Measuring the Effectiveness Factors in New EU Member States through DEA Approach

J. Hančlová, M. Staníčková

Abstract**—**The paper deals with an application of Data Envelopment Analysis (DEA) method to multi-criteria performance evaluation of the New European Union (EU) Member States in the reference period 1995-2010. Efficiency of the Member States can be seen as the source of national performance and subsequent competitiveness. The aim of the paper is to analyze an efficiency of effectiveness factors and a level of productive potential achieved of the Member States with the help of specialized DEA approach – the Malmquist (Productivity) Index (MI/MPI) in the reference period. The main purpose of this approach is to evaluate numerical grades of efficiency of economical processes within New EU Member States. Using of DEA method for efficiency evaluation seems to be convenient because there is not only one factor evaluated, but a set of different factors that determine the degree of economic development. DEA method is based on inputs and outputs of used indicators and evaluates the efficiency how countries are able to transform their inputs into outputs. Therefore, efficiency of the Member States can be considered as a 'mirror' of competitiveness and a source of national performance. The theoretical part of the paper is devoted to the fundamental bases of competitiveness in the context of performance theory. The empirical part is aimed at measuring the change of technical efficiency and the movement of the productive frontier level in evaluated countries by MI/MPI. The final part of the paper offers a comprehensive comparison of results obtained by MI/MPI method.

Keywords**—**CCR CRS model, Competitiveness, DEA method, Evaluation, Efficiency/Inefficiency, Malmquist productivity index, New EU Member States, Performance

I. Introduction

In the European Union (EU), the process of achieving an increasing trend of performance and a higher level of competitiveness is significantly difficult by the heterogeneity of countries and regions in many areas. Although the EU is one of the most developed parts of the world with high living standards, there exist significant and huge economic, social and territorial disparities having a negative impact on the balanced development across Member States and their regions, and thus weaken EU's performance in a global context.

The concept of competitiveness in the EU is specific regarding the inclusion of elements of European integration that goes beyond the purely economic parameters. The economy may be competitive and efficient but if the society and the environment suffer too much the country will face major difficulties, and vice versa. Therefore governments in the long run period cannot focus alone on the economic competitiveness of their country; instead they need an integrated approach to govern the country and focus on the broadest aspects affecting competitiveness, subsequent performance and thus efficiency [1]. In relation to competitiveness, *performance* and *efficiency* are *EU's key complementary objectives*, which determine the long-term development of countries and regions. *Measurement, analysis and evaluation of productivity changes, efficiency and level of competitiveness are controversial topics* acquire great interest among researchers; see e.g. [2], [14].

The aim of this paper is to measure and evaluate the efficiency level of European countries joining the EU in 2004, i.e. Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia, and Bulgaria and Romania joining the EU in 2007, by application of specialized *Data Envelopment Analysis* (DEA) approach – the Malmquist (Productivity) Index (MI/MPI). The performance analysis is used for evaluating national development quality and potential (with respect to the national factors endowment). DEA method becomes a suitable tool for ranking competitive (uncompetitive) position of countries based on efficiency within the group of new EU Member States. Application of DEA method is based on assumption that *efficiency* of calculated by DEA method can be seen as the *source of national competitiveness (competitive potential)*; see e.g. [12].

II. Basic Framework of Efficiency Analysis in the Context of Performance

In recent years, the topics about measuring and evaluating of *competitiveness* and *efficiency* have enjoyed economic interest. Although there is no uniform definition and understanding of these terms, these concepts remain ones of the basic standards of performance evaluation and it is also seen as a reflection of success of area (country/region) in a wider (international/inter-regional) comparison. Performance, efficiency and competitiveness are *complementary objectives*,

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which determine the long-term development of an organization (e.g. companies, states, regions).

A. Concepts of Performance and Efficiency

Performance management is one of the major sources of sustainable national effectiveness and a systematic understanding of the factors that affect productivity, and subsequently also competitiveness, is very important. Performance is also highly important for many economic subjects (e.g. companies, states, regions) as a whole and for the individuals involving in it. Performance comprises both a behavioural and an outcome aspect. It is a multi-dimensional and dynamic concept as well as competitiveness. Despite the great relevance of performance and widespread use of this term as an outcome measure in empirical research, relatively little effort has been spent on clarifying the performance concept.

In relation to competitiveness and performance, *efficiency* is a term that recently has come to the forefront of the scientific world. As the world struggles to accommodate the enormous growth in population and to manage the distribution of resources, to reach higher competitive potential, the effort to make things more efficient has become increasingly more relevant. The economy may be competitive but if the society and the environment suffer too much the country will face major difficulties. The same problem would happen vice versa when the economy is too weak. Therefore governments in the long run period cannot focus alone on the economic competitiveness of their country; instead they need an integrated approach to govern the country and focus on the broadest aspects affecting efficiency. As the world struggles to accommodate the enormous growth in population and to manage the distribution of resources, to reach higher competitive potential, the effort to make things more efficient has become increasingly more relevant. Efficiency is a central issue in analyses of economic growth, the effects of fiscal policies, the pricing of capital assets, the level of investments, the technology changes and production technology, and other economic topics and indicators. In a competitive economy, therefore, the issue of efficiency, resp. dynamic efficiency, can be resolved by comparing these economic issues [18].

Nowadays efficiency is one of the *fundamental criteria for evaluating economic performance* and reflects the success in the broader comparison. Organizations (e.g. companies, states, regions) need *highly performing units* in order to meet their goals, to deliver the products and services they specialized in, and finally *to achieve competitive advantage*. Low performance and not achieving the goals might be experienced as dissatisfying or even as a failure. Moreover, performance – if it is recognized by others organizations (companies, countries, regions) – is often rewarded by benefits, e.g. better market position, higher competitive advantages, financial condition etc. Performance is a major – although not the only – prerequisite for future economic and social development and success in the broader comparison [15], [17],

B. Approaches to Evaluation of Efficiency

Evaluating of efficiency belongs to main issues of economic research, which also lacks a mainstream approach. Efficiency evaluation in terms of differences between countries and regions should be measured through *complex of economic, social, environmental criteria* identifying imbalance areas that cause main disparities. Currently not only quantitative but also qualitative development at national level, and especially at regional level, increase socio-economic attraction and create new opportunities that are fundamentals for subsequent overcoming disparities and increasing the performance of territory [11].

