

# Decision Supporting Procedure for Strategic Planning: DEA Implementation for Regional Economy Efficiency Estimation

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**Abstract.** The algorithm of decision supporting procedure based on Data Envelopment Analysis (DEA) along with the Malmquist Productivity Index is suggested in the paper. The procedure's core consists of evaluations complex for preliminary data processing and adjustment as well as creating of analytic materials in the field of regional strategy planning. The crucial study issue is to define boundaries of DEA applicability in this field and to eliminate DEA shortcoming, such as the scores dependence on a set of inputs and outputs. The efficiency scores of Russian regional agrarian sector are obtained in order to verify the procedure and add knowledge to current indicators' systems of regional economic efficiency by improving approach objectiveness. It is shown how obtained results can be applied in the strategic planning to increase effectiveness of state regional policy activity.

**Keywords.** Efficiency, Malmquist Index, Data Envelopment Analysis, Region, Procedure, Strategy Planning

**Key terms.** DecisionMaking, MathematicalModel, Methodology, Development, Management

## 1 Introduction

Theoretical model of this study is based on the Pareto-Koopmans concept (1951) [1]. System technology is efficient by Pareto-Koopmans if and only if the object does not have an opportunity to improve its resource (input) or product (output) without sacrificing some other input or output. Charnes et al. (1978) have proposed Data Envelopment Analysis (DEA) based on this concept of efficiency that was combined operational research tools within works of Koopmans (1951) and Farrell (1957) [2, 3].

DEA is a non-parametric frontier approach for comparative efficiency measurement in which a set of similar objects with multiple inputs and outputs is analyzed.

The aim of this study is to suggest the procedure for providing strategy planning by analytical reports based on DEA scores implementation.

It is obvious that productivity analysis by DEA has at least three current issues. The first is to define a set of objects which will be compared in the study. The second is to formulate convenient conditions for concrete models' modifications using. The third issue is to improve discrimination capability. Therefore, efficiency assessment procedure by DEA is primarily based on the following grounds: the formation of objects' set to be compared, identification of inputs and outputs, and model selection.

Taking into account issues mentioned above, it is necessary to adapt basic DEA models and its implementation. Furthermore, DEA procedure is considered as a core of the evaluation of regional economy efficiency scores.

This paper consists of five parts. We state the main issues in this, first, part. This study's background is presented in the second part. Part 3 deals to description of suggested evaluation procedure. The applying of investigation of the Russian regions agrarian sector to management tasks by using the procedure is reported in the part 4. We make conclusions in the last part.

## 2 Theoretical and Methodological Background

DEA application has a big number of advantages. First of all, a calculation of an integrated assessment is produced for each region reflecting the efficiency of input factors using for output products. Besides, the Pareto-optimal set of efficient regions in the multidimensional space of inputs and outputs is being obtained. Secondly, it is unnecessary to attract an expert knowledge in a priori assignment of weights for variables corresponding to inputs and outputs. Despite of this, using of additional data on region external factors is helpful for creating the right model. Thirdly, it is very important that there are no restrictions on the functional form of the relation between inputs and outputs.

The study is carrying out with the hypothesis that DEA implementation needs the formal procedure in order to obtain stable scores and apply research results to analytic background of current regional strategic planning.

The multilateral and penetrating analysis of DEA possibilities and its application's restrictions are presented in Dyson et al. (2001), Cook and Seiford (2009) [4, 5]. Along with these works there are reviews of this method application, for instance, in papers of Avkiran and Parker (2010), Liu et al. (2012) [6, 7]. The common bases productivity measurement presented in Caves et al. (1982) [8].

The application possibilities of Malmquist Productivity Index in different intertemporal comparisons are described in the research of Färe and Grosskopf (1996) [9]. Tsuneyoshi et al. (2012) used Malmquist Index for the comparative analysis of 97 countries calculated by DEA models for period 1981-2004 [10]. Yamamura and Shin (2008) determined the nature of inequality impact on capital accumulation and growth performance by evaluation DEA indexes from 1965 to 1990 [11].

According to review presented in [12], although there are a DEA advantages, the general method's shortcoming is considered as crucial because the scores signifi-

cantly depend on a set of inputs and outputs. This study suggests the special procedure for DEA implementation for the needs of regional strategic planning. It is a result of attempting to eliminate the mentioned DEA drawback and provide the decision process of strategic planning by analytic materials. Golany and Roll (1989), Emrouznejad and De Witte (2010) offered procedures of DEA application which are very useful for common case [13, 14]. This study based on results of these works.

### 3 Efficiency Estimation Procedure

Different levels of the regional economy scale and the return to scale effect are considered as a reason of inequality between regional output performances. That is why the model with variable return to scale is suggested for this study. This model was introduced by Banker et al. (1984).

