Pak. j. life soc. Sci. (2024), 22(2):13756-13773 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Clarivate Web of Science Zoological Record

Pakistan Journal of Life and Social Sciences

www.pjlss.edu.pk

Scopus

https://doi.org/10.57239/PJLSS-2024-22.2.00989

RESEARCH ARTICLE

Evaluation of TFP and overall performance for Non-Member Countries of the European Union based on an Alternative Approach of the Malmquist index (2017-2022)

Blerta (Kristo) Nazarko*

Department of Informatics and Technology, European University of Tirana, Faculty of Engineering, Informatics and Architecture Tirana, Albania

ARTICLE INFO

Received: Sep 28, 2024

Accepted: Nov 17, 2024

Keywords

Malmquist Index

TFP

Overall Performance

***Corresponding Author:**

kristoblerta@yahoo.coms

ABSTRACT

This paper aims to investigate and evaluate, based on an alternative approach of applying the Malmquist index DEA, the progress of economic development in the European area of non-member countries of the European Union. The evaluation of TFP (total factor productivity) and of the overall performance on the basis of two statistical factors is done by evaluating the Malmquist index in two ways, with the empirical evaluation and with the evaluation of super efficiencies. An extended number of indicators of variable quantities have been selected for the observation of the production process from three production sub-processes (A, B, C) with specific goals. The aggregate Malmquist index is calculated by applying the "approximation" with the Cobb Douglas production function based on the "weight" of the input-output number that each formatted group has. The application of statistical tests for the bilateral comparison of performances in DEA and the rank correlation test for the transitions from period t to t+1 is combined with the aims to expand the cognitive study analysis. The alternative application approach, "Structure in some connection of grouping-form", evaluated the TFP in each grouping format, highlighting the best practices and the role and influence of each variable factor. This paper includes 16 non-member countries of the European Union for the period 2017-2022.

INTRODUCTION

Knowing the dynamics in the course of economic development observed along a certain time course is a complex field of study related to the interaction of a series of selective factors as well as their role as contributors to production. The general expansion in the dimension of stimulating and source factors constitutes the fundamental problem that evaluates the progress of the dynamics of economic development. The space of production possibilities in the economy expressed by the distribution of different combinations conditioned on the production of goods and services, using a certain production technology, also determines an evaluative efficiency that shows progress or regression of decision-making units in their production process. The most advanced innovative technologies enable the increase of productivity, generating research and development as the necessity of selecting and applying what and how should be produced in the conditions of a very competitive global economy, which further determines the special features in the dynamic developments of each country and region. Visible features that appear between the formatted groups "Cluster", which also comprise the region of non-member countries of the European Union will be investigated and analyzed during the study and the defined time course (2017-2022). The main priority of membership in the European Union requires the economic integration of these countries, considering them in particular with the possibilities of facing their challenges, confronting competition in the global and regional economy. Non-member countries of the European Union occupy around 30% of the population of the European continent. Out of 47 sovereign states of Europe, 27 of them make up the European Union and 20 other states are non-members of the EU. The study includes 16 countries that are not members of the European Union, not including the Vatican, San Marino, Monaco and Andorra (countries with a population of less than 100,000 inhabitants). Acquaintance with the way of economic thinking, exploring how the economy of these countries has functioned over a period of time (2017-2022) is the main goal of this study. In evaluating the problems that have stimulated progress or regression, efficiency or inefficiency in the course of their economic development, cognitive perception is seen as a contribution instrument for this study. The European Union is a very powerful organization in the global economy, but also has more influence on non-member countries of the European Union to accelerate their economic integration. The average of GDP per capita Purchasing, Power Parity for 2022 based on 179 countries was $22,555 where all EU member countries are ranked above the average value of GDP per capita [53]. Among the countries of the European Union, Bulgaria ranks last (also above the average value) for the value of GDP per capita ($26,961), and after it are ranked the 13 non-EU countries included in this study (with the exception of Switzerland, Iceland and Turkey) ranked from 58th to 107th place The average score in the global innovation index for 2022 (estimated for 132 countries) is 32.09 points [41]. Among the countries of the European Union, Romania ranks last (rank 49), although this is also above the average of scores and again behind it are the 13 non-member countries of the European Union, ranked from 55th to 93rd. Even in labour productivity (2022) GDP hour worked (US$PPP) where the EU has an average of $74.6, Bulgaria ranks last among the EU countries. Again, 12 of the non-member countries of the European Union included in the study are ranked below Bulgaria [54]. The above indicators indicate a stronger economic development potential for the countries of the European Union, so a more fundamental study analysis is also required for the countries that are not members of the European Union with the aim of exploring the nature of their economic development and the influential factors for the acceleration of their membership them in the EU. In order to make a more detailed assessment of the economic development of these countries, the number of variable factors in the study is taken extended, so three groups formatted in inputs-outputs combinations are built. In harmony with the expansion of the number of variable factors, in this study a new approach of calculating the Malmquist index (based on the evaluation of the groups that have the sum of not the same number of inputs and outputs) is applied for the evaluation of the total factor of productivity (TFP) as well as the evaluation of the overall performance of each DMU. The approach called: "Structure in some connection of grouping-form" is aimed at better clarifying the impact of variable factors, which will be treated in the methodology of this study. In this study, 15 variable factors are included as inputs and outputs for a study opportunity and a more complete analysis in the recognition of stimulus factors. In the literature of contemporary economic studies, different visions are encountered for the evaluation of economic growth, where they are used in addition to the nonlinear programming method and the linear programming method, as well as the theory of optimal correction, dynamic programming, regression, the assumption of a specific function, sketching the curve of growth of indifference, the curve of the possibilities of the growth of the given production and with time series graphics, etc. A sustainable expansion of production possibilities studied by applying the Malmquist index DEA evaluates the efficiency and performance of DMUs. Economic efficiency is production efficiency that evaluates the maximum productivity with the minimum of resources. It is also allocative, which is also related to meeting the needs of society. Analytical recognition for a more balanced development of the European region and to narrow the big differences in economic development between regions coincides with goals and support that the European Union has for non-member countries. Among the non-member countries of the European Union, in the macroeconomic indicators of the values for each indicator, there is not a small slope between the values of variable sizes along the course of time. The slope of the value of GDP per capita (PPP) even among non-member countries of the European Union on average as a period is 0.147 (or 6.8 times). For the year 2022, this slope is 0.156 (or 6.4 times). The slope of the inflation value for 2022 is 0.026, where Switzerland has the lowest value and Turkey, Ukraine has the highest value. The slope between the values of GDP per employed person for the year 2022 between non-member countries of the European Union is 0.17(or 5.9 times). The effectiveness of work in agriculture as the ratio of added value (as a percentage to the total) to the percentage of employment (to the total) belongs to the segment [0.177; 1.307] and the effectiveness of work in industry belongs to the segment [0.7; 3.88]. In the analysis study of this paper for the recognition of economic development among non-member countries of the European Union, a stable trend in the ranking positions between consecutive years (between the period t and t+1) is also found, where the average Spearman correlation coefficient has the value greater than 0.9 for the three groups. This tendency of the stability of the correlation shows as if there is a "status quo" tendency of the economic development of these countries with the same differences throughout the period. Therefore, it is necessary to study the influence of each variable factor to increase the economic optimization for each DMU. In this study, the non-member countries of the European Union are formatted into three Cluster groups based on in the theoretical experience [36, 37], geographic location, differences in variable sizes and goals determined in the study, as well as the experience of the economic literature for Cluster classifications. In this paper, the DEA method is applied to evaluate the progress of economic development combined with statistical tests and multiple linear regression. In this paper, the Malmquist index was used, applied as a new approach: "Structure in some connection of grouping-form", since it evaluates several sub-processes of production with a different number of inputs and outputs.

The study analysis in this paper also tests the following hypotheses:

1. Indicators of the sensitivity of the total factor of productivity in the evaluation of the general economic progress for each DMU as well as for each Cluster grouping appear clearly between countries and regions.
2. Indicators of the sensitivity of the measurement levels of the total productivity factor appear in the differences between the formatted groups A, B, C along the course of time (period 2017-2022).
3. The dimensionality of the variable selection factors in the relations of inputs and outputs combinations have obvious impacts on the evaluation of the general economic progress.
4. In the evaluations of the overall performance of the DMUs calculated by means of statistical factors and the application of the Malmquist index, the differences between the Cluster groups appear.