The primary problem in creating an effective evaluation system is establishing clear performance and efficiency standards and priorities at the beginning of the performance cycle. The early research on this problem focused on separate measures for productivity and there was a failure to combine the measurements of multiple inputs into any satisfactory measure of efficiency. These inadequate approaches included forming an average productivity for a single input (ignoring all other inputs), and constructing an *efficiency index* in which a weighted average of inputs is compared with output. Responding to these inadequacies of separate indices of labour productivity, capital productivity, etc., Farrell [9], proposed an activity analysis approach that could more adequately deal with the problem. His measures were intended to be applicable to any productive organization; in other words, *from a workshop to a whole economy* [15]. Farrell confined his numerical examples and discussion to single output situations, although he was able to formulate a multiple output case. Twenty years after *Farrell's model*, and building on those ideas, Charnes et al. [4], responding to the need for satisfactory procedures to assess the relative efficiencies of multi-input/multi-output production units, introduced a powerful methodology which has subsequently been titled *Data Envelopment Analysis* (DEA) [13 and 21].

Measurement and evaluation of performance, efficiency and productivity is an important issue for at least *two reasons*. One is that in a group of units where only limited number of candidates can be selected, the performance of each must be evaluated in a fair and consistent manner. The other is that as time progresses, better performance is expected. Hence, the units with declining performance must be identified in order to make the necessary improvements [10]. The performance of a countries and regions can be evaluated in either a cross-sectional or a time-series manner, and the DEA is a useful method for both types of efficiency evaluation [16].

III. Measuring of National Efficiency and Productivity by the DEA Approach

Based on the above facts, the performance analysis provided by the DEA method can be used in evaluating national development efficiency with respect to the national factor endowment.

A. *The Theoretical Background of the DEA Method*

The Data Envelopment Analysis was first proposed and introduced by *A. Charnes*, *W.W. Cooper* and *E. Rhodes* in 1978. Since that time, the DEA is the subject of a number of research studies, because researchers in a number of fields have quickly recognized that it is an excellent and easily used methodology for modeling operational processes for performance evaluation. This has been accompanied by other developments. The DEA is based on the *Farrell model* [9], for measuring the effectiveness of units with one input and one output, which expanded in 1978 by *A. Charnes*, *W.W. Cooper* and *E. Rhodes* (CCR model) and later modified in 1984 by *R. A. Banker*, *A. Charnes* and *W. W. Cooper* (BCC model). DEA methods also include advanced additive models, such as *Slack-Based Model* (SBM) performed by *K. Tone* in 2002 or *Free Disposal Hull* (FDH) and *Free Replicability Hull* (FRH) models that have been firstly formulated in 1984 by *D. Deprins*, *D. Simar* and *H. Tulkens* [6].

The DEA is a relatively new ”data oriented” approach for providing a relative efficiency assessment (DEA efficient) and evaluating the performance of a set of peer entities called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs. DEA is thus a multi-criteria decision making method for evaluating effectiveness, efficiency and productivity of a homogenous group (DMUs). The definition of a DMU is generic and flexible. The DEA is convenient to determine the efficiency of the DMU, which are mutually comparable – using the same inputs, producing the same outputs, but their performances are different. Determining whether a DMU is efficient from the observed data is equivalent to testing whether the DMU is on the ‘frontier’ of the production possibility set. A DMU is efficient if the observed data correspond to testing whether the DMU is on the imaginary ‘*production possibility frontier’*. All other DMU are simply inefficient. The best-practice units are used as a reference for the evaluation of the other group units. The aim of this method is to decide if DMU are effective or not effective by the size and quantity of consumed resources and by the produced output. It should be noted that the DEA is primarily a diagnostic tool and does not prescribe any reengineering strategies to improve performance of DMUs. The efficiency score of DMU in the presence of multiple input and output factors is defined by the following equation (1) [20]:

$$Efficiency = \frac{weighted\_sum\_of\_outputs}{weighted\_sum\_of\_inputs}. \quad (1)$$

The aim of DEA method is to examine DMU if they are *effective* or *not effective* by the size and quantity of consumed resources by the produced outputs (Andresen and Petersen, 1993). The best-practice units are used as a reference for evaluation of other group units. DMU is *efficient* if the observed data correspond to testing whether the DMU is on the imaginary *production possibility frontier*. All other DMU are simply *inefficient*. For every inefficient DMU, DEA identifies a set of corresponding efficient units that can be utilized as benchmarks for improvement. However DEA is primarily a diagnostic tool and does not prescribe any reengineering strategies to improve performance of DMUs [5].

In recent years, we have seen a great variety of applications of the DEA for evaluating the performances of many different kinds of entities engaged in many different activities. Because of low assumption requirements the DEA has also opened up possibilities for use in cases which have been resistant to other approaches because of the complex (often unknown) nature of the relations between the multiple inputs and multiple outputs involved in DMUs. Using the DEA method for national performance evaluation is suitable because it does not evaluate only one factor, but a set of different factors that determine the degree of economic development. The DEA method used for our evaluation is based on a particular set of input and output indicators. The inputs and outputs form the key elements of the system evaluated for every country in the sense of their effective/ineffective economic position. For this purpose, DEA method can identify a competitive/uncompetitive position of each country.

For solution of DEA models software tools based on solving linear programming problems are used, e.g. Solver in MS Excel, such as the *DEA Frontier* [6], this is used in the paper.

B. *The Fundamental Characteristics of the Empirical Analysis*

Based on the above facts, it is possible to determine the *initial hypothesis* of the analysis. The hypothesis is based on the assumption that new EU Member States achieving best results in efficiency (more advanced European Countries, e.g. Czech Republic, Poland, Slovakia and Slovenia) are countries best at converting inputs into outputs and therefore having the greatest performance and productive potential.

The DEA is in following analysis applied for the 10 countries within the groupings of European countries joining the EU in 2004 – Cyprus (CYP), Czech Republic (CZE), Estonia (EST), Hungary (HUN), Latvia (LVA), Lithuania (LTU), Malta (MLT), Poland (POL), Slovakia (SVK) and Slovenia (SVN). Analysis is also applied to the 2 Balkan countries joining the EU in 2007 – Bulgaria (BGR) and Romania (ROM). Because of the lack of data background for Cyprus and Malta, these states were excluded from the analysis and Malmquist index is computed only for the 10 states. At first glance, it could seem that new EU Member States is incomparable group, because there is different geographic size, number of population, regional administrative structure and segmentation, different economic performance as well as different levels of economic, social and territorial disparities. On the other hand, these countries have (to certain extent) identical features, as especially common historical background, similar cultural backgrounds, traditions and interdependent economic relations. As well as trends in production and elimination of regional disparities in these countries are very similar. However, despite similar historical, political, and economic characteristics of countries, each country disposes of different economic and social conditions at the beginning of the new millennium. This fact is also reflected in the success of convergence process in achieving old EU Member States competitiveness level.

