and institutional terms, among others (Narbón-Perpiñá and De Witte, 2017). The selection of the variables depends on the availability of data. In particular, 6 basic categories of variables are examined:

Z1= Population (Z1.1=Density, Z1.2 =Growth, Z1.3= Size, Z1.4 = Age distribution, Z1.5 = Education level, Z1.6 = Immigration share, Z1.7 = Share of homeowners, Z1.8 = Others);

Z2 = Economic (Z2.1 = Unemployment, Z2.2 = Income, Z2.3 = Economic status, Z2.4 = Tourism, Z2.5 = Commercial activity, Z2.6 = Industrial activity, Z2.7 = Others); Z3 = Political (Z3.1 = Ideological position, Z3.2 = Political concentration, Z3.3 = Voter turnout, Z3.4 = Re-election and number of years for elections, Z3.5 = Others); Z4 = Financial (Z4.1 = Self-generated revenues, Z4.2 = Transfers, Z4.3 = Financial liabilities, Z4.4 = Fiscal surplus, Z4.5 = Infrastructure investments, Z4.6 = Others); Z5 = Geographical (Z5.1 = Distance from center, Z5.2 = Area, Z5.3 = Type of municipalities (sea, mountain), Z5.4 = Others); Z6 = Institutional (Z6.1 = Computer usage, Z6.2 = Mayor and municipal employees, Z6.3 = Amalgamation, Z6.4 = Municipal externalization, Z6.5 = Others).

Table A3 in the Appendices presents the classification of empirical studies (European and non-European Countries). More specifically, as can be inferred from Table A3, the large majority of the studies have used only one approach (Data Envelopment Analysis –DEA or Stohastic Frontier Analysis – SFA or Free Disposal Hull – FDH) and the rest combine more than one method. From the studies which employ DEA, the more use Input Orientation (I.O.) and the rest use Output Orientation (O.O.) or both I.O. and O.O. approach. Local governments' efficiency analysis is best studied in Europe. The most popular methods of estimating the influence of the environmental variables on efficiency are Tobit and Ordinary Least Squares (O.L.S.)

3. Methodology and models

The techniques adopted to assess efficiency are usually classified in parametric (Stohastic Frontier Analysis - S.F.A.) and nonparametric methods (deterministic frontier – D.E.A. model). We estimate here the functional form of the best-practice frontier, relying on the nonparametric technique of DEA by output orientation.

Efficiency measurement begins with Farrell (1957), who drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. Data Envelopment Analysis (DEA) is widely accepted and used by scholars for its strengths and well recognized as a valuable decision support tool for managerial control and organizational diagnosis, and for conducting benchmarking studies. DEA measures the efficiency of different units, called "Decision Making Units" (DMUs). DEA is the non-parametric deterministic mathematical linear programming approach that estimates the relative efficiency of homogeneous DMUs. It introduces very weak assumptions related to the estimation of an empirical production function which converts the inputs into outputs, assuming the existence of a convex production frontier and strong free disposability in inputs and outputs (Charnes, Cooper and Rhodes, 1978). The piecewise-linear convex hull approach to frontier estimation received wide attention. The production frontier is generated by solving a sequence of linear programming problems, one for each municipality, while the relative Technical Efficiency (T.E.) of the municipality is measured by the distance between the actual observation and the frontier obtained from all the municipalities under examination. Thus, a municipality results efficient if TE=1, but it is inefficient or technically not efficient if TE < 1. DEA calculates the efficiency of a DMU by dividing a weighted sum of its outputs by a weighted sum of inputs. Weights of inputs and outputs are not given in advance, but they are determined as part of the solution to the optimizing problem. In the simplest case, each DMU is allowed to weigh its inputs and outputs freely to maximize its relative efficiency. DEA models can be either input (determination of minimum inputs for producing a given level of output) or output (maximization of outputs with given levels of inputs) oriented. However, in this study an output orientation is adopted because municipal administrations have greater control over outputs and the production function is constructed by searching for the maximum possible proportional augmentation in output usage, while input levels are held fixed. As the sample includes municipalities having very different sizes, the efficiency score is calculated adopting two conceptualizations, the first one suggested by Charnes et al. (1978) (CCR model) that assumes constant returns to scale (CRS) and the second one that follows Banker, Charnes, and Cooper (1984) (BCC model), assuming variable returns to scale (VRS). In particular, an output-oriented model is defined as:

- Output – oriented – CRS

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

- Output – oriented – VRS

$$\max_{\phi,\lambda} \phi,$$
$$\text{st} \quad -\phi q_i + Q\lambda \geq 0,$$
$$x_i - X\lambda \geq 0,$$
$$N1'\lambda = 1$$
$$\lambda \geq 0,$$

where λ is the vector of relative weights (N × 1) given to each unit and N is the number of unit. Assuming that there data on I inputs and O outputs: X represents the matrix of inputs (I × N) and Y is the matrix of outputs (O × N). For the i^{th} unit these are represented by the column vectors Xi for the inputs and Yi for the outputs. These refer to CRS model. The CRS assumption is avoided in the VRS model (Banker et al., 1984) by the introduction of an additional constraint on the λ, allowing returns to scale, i.e., N1′λ = 1, where N1′ is a vector of ones. This restriction imposes convexity of the frontier. Finally, the efficiency score (θ) is a scalar and estimate the technical efficiency by assuming values between 0 and 1, with a value of 1 indicating a point on the frontier and hence a technical efficient unit (Farell, 1957). In our analysis, we computed both CRS and VRS efficiency scores. Also, we interpret the ratio CRS/VRS as the scale efficiency (SE), which refers to the ability of each unit to operate at its optimal scale of operations. In order to find out whether a municipality is scale efficient and qualify the type of returns of scale, a DEA model under the non-increasing returns to scale (NIRS) can be implemented by replacing the $N1'\lambda=1$ restriction with $N1'\lambda \leq 1$, putting SE= TECRS / TENIRS. As Fare, Grosskopf, and Lovell (1985) suggest the following rule can be applied: a) if SE = 1, then the municipality is scale efficient, both under CRS and VRS; b) if SE = 1 the municipality operates under increasing returns to scale; c) if SE<1 the municipality operates under decreasing returns to scale.