Data for a research by DEA is presented by a number of indicators in form of the matrix of inputs  $X^j = \{x_{ij}^j\}$  and matrix of outputs  $Y^j = \{y_{kj}^j\}$ . The efficiency criterion for a multidimensional assessment of an object is to assign some input and output parameters for all objects, some weights and then to calculate and maximize the ratio for each object:

$$\theta_j = \frac{\sum_{k=1}^s u_k y_{kj}^j}{\sum_{i=1}^m w_i x_{ij}^j} \tag{1}$$

where:

- $j$  – index of the estimated production facility,  $j=1, \dots, n$ ;
- $x_{ij}$  – matrix of input parameters that reflect the system resources,  $i=1, \dots, m$ ;
- $y_{kj}$  – matrix of outputs which reflect the products of system,  $k=1, \dots, s$ ;
- $u_k, w_i$  – weights for outputs/inputs.

According to the DEA framework, this function should be maximized under restrictions for all objects:

$$\frac{\sum_{k=1}^s u_k y_{kj}^j}{\sum_{i=1}^m w_i x_{ij}^j} \leq 1 \quad \forall j = 1, \dots, n; \quad u_k \geq 0, w_i \geq 0 \tag{2}$$

The Malmquist Productivity Index is calculated using such DEA efficiency scores for evaluation of total factor productivity change:

$$M_j^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \left[ \frac{\theta_j^t(x^t, y^t) \theta_j^{t+1}([x]^{t+1}, y^t)}{\theta_j^t([x]^{t+1}, y^{t+1}) \theta_j^{t+1}([x]^{t+1}, y^{t+1})} \right]^{\frac{1}{2}} \tag{3}$$

The suggested procedure for regional efficiency assessment has the complex of procedures for preliminary data processing and adjustment (fig.1).

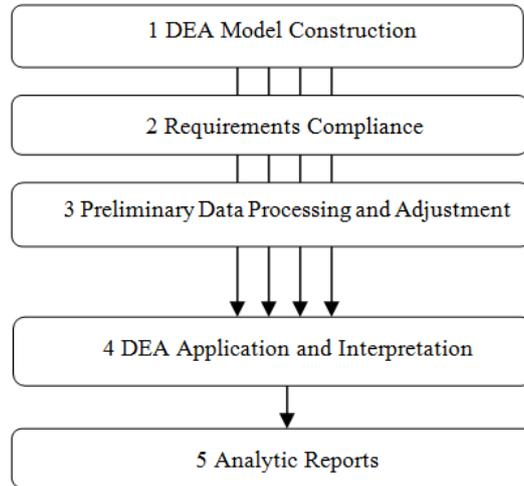


Fig. 1. Five stages of Efficiency Estimation Procedure

The dual linear program model for evaluation the criterion given above is:

$$\begin{aligned}
 \min_{\eta, \lambda} \eta \quad \text{subject to} \quad & y_{ku} - \sum_{j=1}^n \lambda_j y_{kj} \geq 0, \quad k = 1, \dots, s, \\
 \eta x_{i0} - \sum_{j=1}^n \lambda_j x_{ij} \geq 0 \quad & i = 1, \dots, m, \quad \sum_{j=1}^n \lambda_j = 1, \quad \lambda_j \geq 0, j = 1, \dots, n
 \end{aligned}
 \tag{4}$$

where:

$\eta$  – comparative efficiency score of region  $j$  ( $j=1 \dots, n$ );

$\lambda_j$  – dual model variables.

If  $\eta < 1$  then the region belongs to inefficient set, otherwise ( $\eta = 1$ ) it is a part of Pareto set.

According to procedure carrying out, the result of all evaluations using (3), (4) is a set of regional types by dynamics character.

Generally, the result of DEA application is the set of scores also which shows the ways of comparative efficiency improvement for each inefficient region. Nevertheless, this issue is not treated in this procedure because it requires the special attention and investigation due to its complexity.

#### 4 Evaluation by Using Procedure

We examined the issue of inequality of regional economy performance for the period from 2008 to 2010. Federal State Statistics Data is used from [www.gks.ru](http://www.gks.ru) [15]. We

evolved a set of indicators that can be used in a broader context in order to identify factors influencing on a regional underdevelopment.

**Stage 1.** The set of indicators for models consists of resources and results of regional agrarian sector performance. Indicators are reported in Table 1.

**Stage 2.** Set of model’s variables defined this way: five resources are taken as inputs while three results are taken as outputs. The volume of region population is considered as the special variable for the set’s normalization.