The first part of empirical analysis was devoted to evaluation the efficiency level of production possibilities for new EU Member States. The second part of empirical analysis was devoted to analysis of development determinants for this efficiency in the reference period 1995-2010, through Malmquist index. This index enables a decomposition of efficiency changes in relative efficiency change monitored production possibilities of evaluated country within group of new EU Member States. The second component of Malmquist index is change of production possibility frontier due to evolution/development of technologies. Empirical analysis is thus based on a frontier non-parametric approach and aims to study productivity growth and performance effectiveness. This is based on measuring the change of technical efficiency and the movement of the frontier in terms of individual European countries [8]. Firstly, we evaluate the level of efficiency for each country in each reference year based on CCR CRS model. Subsequently, we analyse productivity changes that occurred between evaluated reference years, i.e. between 1995-1996, 1996-1997, 1997-1998, and so on, and 2009-2010 compared to previous period, not to basis period; see also [18]. Furthermore, we evaluate the change which individual countries achieved in its overall performance in the time periods 1995-2003 (period when countries were associate and candidate countries for accession to the EU), 2004-2010 (period after joining the EU to the present) and in overall period 1995-2010.

The efficiency analysis starts from building a database of indicators that are part of The World Bank Databank – World Development Indicators & Global Development Finance [20] and The Conference Board Total Economy Database [7]. One of the crucial issues is in building a model for evaluation of national performance is the identification of appropriate inputs and outputs. In this paper, database analysis consists of 3 selected indicators – 2 of which are inputs and 1 output. The input and output variables used in the DEA analysis are *Y = Industry, value added* (constant 2000 US$) as *output* and *L = Total annual hours worked* (in thousands) and *C = Gross fixed capital formation* (constant 2000 US$) as *inputs*. The source of output indicator Y (indicator NV.IND.TOTL.KD) and input indicator C (NE.GDI.FTOT.KD) was The World Bank database. The source of input indicator was The Conference Board Total Economy Database.

Since the publication of Färe et al. [8], several studies have analysed the reasons for differing performance in different countries from a frontier approach estimated through non-parametric methods. Research effort has focused on the investigation of the causes of productivity change and on its decomposition. In recent years, the Malmquist (Productivity) Index (MI/MPI) has become the standard approach in the productivity measurement over time within the non-parametric literature. The Malmquist index was introduced by Caves, Christensen and Diewert (1982), whose use became generalized after Färe et al. [8], was published. Färe et al. defined an input-oriented productivity index as the geometric mean of two Malmquist indices developed by Caves et al. [3].

Although it was developed in a consumer context, MI/MPI recently has enjoyed widespread use in a production context, in which multiple but cardinally measurable output replaces scalar-valued but ordinal measurable utility. In producer analysis Malmquist indexes can be used to construct indexes of input, output or productivity, as ratios of input or output distance functions. There are various methods for measuring distance functions, and the most famous one is the linear programming method. The Malmquist index allows measuring of total productivity by means of distance-functions calculation, which can be estimated through the solution of mathematical programming problems of the DEA kind.

Suppose we have a production function in time period t as well as period $t+1$. The Malmquist index calculation requires two single period and two mixed period measures. The two single period measures can be obtained by using the *CCR model with Constant Returns to Scale* (CRS). For simplicity of the Malmquist index calculation, we present basic DEA models based on assumption of a single input and output.

In calculating the Malmquist index, we evaluate the effectiveness of production units *DMUj (j = 1, 2 ... n)* during the time period $t = 1, 2,..., T$. Production technology S^t is known for each time period. This production technology S^t transforms inputs into outputs. Suppose each DMU_j $(j=1, 2,..., n)$ produces a vector of output $y_j^t = \left(y_{1j}^t, \dots, y_{sj}^t\right)$ by using a vector of inputs $x_j^t = \left(x_{1j}^t, \dots, x_{mj}^t\right)$ at each time period t, $t=1... T$. From t to $t+1$, DMU_j's efficiency may change or (and) the frontier may shift. $D_q^t\left(\boldsymbol{x}^t, \boldsymbol{y}^t\right)$ is a function that represents the production technology S^t and assigns to evaluated production unit the efficiency rate U_q. In input oriented model, if $D_q^t\left(\boldsymbol{x}^t, \boldsymbol{y}^t\right) < 1$, than unit q is inefficient and if $D_q^t\left(\boldsymbol{x}^t, \boldsymbol{y}^t\right) = 1$, than unit q is efficient. Effective units then specify the production possibility frontier. Function $D_q^{t+1}\left(\boldsymbol{x}^t, \boldsymbol{y}^t\right)$ gives the relationship of inputs and outputs of the time period t with production technology S^t in the time period $(t+1)$ and function $D_q^t\left(\boldsymbol{x}^{t+1}, \boldsymbol{y}^{t+1}\right)$ present inputs and outputs of the time period $(t+1)$ with production technology S^t in the time period t. On conditions that $\left(\boldsymbol{x}^{t+1}, \boldsymbol{y}^{t+1}\right)$ does not belong to the production technology S^t, may be the case that $D_q^t\left(\boldsymbol{x}^t, \boldsymbol{y}^t\right) > 1$, therefore evaluated unit q achieve greater level of effectiveness than production possibility frontier allowed in the previous period. Of course, the opposite case can also occur, that $D_q^{t+1}\left(\boldsymbol{x}^t, \boldsymbol{y}^t\right) > 1$, which characterizes a situation that process of production possibility frontier was reduced during due to the previous period.

For computation of the Malmquist productivity index, it is necessary to calculate four mathematical programming problems for obtaining the values of $D_q^t\left(\mathbf{x}^t,\mathbf{y}^t\right)$, $D_q^t\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)$, $D_q^{t+1}\left(\mathbf{x}^t,\mathbf{y}^t\right)$ and $D_q^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)$.