After the DEA analysis, we carry out also an analysis using the Malmquist productivity index (MPI) to evaluate the possible changes in the efficiency level or technological progress (TC). Technological changes might occur and could affect and shift the frontier. The 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: change in productivity (efficiency) and change in production frontier. Fare et al. (1994) defined the I.O. MI between year t and t + 1 as the ratio of the distance function for each year relative to a common technology, as follows:

$$(1) \qquad M^t = \frac{M_1^t(x_t + 1\ ,\ y_t + 1)}{D_1^t(x^t, y^t)}$$

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

$$(2) \qquad M^{t+1} = \frac{D_1^{t+1}(x_t + 1\ ,\ y_t + 1)}{D_1^{t+1}(x^t, y^t)}$$

where the subscript I indicates an input-oriented, M is the productivity of the most recent production point (xt+1, yt+1) (using period t + 1 technology) relative to the earlier production point (xt, yt) (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:

(3) $$M_I(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_1{}^t(x^{t+1}, y^{t+1})}{D_1{}^t(x^t, y^t)} \frac{D_1{}^{t+1}(x^{t+1}, y^{t+1})^{1/2}}{D_1{}^{t+1}(x^t, y^t)}$$

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

(4) $$M_I(x^{t+1}, y^{t+1}, x^t, y^t) = \underbrace{\frac{D_1{}^{t+1}(x^{t+1}, y^{t+1})}{D_1{}^t(x^t, y^t)}}_{\text{Efficiency change}} \underbrace{\frac{D_1{}^t(x^{t+1}, y^{t+1})}{D_1{}^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_1{}^t(x^t, y^t)^{1/2}}{D_1{}^{t+1}(x^t, y^t)}}_{\text{Technological change}}$$

The methodology can be further extended by decomposing the efficiency change into scale efficiency (SEC) and pure technical efficiency (PEC) components. The appropriate required distance functions can be estimated via DEA technologies, as described above (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 (Worthington, 2000).

4. Empirical analysis

In this study we employ the non-parametric output-oriented D.E.A. and Malmquist Analysis (MA) in order to measure the relative TE, SE and the Total Factor Productivity Change (TFP change) of the investigated municipalities. Methodologically, we use a two-step procedure in empirical analysis. Our decision making units are municipalities. In the first stage, we only use information of their output and input volumes and apply Data Envelopment Analysis (DEA) to derive frontier production functions and related efficiency scores for each municipality. In the second stage we use regression model to explain the variation of efficiency scores among municipalities.

a. Data and sources

In Greece, municipalities provide a wide array of essential services. In this study we use three input and four output variables per inhabitant:

X1: total annual expenditures;

X2: total number of employees;

X3: the number of vehicles-machinery;

Y1: the number of pupils enrolled in the pre-primary / primary / secondary municipal infrastructures;

Y2: The total quantity of mixed waste in tons leading to landfill or to uncontrolled disposal;

Y3: The number of pre-primary / primary / secondary municipal infrastructures;

Y4: The number of beneficiaries from municipal grants.

In particular, the variables are derived from: X1, X3 - the municipalities, X2 - the Ministry of Administrative Reconstruction, Y1, Y3 - the Regional Education Directorates, Y2 - the Solid Waste Management Associations, Y4 - the Ministry of Labor, Social Security and Social Solidarity. All data were used for research purposes only, without being published in any public repository. These variables have been used, measured by several authors in order to formulate, analyze and measure efficiency and productivity change of municipalities.

For the data analysis we use the DEAP Version 2.1 software package (Coelli, 1996).

b. Descriptive Statistics

Table 1 reports descriptive statistics of inputs and outputs (means, standard deviations maxima and minima). The findings show that the average trend for X1, X2, Y1, Y2 and Y4 is downward, since most output variables tend to decrease over the period with the exception of the X3 and Y3 that remain more stable. The average total annual expenditures per inhabitant is about 456-573€. The average number of employees per inhabitant is 0.0051-0.0059. The average number of vehicles-machinery per inhabitant is 0.0025. The average number per inhabitant of pupils enrolled in the pre-primary / primary / secondary municipal infrastructures is 0.1051-0.1093. The average total quantity per inhabitant is 0.3467-0.3626 and the average number of beneficiaries from municipal grants per inhabitant is 0.0057-0.0070. Moreover, the average total annual expenditures per inhabitant of Central Greece is 546,12€ whereas the average total annual expenditures per inhabitant of Thessaly is 476,43€. This means that the municipalities of the Region of Central Greece spend more per inhabitant compared to the municipalities in the region of Thessaly.

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

Statistics / Variable	**Inputs**			**Outputs**			
	Thessaly & Central Greece						
	X_1	**X_2**	**X_3**	**Y_1**	**Y_2**	**Y_3**	**Y_4**
2012							
Mean	543,1554	0,0059	0,0025	0,1093	0,3626	0,0017	0,0070

Min	249,1558	0,0024	0,0008	0,0034	0,0417	0,0003	0,0000
Max	1.444,4970	0,0176	0,0106	0,2050	1,0869	0,0027	0,0890
Std. Dev.	266,8350	0,0029	0,0017	0,0462	0,1803	0,0004	0,0174
2013							
Mean	573,3149	0,0055	0,0025	0,1082	0,3564	0,0017	0,0059
Min	212,0850	0,0022	0,0008	0,0030	0,0325	0,00004	0,0000
Max	1.381,4262	0,0152	0,0112	0,1991	1,2259	0,0027	0,0682
Std. Dev.	273,8456	0,0028	0,0017	0,0458	0,1946	0,0004	0,0143
2014							
Mean	515,5570	0,0052	0,0025	0,1074	0,3549	0,0017	0,0058
Min	152,8705	0,0019	0,0008	0,0031	0,0317	0,0004	0,0000
Max	1.685,8997	0,0142	0,0112	0,2000	1,2549	0,0027	0,0610
Std. Dev.	253,1630	0,0025	0,0017	0,0460	0,1964	0,0004	0,0136
2015							
Mean	467,8934	0,0052	0,0025	0,1061	0,3467	0,0017	0,0057
Min	145,3499	0,0019	0,0008	0,0024	0,0291	0,0004	0,0000
Max	1.155,6333	0,0144	0,0112	0,2036	1,3553	0,0027	0,0576
Std. Dev.	199,2975	0,0025	0,0018	0,0465	0,2128	0,0004	0,0133
2016							
Mean	456,4506	0,0051	0,0025	0,1051	0,3536	0,0017	0,0066
Min	205,3591	0,0019	0,0009	0,0022	0,0276	0,0004	0,0000
Max	1.220,0896	0,0144	0,0117	0,2055	1,3451	0,0027	0,0523
Std. Dev.	194,4456	0,0025	0,0018	0,0473	0,2077	0,0004	0,0129

Source: author's calculation

c. First stage: Measuring Relative Efficiency, Productivity Change and Discussion

The analytical results (CRSTE, VRSTE, SE, EC, TC, PEC, SEC, TFP change) of the municipalities for each of the five years are presented in the Appendices. The average performance values for the period 2012-2016 are presented in the Table A1.

