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MEASURING THE EFFICIENCY OF LOCAL GOVERNMENT UNITS MANAGEMENT IN THE CENTRAL REGION OF POLAND IN A DYNAMIC PERSPECTIVE

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Abstract: Local government units in Poland are obliged to improve the quality of life of their inhabitants concerning rules of sustainable development. The study described in the article is intended to measure the relative efficiency of management including examination of the relationship between various inputs and outputs in local government units. The analysis in the paper shows efficiency differences between local governments in comparison with sub-region leaders (group frontiers) and region leaders (meta-frontiers). The division into sub-regions and regions was made according to NUTS classification. The measurement of inputs and outputs in local government management units was based on indicators of sustainable development from SAS (Local Government Research System) database. Apart from static comparison (for a particular year) the main purpose of the article is to show changes of efficiency in 5 years horizon with application of dynamic meta-frontier approach. The outcome of the analysis made it possible to indicate some reference points (benchmarks), which may contribute to improve the efficiency of management in the local government units in Poland under research. The concepts delivered in the paper are employed for the purpose of assessing growth performance of local governments using a data set covering 128 cities in period 2006-2010.

Keywords: meta-frontier approach, Malmquist index, catch-up index, relative efficiency measurement, management in local governments, operations research, sustainable development

INTRODUCTION

Effective delivery of public services by local governments is a very important factor in improving the quality of life in the community. The local

governance is assessed by indicators of sustainable development. The analysis in the paper is based on measuring the efficiency of municipalities in Poland. Thanks to the advantages of Data Envelopment Analysis (DEA) the performance of local governments is assessed in a multivariate way. Many factors (indicators of sustainable development), beside standard univariate interpretation, can also be treated as a whole, as measures of costs and benefits borne by the community to achieve the goal of sustainable development and to improve the quality of life of the inhabitants of the local community. Particular indicators of sustainable development are recognized as inputs or outputs for local government activities. DEA, as a result, gives a relative efficiency measure which is one, multivariate indicator of efficiency in a particular local government. Nevertheless, in the paper there is considered a novel in DEA approach, which is holistic analysis of group of local governments in particular sub-regions to recognize sub-region leaders. Thanks to the concept of Rambaldi, Rao and Dolan [Rambaldi et al. 2007] there is measured the efficiency gap between local governments in the sub-region in comparison to region leaders. Finally, having efficiency measures for all considered units it is possible to get average technology gap between sub-region and region, both in static (Technology Gap Ratio measure) and dynamic (catch-up index measure) points of views.

EFFICIENCY IN LOCAL GOVERNMENT

Conceptual basis of the analysis in the paper is taken from SAS[1] (Local Government Research System) database which is also used in the empirical part of research. SAS is based on Potkanski and Rogala's model [Rogala et al. 2008] of hierarchical relationship between quality of life, sustainable development and public services provided by local governments (municipalities). Quality of life of inhabitants is the main goal of local governance. Social, economic and environmental-spatial dimensions are achieved together through the concept of sustainable development, which is required by Polish Constitution[2]. Instrumentation of sustainable development is a public service provided by the municipality, which manages the economic, social and environmental spheres in the local area.

To differentiate the levels of local governments there is used a NUTS system introduced by the European Union and applied for statistical offices in the United Europe.[3] In this paper there are considered NTS1 level (central region of Poland only), NTS2 level (lodzkie voievodeship-the province of Lodz and

[1] Documentation and database available in internet: www.sas24.org (only Polish language)
[2] Polish Constitution - „Konstytucja Rzeczpospolitej Polskiej", Chapter I, art. 5
[3] For more information about NUTS nomenclature see European Commision Web site: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction

mazowieckie voievodeship/province as two sub-regions of central region), and NTS5 level (all gminas in considered central region of Poland).