The two single period measures can be obtained by using the *Charnes-Cooper-Rhodes (CCR) model with Constant Returns to Scale* (CRS). The calculation of $D_q^t\left(\mathbf{x}^t,\mathbf{y}^t\right)$ for production unit *q*, for *m* inputs and *r* outputs, present to minimize a linear programming equation (2) [21]:

$$\min\ D_q^t\left(\mathbf{x}^t,\mathbf{y}^t\right)=\theta_q, \tag{2}$$

$$\text{subject to} \sum_{j=1}^{n}\lambda_j x_{ij}^t \le \theta_q x_{iq}^t,\quad i=1,2,...,m,$$
$$\sum_{j=1}^{n}\lambda_j y_{ij}^t \ge y_{iq}^t,\quad i=1,2,...,r,$$
$$\lambda_j \ge 0,\qquad j=1,\dots,n.$$

Formulation of equation (2) assumes constant returns to scale, which follows from the nonnegative conditions for all variables λ_j.

To obtain $D_q^t\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)$ assuming constant returns to scale, we solve a linear programming equation (3) in the form [21]:

$$\min\ D_q^t\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)=\theta_q, \tag{3}$$

$$\text{subject to} \sum_{j=1}^{n}\lambda_j x_{ij}^t \le \theta_q x_{iq}^{t+1},\quad i=1,2,...,m,$$
$$\sum_{j=1}^{n}\lambda_j y_{ij}^t \ge y_{iq}^{t+1},\quad i=1,2,...,r,$$
$$\lambda_j \ge 0,\qquad j=1,\dots,n.$$

The optimization problem (2) and (3) differ in evaluated observation of production unit *q* due to the production possibility frontier *t*.

The calculation of $D_q^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)$ is similarly given by optimization equation (4) [20]:

$$\min\ D_q^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)=\theta_q, \tag{4}$$

$$\text{subject to} \sum_{j=1}^{n}\lambda_j x_{ij}^{t+1} \le \theta_q x_{iq}^{t+1},\quad i=1,2,...,m,$$
$$\sum_{j=1}^{n}\lambda_j y_{ij}^{t+1} \ge y_{iq}^{t+1},\quad i=1,2,...,r,$$
$$\lambda_j \ge 0,\qquad j=1,\dots,n.$$

The last linear programming equation to determine $D_q^{t+1}\left(\mathbf{x}^t,\mathbf{y}^t\right)=\theta_q$, in the following input oriented CCR CRS model is in the form (5):

$$\min\ D_q^{t+1}\left(\mathbf{x}^t,\mathbf{y}^t\right)=\theta_q, \tag{5}$$

$$\text{subject to} \sum_{j=1}^{n}\lambda_j x_{ij}^{t+1} \le \theta_q x_{iq}^t,\quad i=1,2,...,m,$$
$$\sum_{j=1}^{n}\lambda_j y_{ij}^{t+1} \ge y_{iq}^t,\quad i=1,2,...,r,$$
$$\lambda_j \ge 0,\qquad j=1,\dots,n.$$

On consider that production function assuming variable returns to scale (BBC model), then optimization problems include a further condition $\sum_{j=1}^{n}\lambda_j=1.$ That formulation does not have a solution, if we compare unit *q* from period *(t +1)* with the production frontier in period *t*, because unit *q* may lie outside the frontiers of earlier technologies.

The input oriented Malmquist index MI_q measuring the efficiency change of production units between successive period's *t* and *t+1* (i.e. *total productivity change*), is formulated in the following form (6) [21]:

$$MI_q\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{x}^t,\mathbf{y}^t\right)=TEC_q\cdot TFS_q, \tag{6}$$

where TEC_q is change in the relative efficiency of DMU_q in relation to other units, i.e. due to the production possibility frontier between time periods *t* and (*t+1*). TEC_q measures the magnitude of *technical efficiency change* and TEC_q < 1 or TEC_q = 1 or TEC_q > 1 indicates that technical efficiency declining or remaining or improving. The second component TFS_q on the right hand side describes the change in the production possibility frontier as a result of the technology development between time periods *t* and (*t+1*). This second terms measures the shift in the possibility frontier, i.e. *technology frontier shift* (*TFS*). Productivity declines if TFS_q < 1, remains unchanged if TFS_q = 1 and improves if TFS_q > 1. These components TEC_q and TFS_q are defined as follows in equations (7) and (8) [21]:

$$TEC_q=\frac{D_q^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)}{D_q^t\left(\mathbf{x}^t,\mathbf{y}^t\right)}, \tag{7}$$

$$TFS_q=\left[\frac{D_q^t\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)\cdot D_q^t\left(\mathbf{x}^t,\mathbf{y}^t\right)}{D_q^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)\cdot D_q^{t+1}\left(\mathbf{x}^t,\mathbf{y}^t\right)}\right]^{1/2}. \tag{8}$$

If the Malmquist index on the basis of minimization of production factors was less than one, it indicates productivity improvement.

Table I Characteristics and trends of the Malmquist index and efficiency change

Malmquist Index	Productivity
> 1	Improving
= 1	Unchanging
< 1	Declining
Efficiency Change	**Technical Efficiency**
< 1	Declining
= 1	Unchanging
> 1	Improving

Source: Own elaboration, 2012

On the other hand, if on the basis of maximization of production factors, the MI index or any of its elements were less than one, it signifies productivity getting better, while if the index is bigger than one, it indicates productivity decrease. In Table I characteristics of Malmquist index and efficiency change are shown.

IV. Application of DEA Approach to Efficiency Evaluation in New Eu Member States

The initial assumption ´*that areas achieving best results in efficiency are areas best at converting inputs into outputs and therefore having the greatest performance and productive potential*´ was confirmed by analysis as show following evaluation.

A. Efficiency Analysis of New EU Member States by CCR Input Oriented Model with CRS

Firstly, empirical analysis was devoted to computation of the efficiency level of production possibilities for each country in each reference year by DEA model. As results show, the best results are traditionally achieved by more economically powerful countries (in most cases) which were *efficient* or *highly efficient* during the whole referred period, so the resulting efficiency index is equal to 1 in input oriented CCR CRS model. This means that the outputs achieved were greater than those incurred inputs. *Efficient* country, in this case only one – *Slovenia*, is mentioned by dark grey colour in Table II.

To efficient country Slovenia it is possible include also countries which were not *efficient* during the whole referred period, but the resulting efficiency index was equal to 1 in CCR CRS model in one or several years in the reference period. These *highly efficient countries* are *Slovakia, Romania, Lithuania and Bulgaria* in selected years. These countries are mentioned by medium grey colour in Table II.