LITERATURE REVIEW

The assessment of economic growth is a research object that analyzes and the entirety of the supporting factors in the economy, constantly attracting the attention of researchers as well as decision-making policies. The approaches used to evaluate and measure the change in productivity apply different study methods. The production function in the economic literature, $Q_t = B(L_t)^{\alpha}(K_t)^{\beta}$ uses two inputs(labor and capital), where Q_t, L_t and K_t represent (aggregate) output, labor and capital respectively and B is a constant [1]. This production was introduced using as an approach that explains and evaluates the possible production curve, where α and β are flexible elasticity coefficients of each factor in relation to the production function. The effectiveness of the assessment of economic growth depends on the form of the function. This belongs to the econometric approach. Another technique brought to analyze the dynamics of indicators of variable quantities (inputs-outputs) in the transformation of changes in production growth is the DEA method used. The basic concept is the evaluation of technical efficiency. The American Nobel laureate mathematician and economist (in economics) Koopmans in 1951 in the analysis of production as an efficient combination of activities gives the theoretical consideration of efficiency [2, 38]. Robert M. Solow constructed the aggregate production function, exogenous growth model which is an economic model of long-run economic growth and proposed total factor productivity [3, 12]. Debreu introduced the concept of the distance function as a method of a mathematical model for evaluation by measuring the radial distance of a producer from a frontier with the aim of expanding production [4,5]. In 1953, Shephard [6] showed that the evaluation of the measurement of radial distances can be done with other directions as well as with the direction of data conservation. Sten Malmquist (1953) [7] applied the concept of the distance function in economics with the reasoning as a quantitative index that can be used in consumption analysis. The Malmquist index is thus defined as a general structure for evaluating production productivity. Farrell (1957) [8] based on the experience given by Debreu, Koopman, Shephared emphasizes that the problem of measuring the efficiency of production for an industry is of double importance both from the economic theoretical side and the economic direction. Using two measurable input and output factors in quantitative reports, he emphasizes that the difference between price and technical efficiency is important. He provides illustrative examples of efficiency in agriculture for 48 production units by selecting the variable labor, material costs, capital-value, use and the Cobb-Douglas approximation very similar in principle to the efficient production function, , $x_1^{\alpha_1} \cdot x_2^{\alpha_2} \cdot x_3^{\alpha_3}$ = k, ku $\alpha_1 + \alpha_2 + \alpha_3 = 1$, dhe $\alpha_1 \cdot \log x_1 + \alpha_2 \log x_2 + \alpha_3 \log x_3 = \log k$, and with the definition of a convex surface. For the measurement and evaluation of efficiency using many inputs and outputs in 1978 Charnes, Cooper and Rhodes [9] proposed the DEA method, a non-parametric linear programming method with very wide applications today in many fields of production, science, business, etc. The technique of measuring and evaluating the efficiency in a production process by measuring the relative technical efficiency, by means of non-parametric linear programming, was called the data envelopment analysis method. Caves et al. [10] retaken Sten Malmquist's concept for production analysis, calling it the productivity change index, with the aim of studying economic growth, progress and recognition of technological change, evaluated in terms of the distance function, giving two indices of production change according to technology referred to and according to periods t and t+1, $M^t(x^t, y^t, x^{t+1}, y^{t+1}) = D^t(x^{t+1}, y^{t+1})/D^t(x^t, y^t) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \cdot \frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}$ and $M^{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = D^{t+1}(x^{t+1}, y^{t+1})/D^{t+1}(x^t, y^t) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \cdot \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}$.

Färe et al.[11] interpreted the idea given by Caves et al. combining the two indices and evaluating their geometric mean, thus determining a single Malmquist index of productivity of two consecutive periods t, t+1, MI = $\sqrt{\frac{D^{t+1}(x^{t+1}, y^{t+1}) \cdot D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t) \cdot D^t(x^t, y^t)}}$. By means of an algebraic decomposition MI is presented decomposed into two components. The first component of efficiency change is called the "Catch up" component, and the second component is called "frontier shift" (technological change), adjacent_MI = $\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \cdot \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \cdot \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{1/2}$. In the Data envelopment analysis method, the two basic models for evaluating efficiency are the CRS model (with constant returns to scale) [9] and the VRS model (with variable returns to scale) [13] according to input or output orientation. The model that combines both input-oriented and output-oriented orientations is the model called Additive [14]. The DEA method has been expanded with many other models to increase the discriminating power in the classification of efficient and inefficient evaluated units, such as models for calculating super efficiency [15, 39, 40], fuzzy DEA models [16] using data along a time series, etc. DEA minimizes inputs and maximizes outputs. Färe et al., [17, 11] the Malmquist index based on the study of Farell (1957), Charnes, Cooper (1978) and Caves (1982), brought it according to the DEA analysis that evaluates the technical efficiency on the basis of the efficient productivity frontier being thus used in numerous applications. The Malmquist index has a very wide use in macroeconomic studies in the evaluation of the total factor of productivity. In [4], a summary of the literature on studies of economic growth using DEA is given. Thus Lovell et al. [18] using 6 factors of variable size in the study of 19 OECD countries studied for the period 1970 -1990 evaluates economic growth for each country, Golany and Thore [19] studied 72 developed and developing countries using seven variable size. Debnath and Shankar [20] studied economic growth for 130 rich and poor countries for the period 2000-2009 using 6 variable sizes. In [21] the agricultural total factor productivity aggregate rate in agricultural management is estimated which can be calculated through the equation TFP$A_i^{k,T} = \prod_{j=1}^{T-t} M_i^{k,t+j}$. [22] evaluates the change in productivity in the manufacturing industry using as indicators of variable quantities number of permanent employees, value added at constant market prices, capital stock at a constant prices in the period of time 2002-2016, making the individual assessment of the performance of DMUs in which it evaluates mean technical efficiency change, technical change, total factor productivity. In [23] a new approach is proposed where the index of total productivity is evaluated and does not need to resort to a base period or ad hoc reference. [24] proposed a global Malmquist productivity index with the aim of being circular to provide a single measure of productivity change. Also [25] applies the Malmquist productivity index when adding a new time period and a data set called the biennial Malmquist. The examination of productivity growth using the biennial Malmquist index approach is given in [26]. In [27], an approach to the biennial Malmquist index is given, including negative data. [28] evaluates the application to measure the biennial Malmquist index of the system and internal processes at the same time, for parallel production systems. In [29], the Malmquist productivity index model of the virtual frontier is presented for evaluating the efficiency of scientific and technological innovation. The application of the Malmquist-Luenberger index for the assessment of eco efficiency and productivity change when desirable and undesirable factors are produced together in some production processes is given in [30]. In [31], the evaluation for economic productivity improvement or regression with the Malmquist Global Index is given. [32] calculate the overall profit Malmquist index in situations where some inputs or outputs and input-output prices are imprecise and vary over intervals. The global productivity index approach integrating the Nash Bargaining game enhanced model with the aim of a comprehensive framework that combines cross-assessment and global technology to increase the reliability of the assessment is given in [33]. [34, 35] evaluates the overall performance in macroeconomics by means of the "chain" of measuring efficiency values using the Malmquist index and two statistical factors given by formulas in the evaluation of the overall performance of each DMU. In this study paper, a new alternative approach to the application of the Malmquist index is presented.

METHODOLOGY

The comparative determination and evaluation of the aggregate index of production productivity in relation to the operating factors with a role in the development of economic growth will be calculated using the DEA method as a methodology. TFP is an essential instrument in evaluating the overall performance of each DMU. This paper presented as an alternative approach for the recognition, reasoning and judgment of economic growth assessment for TFP calculation by evaluating the constituent components (change in technical efficiency (EC) and change in technological factor (TC)) through several processes production along the same time course enables the provision of positive experience as well as the obstacles appearing in the progress of economic growth. The Malmquist index for evaluating productivity in DEA is a well-known approach with numerous applications in the field of economics and macroeconomics. In the literature review (above rubric), the Malmquist index presented has different conceptual and application aspects. The presented model is an alternative approach connected by different factors of variable inputs-outputs and contains several production processes over the same time series for each DMU. The model is called: "Structure in some connection of grouping-form", since each grouping may not have the same number of inputs and outputs, and each production process is formatted according to specific goals. In [42] it is emphasized that when the range of possible potential factors is relatively greater than the number of observations, the uncertainty of the model is a fundamental problem. For the evaluation of the global innovation index [41] for 132 countries, about 80 variable indicators are included. Also in the DEA rule it is defined that $n \geq \max\{(m+s), 3(m+s)\}$ [14], where m is the number of inputs, s is the number of outputs and n is the number of DMUs. Thus, cognitive reasoning can be more complete when several production sub-processes are studied over the same time series with the expansion of the number of indicators of variable quantities and for the subsequent evaluation of the aggregate Malmquist index and the evaluation of the overall performance of DMUs. The following figure presents the idea of applying the Malmquist index.

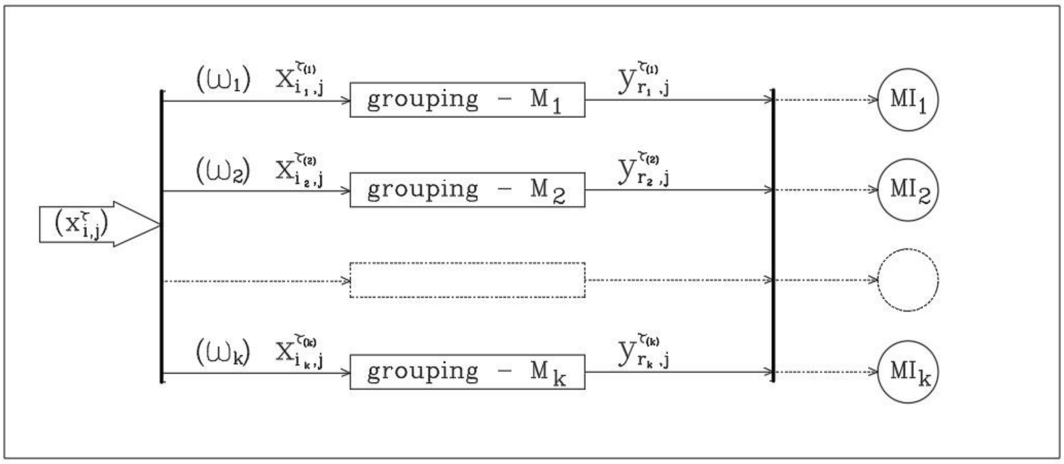

Figure 1: Structure in some connection of grouping-form

Source: Created by the author

Each grouping model has its own set of production possibilities over time

$P_c^{\tau(k)} = \{(x^{\tau(k)}, y^{\tau(k)}) | x^{\tau(k)}$ to produce $y^{\tau(k)}\} \subset R_+^{m_k+s_k}$.