When focus is on the whole sample, average CRSTE efficiency score is 0.763 (76.3%). This means that municipalities could produce on average the same quantity of inputs with 23.7% more quantity of outputs. Minimum efficiency score is 0.314 and maximum 1.000. The number of 100% efficient municipalities is 5 (DMUs: 4, 8, 31, 33, 50). Average VRSTE efficiency score is 0.896 (89.6%). This means that municipalities could produce on average the same quantity of inputs with 10.40% more quantity of outputs. Minimum efficiency score is 0.539 and maximum 1.000. The number of 100% efficient municipalities is 17 (DMUs: 4, 8, 13, 14, 26, 29, 30, 31, 33, 34, 35, 36, 40, 44, 45, 47, 50). Furthermore, municipalities operate close to the optimal scale, SE=0.851 (refrain 14.90% from the optimal scale).The results are consistent with previous studies (Worthington and Dollery 2000; Pevcin, 2014; Lo Storto, 2016).

The findings also show that relatively large municipalities with population criteria (population>average population) have comparatively higher efficiency rates (CRSTE=0.874, VRSTE=0.924, SE=0.942) than smaller municipalities (CRSTE=0.727, VRSTE=0.887, SE=0.822). Relatively large municipalities are producing more quantity of outputs than relatively small ones. Also, municipalities of Thessaly could on average produce the same quantity of inputs with 20.7% more quantity of outputs, whereas municipalities of Central Greece with 26.80%. Table 2 reports the number of municipalities and the average efficiency scores and shows that 18 municipalities have average CRSTE ranging between 0.600 and 0.800, 31 municipalities have average VRSTE ranging between 0.900 and 1.000 and 27 municipalities have average SE ranging between 0.900 and 1.000.

Table 2. Number of municipalities & efficiency score

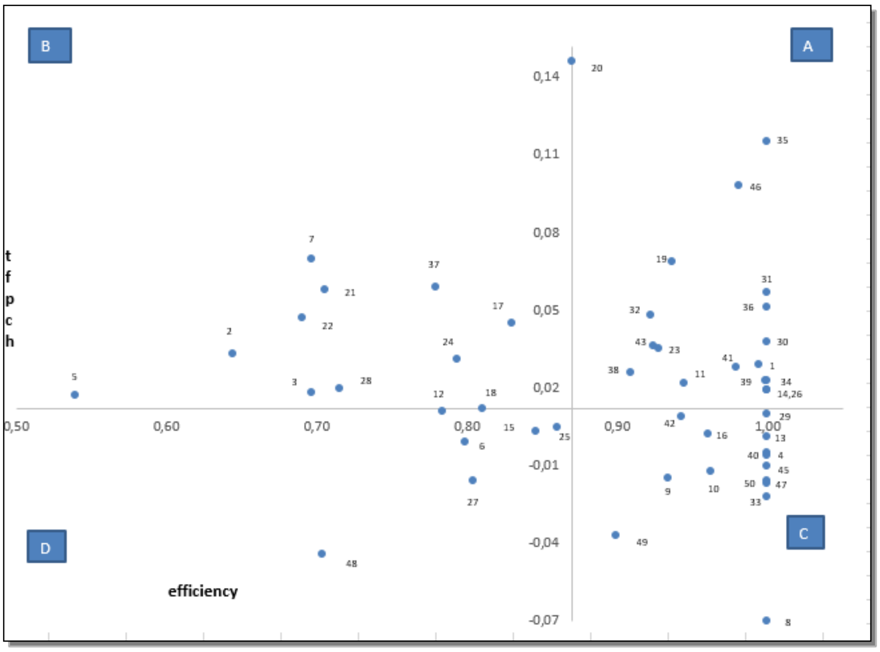
EFFICIENCY SCORE	CRSTE	VRSTE	SE
[0 - 0.600)	9	1	4
[0.600 – 0.800)	18	11	12
[0.800 – 0.900)	8	7	7
[0.900- 1.000]	15	31	27

Source: author's calculation

The Malmquist TFP results (Agasisti et al., 2015; Sung, 2007; Kutlar and Bakirci, 2012) indicate that municipalities experienced an approx. 0.6% increase in average productivity. On examining the components of the productivity change, it becomes evident that the productivity gain may be primarily attributed to a change in relative efficiency and especially to the combination of both positive annual average EC (2.7%) and negative annual average TC (-2.1%). On average, improvements in PEC are the main reasons for the improvements in EC. The average PEC, which measures changes in VRSTE, indicates that there is an improvement of 1.5% over the examined period. Municipalities of Central Greece have higher values of TFP change than municipalities of Thessaly. Also, municipalities of Central Greece have higher values of EC and TC than municipalities of Thessaly. The results show that 34 Municipalities have TFP change >1, ranging between 0,10% and 14,40%.

15 municipalities have TFP change < 1 ranging between –0.10% and –46.40%. This means that it was poor technology which needed to be updated or that it has not been used best-practice technology in the management. 12% of Municipalities have no change in efficiency, 60% of municipalities (experience increase (EC > 1) and the remaining 28% decrease (EC < 1). As a next step, we classify municipalities on the basis of their average VRSTE in the years 2012-2016 and the results of the average TFP change in the period 2012–2016.

Figure 1. Average VRSTE and TFP change



Source: author's calculation

The incision of the axes is the point O (mean VRSTE = 0.870, mean TFP = 0.010). The four groups in Figure 1 are characterized as follows:

Quadrant A: High efficiency and positive productivity growth.

Municipalities (DMUS: 35, 46, 19, 32, 43, 23, 38, 11, 41, 39, 31, 36, 30, 1, 34, 14, 26) have the best performance and can be benchmarks for other municipalities. This suggests that they should maintain their position by continuing to implement good strategies so as to fulfill their mission.

Quadrant B: Low efficiency and positive productivity growth.

Municipalities (DMUS: 20, 7, 5, 2, 21, 22, 37, 17, 24, 3, 28, 12, 18,) with medium to low efficiency have positive productivity growth. Special consideration should be given to these municipalities in order to improve their efficiency by implementing current strategies of productivity improvement.

Quadrant C: High efficiency and negative productivity growth.

Municipalities (DMUS: 42, 29, 16, 13, 40, 4, 45, 47, 33, 9, 10, 50, 49, 8, 44) still maintains a good efficiency in managing their resources, in spite of their productivity decline. Moreover, if they do not want to lose their current position they have to maintain a rapid growth, by maintaining positive technological change.

Quadrant D: Low efficiency and negative productivity growth.

Municipalities in the bottom-left quadrant (DMUS: 15, 25, 6, 27, 48) are those that have medium-low efficiency in managing their resources. Special attention should be given to those municipalities so as to diagnose their problems and to improve their efficiency.

d. Second Stage: OLS Analysis/Tobit Analysis

At the second stage of our two step analysis, differences in the DEA efficiency scores are explained by characteristics of municipalities. The regression model explaining variation of efficiency scores among municipalities were estimated with the 2012-2016 data. OLS and Tobit are the estimation models.