METHODOLOGY

To measure efficiency of local governance there is used a Data Envelopment Analysis (DEA) method. It is a non-parametric mathematical modeling method which measures "technical efficiency" as ratio of weighted sum of inputs divided by weighted sum of outputs.[4] Using DEA terminology, local government is named DMU – Decision Making Unit. Development level of local government (DMU) is considered as technology used by all other local governments (other DMUs) in particular sub-regions and the region considered in the analysis.
To obtain the efficiency measure results there was used a basic DEA output oriented BCC model[5] for every DMU (for every object *o*) (1-4):

$$\theta_o \rightarrow \max \tag{1}$$

$$\sum_{j=1}^{n} x_{ij}\lambda_{oj} \leq x_{no} \qquad \text{for } i = 1, \ldots, m \tag{2}$$

$$\sum_{j=1}^{n} y_{rj}\lambda_{oj} \geq \theta_o y_{ro} \qquad \text{for } r = 1, \ldots, s \tag{3}$$

$$\sum_{j=1}^{n} \lambda_{oj} = 1 \tag{4}$$

$$\theta_o, \lambda_{o1}, \lambda_{o2}, \ldots, \lambda_{on} \geq 0 \tag{5}$$

where:

- θ_o - output level coefficient (technical efficiency measure) for considered object o, ($\theta_o = 1$ means that object o is effective, is a frontier)
- y_{rj} – *r*-th ouput of object *j*,
- x_{ij} – *i*-th input of object *j*,
- y_{ro} – *r*-th ouput of object *o*,
- x_{io} – *i*-th input of object *o*,
- *m* – number of inputs,
- *s* – number of outputs,
- *n* – number of objects,
- λ_{oj} – optimal technology coefficient for object *j* (variable in the model, value bigger than 0 says that effective object *j* is benchmark for ineffective object *o*)

The model above brings static (one year) comparison between DMUs (local governments). To achieve a dynamic perspective there is used a Malmquist index which shows efficiency change from year to year for particular DMUs.

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[4] For theoretical background see Charnes et al. (1996)

[5] BCC model assumes variable return of scale (vrs), constrain (4); for more theoretical background of choice vrs model see O'Donnell et al. (2008)

To assess changes in efficiency of DMU in time there is used the Malmquist index:

$$M^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1}) = \sqrt{\frac{\frac{1}{D^t(y^{t+1},x^{t+1})}}{\frac{1}{D^t(y^t,x^t)}} \times \frac{\frac{1}{D^{t+1}(y^{t+1},x^{t+1})}}{\frac{1}{D^{t+1}(y^t,x^t)}}} \quad (6)$$

and

$$D^t(y^{t+1}, x^{t+1}) = \frac{1}{\theta} \quad (7)$$

where:
$D^t(y^{t+1}, x^{t+1})$ is a measure of distance between object in period t+1 and technology (all considered DMUs input-output mix) in period t.

Malmquist index can be decomposed with use of algebraic transformation into technical change (TC) and technical efficiency change (TEC).

$$TEC^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1}) = \frac{\frac{1}{D^{t+1}(y^{t+1},x^{t+1})}}{\frac{1}{D^t(y^t,x^t)}} \quad (8)$$

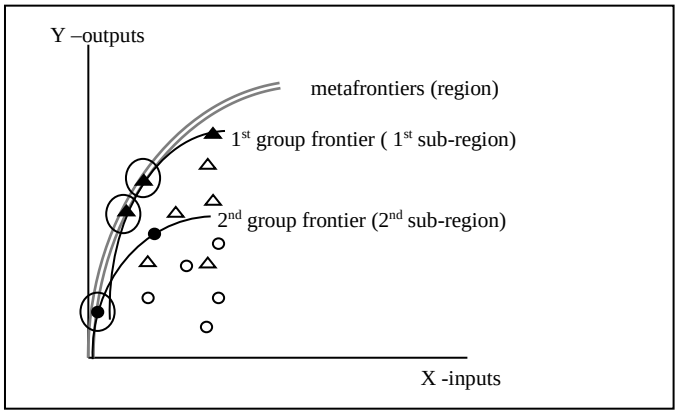
$$TC^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1}) = \sqrt{\frac{\frac{1}{D^t(y^{t+1},x^{t+1})}}{\frac{1}{D^{t+1}(y^{t+1},x^{t+1})}} \times \frac{\frac{1}{D^t(y^t,x^t)}}{\frac{1}{D^{t+1}(y^t,x^t)}}} \quad (9)$$

where:
TEC – efficiency change which does not consider change in technology in time (frontiers change)
TC – efficiency that considers changes in technology development between periods t and t+1