The overall set of production possibilities is given by the union of the sets of production possibilities of the sub-processes. For the evaluation of the aggregate Malmquist index, the "approximation" of the Cobb-Douglas production function is used, an experience also known by Farrell (1957), so $MI_0 = MI_{01}^{\alpha_1} \cdot MI_{02}^{\alpha_2} \cdot \ldots \cdot MI_{0k}^{k}$ (1) where $\alpha_1 + \alpha_2 + \cdots + \alpha_k = 1$ and an α_i can be calculated $\alpha_i = \frac{\omega_i}{\sum_{i=1}^{k} \omega_i}$ (i = 1,2,..,k) , k is the number of groups and ω_i is the number of the input-output sum for each grouping. In equation (1), we logarithm both sides and we have: ln $MI_0 = \alpha_1 \ln MI_{01} + \alpha_2 \ln MI_{02} + \ldots + \alpha_k MI_{0k}$.

The evaluation of the MI_0 index can be calculated by applying the linear combination

$MI_0 = \sum_{i=1}^{k} \alpha_i MI_{0i}$, (i=1,2, …,k). Also, the evaluation of the Malmquist index is calculated in two ways, from the evaluation of Eff_0^{CCR} (without evaluation of super efficiency for the evaluated efficient units) and from the calculation on the basis of evaluation of super efficiencies. Especially for units revalued by means of super efficiency for EC and TC, the vector length can be calculated: $\|EC\| = \sqrt{(EC_1)^2 + (EC_2)^2 + \cdots + (EC_t)^2}$, (in accordance with the length of the period t taken in the study).

The lowest value (largeness falling) of the Malmquist index is also evaluated in percentage, MI = 100 · (1-min(MI_{01}, MI_{02},…,MI_{0t}) (%) .

The evaluation of the Malmquist index according to composition with the production of components (EC, TC, PC, SE) evaluated according to DEA is: $MI_0^{I-C} = \frac{Ef_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{Ef_0^{t}(x_0^{t}, y_0^{t})} \sqrt{\frac{Ef_0^{t}(x_0^{t+1}, y_0^{t+1})}{Ef_0^{t+1}(x_0^{t+1}, y_0^{t+1})} \cdot \frac{Ef_0^{t}(x_0^{t}, y_0^{t})}{Ef_0^{t+1}(x_0^{t}, y_0^{t})}}$ (the first component is EC and the second component is TC) [43].

- If $MI_0 > 1$ indicates that there has been improvement in economic dynamics.
- If $MI_0 < 1$ indicates that there has been regress in economic dynamics.
- If $MI_0 = 1$ indicates a stationary evaluation.

We also have, $MI_0 = \frac{V\_Ef_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{V\_Ef_0^{t}(x_0^{t}, y_0^{t})} \cdot \frac{SE\_Ef_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{SE\_Ef_0^{t}(x_0^{t}, y_0^{t})} \cdot \sqrt{\frac{Ef_0^{t}(x_0^{t+1}, y_0^{t+1})}{Ef_0^{t+1}(x_0^{t+1}, y_0^{t+1})} \cdot \frac{Ef_0^{t}(x_0^{t}, y_0^{t})}{Ef_0^{t+1}(x_0^{t}, y_0^{t})}}$ [43]

(the first component is PC (the change in pure technical efficiency), the second component is SE (the change in the scale component in the transition from period t to period t+1), the second component is the TC component).

For efficiency calculation $Ef^t(x^{t+1}, y^{t+1})$ model [M.1] is used: [43]

Min ω_0

subject:

$\sum_{j=1}^{n} \lambda_j x_{ij}^{t} \leq \omega_0 x_{ij_0}^{t+1}$, i = 1,2,…,m [M.1]

$\sum_{j=1}^{n} \lambda_j y_{rj}^{t} \geq y_{rj_0}^{t+1}$, r = 1.2,…,s

j = 1,2,…,n

For efficiency calculation $Ef^{t+1}(x^t, y^t)$ model [M.2] is used:

Min Z_0

subject:

$\sum_{j=1}^{n} \lambda_j x_{ij}^{t+1} \leq z_0 x_{ij_0}^{t}$, i = 1,2,…,m [M.2]

$\sum_{j=1}^{n} \lambda_j y_{rj}^{t+1} \geq y_{rj_0}^{t}$, r = 1.2,…,s

j = 1,2,…,n

To evaluate the overall performance for each DMU, the two statistical factors [34] are applied: $Z_1 = 1 - \exp[-(1-\frac{R_i}{n+1})]$, ($R_i$ is the ranking position evaluated according to the harmonic mean of the efficiency value (Eff^{CRS}) for each DMU, n+1 is used instead of n so that the value of Z_1 is greater than zero) and $Z_2 = 1-\exp(-MI)$, (MI is the Malmquist index value evaluated for each DMU) and the overall performance evaluation for each DMU is calculated from the norm value of $\|E\| = \sqrt{Z_1 \cdot Z_2}$.

The rank change coefficient for each DMU and according to each grouping during the transition from period t to t+1 is estimated by $S_r = \frac{\sum_{i=1}^{t-1}(d_i)^2}{t-1}$, (where S_r can also be called the variance of the rank change), $d_i = R_i^{t+1} - R_i^{t}$.

Spearman's rank correlation test and the bilateral comparison test in DEA (Rank-Sum-Test, Wilcoxon-Mann-Whitney) [14] are used as statistical tests.

For undesirable outputs in DEA, the known practice in DEA is applied [44],[45].

Numerical application

This paper includes 16 DMUs, countries in the European region that are not members of the European Union. They are: Albania (Cl_{11}), Bosnia and Herzegovina (Cl_{12}), Kosovo (Cl_{13}), North Macedonia (Cl_{14})), Montenegro (Cl_{15}), Serbia (Cl_{16})), Switzerland (Cl_{21}), Iceland (Cl_{22}), Turkey (Cl_{23}), Armenia (Cl_{31}), Azerbaijan (Cl_{32}), Belarus (Cl_{33}), Georgia (Cl_{34}), Kazakhstan (Cl_{35}), Moldova (Cl_{36}), Ukraine (Cl_{37}). With 16 DMUs, there are 3 Cluster formats according to these criteria:

• Regional geographic location

• Indicators of variable factor quantities

• In harmony with the goals of the study analysis

Cluster 1 (Cl_1) are the six countries of the Western Balkans, Cluster

(Cl_2) are the three countries: Switzerland, Iceland and Turkey and the third Cluster (Cl_3) are the other seven countries. The study covers the period 2017-2022. For the evaluation and study of the growth and change of the economic performance, of the productivity of production during this period for each DMU in this work, 16 variables have been selected in harmony with the overall objectives of the study. These variables are:

- GDP per capita, PPP (current international $)
- GDP per person employed (constant 2021 PPP $)
- Foreign direct investment: Inward, Stock, annual. Percentage of gross domestic product.
- Gross national expenditure (% of GDP)
- Goods imports (BoP, current US$)
- Communications, computer, etc. (% of service imports, BoP)
- Goods exports (BoP, current US$)
- Computer, communications and other services (% of commercial service exports)
- Trade (% of GDP)
- Inflation, GDP deflator (annual %)
- Employment to population ratio, 15+, total (%) (modeled ILO estimate)
- Unemployment, total (% of total labor force) (modeled ILO estimate)
- Employment in agriculture (% of total employment) (modeled ILO estimate)
- Employment in industry (% of total employment) (modeled ILO estimate)
- Agriculture, forestry, and fishing, value added (constant LCU)
- Industry (including construction), value added (constant LCU)

The data are taken from the *World Development Indicators* database (Last Updated: 05/30/2024) [46] while the data for "Foreign direct investment: Inward, Stock, annual. Percentage of gross domestic product" are taken from UNCTADstat [47].

The data of Kosovo: for "Employment in agriculture (% of total employment) (modeled ILO estimate)", "Employment in industry (% of total employment) (modeled ILO estimate)", "Unemployment, total (% of total labor force) (modeled ILO estimate)" and "Employment to population ratio, 15+, total (%) (modeled ILO estimate)" are taken from *Agjencia e statistikave të Kosovës, respectively [48], [49], [50] ;*and for GDP per person employed are taken from the World bank as GDP Current US $.

The data for Ukraine only for the year 2022: for "Unemployment, total (% of total labor force) (modeled ILO estimate)" are taken from [51] and "Employment to population ratio, 15+, total (%) (modeled ILO estimate)" are taken from [52] (*By the end of 2022, the level of employment in Ukraine was 15.5% below the level of 2021.*)

The study analysis is based on the application of the Malmquist index DEA. According to the methodology discussed above, three groups (A, B, C) are formed. The goals of each group are: Grouping model A evaluates the progress of economic development, the production productivity index in relation to GDP per capita and the quantity of the added value according to the sectors of the economy under the influence of the included inputs. Table 1 and Table 2 give the values of the variable quantities of this grouping.