In group of efficient or highly efficient countries, the socio-economic situation is significant different from other countries, this fact confirms the combination of countries to one "slightly" homogeneous group. This "slightly" homogenous group of efficient or highly efficient countries confirms the persistent disparities between more advanced and developed central European countries (including Slovenia) and Balkan and Baltic states. These countries, in the frame of our hypothesis, could be countries with the best competitive potential and perspective to further development.

The efficient or highly efficient countries are followed by a group of countries which are *slightly inefficient*. These countries do not achieved efficiency equal to 1 in CCR CRS model, but their efficiency indices reached consistently highly effective values close during several years in the referred period (coloured by light grey colour in Table II). Best results in coefficients of efficiency, *Czech Republic, Hungary, Lithuania* and *Poland* were reached. These countries are thus the main representatives of this group.

In Table II, average coefficient of efficiency is also mentioned. This index indicates an average rate of efficiency of each country during the whole time period. According to the average values of efficiency coefficient, *Slovenia* is the most efficient countries of all. Countries such as *Slovakia, Romania, Poland, Lithuania* and *Czech Republic* have reached also decent rate of coefficient of efficiency. These countries thus indicate considerable competitive potential and development perspective. Opposite to these results, *Hungary, Bulgaria, Estonia* and *Latvia* are countries with the lowest average levels of efficiency coefficient and thus indicate the worst productive perspectives. In Table II, the efficiency gap is recorded, which indicate distance of efficiency coefficient of each country from the production possibility frontier.

Table II Application of CCR CRS Model for New EU Member States – Level of Efficiency Indexes

CO*	BGR	CZE	EST	HUN	LVA	LTU	POL	ROM	SVK	SVN
1995	1,000	0,686	0,382	0,486	0,332	0,486	0,601	0,331	0,749	1,000
1996	1,000	0,801	0,667	0,751	0,815	1,000	0,944	1,000	0,840	1,000
1997	1,000	0,847	0,665	0,829	0,817	0,923	0,921	0,935	0,749	1,000
1998	1,000	0,866	0,638	0,843	0,624	0,935	0,912	0,953	0,789	1,000
1999	0,902	0,966	0,750	0,909	0,692	0,996	0,960	1,000	0,941	1,000
2000	0,865	0,917	0,728	0,864	0,628	1,000	0,923	1,000	1,000	1,000
2001	0,782	0,866	0,702	0,856	0,611	1,000	0,959	1,000	0,921	1,000
2002	0,760	0,832	0,609	0,817	0,595	0,966	0,980	1,000	0,964	1,000
2003	0,747	0,769	0,532	0,796	0,552	0,965	0,988	1,000	1,000	1,000
2004	0,699	0,758	0,498	0,719	0,453	0,862	0,949	0,996	1,000	1,000
2005	0,480	0,828	0,528	0,729	0,415	0,834	0,914	1,000	1,000	1,000
2006	0,544	0,823	0,450	0,769	0,379	0,778	0,897	0,986	1,000	1,000
2007	0,539	0,769	0,437	0,763	0,372	0,678	0,833	0,795	1,000	1,000
2008	0,438	0,735	0,452	0,682	0,384	0,674	0,755	0,670	1,000	1,000
2009	0,477	0,713	0,528	0,640	0,449	0,845	0,738	0,761	1,000	1,000
2010	0,610	0,838	0,716	0,838	0,633	0,969	0,887	0,859	1,000	1,000
ACO**	**0,740**	**0,813**	**0,580**	**0,768**	**0,547**	**0,869**	**0,885**	**0,893**	**0,934**	**1,000**
EG***	*0,206*	*0,074*	*0,119*	*0,104*	*0,155*	*0,149*	*0,105*	*0,182*	*0,096*	*0,000*

Note: * Coefficient of efficiency = efficiency rate of country in reference years

** Average rate of coefficient of efficiency during the whole reference period

*** Efficiency gap = standard deviation from the average efficiency rate

Source: Own calculation and elaboration, 2012

Fig. 1 indicates efficiency level of production possibility of evaluated European countries in the reference period. In terms of efficiency level, the lowest coefficients have reached LVA (0.547) and EST (0.580). On the other hand, SVN (1.000) has recorded the highest average rate of efficiency. Slovenia thus determined efficient production possibility frontier throughout the period. The highest degree of variability in the assessment of effectiveness was found in BGR, which demonstrates a departure from efficient frontier in the years 1995-1998 and fall to the level of 0.438 in the crisis year 2008.

Regarding the development of the coefficient of efficiency in evaluated countries, we distinguish following groups of these countries: *(1)* Stable development of the production possibility frontier for SVN; *(2)* For BGR decreasing trend since 1999 to the crisis year 2008, even after slight increase;

(3) The growth of efficiency rate until 1999 (for CZE, EST, HUN, LVA, LTU) resp. up to year 2003 (for POL, ROM, SVK), then drop into the crisis in 2008 and the subsequent re-modest growth with varying intensity, which usually does not reach the level of year 1999, resp. 2003.

Fig. 1 Efficiency Level of Production Possibility of EU 10 in the Period 1995-2010

B. *Evaluation of Performance in New EU Member States by Malmquist Productivity Index*

According to the use of the minimization-based Malmquist productivity index in this paper, therefore, if it was equal to 1, signifies no change in performance, if bigger than 1 it shows performance advancement, and in the case it is less than 1 it signifies performance getting worse. The amount of total productivity changes that occurred between evaluated reference years, i.e. between 1995-1996, 1996-1997, 1997-1998, and so on, and 2009-2010 compared to previous period, not to basis period, is shown in Table III, Table IV and Table V. These tables also show results in *Malmquist index (MI)*, *technical efficiency change (TEC)* and *technology frontier shift (TFS)*, which individual countries achieved in its overall performance in the time periods 1995-2003 (period when countries were associate and candidate countries for accession to the EU), 2004-2010 (period after joining the EU to the present) and in overall period 1995-2010.

Considering the information of Table III, Table IV and Table V, some of countries have recorded predominantly *total productivity increase* through the time period (*Slovenia*, *Slovakia*, *Hungary* and *Czech Republic*) and countries have reached predominantly *total productivity decrease* in reference period (*Bulgaria*, *Estonia*, *Latvia*, *Lithuania*, *Poland* and *Romania*). Table III also show results between selected reference years 1995-2003, 2004-2010 and 1995-2010, which are very similar to results of comparing individual years. Traditionally, *Slovenia-Slovakia-Czech Republic* have reached the best results and recorded productivity increase. The worst results, *Balkan* and *Baltic states* have recorded alternately productivity increase and decrease.