Table 3. OLS Regression analysis results

Variables	Coefficient
Z1	1.384 *(1.22)* *n.s.*
Z2	-0.003 *(-0.09)* *n.s.*
Z3	0.129 (2.14) **
Z4	0.0004 *(1.62)* *n.s.*
Z5	0.033 *(0.48)* ns
Z6	-0.006

Variables	Coefficient
	(-0.75) ns
Z7	-0.00003 (-0.11) ns
R	0.2326
Adj. R^2	0.1047
F	1.82

Note: 1)***, **, * level of statistic significance 1%, 5% και 10%, n.s. non-significant

2) Numbers in parentheses show the t- statistic values

Source: author's calculation

Table 3 reports the results of the OLS regression analysis and presents the variables that were considered in the DEA second stage analysis: number of unemployed as percentage of population (Z1), education level of mayor (Z2), type of municipality (Z3), population density (Z4), mayor's gender (Z5), number of amalgated municipalities (Z6), distance from the center of the region (Z7). The use of these variables are consistent with the existing literature. For this purpose, the exogenous variables regressed with efficiency score include values between zero and one. Relationships between these variables in the regression model are formulated as follows:

$$T.E.i = a + b_1Z_1 + b_2Z_2 + b_3Z_3 + b_4Z_4 + b_5Z_5 + b_6Z_6 + b_7Z_7 + e_i \quad (5)$$

where, i is the municipality to i (i = 1, ..., 50), T.E. is the efficiency score, and ϵ is the error term. A positive sign of the coefficient indicates that this latter is positively associated to VRSTE while a negative sign denotes an unfavorable association. The value of R2 is satisfactory, since the data are cross-section and show a satisfactory interpretive capacity of the equation. Prob(F-statistics) depicts the probability of null hypothesis being true. As per the above results, probability is close to zero (1.82). This implies that, overall, the regression is meaningful. It turned out that number of unemployed as percentage of population, education level of mayor, mayor's gender, number of amalgamated municipalities, distance from the center of the region and population density did not explain efficiency differences and had no effect on efficiency. Of the variables examined, only Z3 have statistically significant and positive effect on VRSTE. As expected, the type pf municipality is related to high efficiency. Our location variable (Z3) proved to be the most significant explanatory variable in our estimation results, getting high t-value.

The results are further interpreted using the Tobit model. The results are given in Table 4 and show that Z3, Z4 have statistically significant and positive effect on VRSTE (Z3 higher statistical effect than Z4). This relationship, according to Borger and Kerstens (1996) and Afonso and Fernandes (2008), is interpreted in a sense that a dense residential structure with a portion of the population who live in it, has relatively higher positive effect on efficiency that have a population structure that is relatively less dense. For the data analysis we use the STATA® Statistics / Data Analysis 14.2 SE software package (1985-2015 Stata Corp LLC, USA).

Table 4. Tobit Regression analysis results

Variables	**Coefficient**
Z1	1.343 *(1.27)* *n.s.*
Z2	-0.001 *(-0.03)* *n.s.*
Z3	0.129 (2.28) **
Z4	0.0004 *(1.76)* *
Z5	0.033 *(0.51)* ns
Z6	-0.006 *(-0.80)* ns
Z7	-0.00002 (-0.08) ns
LR chi2(7)	12.86
Pseudo R2	-0.2035
Log likelihood	38.018
/sigma	0.107

Variables	Coefficient

Note: 1)***, **, * level of statistic significance 1%, 5% και 10%, n.s. non-significant

2) Numbers in parentheses show the t- statistic values

Source: author's calculation

5. Concluding remarks and policy implications

This paper contributes to the literature on the empirical understanding of relative efficiency and productivity change in the two Greek representative regions (Thessaly and Central Greece). Additionally, it determinates the factors which affect the efficiency coefficients. From empirical analysis and discussion, the following key conclusions are drawn:

i. The average values of technical efficiency under variable and constant returns to scale, scale efficiency and total factor productivity change of the municipalities are in line with the results of European and non- European countries.

ii. Over the five years considered, there was a gradual improvement (year by year) of the average efficiency and productivity of the municipalities.

iii. The best performance (efficiency> mean VRSTE, productivity> mean TFP) have 17 of the 50 municipalities (34%) and they can be benchmarks for the other municipalities. The rest of them should try to learn from best practices in order to improve their own performance. That is paramount for a better use of scarce public resources in the context of the European Union's strategic direction to optimize the resource use.

iv. Relatively large municipalities with population criteria have comparatively better performances on average than relatively small ones.

v. The environmental variables - population density and type of municipality - have statistically significant positive effect on the municipality efficiency score.

vi. Municipalities of Thessaly have on average better performance than municipalities of Central Greece.

In fact, by giving insight into the causes of inefficiency, this helps to further identify the reasons for local inefficient behavior and may support effective policy measures to correct and or control them. Our study also helps to the ongoing discussion about the need and form of reforms in basic service provision. The proposals have included increasing municipality sizes by mergers or increasing voluntary cooperation of municipalities to make them more efficient. Decision makers at both municipal and central government levels have to acknowledge the significance of the findings.

Appropriate policy measures will lead to an improvement in the performance of all municipalities and, especially, of those with low performance. By merging two or more municipalities into a single new municipality or sharing the provision of public services creating an association or a consortium of municipalities has also benefits in terms of elimination of administrative and political body duplication. Also, the establishment of an observatory that aims to systematically measure and monitor the efficiency and productivity change of municipalities contributes positively to linking performance to resource allocation. In this direction, the introduction of an incentive-based system which will reward efficient municipalities and trigger surveillance programmes for those who need to improve is very important as well.

Undoubtedly, a need exists to continue the study and to improve certain factors that have not been adequately considered herein. Further research is needed to broaden the scope of services analyzed, with different combinations of inputs and outputs. Besides, repeating the survey year after year would enhance comparisons and allow investigating the evolution of municipal efficiency while the country has come out of the strict monitoring of the memorandums.

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Appendices

Table A1. Average Efficiency with CRS/VRS, (O.O.)