Table1: DEA variables of group A

Inputs	The unit of measure	Outputs	The unit of measure
1. Employment in agriculture	percentage	1.Agriculture, forestry, and fishing, value added (constant LCU) to the total value added	percentage
2. Employment in industry	percentage	2. Industry (including construction), value added (constant LCU) to the total value added	percentage
		3.GDP per capita, PPP (current international $)	dollars

Table 2: Descriptive summary of values of variable quantities of grouping A according to Cluster divisions (2017-2022)

Clusters	Indicators	a_1	a_2	a_3	a_4	a_5
Cluster 1	Min.	2.2 (Cl_{13})	17.084 (Cl_{15})	5.267 (Cl_{16})	17.249 (Cl_{15})	9381.024 (Cl_{13})
	Avg.	15.259	26.160	9.477	23.947	17484.842
	Max.	38.078 (Cl_{11})	34.626 (Cl_{12})	19.259 (Cl_{11})	28.713 (Cl_{13})	28324.569 (Cl_{15})
	SD	10.481	5.320	4.442	3.013	4458.106
Cluster 2	Min.	2.305 (Cl_{21})	17.473 (Cl_{22})	0.447 (Cl_{21})	19.651 (Cl_{22})	28193.174 (Cl_{23})
	Avg.	8.176	21.607	3.829	22.492	55772.302
	Max.	19.383(Cl_{23})	27.731 (Cl_{23})	6.261 (Cl_{23})	26.165 (Cl_{23})	90746.453 (Cl_{21})
	SD	6.910	3.782	2.372	1.994	19836.836
Cluster 3	Min.	10.631 (Cl_{33})	9.886 (Cl_{36})	4.477 (Cl_{35})	16.934 (Cl_{34})	11252.114 (Cl_{36})
	Avg.	32.285	18.533	9.067	29.634	18923.514
	Max.	59.362(Cl_{36})	30.772(Cl_{33})	17.136 (Cl_{31})	59.995 (Cl_{32})	36619.569 (Cl_{35})
	SD	17.759	6.444	3.528	11.861	6246.550

Note: a_1- Employment in agriculture (% of total employment) (modeled ILO estimate); a_2 – Employment in industry (% of total employment) (modeled ILO estimate); a_3 - Value added as a percentage of total value added in Agriculture, forestry, and fishing; a_4 - Value added as a percentage of total value added in Industry (including construction),; a_5 - GDP per capita, PPP (current international $)

The model of grouping B evaluates the progress of economic development, the production productivity index, in relation to GDP per employed person and Trade (as output) under the influence of included inputs.

Table 3: DEA variables of group B

Inputs	The unit of measure	Outputs	The unit of measure
1. Foreign direct investment: Inward, stock, Percentage of gross domestic product	percentage	1. Trade (% of GDP)	percentage
2. The ratio of the import of goods to the export of goods	level index	2. GDP per person employed (constant 2021 PPP $)	dollars
3.Communications, computer, etc. (% of service imports, BoP) in ratio to Computer, communications and other services (% of commercial service exports)	level index		

Table 4: Descriptive summary of values of variable quantities of grouping B according to Cluster divisions (2017-2022)

Clusters	Indicators	b_1	b_2	b_3	b_4	b_5
Cluster 1	Min.	38.09 (Cl_{12})	1.285 (Cl_{16})	0.360 (Cl_{11})	59.830 (Cl_{11})	23116.2 (Cl_{13})
	Avg.	63.50	3.450	1.181	103.900	46223.28
	Max.	121.72 (Cl_{15})	8.269 (Cl_{13})	3.414 (Cl_{15})	170.818 (Cl_{14})	66984.48 (Cl_{15})
	SD	22.25	2.214	0.829	23.418	12464.3
Cluster 2	Min.	17.07 (Cl_{23})	0.735 (Cl_{21})	1.285 (Cl_{22})	55.762 (Cl_{23})	78720.3 (Cl_{23})
	Avg.	66.86	1.072	2.250	92.018	113252.6
	Max.	160.42 (Cl_{21})	1.354 (Cl_{23})	4.204 (Cl_{23})	140.17 (Cl_{21})	153234.6 (Cl_{21})
	SD	56.02	0.217	0.954	27.068	25460.39
Cluster 3	Min.	21.04 (Cl_{33})	0.331 (Cl_{32})	0.239 (Cl_{37})	56.825 (Cl_{35})	24076.46 (Cl_{36})
	Avg.	56.17	1.340	1.705	93.11	43905.6
	Max.	117.72 (Cl_{34})	2.668 (Cl_{36})	6.117 (Cl_{35})	139.39 (Cl_{33})	74418.11 (Cl_{35})
	SD	29.18	0.647	1.514	21.326	13496.3

Note: b_1- Foreign direct investment: Inward, Stock, annual. Percentage of gross domestic product; b_2- The ratio of the import of goods to the export of goods; b_3- Communications, computer, etc. (% of service imports, BoP) in ratio to Computer, communications and other services (% of commercial service exports); b_4- Trade (% of GDP); b_5- GDP per person employed (constant 2021 PPP $)

The model of grouping C evaluates the progress of economic development, the production productivity index in relation to the expansion of the employment rate and the reduction of the unemployment rate under the influence of the included inputs.

Table 5: DEA variables of group C

Inputs	The unit of measure	Outputs	The unit of measure
1.Inflation, GDP deflator (annual %)	percentage	1.Employment to population ratio, 15+, total (%) (modeled ILO estimate)	percentage
2.Gross national expenditure (% of GDP)	percentage	2.Unemployment, total (% of total labor force) (modeled ILO estimate)	percentage

Output, Unemployment, total (% of total labor force) (modeled ILO estimate), for the DEA variable is an undesirable output, so it is turned into a desirable output with the formula: $\bar{y}_{rj} = -y_{rj} + \eta > 0$, where η satisfies the condition, $\eta = \max\{y_{rj}\} + 1$ [44].

Table 6: Descriptive summary of values of variable quantities of grouping C according to Cluster divisions (2017-2022)

Clusters	Indicators	C_1	C_2	C_3	C_4
Cluster 1	Min.	-0.18 (Cl_{15})	106.58 (Cl_{16})	28.40 (Cl_{13})	8.68 (Cl_{16})
	Avg.	3.65	118.07	43.83	16.28
	Max.	12.36 (Cl_{15})	135.01 (Cl_{15})	54.01 (Cl_{16})	30.50 (Cl_{13})
	SD	3.16	7.46	7.36	5.29
Cluster 2	Min.	-0.70 (Cl_{21})	86.30 (Cl_{21})	42.84 (Cl_{23})	2.70 (Cl_{22})
	Avg.	11.78	96.47	60.87	6.85
	Max.	96.04 (Cl_{23})	104.00 (Cl_{23})	75.06 (Cl_{22})	13.67 (Cl_{23})
	SD	21.79	5.54	11.09	3.67
Cluster 3	Min.	-7.40 (Cl_{32})	67.01 (Cl_{32})	33.77 (Cl_{37})	0.79 (Cl_{36})
	Avg.	10.58	103.74	59.99	7.59
	Max.	37.25 (Cl_{32})	128.25 (Cl_{36})	71.94 (Cl_{36})	33.45 (Cl_{37})
	SD	8.52	14.03	7.33	5.58

Note: c_1- Inflation, GDP deflator (annual %); c_2- Gross national expenditure (% of GDP); c_3- Employment to population ratio, 15+, total (%) (modeled ILO estimate); c_4- Unemployment, total (% of total labor force) (modeled ILO estimate)

Based on the application of the Malmquist index for each grouping (A, B, C), and for each transition from period t to t+1 (adj_MI_0), the procedure dealt with in the methodology with empirical evaluation and evaluation according to super efficiencies was followed. The aggregate Malmquist index in matching with the two methods is also evaluated with the "approximation" of the Cobb Douglas production function and with the linear combination, since the total input-output number is not the same for each grouping.