Table III Overall Productivity of Countries Based on Malmquist Index (MI)

MI	**BGR**	**CZE**	**EST**	**HUN**	**LVA**	**LTU**	**POL**	**ROM**	**SVK**	**SVN**
1995/1996	3.375	0.953	1.057	0.996	1.047	1.031	1.041	0.979	1.003	0.971
1996/1997	0.881	0.997	1.055	0.954	1.046	1.140	1.079	1.114	1.182	0.988
1997/1998	1.135	1.038	1.106	1.043	1.390	1.048	1.072	1.040	1.008	1.021
1998/1999	1.222	0.969	0.915	0.998	0.964	1.007	1.024	0.998	0.910	1.022
1999/2000	1.023	0.992	0.967	0.989	1.033	0.933	0.978	0.983	0.888	0.950
2000/2001	1.095	1.056	1.027	0.998	1.008	0.984	0.953	1.003	1.082	0.979
2001/2002	1.006	1.008	1.125	1.027	1.020	1.029	0.965	0.999	0.922	0.970
2002/2003	1.035	1.009	1.071	0.969	1.030	0.959	0.947	1.030	0.896	0.981
2003/2004	1.085	0.924	0.973	1.024	1.135	1.048	0.977	1.028	0.904	0.979
2004/2005	1.189	0.981	1.016	1.013	1.123	1.027	1.016	0.777	1.056	0.950
2005/2006	1.027	0.938	1.072	0.927	1.044	1.062	1.031	1.290	0.901	0.941
2006/2007	0.999	1.059	1.008	0.998	1.010	1.136	1.066	1.229	0.976	0.962
2007/2008	1.149	0.976	0.904	1.044	0.905	0.939	1.030	1.107	0.938	1.023
2008/2009	0.874	0.991	0.817	1.014	0.813	0.759	0.973	0.839	1.018	1.131
2009/2010	0.868	0.944	0.818	0.847	0.787	0.968	0.923	0.983	1.062	0.956
1995/2003	*4.308*	0.986	1.078	0.881	1.290	0.946	0.992	1.016	0.808	**0.852**
2004/2010	*1.125*	0.883	0.683	0.842	0.702	0.874	1.050	1.140	0.933	**0.911**
1995/2010	*4.529*	0.753	0.774	0.773	1.089	0.882	0.917	0.945	0.656	**0.758**

Source: Own calculation and elaboration, 2012

The most productivity growth was in *Slovenia*, which has illustrated the biggest performance change and thus productivity trend (according to the values of MI). By analysing the elements of Slovenia's MI we can see that technical efficiency change equals 1 and meaning no change. The shift in the possibility frontier is predominantly less than

1, thus Slovenia approximates the possibility frontier. *Slovakia*, *Hungary* and *Czech Republic* illustrate very similar results, as Table IV shows.

The worst performance was produced by *Bulgaria* because its total productivity was the lowest through the whole time period. But Bulgaria's MI has decreasing, thus illustrating positive trend. Hungary's TEC indicates deteriorating technical efficiency. The Hungary's shift in the possibility frontier is predominantly greater than one (and has a irregular trend), so Hungary approximates irregularly the possibility frontier. Other *Balkan* and *Baltic states* indicate comparable results as Table V illustrates.

Table IV Total Technical Efficiency Change (TEC) of Countries

TEC	BGR	CZE	EST	HUN	LVA	LTU	POL	ROM	SVK	SVN
1995/1996	1.000	0.857	0.572	0.648	0.407	0.486	0.636	0.331	0.891	1.000
1996/1997	1.000	0.946	1.002	0.906	0.998	1.083	1.025	1.070	1.121	1.000
1997/1998	1.000	0.978	1.042	0.983	1.310	0.987	1.011	0.981	0.950	1.000
1998/1999	1.108	0.896	0.851	0.927	0.901	0.939	0.950	0.953	0.839	1.000
1999/2000	1.044	1.054	1.030	1.053	1.103	0.996	1.040	1.000	0.941	1.000
2000/2001	1.106	1.059	1.038	1.009	1.027	1.000	0.963	1.000	1.086	1.000
2001/2002	1.029	1.041	1.153	1.048	1.028	1.035	0.979	1.000	0.955	1.000
2002/2003	1.018	1.082	1.145	1.026	1.078	1.002	0.992	1.000	0.964	1.000
2003/2004	1.068	1.014	1.068	1.107	1.219	1.120	1.041	1.004	1.000	1.000
2004/2005	1.456	0.915	0.943	0.986	1.090	1.033	1.038	0.996	1.000	1.000
2005/2006	0.882	1.007	1.172	0.949	1.095	1.072	1.019	1.014	1.000	1.000
2006/2007	1.009	1.070	1.030	1.008	1.020	1.147	1.077	1.242	1.000	1.000
2007/2008	1.231	1.046	0.967	1.118	0.969	1.006	1.104	1.185	1.000	1.000
2008/2009	0.918	1.032	0.856	1.066	0.854	0.798	1.023	0.881	1.000	1.000
2009/2010	0.782	0.851	0.737	0.763	0.710	0.872	0.832	0.886	1.000	1.000
1995/2003	*1.339*	0.893	0.718	0.611	0.601	0.504	0.608	0.331	0.749	**1.000**
2004/2010	*1.145*	0.904	0.695	0.857	0.715	0.889	1.069	1.160	1.000	**1.000**
1995/2010	*1.638*	0.819	0.533	0.580	0.524	0.502	0.677	0.386	0.749	**1.000**

