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Quantification of the efficiency of public administration by data envelopment analysis

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Abstract

The issue of public administration effectiveness and its ensuring is increasingly gaining prominence in the macro-economic situation in the euro area. The public sector like the business sector must look for the opportunities to increase its efficiency. There are few ways of efficiency quantification, but considering the comprehensive assessment need of the research problems the most appropriate tool for performance quantification of public administration seems the packaging data analysis–DEA (Data Envelopment Analysis). Packaging data analysis as a statistical method is an important tool in public administration officials' future decision making, rationalization and optimization of public administration performance. The submitted article is focused to the application of DEA method in evaluating the effectiveness of the public administration in Slovakia.

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1. Introduction

Public administration represents an intentional activity which pursues a specific objective, namely regulation of the conditions and methods of governance implementation (Machyniak, 2013). Public administration in the Slovak Republic is divided into three components: government, local government and public corporations, which reflects fulfilling of the democratic fundamentals of governance (Šebík, 2012).
Since the 1989, the government undergoes many reform processes. The latest one was the fiscal decentralization, or the change in funding of local government. One of the basic features of the reforms of public administration is its uniqueness and specificity for every single state. The European Union as well as the rest of the world has no unified or universal concept of public administration that could serve as a model. (Andrejovská, 2010; Papcunová and Gecíková, 2011, Raisová and Bánociová, 2012, Šoltés and Modráková, 2012, Pavlíková and Šoltés and Modráková, 2012).

Public administration has to be distinguished from private administration. Public administration as the management of public affairs represents the public interest and the executing subjects realize it as a duty imposed by law from their legal status of public entities (Horváth, 2003).

![Fig. 1 Structure of the public administration in the Slovak Republic](image)

Fundamentals of public administration are constituted as the management of public affairs, which is realized as a manifestation of executive power in the state (Horváth, 2007). This executive power is defined by its primarily public character, disposable for the state and other non-state subjects performing management of public affairs.

Despite these substantial differences there are some features common for both, public and private administration. Such features could be classified as follows (Hamalová, 2007):
- High degree of autonomy;
- Following the interests of their own communities;
- The pursuit of efficient management of its own property;
- Own budgeting.

For completeness, we consider it necessary to emphasize that the fact that public administration includes in its title the term public is not yet eliminating its impact on the private sector. Conversely, depending on the size and structure of the public sector and the public administration, the administration has in modern democracies important and irreplaceable role in relation to the private sector (Klus, 2007).

Effectiveness of public administration is increasingly gaining importance in the macro-economic situation in the Euro area nowadays. The business sector as well as the public sector has to look for the opportunities to increase its efficiency.

2. Material and Methods

The aim of the submitted article is to draft a new methodological approach to the quantification of public administration through the quantitative methods, namely the application of data envelopment analysis (DEA) method in evaluating the effectiveness of public administration in the Slovak Republic.

The fundamental approaches to quantitative evaluation of the effectiveness of public administration contain following methods: data envelopment analysis: assessment of efficiency of public administration bodies - comparison of effectiveness of selected specialized state agencies and local governments (methods of assessment of DEA effectiveness), benchmarking in the analysis of effectiveness of public administration - the use of FDK methods (named after Farrell, Debreu, and Koopmans) (Luo and Donthu, 2001). Methods of
assessment of efficiency development and the impact of time - the dynamic analysis of the development effectiveness of selected offices, application of Malmquist total factor productivity (TFP) indices (Malmquist, 1953; Banker et al., 1984; Berg et al., 1992).

Due to the limited space, we decided to introduce a new methodological approach for assessing the efficiency of public administration based on data envelopment analysis. We used secondary literary resources for processing of this article.

3. Results and Discussion

For the development of specific methods, which take into account the conditions of the decision making process in public administration, is first necessary to know the substance of particular methods of assessing the effectiveness, and subsequently to develop a general assessment methods utilization.

One of the leading experts on public administration in Central Europe, Prof. Ochrana, in its publication states the following classification of methods of effectiveness assessment (Ochrana, 2004):

Table 1. Possibilities of efficiency quantification

| Type of the method                        | Name of the method               | Utilization                                                                 |
|-------------------------------------------|----------------------------------|------------------------------------------------------------------------------|
| Input-output methods                      | CMA (cost minimization analysis) | - single criterion decision making, e.g. removal and disposal of municipal waste |
|                                           | CBA (cost-benefit analysis)      |                                                                              |
|                                           | CEA (cost-effectiveness analysis) |                                                                              |
|                                           | CUA cost-utility analysis        |                                                                              |
| Methods of financial analysis             | NPV (net present value)          | - investment project decision making, outputs can be expressed in financial units, e.g. waste dump construction |
|                                           | PB (pay back method)             |                                                                              |
|                                           | IRR (internal rate of return)    |                                                                              |
| Decision making supporting methods        | methods of managerial science:   | - support analysis of final decision making, time dynamics and expected consequences (simulation) etc. |
|                                           | - calculation of critical path method |                                                                              |
|                                           | - linear programming             |                                                                              |
|                                           | - dynamic programming            |                                                                              |
|                                           | - numerical simulation, etc.      |                                                                              |
| Methods of evaluation and comparison of   | benchmarking (comparison studies) | - evaluation of performance and quality of provided services, reorganization and performance evaluation of organizational units of the municipality |
| performance and quality / services        | BSC (balanced scorecard)         |                                                                              |
|                                           | ISO etc.                         |                                                                              |