DMUs	Output - oriented										
	TE				SE		Productivity Change				
	CRS	Rank	VRS	Rank	S.E	Rank	EC	TC	PEC	SEC	Total Factor Productivity Change
1	0.991	6	0.994	19	0.997	6	1.011	1.016	1.008	1.003	1.027
2	0.512	45	0.644	49	0.798	35	1.007	1.024	1.026	0.981	1.031
3	0.651	38	0.697	46	0.938	22	1.098	0.925	1.101	0.997	1.016
4	1.000	1	1.000	1	1.000	1	1.000	0.992	1.000	1.000	0.992
5	0.502	46	0.539	50	0.930	25	0.973	1.043	1.000	0.973	1.015
6	0.628	40	0.799	39	0.784	38	1.054	0.946	1.031	1.022	0.997
7	0.595	42	0.696	47	0.850	32	1.133	0.943	1.044	1.085	1.068
8	1.000	1	1.000	1	1.000	1	1.000	0.928	1.000	1.000	0.928
9	0.864	17	0.934	27	0.927	26	0.967	1.016	1.001	0.966	0.983
10	0.703	32	0.962	22	0.731	42	0.968	1.018	1.001	0.967	0.986
11	0.838	21	0.945	24	0.885	28	1.051	0.970	1.026	1.025	1.020
12	0.678	34	0.784	41	0.866	29	1.009	0.999	1.021	0.988	1.009
13	0.646	39	1.000	1	0.646	45	1.079	0.926	1.000	1.079	0.999
14	0.957	10	1.000	1	0.957	15	1.004	1.013	1.000	1.004	1.017
15	0.673	36	0.846	35	0.798	35	0.985	1.017	1.026	0.960	1.001
16	0.939	13	0.960	23	0.973	9	1.095	0.913	1.057	1.036	1.000
17	0.773	26	0.830	36	0.932	24	1.078	0.967	1.076	1.002	1.043
18	0.607	41	0.810	37	0.749	40	1.047	0.964	1.001	1.047	1.010
19	0.924	14	0.936	26	0.986	7	1.036	1.029	1.036	1.001	1.067
20	0.736	30	0.870	33	0.838	33	1.153	0.992	1.072	1.076	1.144
21	0.394	48	0.706	44	0.560	48	1.110	0.951	0.983	1.129	1.056
22	0.426	47	0.691	48	0.617	46	1.055	0.990	0.997	1.059	1.045
23	0.853	19	0.928	28	0.920	27	0.992	1.041	1.021	0.971	1.033
24	0.577	43	0.794	40	0.726	43	1.032	0.998	1.009	1.023	1.029
25	0.830	22	0.860	34	0.965	11	1.074	0.934	1.067	1.006	1.003
26	0.964	7	1.000	1	0.964	12	1.020	0.997	1.000	1.020	1.017
27	0.760	27	0.804	38	0.945	19	1.026	0.958	1.033	0.993	0.982
28	0.676	35	0.716	43	0.944	20	0.984	1.035	0.994	0.990	1.018
29	0.851	20	1.000	1	0.851	31	0.988	1.020	1.000	0.988	1.008
30	0.960	8	1.000	1	0.960	13	1.008	1.028	1.000	1.008	1.036
31	1.000	1	1.000	1	1.000	1	1.020	0.997	1.000	1.020	1.017
32	0.906	15	0.922	30	0.983	8	1.026	0.958	1.033	0.993	0.982
33	1.000	1	1.000	1	1.000	1	1.000	0.976	1.000	1.000	0.976
34	0.564	44	1.000	1	0.564	47	1.017	1.004	1.000	1.017	1.021
35	0.314	50	1.000	1	0.314	50	1.115	0.999	1.000	1.115	1.113
36	0.794	25	1.000	1	0.794	37	1.028	1.021	1.000	1.028	1.049
37	0.737	29	0.780	42	0.944	20	1.046	1.011	1.023	1.022	1.057
38	0.878	16	0.909	31	0.967	10	1.000	1.024	0.999	1.001	1.024
39	0.946	12	0.998	18	0.948	18	1.014	1.006	1.002	1.012	1.021
40	0.951	11	1.000	1	0.951	17	0.968	1.025	1.000	0.968	0.993
41	0.679	33	0.979	21	0.692	44	1.052	0.975	1.010	1.042	1.026
42	0.710	31	0.943	25	0.754	39	0.992	1.016	1.035	0.958	1.007
43	0.795	24	0.924	29	0.859	30	1.042	0.992	1.024	1.018	1.034
44	0.821	23	1.000	1	0.821	34	0.980	0.548	1.000	0.980	0.536
45	0.321	49	1.000	1	0.321	49	0.993	0.995	1.000	0.993	0.988
46	0.740	28	0.981	20	0.749	40	1.199	0.914	1.019	1.176	1.096
47	0.960	8	1.000	1	0.960	13	0.988	0.994	1.000	0.988	0.982
48	0.658	37	0.703	45	0.936	23	0.980	0.973	0.988	0.992	0.954
49	0.854	18	0.899	32	0.952	16	0.961	1.000	1.000	0.961	0.961
50	1.000	1	1.000	1	1.000	1	1.000	0.981	1.000	1.000	0.981
Mean	0.763		0.896		0.851		1.027	0.979	1.015	1.012	1.006

DMUs	Output - oriented										
	TE				SE		Productivity Change				
	CRS	Rank	VRS	Rank	S.E	Rank	EC	TC	PEC	SEC	Total Factor Productivity Change
Mean Central Greece	0.732		0.849		0.855		1.039	0.981	1.024	1.015	1.020
Mean Thessaly	0.793		0.942		0.847		1.015	0.977	1.005	1.010	0.992
Source: Author Calculation											

Table A2. Efficiency with CRS/VRS, (O.O.)