Source: Own calculation and elaboration, 2012

Table V Technology Frontier Shift (TSF) of Countries

TSF	BGR	CZE	EST	HUN	LVA	LTU	POL	ROM	SVK	SVN
1995/1996	3.375	1.112	1.848	1.538	2.574	2.119	1.637	2.953	1.125	0.971
1996/1997	0.881	1.054	1.053	1.053	1.048	1.052	1.053	1.042	1.054	0.988
1997/1998	1.135	1.061	1.061	1.061	1.061	1.061	1.061	1.061	1.061	1.021
1998/1999	1.103	1.081	1.076	1.077	1.071	1.072	1.079	1.047	1.085	1.022
1999/2000	0.981	0.941	0.939	0.939	0.937	0.937	0.940	0.983	0.943	0.950
2000/2001	0.990	0.996	0.989	0.989	0.982	0.984	0.989	1.003	0.996	0.979
2001/2002	0.978	0.969	0.976	0.980	0.992	0.994	0.986	0.999	0.965	0.970
2002/2003	1.017	0.933	0.936	0.945	0.955	0.958	0.954	1.030	0.930	0.981
2003/2004	1.015	0.910	0.911	0.924	0.931	0.936	0.938	1.024	0.904	0.979
2004/2005	0.816	1.073	1.077	1.027	1.031	0.994	0.979	0.780	1.056	0.950
2005/2006	1.165	0.932	0.914	0.978	0.953	0.991	1.012	1.272	0.901	0.941
2006/2007	0.990	0.990	0.979	0.990	0.990	0.990	0.990	0.990	0.976	0.962
2007/2008	0.934	0.934	0.935	0.934	0.934	0.934	0.934	0.934	0.938	1.023
2008/2009	0.952	0.961	0.954	0.952	0.952	0.952	0.952	0.952	1.018	1.131
2009/2010	1.110	1.110	1.110	1.110	1.110	1.110	1.110	1.110	1.062	0.956
1995/2003	*3.216*	1.104	1.502	1.442	2.146	1.877	1.631	3.066	1.080	**0.852**
2004/2010	*0.982*	0.977	0.982	0.982	0.982	0.982	0.982	0.982	0.933	**0.911**
1995/2010	*2.764*	0.919	1.453	1.333	2.078	1.756	1.354	2.450	0.876	**0.758**

Source: Own calculation and elaboration, 2012

For evaluation of the overall efficiency changes and its determinants in the period 1995-2003, Malmquist index and its components were used. According to this analysis, European countries can be distributed to four groups A-D. Fig. 2, Fig. 3 and Fig. 4 have illustrated these groupings according to MI, TEC and TSF in period 1995-2003 in comparison with period 2004-2010.

Group A includes *Romania* and *Poland*; these countries have recorded the worst level of efficiency change (MI – Fig. 2) – in comparison years 2010 to 2004, for ROM 1.14 and 1.05 for POL. This situation has worsened also by changes of MI in years 1995 and 2003 (ROM: 1.02 and POL: 0.99). Fig. 3 and Fig. 4 evident show, that development in these countries is caused by high-changing of TSF in the period 1995 to 2003 (TSF ROM: 3.07). This situation was partially compensated by improvements of TEC in Romania in comparison with other evaluated countries (TEC ROM: 0.33). Similarly, in Poland, the total technical efficiency change was 0.61 (TEC POL: 0.61) in period 1995-2003, TEC thus compensated adverse change in technology frontier shift (TSF POL: 1.63). In the second period 2004-2010, the overall technical and technology efficiency has reached level around 1.

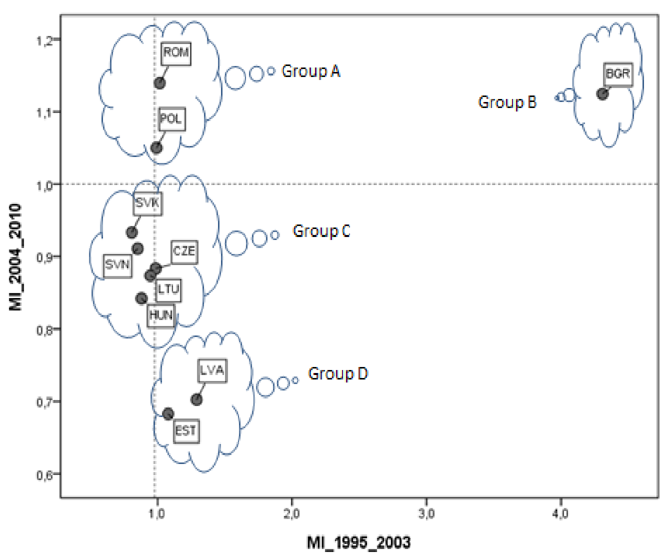

Fig. 2 Malmquist index in periods 1995-2003 and 2004-2010

Another specific **group B** is *Bulgaria*, which had the worst efficient level of overall efficiency changes in period 1995-2003 (MI BGR: 4.31) and (similar to ROM and POL) in period 2004-2010 (MI BGR: 1.12). The main source of the overall efficiency development was a significant decrease in technology efficiency in period 1995-2003 (TSF BGR: 3.22), but also deterioration of technical efficiency (TEC BGR: 1.34). This situation has significantly improved in comparison years 2010 to (TSF BGR: 0.98; TEC BGR: 1.14).

The third **group C** included *Slovakia, Slovenia, Czech Republic, Hungary* and *Lithuania*. In these economies, development of total efficiency changes was moved in the years 1995-2003 in the range of 0.81 to 0.99 and in the following period 2004-2010 in the interval 0.84 to 0.93, i.e. re-improvement. In the case of *Hungary*, to better overall efficiency contribute mainly technical efficiency in the first period 1995-2003 (TEC HUN: 0.61), while a negative determinant was changes of technology changes efficiency (TSF HUN: 1.44). In the following period 2004-2010, technical efficiency change has worsened to 0.86. These changes were also accompanied by improvements of technology efficiency to 0.98.

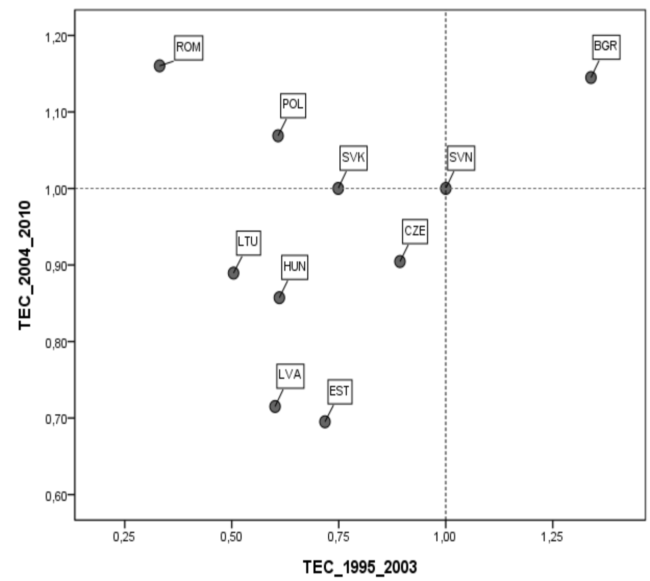

Fig. 3 Technical Efficiency Change in 1995-2003/2004-2010

Czech Republic and *Latvia* have very similar evaluation, i.e. in the first period 1995-2003, the main source of negative total efficiency was technology changes, but these changes were compensated by prosperous production possibility frontier shift of EU10 countries.