Table 7 and Table 8 present the evaluations in two ways, the empiric evaluation (without super efficiencies) and with the evaluation of super efficiencies

Table 7: Summary results as a period (2017-2022) for MI_0 components (EC, PE, SE, TC)

DMU	Technical efficiency change index (EC)			Pure technical efficiency change index (PE)			Scale efficiency change index (SE)			Technological change index (TC)		
	A	B	C	A	B	C	A	B	C	A	B	C
Cl_{11}	1.000	0.979	1.022	1.000	0.974	0.988	1.000	1.005	1.035	1.000	1.096	1.033
Cl_{12}	0.979	0.972	1.065	0.985	0.987	0.995	0.995	0.985	1.071	1.018	1.041	1.051
Cl_{13}	1.000	1.062	1.092	1.000	0.953	0.977	1.000	1.115	1.117	1.000	1.028	1.067
Cl_{14}	0.990	1.029	1.012	1.017	1.023	0.977	0.974	1.006	1.036	1.017	1.006	1.052
Cl_{15}	0.976	1.109	1.015	1.000	1.143	0.985	0.976	0.971	1.031	1.009	1.051	1.042
Cl_{16}	0.995	1.027	1.031	0.992	1.023	0.977	1.002	1.004	1.056	1.010	1.027	0.998
Avg. Cl_1	0.990	1.030	1.040	0.999	1.017	0.983	0.991	1.014	1.058	1.009	1.041	1.041
Cl_{21}	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996
Cl_{22}	1.000	1.000	0.986	1.000	1.000	1.000	1.000	1.000	0.986	1.000	1.000	1.010
Cl_{23}	0.982	1.001	0.959	1.001	1.000	0.949	0.981	1.001	1.011	1.007	1.007	1.047
Avg. Cl_2	0.994	1.000	0.982	1.000	1.000	0.983	0.994	1.000	0.999	1.002	1.002	1.017
Cl_{31}	1.007	0.984	1.036	1.001	0.989	1.005	1.005	0.995	1.031	0.970	1.048	1.014
Cl_{32}	1.000	1.024	1.012	1.000	1.000	1.009	1.000	1.024	1.003	1.000	1.024	1.000
Cl_{33}	0.979	1.000	1.010	0.974	1.000	1.019	1.005	1.000	0.992	1.014	1.000	0.992
Cl_{34}	1.040	1.085	1.003	1.012	1.067	0.988	1.028	1.017	1.015	0.983	1.029	1.030
Cl_{35}	1.030	1.007	0.988	1.036	0.970	0.987	0.994	1.038	1.001	0.999	1.048	1.007
Cl_{36}	1.000	1.058	0.980	1.000	1.015	1.000	1.000	1.042	0.980	1.000	1.029	0.991
Cl_{37}	1.016	1.000	0.895	1.020	1.000	0.959	0.996	1.000	0.933	1.004	1.004	0.974
Avg. Cl_3	1.010	1.023	0.989	1.006	1.006	0.995	1.004	1.017	0.994	0.996	1.026	1.002
Total Avg.	1.000	1.021	1.007	1.002	1.009	0.988	0.997	1.013	1.019	1.002	1.027	1.019

Table 8: Summary results of MI_0 evaluated according to two methods (without super efficiency and with super efficiency) (2017-2022)

DMU	MI_0 (No super efficiency)			Malmquist index evaluated according to super efficiency								
				Technical efficiency change index (EC)			Technological change index (TC)			MI_0		
	A	B	C	A	B	C	A	B	C	A	B	C
Cl_{11}	1.000	1.061	1.054	1.018	0.979	1.022	0.996	1.096	1.034	1.007	1.061	1.054
Cl_{12}	0.996	1.009	1.117	0.979	0.967	1.065	1.018	1.045	1.051	0.996	1.006	1.117
Cl_{13}	1.000	1.072	1.193	1.089	1.062	1.092	0.971	1.028	1.066	1.039	1.072	1.193
Cl_{14}	1.006	1.032	1.056	0.990	1.053	1.012	1.017	0.995	1.052	1.006	1.044	1.056
Cl_{15}	0.984	1.160	1.059	0.969	1.109	1.015	1.015	1.051	1.042	0.980	1.160	1.059
Cl_{16}	1.004	1.052	1.026	0.995	1.027	1.031	1.010	1.027	0.999	1.004	1.052	1.026
Avg. Cl_1	0.998	1.064	1.084	1.007	1.033	1.040	1.005	1.040	1.041	1.005	1.066	1.084
Cl_{21}	1.000	1.000	0.996	1.013	1.000	1.330	0.994	1.003	0.948	1.006	0.999	1.116
Cl_{22}	1.000	1.000	0.996	1.010	1.010	0.925	0.998	0.997	1.045	1.004	1.004	0.964
Cl_{23}	0.988	1.010	1.000	0.982	1.001	0.959	1.007	1.007	1.047	0.988	1.010	1.000
Avg. Cl_2	0.996	1.003	0.997	1.002	1.003	1.071	0.999	1.002	1.013	1.000	1.004	1.027
Cl_{31}	0.975	1.028	1.049	1.012	0.974	1.036	0.971	1.055	1.014	0.977	1.023	1.049
Cl_{32}	1.000	1.059	1.012	0.923	1.025	1.096	1.044	1.024	0.967	0.960	1.060	1.052
Cl_{33}	0.990	1.000	0.998	0.979	1.105	1.010	1.014	0.983	0.992	0.990	1.039	0.997
Cl_{34}	1.021	1.107	1.033	1.040	1.085	1.003	0.983	1.030	1.031	1.021	1.107	1.033
Cl_{35}	1.028	1.060	0.995	1.030	1.007	1.081	0.999	1.048	0.973	1.028	1.060	1.036
Cl_{36}	1.000	1.081	0.960	0.985	1.058	0.980	1.011	1.029	0.991	0.990	1.081	0.960
Cl_{37}	1.019	1.004	0.858	1.016	1.128	0.895	1.004	0.954	0.974	1.019	1.064	0.858
Avg. Cl_3	1.005	1.049	0.987	0.998	1.055	1.014	1.004	1.017	0.992	0.998	1.062	0.998
Total Avg.	1.001	1.046	1.025	1.002	1.037	1.035	1.003	1.023	1.014	1.001	1.053	1.036

In the empirical evaluation (without super efficiency), it was noticed that for group A, the countries with stationary evaluation (no change in productivity, MI_0=1) of the Malmquist index for the entire period under study are Albania, Kosovo, Switzerland, Iceland and Azerbaijan and with repeated stationary evaluation only in two observations are North Macedonia and Moldova. The countries showing improvement (MI_0 >1) throughout the period for this grouping are Kazakhstan (throughout the period under study), Georgia (for 4 observations) and the states Macedonia, Belarus, Ukraine appear with 3 observations, while with 1-2 observations appear in other countries. In the regress (MI_0 <1) appearing in 4 observations are Montenegro, Turkey and Armenia, with 3 observations are the states of Bosnia-Herzegovina and Serbia; and 1-2 observations other states appear. For group B, the countries Switzerland, Iceland and Belarus appear with stationary evaluation throughout the entire period (in all 5 observations). Stationary in three observations are Bosnia-Herzegovina, Turkey and Ukraine. The countries that show improvement in 4 observations are Albania, Kosovo, Macedonia, Georgia, Moldova and with 2 observations are Montenegro and Kazakhstan. In regress, Armenia appeared with three observations. For group C with stationary evaluation ($MI_0 = 1$) it is Switzerland in 4 observations and Azerbaijan in 3 observations. Improvement ($MI_0 > 1$) appears in Bosnia and Herzegovina, Macedonia, Montenegro in 4 observations, and with three observations are Albania, Kosovo, Serbia, Armenia and Belarus. Turkey and Ukraine appear in regress with 4 observations, Georgia and Kazakhstan with three observations. From Table 8, it can be seen that the percentage improvement for Cluster Cl_1 according to groups (A, B, C) throughout the period under study is 0.5%, 6.6% and 8.4%, respectively. The results for Cl_3 are: group A results in a regression of 0.2%, while for group B and C there is an improvement of 5.3% and 3.6%, respectively.

The lowest value (largeness falling, $MI = 100 \cdot (1\text{-}\min(MI_{01}, MI_{02,\ldots,}MI_{0t})\ (\%))$ of the Malmquist index in the transitions from period t to t+1 in group A has appeared: for Cl_1 with 6.5% (2018/219) in Albania, in Cl_2 with 6.5% (2020/2021) in Turkey, to Cl_3 with 7.4% (2017/2018) in Armenia; for group B it appeared: for Cl_1 with 17.3% (2020/2021) in Montenegro, in Cl_2 with 11.5% (2019/2020) in Turkey, in Cl_3 with 32.4% (2019/2020) in Azerbaijan; for group C it appeared: for Cl_1 with 14.4% (2019/2020) in Albania, for Cl_2 with 15% (2018/2019) in Turkey, for Cl_3 with 41.3% (2021/2022) in Ukraine.

Tables 9.a and 9.b are the summary results of each cluster that present the observations when $MI_0 > 1$ (improvement), $MI_0 < 1$ (regress) and $MI_0 = 1$ (stationary, no change in productivity). Also, from the sum of ranking positions (S) it is found that for Cluster Cl_1 there is a value according to groups, S(A) = 44, S(B) = 44, S(C) = 29, while for Cl_3 it is S(A) = 63, S(B) = 48 and S(C) = 78.

Table 9a: Summary results of MI_0 without super efficiency (2017-2022)

Cluster	A			B			C		
	improvement	regress	stationary	improvement	regress	stationary	improvement	regress	stationary
Cl_1	8	11	11	21	6	3	21	9	0
Cl_2	1	4	10	1	1	13	2	7	6
Cl_3	17	11	7	16	9	10	14	17	4
Tot.(%)	32.5	32.5	35	47.5	20	32.5	46.25	41.25	12.5

Table 9b: Summary results of MI_0 with super efficiency (2017-2022)

Cluster	A			B			C		
	improvement	regress	stationary	improvement	regress	stationary	improvement	regress	stationary
Cl_1	13	16	1	22	8	0	21	9	0
Cl_2	6	8	1	5	7	3	5	10	0
Cl_3	19	15	1	21	14	0	16	19	0
Tot.(%)	47.5	48.75	3.75	60	36.25	3.75	52.5	47.5	0

In the evaluation with super efficiency, a more detailed distinction can be made between the evaluated DMUs without change in productivity (stationary evaluation).