Source: Ochrana (2004)

In the article we introduced a new methodological approach that can measure the effectiveness of public administration. In this context, we come to the point where the public administration meets economics, but especially to the intersection of observed topics with quantitative approaches.

Data Envelopment Analysis (DEA) is a nonparametric method for measuring of efficiency, which uses the tools of mathematical programming, namely linear programming (Fiala et al., 1997). Pioneer work in this area was done by Farrell (1957), who continued in the research of Debreu (1951) and Koopmans (1951). Farrell proposed a new measurement of efficiency, based on the calculation of linear convex envelope curve and the
use of distance functions to measure the distance of the object from the projected point to the efficient curve. This way he proposed also new measure of efficiency, based on the calculation of 2 components of the overall efficiency of the object: technical and allocated efficiency. His approach is based on the measurement of the object's ability to transform its inputs to outputs, therefore is also named as input-oriented approach.

In consideration of the need for a comprehensive assessment of researched topic, the Data Envelopment Analysis seems to be the appropriate tool for quantification of public administration performance. Data envelopment analysis as a statistical method has been successfully applied in quantification of the effectiveness of commercial entities and it can also become an important tool in helping government officials to make the decisions, and rationalization and optimization of public administration.

The aim of DEA is the division of observed subjects into efficient and inefficient objects according to the size of consumed inputs, and the quantity of the production (outputs), or other type of outputs. DEA compares the units in relation to the best units. DEA models are based on Farrell's model for measuring the units of efficiency with one input and one output, later updated by Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Cooper (BCC). Therefore, we now know two types of DEA analysis, CCR and BCC access approach.

Packaging data analysis is based on the principle that for the particular problem set of production possibilities exists, consisting of all permissible combinations of input and output. Production possibility set is determined by the effective border. If a combination of input and output of the unit lies on this border, it is the effective unit. Unit is considered effective unless it consumes a small amount of input to the large amount of output (the principle of effectiveness). In case the unit is not effective (it does not lie on the production possibilities border), it is necessary to adjust the size of its input or output (Schmidt and Sickles, 1984). To find the solution, how to reduce the inputs or increase the outputs, we can find the answer in DEA.

Terminology used for DEA is based on the production economics. Therefore, we consider it important to define the key terms, which will be used in the article. These are:

- Production frontier - describes the optimum relationship between inputs and outputs to maximize output for a given input value;
- DMU (decision making unit, company) - is a term introduced by Charnes et al. (1978) to describe the units that will be analyzed by DEA. This term meant that efficiency analysis did not apply to businesses that show a profit, but to businesses in general;
- TE (technical efficiency) - is defined as the object's ability to achieve maximum output from a given set of inputs (Pitt and Lee, 1981). For the measurement radial rate is used, which measures the distance of the object from the production frontier. Technical efficiency values vary between <0, 1>, where 1 means that the object is efficient (because the subject is on the production possibilities frontier). Otherwise the object is inefficient. The closer to 1 is the value of TE, the more efficiently is the object transforming its inputs into outputs;
- AE (allocative efficiency) – the object's ability to combine inputs in optimal proportions, taking into account the input prices. The technically efficient object does not have to achieve allocating efficiency, because the technical efficiency does not reflect the price of inputs. Similarly to technical efficiency, also allocating efficiency reaches the values from <0, 1>;
- EE (economics (total) efficiency) - is an indicator that incorporate both technical and allocating efficiency. According to the observed aim of the decision-making body it is also referred to as cost efficiency (in case of minimizing costs) or revenue efficiency (in case of maximizing revenues). It must also reach the values from <0, 1>;
- ER (scale efficiency) - is defined as the ratio of values of technical efficiency achieved in the calculation of DEA models under conditions of constant scale returns and DEA models under conditions of variable scale returns. This measure indicates the extent to which investigated object work effectively in their own size group (values are analogously from the range <0, 1>).
Jablonský et al. (2004) emphasize that the benefit of this methodology compared to econometric methods (stochastic production queue) is the fact that it is easier to apply, not burdened by the requirements of parametric methods (normality distribution assumption, or file extension) and require no information about the prices of inputs and outputs. DEA achieves good results in small scale evaluated objects and when used in combination with appropriate statistical tools (regression analysis, analysis of variance, correlation tests of mean values, etc.), it can answer a number of questions related to the effectiveness of investigated object. If we try a more comprehensive assessment (e.g. different institutions of public administration or even the entire public sector), we recommend comparison of the results obtained using the two above-mentioned methods to avoid bias values of calculated measures of technical efficiency.