Municipality	2012			2013			2014			2015			2016		
	CRS	VRS	SE	CRS	VRS	SE	CRS	VRS	SE	CRS	VRS	SE	CRS	VRS	SE
Lamia	0.957	0.970	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Amfiklia-Elatia	0.487	0.605	0.804	0.556	0.614	0.907	0.509	0.656	0.776	0.510	0.676	0.755	0.500	0.670	0.746
Domokos	0.499	0.506	0.986	0.593	0.687	0.863	0.707	0.805	0.879	0.734	0.740	0.992	0.724	0.745	0.972
Lokron	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Makrakomi	0.530	0.535	0.989	0.539	0.547	0.985	0.472	0.537	0.879	0.492	0.542	0.908	0.475	0.536	0.887
Molos-Ag.Konstantinou	0.516	0.725	0.711	0.622	0.782	0.795	0.698	0.841	0.830	0.668	0.826	0.808	0.635	0.819	0.776
Stylida	0.434	0.624	0.694	0.568	0.690	0.823	0.603	0.719	0.839	0.658	0.706	0.932	0.714	0.743	0.961
Livadia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Aliartos-Thespieon	0.935	0.936	1.000	0.884	0.888	0.996	0.822	0.905	0.908	0.860	1.000	0.860	0.817	0.939	0.870
Distomo-Arachova-Antikyra	0.738	0.952	0.775	0.729	0.953	0.765	0.715	0.965	0.740	0.685	0.984	0.696	0.648	0.957	0.677
Thebes	0.771	0.893	0.864	0.678	0.873	0.777	0.950	0.969	0.980	0.848	1.000	0.848	0.942	0.988	0.954
Orchomenos	0.670	0.743	0.903	0.660	0.784	0.842	0.662	0.774	0.855	0.705	0.811	0.870	0.695	0.808	0.860
Tanagra	0.536	1.000	0.536	0.598	1.000	0.598	0.681	1.000	0.681	0.688	1.000	0.688	0.726	1.000	0.726
Chalkida	0.983	1.000	0.983	0.960	1.000	0.960	0.966	1.000	0.966	0.875	1.000	0.875	1.000	1.000	1.000
Dirfyon-Messapion	0.743	0.789	0.941	0.717	0.851	0.843	0.585	0.842	0.695	0.621	0.873	0.711	0.698	0.875	0.798
Eretria	0.695	0.802	0.867	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Istiaia-Aidipsos	0.633	0.679	0.932	0.770	0.834	0.923	0.775	0.856	0.906	0.834	0.871	0.958	0.855	0.910	0.940
Karystos	0.552	0.810	0.682	0.629	0.800	0.786	0.606	0.800	0.758	0.581	0.829	0.701	0.665	0.812	0.818
Kymi-Aliveri	0.867	0.869	0.997	0.831	0.876	0.948	0.922	0.937	0.984	1.000	1.000	1.000	1.000	1.000	1.000
Mandoudi-Lake-Ag.Anna	0.565	0.756	0.747	0.723	0.847	0.854	0.591	0.857	0.690	0.800	0.890	0.899	1.000	1.000	1.000
Skyros	0.323	0.742	0.435	0.372	0.689	0.540	0.399	0.705	0.566	0.386	0.699	0.552	0.490	0.693	0.707
Karpenisi	0.368	0.674	0.546	0.422	0.694	0.608	0.450	0.712	0.632	0.436	0.708	0.615	0.456	0.665	0.686
Agrafa	0.844	0.858	0.984	0.913	0.945	0.966	0.846	0.958	0.883	0.846	0.946	0.894	0.816	0.933	0.875
Delphi	0.574	0.783	0.733	0.495	0.772	0.642	0.589	0.798	0.738	0.574	0.805	0.713	0.651	0.811	0.803
Dorida	0.676	0.726	0.931	0.839	0.846	0.992	0.830	0.859	0.966	0.907	0.925	0.981	0.899	0.943	0.953
Larisa	0.923	1.000	0.923	0.932	1.000	0.932	0.986	1.000	0.986	0.977	1.000	0.977	1.000	1.000	1.000
Agia	0.669	0.710	0.942	0.799	0.831	0.961	0.804	0.852	0.944	0.786	0.817	0.961	0.741	0.810	0.915
Elassona	0.696	0.712	0.978	0.727	0.740	0.983	0.687	0.735	0.935	0.617	0.697	0.886	0.651	0.694	0.938
Kileler	0.884	1.000	0.884	0.824	1.000	0.824	0.828	1.000	0.828	0.875	1.000	0.875	0.843	1.000	0.843
Tempi	0.970	1.000	0.970	0.901	1.000	0.901	0.928	1.000	0.928	1.000	1.000	1.000	1.000	1.000	1.000
Tirnavos	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farsala	0.858	0.860	0.998	1.000	1.000	1.000	0.907	0.936	0.969	0.869	0.914	0.951	0.896	0.90	0.995
Karditsa	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Argithea	0.510	1.000	0.510	0.545	1.000	0.545	0.612	1.000	0.612	0.608	1.000	0.608	0.546	1.000	0.546
Límni Plastíra	0.218	1.000	0.218	0.306	1.000	0.306	0.349	1.000	0.349	0.360	1.000	0.360	0.336	1.000	0.336
Mouzaki	0.704	1.000	0.704	0.869	1.000	0.869	0.793	1.000	0.793	0.819	1.000	0.819	0.785	1.000	0.785
Palama	0.657	0.726	0.904	0.797	0.805	0.989	0.745	0.793	0.940	0.701	0.779	0.900	0.785	0.795	0.986
Sofades	0.871	0.877	0.994	0.898	0.996	0.901	0.849	0.870	0.976	0.898	0.930	0.966	0.873	0.874	0.999
Volos	0.944	0.992	0.952	0.942	1.000	0.942	0.922	1.000	0.922	0.922	1.000	0.922	1.000	1.000	1.000
Almyros	0.998	1.000	0.998	0.990	1.000	0.990	1.000	1.000	1.000	0.889	1.000	0.889	0.878	1.000	0.878
Zagora-Mouresi	0.627	0.962	0.652	0.669	0.957	0.669	0.664	0.979	0.678	0.665	1.000	0.665	0.768	0.999	0.768
South Pelion	0.660	0.837	0.788	0.769	0.927	0.829	0.790	1.000	0.790	0.691	0.988	0.699	0.638	0.962	0.664
Riga Feraiou	0.801	0.909	0.880	0.771	0.864	0.893	0.752	0.908	0.828	0.703	0.938	0.749	0.946	1.000	0.946
Skiathos	1.000	1.000	1.000	0.573	1.000	0.573	0.783	1.000	0.783	0.829	1.000	0.829	0.921	1.000	0.921

Municipality	2012			2013			2014			2015			2016		
	CRS	**VRS**	**SE**	**CRS**	**VRS**	**SE**	**CRS**	**VRS**	**SE**	**CRS**	**VRS**	**SE**	**CRS**	**VRS**	**SE**
Alonissos	0.325	1.000	0.325	0.337	1.000	0.337	0.308	1.000	0.308	0.319	1.000	0.319	0.317	1.000	0.317
Skopelos	0.438	0.927	0.473	0.522	0.978	0.534	0.853	1.000	0.853	0.980	1.000	0.980	0.905	1.000	0.905
Trikala	1.000	1.000	1.000	0.970	1.000	0.970	0.974	1.000	0.974	0.906	1.000	0.906	0.951	1.000	0.951
Kalambaka	0.678	0.726	0.934	0.626	0.685	0.914	0.663	0.693	0.957	0.700	0.721	0.971	0.625	0.692	0.903
Pylis	0.990	1.000	0.990	0.851	0.853	0.998	0.806	0.842	0.957	0.778	0.802	0.971	0.845	1.000	0.845
Farkadona	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Source: Author calculation