From Tables 9.a and 9.b it can be observed that DMUs with stationary evaluation (no change in productivity) according to groups (A, B, C) in the evaluations without super efficiency in percentage values are 35%, 32.5% and 12.5%, while DMU_s in the evaluation with super efficiency with a stationary evaluation are respectively 3.75%, 3.75% and 0%. From the super-efficiency evaluation for group A with stationary evaluation, there are only three observations shown with only one observation for the countries of Switzerland, Moldova and Kosovo. For group B, only Turkey has appeared in three observations, for group C there is no country with a stationary evaluation. These evaluations of the application of the Malmquist index in two ways with and without super efficiency show that the evaluation with super efficiency is more interpretative. Table 10. presents the impact of the EC factor and the TC factor with an impact on the value of the Malmquist index for each grouping in the cases where we have TC = EC (the first digit in each cell of the table), TC > EC (the second digit in each cell of table) and TC < EC (third digit in each cell of the table) according to each grouping and two ways of applying the Malmquist index (without super efficiency and with super efficiency).

Table 10: Summary results of the comparative evaluations of the components (TC = EC, TC > EC, TC < EC) (2017-2022)

DMU	Evaluation with no super efficiency			Evaluation according to super efficiency		
	A	B	C	A	B	C
Cl_1	10; 12; 8	3; 15; 12	0; 11; 19	0; 17; 13	0; 16; 15	0; 12; 18
Cl_2	10; 4; 1	13; 2; 0	6; 4; 5	1; 8; 6	3; 8; 4	0; 9; 6
Cl_3	8; 11; 16	10; 14; 11	3; 13; 19	1; 16; 18	0; 19; 16	0; 12; 23
Total	28; 27; 25	26; 31; 23	9; 28; 43	2; 41; 37	3; 43; 34	0; 33; 47

Estimating the "lengths" of the vectors $\|EC\| = \sqrt{(EC_1)^2 + (EC_2)^2 + \cdots + (EC_5)^2} > \sqrt{1+1+1+1+1}$= 2.236 for each DMU in the change of the relative technical efficiency, we noticed that the decision-making units, this vector length greater than this value, for the group A have the countries of Kosovo, Switzerland, Kazakhstan, Iceland, Albania; for group B there are the countries Belarus, Montenegro, Ukraine, Azerbaijan, Iceland and for group C there are the countries Switzerland, Kazakhstan, Azerbaijan. These values make the difference between decision-making units shown before with stationary evaluations in the change of relative technical efficiency.

Calculation of the aggregate Malmquist index that evaluates TFP (Total Factor Productivity) for each DMU as a period (2017-2022) based on the Malmquist index estimates for each separate grouping and method of assessment treated in the methodology: MI_0 (aggregate) = $MI_{01}^{\alpha_1} \cdot MI_{02}^{\alpha_2} \cdot MI_{03}^{\alpha_3}$, ku $\alpha_i = \frac{\omega_i}{\sum_{i=1}^{k}\omega_i}$, k=3 (the number of groups) and ω_i the number of the input-output sum for each grouping is given in Table 11. This evaluation was done separately in evaluations without super efficiency and with super efficiency. Also in the table is given the evaluation of the Malmquist index by means of the linear combination presented in the methodology. The overall performance was also calculated based on the two statistical factors Z_1 and Z_2 treated in the methodology.

Table 11: Results of Malmquist aggregate index and overall performance assessment for each DMU (2017-2022)

DMU	MI_0 (Aggregate)				Evaluation of the overall performance						Rank of OP
	MI_0^*		MI_0^s		$\|\|E\|\|$ for each grouping			$\|\|E\|\|$ agregate			
	MI_0^{C-D}	MI_0^d	MI_0^{C-D}	MI_0^d	A	B	C	Z_1	Z_2	$\sqrt{Z_1 \cdot Z_2}$	
Cl_{11}	1.033	1.037	1.039	1.040	0.583	0.441	0.407	0.375	0.644	0.492	9
Cl_{12}	1.031	1.035	1.033	1.034	0.190	0.567	0.273	0.210	0.643	0.367	13
Cl_{13}	1.069	1.081	1.093	1.095	0.615	0.270	0.199	0.057	0.657	0.194	16
Cl_{14}	1.028	1.030	1.034	1.034	0.265	0.516	0.370	0.255	0.642	0.405	12
Cl_{15}	1.052	1.068	1.064	1.067	0.484	0.198	0.325	0.162	0.651	0.324	14
Cl_{16}	1.025	1.027	1.027	1.027	0.364	0.469	0.465	0.297	0.641	0.437	11
Avg. Cl_1	1.040	1.046	1.048	1.049	0.417	0.410	0.340	0.226	0.646	0.370	75
Cl_{21}	0.999	0.999	1.034	1.035	0.550	0.609	0.640	0.610	0.632	0.621	1
Cl_{22}	0.999	0.999	0.992	0.993	0.596	0.582	0.589	0.586	0.632	0.609	2
Cl_{23}	0.995	0.999	0.999	0.999	0.319	0.532	0.434	0.338	0.630	0.461	10
Avg. Cl_2	0.998	0.999	1.009	1.009	0.488	0.574	0.554	0.511	0.631	0.563	13
Cl_{31}	1.012	1.015	1.014	1.014	0.527	0.490	0.537	0.445	0.637	0.532	7
Cl_{32}	1.016	1.025	1.021	1.022	0.613	0.558	0.618	0.561	0.638	0.598	3
Cl_{33}	0.995	0.996	1.009	1.010	0.432	0.628	0.565	0.535	0.630	0.580	4
Cl_{34}	1.051	1.055	1.055	1.055	0.404	0.329	0.515	0.111	0.650	0.269	15
Cl_{35}	1.027	1.030	1.042	1.042	0.514	0.370	0.587	0.506	0.642	0.570	5
Cl_{36}	1.015	1.018	1.013	1.014	0.564	0.410	0.542	0.476	0.638	0.551	6
Cl_{37}	0.961	0.968	0.986	0.989	0.464	0.606	0.465	0.411	0.617	0.504	8
Avg. Cl_3	1.011	1.015	1.020	1.021	0.503	0.485	0.547	0.435	0.636	0.515	48
Total Avg.	1.019	1.024	1.028	1.029	0.468	0.473	0.471	0.371	0.639	0.470	

Note: MI_0^* is the estimate of the Malmquist index without super efficiency (in the "approximation" of the Cobb Douglas production function _ MI_0^{C-D} and MI_0^d with linear combination) and MI_0^s are the estimates of the Malmquist index with super efficiency.

Using the Rank-Sum-Test (Wilcoxon-Mann-Whitney) statistical test of Bilateral comparisons in DEA, "This statistic, S, follows an approximately normal distribution with mean mn(m+n+1)/2 and variance mn(m+n+1)/12. By normalizing S, we have $T = \frac{S-m(m+n+1)/2}{\sqrt{mn(m+n+1)/12}}$ [14]. The test is used for grouping Cl_1 in relation to grouping Cl_3. S for grouping Cl_1= 75 and the value of this index of the above test is: T= 4.7. So for $\alpha = 0.01$ (1%), the upper $\alpha/2$ percentile of the standard normal distribution is $T_{0.005} = 2.58$. (T = 4.7 > 2.58 shows that group Cl_3 exceeds the performance of group Cl_1). This is not observed if this test is applied to rankings according to MI values. From the ranking according to the values of relative technical efficiency (Ef_0^{CCR}) made for each year during the period 2017-2022, using the Spearman rank correlation coefficient for every two consecutive years during this period, these correlation values are given in Table 12.

Table 12: The Spearman rank correlation coefficient between the periods t and t+1

Grouping form		**2017/ 2018**	**2018/ 2019**	**2019/ 2020**	**2020/ 2021**	**2021/ 2022**	**Average**	$S_r = \frac{\sum_{i=1}^{5}(d_i)^2}{5}$		
								Cl_1	**Cl_2**	**Cl_3**
Grouping A	a	0.970	0.994	0.915	0.913	0.957	0.950	9	2.2	22.4
	b	0.965	0.991	0.912	0.894	0.976	0.948			
Grouping B	a	0.976	0.997	0.771	0.776	0.899	0.884	32.8	7	35.8
	b	0.947	0.976	0.856	0.865	0.903	0.909			
Grouping C	a	0.985	0.988	0.964	0.975	0.954	0.973	7.2	8.4	14.6
	b	0.976	0.976	0.944	0.974	0.962	0.966			

a. Spearman coefficient according to the ranking of DMUs based on Ef_0^{CCR} values
b. The Spearman coefficient according to the ranking of DMUs based on super efficiency values, where Sr is also based on the ranking of super efficiency values.

Table 12 shows that there is a strong correlation, which means that there are no significant changes in the ranking position of DMUs. More visible changes are observed for Cluster Cl_1 of group B for Bosnia-Herzegovina and Serbia, reflected in the transitions of the period 2020/2021, 2021/2022. For Cluster Cl_3 for group B are the countries Armenia and Azerbaijan that have changes in the transitions of the 2019/2020 and 2020/2021 periods. Armenia has changes for these years also for group A. In group Cl_3, significant changes appear in Moldova in the transitions 2019/2020 and 2020/2021, while in Ukraine for the transitions 2020/2021, 2021/2022 in group C. But, in general, looking at the values in Table 12. for the period 2017-2022, it can be said that a "status quo" is maintained in the ranking positions.