Reflecting the limited scope of the article the method based on DEA model approach of Charnes, Cooper, and Rhodes (the CCR approach) and Banker, Charnes, and Cooper (BCC approach) will be presented only.

CCR approach is known as input oriented model of DEA analysis. For this model we assume constant returns on scale. The coefficient of technical efficiency is defined as the ratio of the weighted sum of output and weighted sum of input. We search for such coefficients, so the coefficient of technical efficiency was in the range $<0, 1>$. Unit with a coefficient of technical efficiency equal to 1 is effective, value less than 1 indicates an inefficient unit and determines the extent of necessary reduction of an entry to ensure the efficiency of the unit. CCR approach of DEA model evaluates the effectiveness of units for any number of inputs and outputs. Unknown in this case is the weight of assigned input and the weight of assigned output $j$ to by the unit $k$. Scales are searched individually, so it is necessary to solve the $p$ models. The number of models has to be solved, because in evaluated set there are totally $p$ units and for each of them a specific model should be constructed. Mathematical notation of the model for unit $H$ (one of the $p$ units) is following: objective function (1), restrictive condition (2), non-negativity condition (3).

$$e_H = \frac{\sum_{j=1}^{m} u_{jH} y_{jH}}{\sum_{j=1}^{n} v_{jH} x_{jH}} \to \text{max}.$$  \hspace{1cm} (1)

Objective function maximizes the ratio of weighted outputs and weighted inputs.

$$\frac{\sum_{j=1}^{m} u_{jH} y_{jH}}{\sum_{j=1}^{n} v_{jH} x_{jH}} \leq 1, (\forall) k = 1, p.$$ \hspace{0.5cm} (2)

Restrictive condition ensures that the ratio of output and input with weights for k-unit will be for other units in the evaluated file less than or equal to one.

$$u_{jH} \geq 0, (\forall) j = 1, n,$$

$$v_{jH} \geq 0, (\forall) j = 1, m.$$ \hspace{0.5cm} (3)

Non/negativity condition requires non-negativity of searched unknowns (i.e. the weights).
BCC approach of DEA analysis was named after abbreviations of its authors’ names: Banker, Charnes, and Cooper. It contains the modification of the CCR model of DEA analysis. This model considers the variable returns on scale. The BCC approach requires the completion of the condition that the virtual unit for the selected unit H will be convex combination of its specimen units. This fact is reflected in the extended model under the condition that the sum of $\lambda_kH$ for $k = 1, 2, \ldots, p$ was equal to 1. In the first model, the condition is manifested by adding one variable, which represents the size of deviation from constant returns on scale.

The initial model then has the form:

$$e_H = \sum_{j=1}^{n} u_{jiH}y_{jiH} + q_H \rightarrow \max$$

$$\sum_{i=1}^{m} v_{ih}x_{ih} = 1$$

$$- \sum_{i=1}^{m} v_{ih}x_{ih} + \sum_{j=1}^{n} u_{jiH}y_{jiH} + q_H \leq 0, (\forall) k = 1, p$$

$$u_{jiH} \geq 0, (\forall) j = 1, n$$

$$v_{ih} \geq 0, (\forall) i = 1, m$$

$$q_H \in R$$

(4)

The extended model can be written as:

$$z_H \rightarrow \min$$

$$x_{ih}z_H - \sum_{i=1}^{m} \lambda_{iH}x_i \geq 0, (\forall) i = 1, m,$$

$$\sum_{i=1}^{m} \lambda_{iH}y_i \geq y_{jH}, (\forall) j = 1, n$$

$$\sum_{i=1}^{m} \lambda_{iH}$$

$$\lambda_{iH} \geq 0, (\forall) k = 1, p$$

$$z_H \in R$$

(5)

4. Conclusion

Extending the application of quantitative methods in economic and administrative sciences (economics and public administration) necessitated the need for ensuring and improving of the efficiency of different activities, from business to the public sector. Data envelopment analysis appears to be an appropriate methodological tool also in case of the quantification of the efficiency of public administration, namely for evaluation of the technical efficiency of production units based on the size of input and output. Quantify performance is possible not only to private economic subjects, financial institutions, medical facilities, commercial establishments, but
also for public sector bodies, including the subjects of public administration. Evaluated inputs and outputs used in DEA could be included into the multi criterion type of decision making.

In submitted article we introduced CCR and BCC approach of DEA analysis. Data envelopment analysis proves to be a suitable methodological approach to verification of so called technical efficiency of units, which are mutually comparable. In case of inefficient units allows DEA method to determine how the particular economic unit should reduce its inputs, or increase its outputs respectively, to become efficient.

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