In the paper there is considered efficiency comparison across regions. It is made by measuring efficiency relative to a metafrontier, which is a boundary of an unrestricted technology set (all region, not only a sub-region). There are also group frontiers to be the boundaries of restricted technology sets in sub-regions (there is assumed that restrictions result from lack of economic infrastructure or other characteristics of the DMU environment in particular sub-region in comparison to other sub-regions). Metafrontiers (region frontiers) envelop the group frontiers (sub-region frontiers). In the paper there are measured two types of efficiency: [O'Donnell et al. 2008]

- distance to the group frontier (common TC) and
- distance between the group frontier and the metafrontier (TGR).

Figure 1. Group frontiers with relation to metafrontiers



Source: self-prepared

The sub-region specific group technologies are sub-sets of the region metatechnology. For all groups ($k = 1,\ldots,K$) the distance in time period t with respect to the k-group frontier is greater than or equal to the distance in time period t with respect to the metafrontier [Rambaldi et al. 2007, p.10].

$$D^t_{meta}(y^t, x^t) \geq D^t_k(y^t, x^t) \tag{10}$$

For the output-oriented model there can be obtained Technology Gap Ratio (TGR) at time *t*:

$$TGR^t_k(y^t, x^t) = \frac{D^t_{meta}(y^t,x^t)}{D^t_k(y^t,x^t)} \tag{11}$$

$TGR^t_k < 1$ shows that between k-sub-region and region frontiers there is a technology gap.

Technology gap ratio can be considered dynamically by the technology gap ratio growth index.

$$TGR\_GR^{t,t+1}_k(y^t, x^t, y^{t+1}, x^{t+1}) = \frac{TGR^{t+1}_k(y^{t+1},x^{t+1})}{TGR^t_k(y^t,x^t)} \tag{12}$$

After a few algebraic manipulations of Rambaldi, Rao and Dolan [Rambaldi et al. 2007, pp. 15-18] there are distinguished two types of technology gap ratio growth indexes concerning decomposition: one for technical efficiency change, another for technical change:

$$TGR\_GR^{t,t+1}_k(y^t, x^t, y^{t+1}, x^{t+1}) = \frac{TEC^{t,t+1}_{meta}(y^t,x^t,y^{t+1},x^{t+1})}{TEC^{t,t+1}_k(y^t,x^t,y^{t+1},x^{t+1})} \tag{13}$$

$$[TGR\_GR^{t,t+1}_k(y^t, x^t, y^{t+1}, x^{t+1})]^{-1} = \frac{TC^{t,t+1}_{meta}(y^t,x^t,y^{t+1},x^{t+1})}{TC^{t,t+1}_k(y^t,x^t,y^{t+1},x^{t+1})} \tag{14}$$

where:

(13)– technology gap ratio growth rate which does not consider change in technology (frontiers change) in time, can be interpreted as the relative

technological progress or regress of the local government (DMU) in sub-region *k* with respect to change in the metatechnology (region technology) change. When $\mathrm{TGR\_GR}_{k}^{t,t+1} < 1$ then the gap between the sub-region frontier and the metafrontier is decreasing (particular sub-region is experiencing technological progress at a faster rate than in the whole region).

(14)– inverse technology gap ratio growth rate TC – efficiency that considers changes in technology development between periods *t* and *t*+1and removes the issue of choosing a relevant benchmark time period by averaging the input-output mixes (technologies) of two different time periods. Interpretation of the ratio is analogical to (13), when $[\mathrm{TGR\_GR}_{k}^{t,t+1}]^{-1} > 1$ then the gap between the sub-region frontier and the region metafrontier is decreasing.