Figure 2. shows that the difference in GDP per capita between Cluster groups has not narrowed. Figure 3. shows that the difference in the values of GDP per person employed between Cluster groups has not narrowed. Figure 4. presents the evaluation of the overall performance according to each country taken into the study.

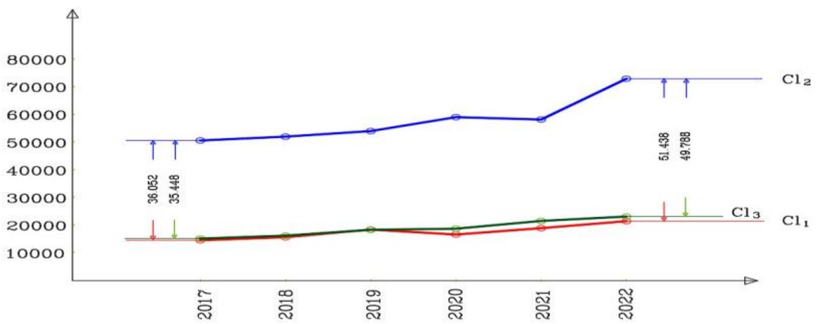

Figure 2: GDP per capita between cluster groups (2017-2022)

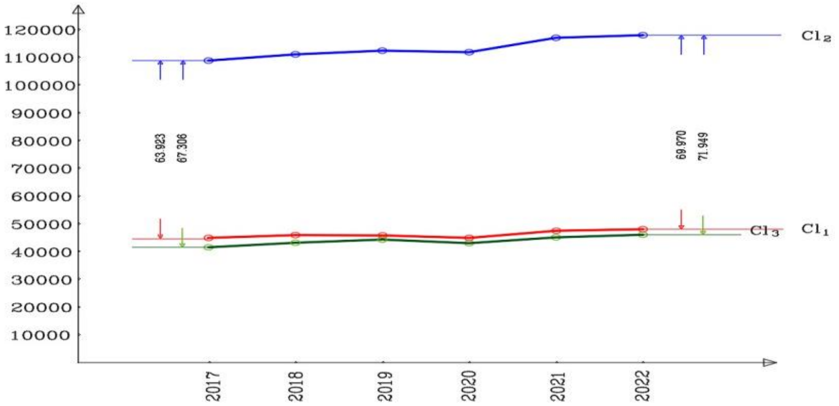

Figure 3: GDP per person employed between cluster groups (2017-2022)

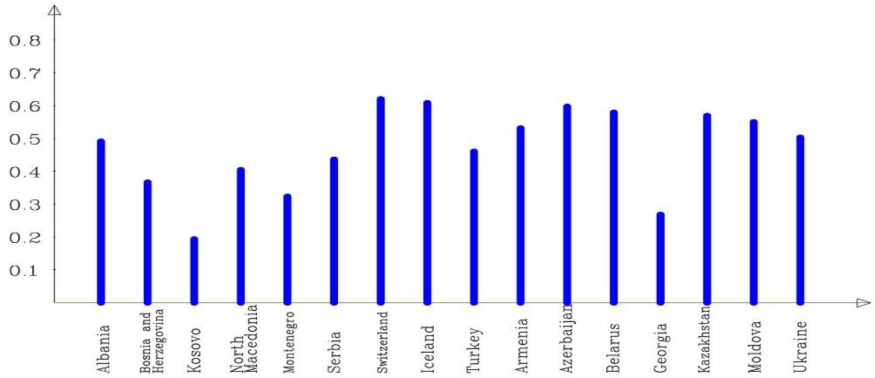

Figure 4: Overall performance evaluated with statistical factors (2017-2022)

GENERAL CONCLUSIONS

In this paper, the progress of the economic development of the 16 non-member countries of the European Union was evaluated, total factor productivity (TFP) decomposed into component components applied in two ways: with empirical evaluation (without calculating the super efficiencies of efficient DMUs) and with the calculation of super efficiencies. This makes it possible to increase the distinguishing power of the evaluated efficient units. An extended number of indicators of variable quantities were used, which were grouped into three groups A, B, C as sub-processes with respective goals. In the general evaluation for TFP, calculated according to the approximation of the Cobb Douglas production function for the two evaluation methods of the Malmquist index (without super efficiency and with super efficiency), it was seen that $\mathrm{M}I_0^s$ has higher values than MI_0 evaluated in empirically. In the evaluation according to $\mathrm{M}I_0^s$ it is noted that for the 16 DMUs taken as a group, there is an increase of 2.8%, for Cluster Cl_1 with 4.9%, Cluster Cl_2 with 0.9% and Cluster Cl_3 with 2%. In the evaluation of the overall performance, using the two statistical factors in the formula $\|E\|=\sqrt{Z_1 \cdot Z_2}$, it was observed that the Cl_2 grouping has a better overall performance than the Cl_1 grouping and the Cl_3 grouping. The statistical test for bilateral comparison in DEA showed that grouping Cl_3 outperforms grouping Cl_1. Also, the Spearman statistical test for the rank correlation in the three groups, the rank change from t to t+1, showed that there are no significant changes. The size of GDP per capita and GDP per person employed throughout the period show that there are big differences between Cluster Cl_2 and Cl_1 and Cl_3. These differences have not decreased during the period. The final results of this work can also contribute to the re-evaluation of the visionary objectives that each non-member country of the European Union can build, but also the aid of the European Union to the countries of the Western Balkans (estimated with the weakest overall performance). In the paper, particular evaluations are given for each DMU. The application of the alternative approach (Structure in some connection of grouping-form), presented in this study, where an expanded number of indicators of variable sizes can be used, is more informative in terms of research analysis. A reconciliation of the DEA method with statistical tests can be evaluated as a contribution of this study. The evaluation of the TFP should be connected with the evaluation of the overall performance.

References

J. Felipe., F. Gerard Adams. "'A Theory of Production' The Estimation of the Cobb-Douglas Function: A Retrospective View." *Eastern Economic Journal* Eastern Economic Journal, Vol. 31, No. 3, pp. 427-445, 2005, https://www.jstor.org/stable/40326423

J.Ruggiero., "Measuring technical efficiency", European Journal of Operational Research, Volume 121, Issue 1, 2000, pp.138-150, https://doi.org/10.1016/S0377-2217(99)00010-7.

Chirwa, Themba G.; Odhiambo, Nicholas M., "Exogenous and Endogenous Growth Models: a Critical Review, Comparative Economic Research. Central and Eastern Europe", De Gruyter, Warsaw, Vol. 21, Iss. 4, pp. 63-84, 2018, https://doi.org/10.2478/cer-2018-0027

Škare, Marinko; Rabar, Danijela (2016) : Measuring Economic Growth Using Data Envelopment Analysis, Amfiteatru Economic Journal, ISSN 2247-9104, The Bucharest University of Economic Studies, Bucharest, Vol. 18, Iss. 42, 2016, pp. 386-406, https://hdl.handle.net/10419/169008

Debreu, G. (1951), "The Coefficient of Resource Utilization". *Econometrica*, *19*(3), 273–292. https://doi.org/10.2307/1906814

Shephard, R. W., 1953. Cost and Production Functions, Princeton University Press, Princeton.

MALMQUIST, S. (1953), "Index numbers and indifference surfaces ", Trabajos de Estadistica, 4, 209-241

M.J.Farell, "The measurement of Productive Efficiency", Journal of the Royal Statistical Society. Series A (General), Vol.120, No.3, 1957, https://links.jstor.org/sici?=0035-9238%281957%29120%3A3%3C253%3ATMOPE%3E2.CO%3B2-U

A. Charnes, W.W. Cooper, E. Rhodes, "Measuring the efficiency of decision making units", European Journal of Operational Research, Volume 2, Issue 6, 429-444,1978, https://doi.org/10.1016/0377-2217(78)90138-8

Caves, Douglas W., Laurits R. Christensen, and W. Erwin Diewert. "The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity." *Econometrica* 50, no. 6, 1393–1414, 1982, https://doi.org/10.2307/1913388.

Färe, R., S. Grosskopf, B. Lindgren, And P. Roos. "Productivity Changes in Swedish Pharamacies 1980-1989: A Non-Parametric Malmquist Approach." *Journal of Productivity Analysis* 3, no. 1/2 85–101, 1992, http://www.jstor.org/stable/41770574.

Solow, Robert M. "Technical Change and the Aggregate Production Function." *The Review of Economics and Statistics* 39, no. 3 l , pp 312–20, 1957, https://doi.org/10.2307/1926047.

Banker, R. D., A. Charnes, and W. W. Cooper. "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis." Management Science 30, no. 9 ,1984, 1078–92. http://www.jstor.org/stable/2631725.

William W. Cooper, Lawrence M. Seiford, Kaoru Tone, "Data Envelopment Analysis, A Comprehensive Text with Models, Applications, References and DEA-Solver Software", Springer New York, NY, 2006, https://doi.org/10.1007/978-0-387-45283-8

Andersen, Per, and Niels Christian Petersen. "A Procedure for Ranking Efficient Units in Data Envelopment Analysis." Management Science 39, no. 10 (1993): 1261–64. http://www.jstor.org/stable/2632964.