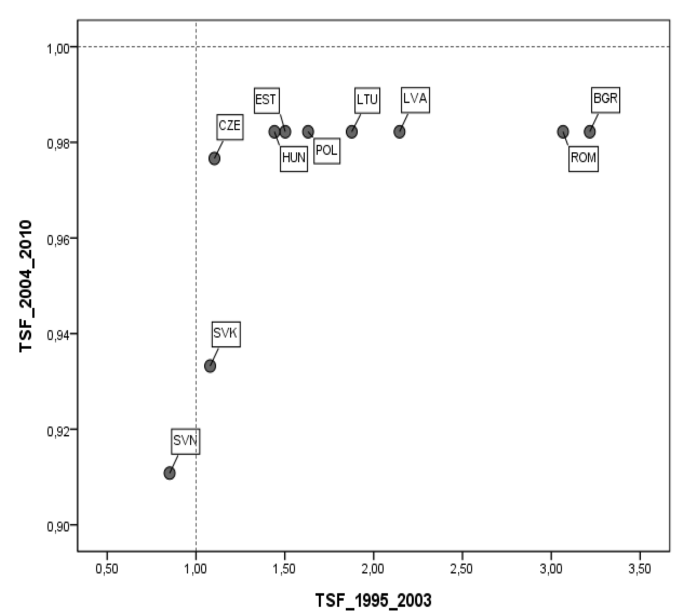

Fig. 4 Technology Frontier Shift in 1995-2003/2004-2010

In *Czech Republic*, *Hungary* and *Lithuania*, total production efficiency has slightly improved in period 2004, and vice versa in *Slovenia* and *Slovakia*, total production efficiency has been slightly worsened. The main determinant was again technology efficiency, but also technical efficiency. Slovakia and Slovenia has recorded a slight increase in values of MI by comparing time periods 1995-2003 and 2003-2010, but there are still below level 1 (MI SVK from 0.81 to 0.93; MI SVN from 0,85 to 0.91). Level of MI of Slovakia SVK in years 2003 to 1995 was primarily designed by very favorable technical efficiency and vice versa slight deteriorating of technology efficiency. In the following period was occurred deteriorating of technical efficiency and improvement of technology efficiency. This situation led to negative changes of total efficiency. In Slovenia, technical efficiency has reached constant level and determined the production possibility frontier and also changes of technology efficiency were less than level 1.

The last **group D** is generated by *Estonia* and *Latvia*. The intensity of total efficiency change has developed very favorably in period 2004-2010 in comparison with period 1995-2003. The main source of deterioration of total efficiency change was a significant negative trend in technology efficiency (TSF EST: 1.50; TSF LVA: 2.15), which has not improved technical efficiency (TEC EST: 0.72; resp. TEC LVA: 0.60), in the first period. Increasing change of total efficiency in period 2004-2010 was supported not only by technology, but also by technical efficiency.

V. Conclusion

Competitiveness, performance and efficiency are complementary objectives, which determine the long-term development of countries. These are also concepts that cannot be avoided in economic theory and practice. Evaluation of competitiveness, performance and efficiency can be performed only if we use existing concept of these terms or selected mainstream. Because of the fact that there is no mainstream in competitiveness, performance and efficiency evaluation, there is space for alternative approach in this area. It is necessary to note that using different approaches to evaluation generate different results. This is logical and predictable. It cannot be expected that different approaches lead to identical conclusions about the level of competitiveness, performance and efficiency. Many methods and approaches to competitiveness, performance and efficiency evaluation are (to a certain extent) incomparable, and therefore their results must be taken into account individually. Measuring the Malmquist index on the basis of DEA method is an important method which has many applications. This index has been used to analyse and evaluate performance of individual new European Union Member States in period 1995-2010. Regarding the findings and the analysis each country can decide whether it had a productivity increase during the time period, or not. By dividing productivity into its elements, the basic trend in productivity whether it be increase or decrease is observed.

The paper deals with evaluation of efficiency in individual countries. Another part of the paper was devoted to assessment of development and main determinants of this efficiency. Evaluation of efficiency in individual countries by input oriented CCR CRS model has confirmed results and conclusions of another papers and studies. The highest level of efficiency coefficients has reached Slovenia, which determined the production possibility frontier, and Slovakia. On the other hand, most far from the production possibility frontier were Latvia and Estonia. Bulgaria has demonstrated specific decreasing trend in efficiency level reference period. Czech Republic, Estonia, Hungary, Lithuania, Latvia, resp. Poland, Romania and Slovakia, has recorded efficiency growth to 1999, resp. 2003 and subsequent decline during the crisis year 2008 and followed by a slight improvement with varying intensity.

Evaluation of total efficiency changes was divided into two time period 1995-2003 and 2004-2010. According to the development in technical and technology changes, evaluated countries were divided into 4 groups. The *first group* consists of Romania and Poland, where the total efficiency change was around level 1 in both periods, but total efficiency change has slightly deteriorated in the second period. In the first period, technology inefficiency was significant, which was compensated by positive change in technical inefficiency. The *second specific group* was created by Bulgaria. Bulgaria was illustrated by significant deterioration of the total efficiency changes in 2003 in comparison with 1995 and especially by technology efficiency deterioration. This technology inefficiency was partially compensated by favorable change in development of technical efficiency. The *third group* of includes countries such as Slovakia, Slovenia, Czech Republic, Lithuania and Hungary. Total efficiency changes measuring by Malmquist index were effective in both periods, but determinants of this effectiveness are different. Slightly worse results or changes in overall efficiency were caused by negative changes in evolution of technology efficiency in the first period. Compensation of favorable changes in technical efficiency could not reverse this conclusion. Production possibilities of Slovenia determined production options. Positive changes in the development of the total efficiency were caused mainly by evolution of technology efficiency in both periods. The *fourth group* consists of *Estonia* and *Latvia*. In the first period, the main determinant of deteriorated of total efficiency change was unfavorable technology efficiency change, which technical efficiency changes did not compensate.

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