The metafrontier approach brings two types of Malmquist indexes:

- considering the region specific technology (k-sub-region frontier) (15), and
- considering the metatechnology (metafrontier) (16).

$$\mathrm{M}_{k}^{t,t+1}(y^{t}, x^{t}, y^{t+1}, x^{t+1}) = \sqrt{\frac{\frac{1}{D_{k}^{t}(y^{t+1}, x^{t+1})}}{\frac{1}{D_{k}^{t}(y^{t}, x^{t})}} \times \frac{\frac{1}{D_{k}^{t+1}(y^{t+1}, x^{t+1})}}{\frac{1}{D_{k}^{t+1}(y^{t}, x^{t})}}} \tag{15}$$

$$\mathrm{M}_{meta}^{t,t+1}(y^{t}, x^{t}, y^{t+1}, x^{t+1}) = \sqrt{\frac{\frac{1}{D_{meta}^{t}(y^{t+1}, x^{t+1})}}{\frac{1}{D_{meta}^{t}(y^{t}, x^{t})}} \times \frac{\frac{1}{D_{meta}^{t+1}(y^{t+1}, x^{t+1})}}{\frac{1}{D_{meta}^{t+1}(y^{t}, x^{t})}}} \tag{16}$$

There are also given respectively to (8) and (9): $\mathrm{TEC}_{meta}^{t,t+1}$, $\mathrm{TC}_{meta}^{t,t+1}$, $\mathrm{TEC}_{k}^{t,t+1}$, $\mathrm{TC}_{k}^{t,t+1}$.

As a summary of algebraic manipulation of Rambaldi, Rao and Dolan [Rambaldi et al. 2007, pp. 15-19] there is achieved an equation as follows (17):

$$\mathrm{catch-up}_{k}^{t,t+1} = \frac{\mathrm{M}_{k}^{t,t+1}}{\mathrm{M}_{meta}^{t,t+1}} \tag{17}$$

The $\mathrm{catch-up}_{k}^{t,t+1} > 1$ means that particular *k*-th sub-region shows catch- up with the whole region (metafrontier) technology over the periods *t* to *t*+1.

Thanks to the DEA BCC output oriented model, Malmquist indexes and metafrontier approach Rambaldi, Rao and Dolan [Rambaldi et al. 2007] assume that three types of efficiency changes can be identified and recognized between *t* and *t*+1:

- changes in the input mix,
- changes in technology at the sub-regional level (shifts of the sub-regional group frontiers), and
- changes in the metatechnology (shifts of the metafrontier).

DATA

The data used in the study come from the SAS (Local Government Research System) database[6]. The basis of SAS brings together in one place data on all municipalities in Poland and the study of quality of life at the local level. Most of the data in the database are especially designed indicators according to the assumptions of authors of the system (database). The indicators are based on data provided by the Polish Central Statistical Office and the Polish Ministry of Finance.

As the input and output to test the efficiency of DEA there were used especially designed sustainable development indicators. The selection of indicators was based on the work methodology of SAS database, which is divided into three main types: economic, environmental - spatial, and social. The indicators of each type are divided into 10 areas. In total, that gives the 30 types of indicators. In the analysis shown in this paper for each area there was chosen a representative indicator. The selection of inputs and outputs (here the indicators of sustainable development) was fairly limited due to the availability of empirical data. The indicators which are classified as inputs as well as those considered to be the outputs do not involve a full picture of the situation of the activities in local governments. In this research selected variables (sustainable development indicators) are treated as symptoms [Guzik, 2009, p.64] of all the studied topic.

EMPIRICAL CASE

Technical efficiency estimated in DEA method is often used for improving management in DMU (in this case local governments). Additional information to design programs gives estimation of the technology gap between group frontiers and the metafrontier. It gives a wider view on the environment of DMU not only at local, but also at sub-regional and regional levels in this case. In the considered case there were measured year-to-year dynamics of considered indicators in 5 year scope (2006-2010).