Table A3 : Literature Review

Authors	Country	Years Reference	No of municipalities	Methodology	Inp	Outp	Envir. Variables
European Countries							
Prieto and Zofio (2001)	Spain	1994	209	DEA	X1	Y5.1,Y5.2,Y6.2,Y6.3, Y7.1, Y7.2, Y7.4	
Afonso and Fernandes (2003)	Portugal	2001	51	F.D.H.	X1	Y1	
Loikkanen and Susiluoto (2005)	Finland	1994-2002	353	T.S.A, D.E.A.- C.R.S-O.O., O.L.S.	X2	Y7.3, Y8, Y9.2, Y10.2, Y10.3,Y10.4	Z1.1, Z1.3, Z1.5, Z2.1, Z2.2, Z4.2, Z5.1, Z6.2, Z6.4
Geys (2006)	Belgium	2000	304	T.S.A.,S.F.A.,O.L.S.	X2	Y5.2, Y7.5, Y9.2,Y10.1	Z1.1, Z1.7, Z2.2, Z3.1, Z3.2, Z4.2, Z4.3, Z4.4, Z6.3
Afonso and Fernandes (2006)	Portugal	2001	51	D.E.A.(I.O., O.O.,VRS)	X1	Y1	
Gimenez and Prior (2007)	Spain	1996	258	T.S.A.,F.D.H.,T.R	X3, X5, X7	Y2, Y3, Y5.2, Y6.1,	Z1.1, Z1.3, Z2.2, Z2.4, Z2.5, Z2.6
Afonso and Fernandes (2008)	Portugal	2001	278	T.S.A.,D.E.A.(I.O.,O.O.,V.R.S.), T.R.	X1	Y1	Z1.1, Z1.2, Z1.5, Z2.2, Z5.1
Benito et al. (2010)	Spain	2002	31	T.S.A.,D.E.A.(V.R.S.,O.O.), Kendall τ test	X2, X3, X7	Y6.1, Y6.3, Y7.1, Y7.2, Y7.3, Y7.4, Y11	Z1.3, Z2.2, Z2.4, Z3.1, Z4.1, Z4.3, Z4.6, Z6.4
Geys et al. (2010)	Germany	1998,2002,2004	987	S.S.A.,S.F.A.	X2	Y2, Y7.5, Y9.1, Y9.2, Y10.2, Y15	Z1.1, Z3.1, Z3.2, Z3.3, Z4.2
Kalb (2010)	Germany	1990-2004	1,111	S.S.A.,S.F.A.	X2	Y2, Y9.2, Y10.2, Y15	Z1.1, Z1.5, Z2.1, Z2.4, Z3.1, Z3.2, Z4.2, Z4.6,
Revelli (2010)	England	2002-2007	148	CPA	X2	Y1, Y9.2	
Balaguer-Coll et al. (2010a)	Spain	1995, 2000	1,221	F.D.H.	X2, X3, X4, X7	Y2 ,Y5.1, Y5.2, Y6.1, Y7.4, Y7.5, Y10.4, Y12	
Balaguer-Coll et al. (2010b)	Spain	1995,2000, 2005	1,164	M.I.,F.D.H.	X1	Y2, Y5.1, Y5.2, Y6.1, Y7.4, Y7.5, Y10.4, Y12, Y16	
Loikkanen et al (2011)	Finland	1994-1996	353	T.S.A.,D.E.A. - C.R.S-O.O., O.L.S.	X2	Y7.3, Y8, Y9.2, Y10.1, Y10.3,Y10.4	Z1.1, Z1.3, Z1.5, Z2.1, Z3.1, Z3.2, Z3.3, Z5.1, Z6.2
Barone and Mocetti (2011)	Italy	2001-2004	1,115	S.F.A.	X2	Y4, Y5.1, Y5.2, Y6.1, Y9.1, Y11	
Kalb et al. (2012)	Germany	2004	1,015	S.S.A., S.F.A.	X2	Y2, Y7.5, Y9.1, Y9.2,Y10.2, Y15	Z1.1, Z2.1, Z2.4, Z3.1, Z3.2
Balaguer-Coll et al. (2013)	Spain	2000	1,198	Order-m	X2, X3 X4, X7	Y5.1, Y5.2, Y6.1, Y7.4, Y7.5, Y10.4, Y12	Z1.1, Z1.2, Z2.2, Z2.3, Z2.7

Authors	Country	Years Reference	No of municipalities	Methodology	Inp	Outp	Envir. Variables
Geys et al. (2013)	Germany	2001	1,021	S.S.A.,S.F.A.	X2	Y2, Y7.5, Y9.1, Y9.2, Y10.2, Y15	Z1.1, Z2.1, Z3.2
Ashworth et al.(2014)	Belgium	2000	308	T.S.A.,D.E.A. - C.R.S. - O.O., B.A.- Simar and Wilson,2007	X1	Y5.2, Y6.1, Y7.5, Y9.2, Y10.1,Y10.2	Z1.1, Z1.3, Z2.2, Z3.1, Z3.2, Z4.1, Z4.2, Z4.3, Z4.4,
Pevcin (2014a)	Slovenia	2011	200	S.S.A.,S.F.A.	X1	Y2, Y9.2, Y10.2, Y15	Z1.1, Z2.1,
ˇStastn´aandGregor (2015)	Czech republic	1995-1998, 2003-2008	202	S.S.A.,SFA-time variant	X2	Y3,Y5.2, Y6.1,Y7.1,Y7.2,Y7.4,Y9.1,Y9.2,Y10.2,Y10.4,Y11,Y13,	Z1.3, Z1.5, Z3.1, Z3.3, Z4.1, Z4.2, Z4.5, Z5.1
Arcelus et al. (2015)	Spain	2005	260	S.S.A.,S.F.A.	X2	Y3, Y4, Y5.1, Y5.2, Y6.3, Y10.2, Y15	Z1.1, Z4.1, Z4.5, Z5.4, Z6.4, Z6.5
Perez-Lopez et al. (2015)	Spain	2001-2010	1,058	T.S.A.,Order-m, B.A.- Simar and Wilson,2007	X2	Y2, Y3, Y5.1, Y6.1, Y6.3, Y7.4, Y17	Z1.3, Z2.1, Z2.4, Z3.1, Z3.2, Z4.1, Z4.2, Z4.3, Z4.4,Z4.6, Z6.4
Asatryan and DeWitte (2015)	Germany	2011	2,000	Conditional FDH	X1	Y7.5, Y9.1, Y9.2, Y10.2	Z1.3, Z2.2, Z3.1, Z3.3
Lampe et al.(2015)	Germany	2006-2008	396	S.S.A., S.F.A.	X1, X2	Y2, Y7.5, Y9.1, Y9.2, Y10.2, Y15	Z1.1, Z1.6, Z2.1, Z2.4
Andrews and Entwistle (2015)	England	2007	386	T.S.A.,Ratios, OLS	X1	Y1	Z1.1, Z1.3, Z1.4, Z1.6, Z1.8, Z2.3, Z3.1, Z4.6, Z5.1, Z6.4 , Z6.5
Cordero et al. (2016)	Portugal	2009-2014	278	Conditional efficiency	X1, X3	Y2,Y4,Y6.1, Y6.3	Z1.1, Z2.1, Z2.2, Z3.1, Z4.3, Z5.3
Cordero et al. (2017)	Portugal	2009-2014	278	Conditional efficiency, M.I.	X1, X3	Y2,Y4,Y6.1, Y6.3	
Non-European Countries							
Grossman et al. (1999)	U.S.A.	1967,1973,1977,1982	49	S.S.A.,S.F.A.	-	Y17	Z1.3, Z3.5, Z4.2, Z5.1, Z6.2
De Sousa et al (2005)	Brazil	2000	4,796	T.S.A.,DEA "Jackstrap"I.O., C.R.S,V.R.S, Quantile regression	X2, X3, X8	Y2, Y6.1, Y6.2, Y6.3, Y9.2, Y10.1	Z1.1, Z2.2, Z2.3, Z2.4, Z2.7, Z5.1 , Z5.4, Z6.1, Z6.2, Z6.4, Z6.5
Moore et al.(2005)	U.S.A.	1993-1996	46	T.S.A.,D.E.A.-O.O.- V.R.S ,T.R.	X2, X3	Y4, Y5.2, Y6.1, Y6.3, Y7.3, Y7.4, Y8, Y11,	Z4.1, Z5.2, Z5.4, Z6.5
Ibrahim and Salleh (2006)	Malaysia	2000	46	S.F.A.	X2	Y2, Y5.2, Y6.1, Y7.4, Y12	
Sung (2007)	Korea	1999-2001	222	T.S.A.,M.I. with D.E.A.,T.R.	X1, X3,	Y4, Y5.2, Y6.2, Y6.3, Y7.4, Y10.4	Z1.1, Z1.3, Z2.5, Z4.1, Z5.2, Z6.1
Revelli and Tovmo (2007)	Norway	-	205	T.S.A., RATIO, O.L.S.	X6	Y1	Z1.1, Z3.2, Z3.3, Z4.1, Z4.3
Borge et al. (2008)	Norway	2001-2005	362-384	T.S.A.,RATIO ,O.L.S.	X6	Y1	Z3.1, Z3.2, Z3.3, Z4.1, Z4.2, Z4.6
Nijkamp and Suzuki (2009)	Japan	2005	34	DEA- DFM-GA (I.O./O.O.- C.R.S.)	X1, X3, X4	Y1, Y17	
Dollery and van der Westhuizen (2009)	South Africa	Fiscal 2006/2007	231 local+46 regional	D.E.A(I.O.,O.O, V.R.S.,C.R.S)	X3	Y6.4	
Shiyi and Jun (2009)	China	1978-2005 1993-2005	27	D.E.A.(V.R.S., O.O.)	X2	Y9.2, Y8, Y3, Y6.4, Y13	
Liu et al. (2011)	Taiwan	2007	22	D.E.A. super-efficiency (C.R.S.-V.R.S.-O.O.)	X3	Y6.2,	