Ali Emrouznejad., Madjid Tavana., "Performance Measurement with Fuzzy Data Envelopment Analysis" ,Springer Berlin, Heidelberg, 2016, DOI: https://doi.org/10.1007/978-3-642-41372-8

Färe, Rolf, Shawna Grosskopf, Mary Norris, and Zhongyang Zhang. "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries." *The American Economic Review* 84, no. 1 (1994): 66–83. http://www.jstor.org/stable/2117971.

C.A. Knox Lovell, Jesús T. Pastor, Judi A. Turner, "Measuring macroeconomic performance in the OECD: A comparison of European and non-European countries", European Journal of Operational Research, Volume 87, Issue 3, pp 507-518, 1995, https://doi.org/10.1016/0377-2217(95)00226-X.

Golany, B. and Thore, "The Economic and Social Performance of Nations: Efficiency and Returns to Scale", Socio-Economic Planning Sciences, Volume 31, Issue 3, pp.191-204, https://doi.org/10.1016/S0038-0121(96)00032-8.

Debnath, Roma Mitra, and Ravi Shankar. "Does Good Governance Enhance Happiness: A Cross Nation Study." *Social Indicators Research* 116, no. 1, 235–253, 2014, http://www.jstor.org/stable/24720528.

B. Wan, E. Zhou, "Research of Total Factor Productivity and Agricultural Management Based on Malmquist-DEA Modeling" Mathematical Problems in Engineering, Hindawi, Volume 2021, 8 pages https://doi.org/10.1155/2021/2828061

Zrelli H, Alsharif AH, Tlili I. Malmquist Indexes of Productivity Change in Tunisian Manufacturing Industries. *Sustainability*. 2020; 12 (4):1367. https://doi.org/10.3390/su12041367

J. Aparicio1; D. Santín., "A New Malmquist Index Based on a Standard Technology for Measuring Total Factor Productivity Changes", MPRA, No. 114467, 2022, https://mpra.ub.uni-muenchen.de/114467/

Pastor, Jesus T. & Lovell, C.A. Knox, "A global Malmquist productivity index," Economics Letters, Elsevier, vol. 88(2), pages 266-271, 2005, doi:10.1016/j.econlet.2005.02.013

Jesús T. Pastor, Mette Asmild, C.A. Knox Lovell, "The biennial Malmquist productivity change index", Socio-Economic Planning Sciences, Volume 45, Issue 1, 2011, pp 10-15, https://doi.org/10.1016/j.seps.2010.09.001.

Krishna Prasad Pokharel, Allen M. Featherstone, "Examining the productivity growth of agricultural cooperatives: The biennial malmquist index approach", Journal of Co-operative Organization and Management, Volume 9, Issue 2, 2021, https://doi.org/10.1016/j.jcom.2021.100148. Narjes Mohammadi, Alireza Yousefpour, "The Biennial Malmquist Index in the of Negative Data" Journal of mathematics and computer Science, 12, pp.1 – 11, 2014 DOI: 10.22436/jmcs.012.01.01

Chiang Kao, "Measurement and decomposition of the Malmquist productivity index for parallel production systems", Omega, Volume 67, pp 54-59, 2017, https://doi.org/10.1016/j.omega.2016.04.001.

Yuan-yu Lou, Guo-liang Yang, Zhong-cheng Guan, Xiao-lei Chen, Hao Pan, Teng Wang, Hai-jun Zheng, "A parallel data envelopment analysis and Malmquist productivity index model of virtual frontier for evaluating scientific and technological innovation efficiency at universities", Decision Analytics Journal, Volume 10, 2024, https://doi.org/10.1016/j.dajour.2023.100384. Susila Munisamy, Behrouz Arabi, "Eco-efficiency change in power plants: Using a slacks-based measure for the meta-frontier Malmquist-Luenberger productivity index", Journal of Cleaner Production, 2015, DOI: 10.1016/j.jclepro.2014.12.081 [31] Esmaeil Mombini, Mohsen Rostamy-Malkhalifeh, Mansor Saraj, Mohsen Zahraei, Reza Tayebi Khorami, "Global malmquist index for measuring the economic productivity changes" Measurement and Control, Vol. 53(7-8) 1278–1285, 2020, DOI: 10.1177/0020294020923096

Akbarian, D., "Overall profit Malmquist productivity index under data uncertainty", Financ Innov **6**, 6 ,2020, https://doi.org/10.1186/s40854-020-0170-0

Fallahnejad R, Mozaffari MR, Wanke PF, Tan Y., "Nash Bargaining Game Enhanced Global Malmquist Productivity Index for Cross-Productivity Index", *Games*; 15(1):3, 2024, https://doi.org/10.3390/g15010003

[34] Blerta (Kristo) Nazarko, "Performance Evaluation in Macroeconomics based on DEA Malmquist Index with a New Approach for the Efficiency Evaluation in a Two-Stage Process," WSEAS Transactions on Information Science and Applications, vol. 21, pp. 169-185, 2024, DOI:10.37394/23209.2024.21.17

Blerta (Kristo) Nazarko, Ditila Ekmekçiu , "An Approach to the Evaluation of the Overall Performance with Efficiency Measurements by Means of an Efficiency Evaluation Chain Using DEA and Fuzzy DEA," Mathematics and Statistics, Vol. 10, No. 5, pp. 1089 - 1104, 2022. DOI: 10.13189/ms.2022.100519.

Hassan Najadat., Ahmad Alaiad., Sanaa Abu Alasal., Ghadeer Anwar Mrayyan., Izzat Alsmadi., "Integration of Data Envelopment Analysys and Clustering Methods", Journal of Information & Knowledge Management, Vol.19,No.01, 2020, https://doi.org/10.1142/S0219649220400055

Pérez-Ortega, J., Almanza-Ortega, N.N., Vega-Villalobos, A., Pazos-Rangel, R., Zavala-Díaz, C., & Martínez-Rebollar, A., "The K-Means Algorithm Evolution", *Introduction to Data Science and Machine Learning.,* 2019, DOI: 10.577/INTECHOPEN.85447

Koopmans, T. C. (1951). An Analysis of Production as an Efficient Combination of Activities. In T. C. Koopmans (Ed.), Activity Analysis of Production and Allocation, Cowles Commission for Research in Economics, Monograph No. 13 (pp. 33-97). Wiley. (https://cowles.yale.edu/sites/default/files/2022-09/m13-all.pdf)

Mehdiloozad Mahmood; Roshdi Israfil., "Analyzing the concept of super-efficiency in data envelopment analysis: A directional distance function approach", arXiv e-prints, 2014, DOI: 10.48550/arXiv.1407.2599

Joe Zhu, "Quantitative Models for Performance Evaluation and Benchmarking", *International Series in Operations Research &Management Science*, (2014) Third Edition, vol 213, Springer,ISBN 978-3-319-06646-2, DOI 10.1007/978-3-319-06647-9

S. Dutta; B. Lanvin, L. Rivera León; S. Wunsch-Vincent "Global Innovation Index 2022 What is the future of innovation-driven growth?" 15th Edition, World Intellectual Property Organization (WIPO) 2022, DOI 10.34667/tind.46596

Durlauf, Steven N. & Johnson, Paul A. & Temple, Jonathan R.W., 2005. "Growth Econometrics," Handbook of Economic Growth, in: Philippe Aghion & Steven Durlauf (ed.),Handbook of Economic Growth, edition 1, volume 1, chapter 8, pages 555-677, Elsevier., DOI: 10.1016/S1574-0684(05)01008-7

E. Thanassoulis, Introduction to the Theory and Application of Data Envelopment Analysis:A Foundation text with Integrated Software, Springer; Softcover reprint of the original 1st ed.2001 edition (March 1, 2013), ISBN-10: 1461355389, ISBN-13: 978-1461355380.

J.Zhu, Quantitative Models for performance evaluation and benchmarking.Data envelopment Analysis with spreadsheets, third Editions, USA:Springer, Iternational Series in Operations Research &Management Science, 2014.DOI:10 1007/978-3-319-06647-9

Y.-H. Chiu, W.-H. Weng & L. C. Lu (2015) The Analysis of Undesirable Output to Countries' Productivity: The Example of the Asian Countries, Energy Sources, Part B: Economics, Planning, and Policy, 10:1, 21-30, DOI: 10.1080/15567249.2010.50493

https://databank.worldbank.org/source/world-development-indicators

https://unctadstat.unctad.org/datacentre/dataviewer/US.FdiFlowsStock

https://askdata.rksgov.net/pxweb/sq/ASKdata/ASKdata__Labour%20market__Anketa%20e%20Fuqis%C3%AB%20Pun%C3%ABtore__Annual%20labour%20market/tab10.px

https://askdata.rksgov.net/pxweb/sq/ASKdata/ASKdata__Labour%20market__Anketa%20e%20Fuqis%c3%ab%20Pun%c3%abtore__Annual%20labour%20market/tab1b.px/table/tableViewLayou

https://askdata.rksgov.net/pxweb/sq/ASKdata/ASKdata__Labour%20market__Anketa%20e%20Fuqis%c3%ab%20Pun%c3%abtore__Annual%20labour%20market/tab1b.px/table/tableViewLayout1/

https://fscluster.org/sites/default/files/labour_market_of_ukraine_2023_en42.pdf

https://www.intechopen.com/online-first/88554

https://www.theglobaleconomy.com/rankings/GDP_per_capita_PPP/1000/

https://www.statista.com/statistics/1096814/cee-labor-productivity/#statisticContainer