**Table 1.** The set of regional performance indicators

Type	Indicator
Resources	number of cattle, thousand heads ( $x_1$ )
	organizations acreage under crops, ha ( $x_2$ )
	average number of employees, thousand people ( $x_3$ )
	power capacity, thousand horsepower ( $x_4$ )
	equipment park (tractors), units ( $x_5$ )
Results	gross grain yield, thousand tons ( $y_1$ )
	production of milk, thousand tons ( $y_2$ )
	production of livestock and poultry, thousand tons ( $y_3$ )
Variable for Normalization	volume of region population, thousand people

**Stage 3.** Next, the homogeneity of conditions was checked for all agrarian regional systems, and asymmetry of land’s quality founded out. The input called “organizations acreage under crops” is adjusted by the coefficient of cadastral value of agricultural land. The rule of ratio of variables’ number and objects’ number is kept, therefore, modeling is made for 53 quite similar agrarian Russian regions.

Additional restriction to weights is used in order to improve the discrimination capability of the model. Direct restriction on the ratio of the quantity of employees and the power capacity presented by the following ratios:

$$\alpha \leq \frac{x_3}{x_4} \leq \beta \tag{5}$$

$$\alpha \min(\text{price}_{x_2}) = \frac{\square}{\min(\text{price}(\square_{x_4}))} \tag{6}$$

$$\beta \max(\text{price}_{x_2}) = \frac{\square}{\max(\text{price}(\square_{x_4}))} \tag{7}$$

where:

$price_{x_3}$  – regions' average monthly salary;

$price_{x_4}$  – regions' average energy price;

$x_3, x_4$  – inputs which are taken in the normalized forms according to the second stage.

**Stage 4.** According to (3) and (4), the calculation cycle is done, and obtained scores are insensitive regarding the model parameters changes. It was approved by decreasing of the set of analyzed objects. Besides, the Malmquist Indices values are similar to current expert opinion on the character of current tendencies of technological progress changes in the industry for analyzed period.

**Stage 5.** The quantitative scores combined with qualitative evaluation of risks and conditions of regional development allow finding out the regions taxonomy by using obtained knowledge on type of efficiency dynamics. The procedure has conducted from the first to the fifth stage given in Fig.1.

The most significant agrarian regions of Russia are located on the Southern territory which consists of two state districts, namely Southern Federal District and Northern Caucasus Federal District. There are two strategies for these regions: Southern Federal District Strategy and Northern Caucasus Federal District Strategy [16, 17]. Obtained results can be part of analytic reports of these policy development documents (tables 2-3). Development scores are presented for period 2008 - 2010 in the tables. The indicator is equal to «+»/«-» in the case of positive/negative dynamics.

**Table 2.** Efficiency Scores for the Southern Federal District Strategy

Region	Development Score	Region Type
Republic of Adygeya	++	Stable Growth
Republic of Kalmykiya	++	Stable Growth
Krasnodar Region	-+	Unstable Decline
Astrakhan Region	+ -	Unstable Growth
Volgograd Region	++	Stable Growth
Rostov Region	+ -	Unstable Growth

**Table 3.** Efficiency Scores for the Northern Caucasus Federal District Strategy

Region	Development Score	Region Type
Daghestan	--	Stable Decline
The Ingush Republic	++	Stable Growth
Republic of Kabardino-Balkariya	--	Stable Decline
Republic of Karachaevo-Cherkesiya	--	Stable Decline
Republic of Northern Osetia Alaniya	-+	Unstable Decline
The Chechen Republic	--	Stable Decline
Stavropol Region	++	Stable Growth

Although analyzed period covers the crisis years, the agrarian production of the South of Russia shows the reserve of stability. Besides, it is brought out that the Southern regions belong to Pareto-Efficient set of Russian regions.

Thus, only 4 regions among 13 of the South are estimated as having the stable decline. The economic development opportunities of this regions are significant, nevertheless the considerable potential of regions is not using.

Such indicators' further analysis can be used for adjustment of scenario data tasks in the field of regional development foresight and strategic planning. The obtained results also can be suitable for equalization policy design in order to steady the level of regional efficiency during long-term period. In addition to this, it is important that risks, conditions and possible consequences of the policy should be assumed for each scenario of regional development.

## 5 Conclusions

The verification of suggested procedure along with the DEA model demonstrates the positive results that approve the possibility of the procedure application to prospective studies in the field of production analysis as well as strategic management.

As it was shown, the obtained results can be part of the quantitative investigations for the current strategies of development policy. In addition to this, the development scores can be used together with regional development risks and opportunities analysis, indicators of economical efficiency, such as gross domestic product per capita, enterprises profitability, etc. Thus, obtained scores will add knowledge to current indicators' systems of regional economic efficiency and improve approach objectiveness and effectiveness of state regional policy activity.

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