In Poland there are 908 cities and in the Central Region there are 128 cities. All are managed by local governments. According to three- stage territorial division of Poland and with respect to NUTS[7] United Europe classification there are distinguished sub-regions which gather cities (local governments, DMUs) in groups. In the paper cities are grouped according to NTS-2 level, provinces (or voivodships). In the analysis there are considered two of them: province of Lodz called lodzkie voivodship which gathers 43 cities and mazowieckie voivodship

[6] Available in internet: www.sas24.org (only Polish language)

[7] More datails at EU WebPage
http://europa.eu/legislation_summaries/regional_policy/management/g24218_en.htm
[15.08.2013]

which gathers 85 cities. Efficiency of 43 cities in lodzkie voivodship (grouped as members of first sub-region) and 85 cities in mazowieckie voivodship grouped as members of second sub-region) are compared to regional frontiers (metafrontiers) of Polish Central Region (which gathers two considered sub-regions into one region NTS-1 level).

The analysis brought about some results for all particular DMUs (cities). For the sake of a wider comparison there were made sub-region results aggregates which are averages of indicators for DMUs for particular sub-regions. Some examples of such aggregated indicators for two considered voivodships (sub-regions) are presented below.

Table 1. Average results for DMUs in two considered voivodships in 2006-2010

lodzkie voivodship									
[%]	TEC_k	TC_k	M_k	TEC _meta	TC _meta	M _meta	TECm /TECk	TCm /TCk	catch_up
2007	98,48	105,54	**103,42**	96,70	106,93	**102,46**	98,07	101,20	**100,98**
2008	106,03	103,95	**109,41**	106,90	104,73	**110,67**	100,73	100,63	**98,87**
2009	97,57	100,42	**97,40**	94,63	100,03	**93,72**	97,18	99,50	**105,24**
2010	90,65	121,52	**106,47**	91,47	121,23	**109,21**	102,69	101,17	**97,65**
mazowieckie voivodship									
[%]	TEC_k	TC_k	M_k	TEC _meta	TC _meta	M _meta	TECm /TECk	TCm /TCk	catch_up
2007	100,67	103,24	**102,91**	101,17	102,88	**102,59**	100,39	99,56	**100,33**
2008	100,86	108,21	**107,19**	102,92	109,36	**110,57**	102,17	101,04	**97,03**
2009	99,44	97,33	**95,35**	100,26	95,83	**94,58**	100,81	98,42	**100,92**
2010	98,42	113,67	**109,29**	95,90	117,43	**109,52**	97,43	103,13	**99,82**

Source: self-prepared with use of computation in EMS and MS Excel

The Table above provides some useful information to consider. For the clarity of observations, it has to be mentioned that Mamquist indexes (with respect to group frontiers and metafrontiers) for average efficiency growth in both voivodships show the efficiency growth in all the periods concerned except for 2009, where the indexes show a decline. Concerning the gap between group and meta frontiers, mazowieckie voivodship in 2007 and 2009 shows a catch-up value closer to 1, which means that more DMUs from this sub-region were metafrontiers in that time. The biggest cath-up for lodzkie voivodship in 2009 can result from

a narrowing gap between this group frontiers and metafrontiers, which can be perceived by means of a technology gap ratio growth rate and inversed technology gap ratio growth rate values below 1 in that period.

CONCLUSIONS AND FUTURE RESEARCH

DEA method gives possibility to measure technical efficiency of several units in a particular group and within a particular period of time. Malmquist approach in DEA enables the comparison of technical efficiency change in several time periods. The metafrontier approach makes it possible to compare different groups of units. Finally, Rambaldi, Rao and Dolan's [Rambaldi et al. 2007] proposal gives connections of these three separate approaches. The DEA approach, enriched by the metafrontier idea accompanied by the Malmquist index method, gives new possibilities of analysis at local, sub-regional, regional, but also (which was shown by Rambaldi, Rao and Dolan) country and world level comparisons. It is especially useful to consider it dynamically through several time periods. The case presented above is an introduction to wider analysis at country level. Promising results of the region analysis give a chance for deeper conclusions from more than two - province comparisons in the future. There was an intention of the author to focus on possibilities created by the DEA method and its metafrontier approach for deeper regional and sub-regional analysis within a particular country in a dynamic perspective. The next step leads to comparative analysis of existing approaches published by other authors.

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