Authors	Country	Years Reference	No of municipalities	Methodology	Inp	Outp	Envir. Variables
Bruns and Himmler (2011)	Norway	2001-2005	362-384	T.S.A.,RATIO, O.L.S.	X6	Y1	Z1.1, Z1.3, Z1.4, Z1.5, Z1.6, Z1.8, Z2.2, Z3.1, , Z3.2, Z3.5
Lin, Ming-Ian & Lee, Yuan-Duen & Ho, Tsai-Neng, (2011)	China	2005-2006	31	DEA (V.R.S.,C.R.S., O.O.) και AHP, MPI	X4	Y17	
Kutlar and Bakirci (2012)	Turkey	2006-2008	27	D.E.A., C.R.S., V.R.S, I.O.,O.O, M.I.	X1, X2, X3, X4, X7	Y2, Y9.2, Y10.2, Y8	
Nakazawa (2013)	Japan	2005	479	S.S.A,S.F.A., O.L.S, HCSEs	X1, X3	Y1	Z1.3, Z1.4, Z1.8, Z5.2, Z6.3
Nikolov and Hrovatin (2013)	Macedonia	-	74	T.S.A.,D.E.A.-V.R.S-O.O., S.F.A.	X2	Y2, Y5.2, Y9.1, Y9.2, Y10.2	Z1.6, Z2.2, Z3.2, Z4.1
Nakazawa (2014)	Japan	2005	479	S.F.A., O.L.S, HCSEs	X1, X2	Y1	
Mahabir (2014)	South Africa	Fiscal 2005/2006-2008/2009	129	F.D.H.	X1	Y6.1,Y6.2,Y6.3,Y6.4	
Sørensen (2014)	Norway	2001-2010	430	T.S.A.,O.L.S ,F.E.R	X6	Y1	Z1.3, Z3.1, Z3.2
Pacheco et al. (2014)	Chile	2008-2010	309	S.S.A., S.F.A.	X2	Y2, Y6.1, Y6.2, Y7.4, Y8, Y9.2,	Z3.2, Z4.2, Z4.5, Z5.1
Yusfany (2015)	Indonesia	2010	491	T.S.A.,D.E.A. - VRS, O.O.,T.R.	X1	Y1	Z1.1, Z2.2, Z3.2, Z4.1, Z4.2, Z4.4,
Helland and Sørensen (2015)	Norway	2001-2010	430	T.S.A.,O.L.S , F.E.R	X6	Y1	Z3.1, Z3.2
RadulovicandDragutinovic (2015)	Serbia	2012	143	S.S.A.,S.F.A.	X2	Y2, Y5.2, Y6.3, Y9.1, Y9.2, Y10.4	Z1.1, Z1.4, Z1.5, Z2.1, Z5.1,
Pougkakioti and Tsamadias (2020)	Greece	2012-2016	50	DEA (I.O., O.O.) TOBIT, MALMQUIST	X1, municipal servants, machinery	Y9.2, Y6.1, Y9.1, Y10.1	Z2.1, Z1.5, Z5.3, Z1.1, Z6, Z6.3, Z5.1,

Notes: D.E.A.= Data Envelopment Analysis, S.F.A.= Stochastic Frontier Analysis, F.D.H.= Free Disposal Hull, I.O.= Input Oriented, O.O.= Output Oriented, C.R.S.= Constant Returns to Scale, V.R.S.= Variable Returns to Scale, S.E.= Scale Efficiency, M.I.= Malmquist Index, T.R.= Tobit Regression, B.A.= Bootstrap Approach, C.P.A.= Comprehensive Performance Assessment, D.F.M.= Distance Friction Minimization, G.A.= Goals Achievement, A.H.P.= Analytic Hierarchy Process, HCSEs= Heteroscedasticity - Consistent Standard Errors, O.L.S.= Ordinary Least Squares, D.T.= Decision Tree, T.S.A.= Two Stage Approach, S.S.A=Single Stage Approach, F.E.R.= Fixed effects regressions