The application of DEA in the analysis of the evaluation of the economic dynamics with the efficiency chain and the ranking of DMUs for the evaluation of the overall performance

Blerta (Kristo) Nazarko

Department of Informatics and Technology
European University of Tirana.

Abstract- **The efficiency evaluation on a process of annual production trends, in order to improve and optimize the performance of DMUs is the aim of this study. The aim of highlighting the impact of supporting resources (financial and non-financial comparative) is for this process to be as profitable as possible as an instrument to examine it as widely as possible. The application of the DEA method is based on a selection of variable factors (input-output) adapted to the practical rule of the number of DMUs with the number of variables. The selection of variable factors is also based on the correlation coefficients. This was used in the construction of the corresponding models of the connection between inputs and outputs. In the study, ten criteria of variable factors selected for the evaluation of relative technical efficiency are applied. The ranking is done according to each model using the values of the "distributive" function determined by the formula (after the super efficiencies are also evaluated before). This is an alternative to the one based on the average of the efficiency values. The study is extended to the period 2012-2022 for the countries of the European region (19 countries with Cluster division).**

Keywords: **DEA method, efficiency chain, overall performance, super efficiency, ranking.**

INTRODUCTION

The economic practices concretized in the development strategy in each country also concretize the variable influencing factors that condition the level of productivity development. Also, factors that determine the connection and application of the expansion of technologies and investments, employment, inflation control, the extent of trade openness, etc. Indicators serve for the most fundamental analysis. Labor productivity also means the concrete efficiency of economic dynamics in the performance of each country and among individual countries among them, measurable according to economic activity. The aim of this study is to investigate and analyze the dynamics of labor productivity in conditioning with other factors of some countries of the European region (members and non-members of the EU), to record and evaluate the positive experience as well as the possibility of economic optimization. The experience of economic studies, followed by many researchers, argue that productivity is the key to prosperity in order to increase the standard of living in a more sustainable way, accompanied by the application of technological progress. Among the factors that influence the growth of economic productivity [1] evaluates innovation, market efficiency, infrastructure and institutions. Labor productivity measures the income received by an employee based on the connection and influence of a number of factors. The labor productivity evaluated and in the competitive comparative aspect between the countries encourages the need to apply studies to identify the factors that influence the labor productivity and the sustainability of the economic development dynamics. The labor productivity on average for the period 2012-2022 for the 19 countries of the European region included in this study is $62,098 (world development indicators), while according to the Cluster classifications obtained in this study, the labor productivity for the countries of the Western Balkans as a period is $42,995, while the EU member countries included in the study have labor productivity of $68,920. Unemployment, total (% of total labor force) (modeled ILO estimate) as a period for the countries included in the study is 10%, while according to the Cluster classification the countries of the Western Balkans have this figure at 17.96% and the EU member countries included in the study they have 8.39%. According to the global innovation index for 2022, the ranking of the countries of the Western Balkans is from the 55th to the 84th place, while the EU member countries are ranked from the 18th to the 49th countries (this ranking was evaluated with the participation of 132 countries). There are significant differences for each year of the period 2012-2022. These indicators and other indicators given in the study are analyzed in more detail by means of the efficiency performance chain of each country. Researchers in the economic sphere, for productivity and the factors influencing emphasize that the increase in productivity is the foundation of sustainable income growth and poverty reduction [2] and in [3] are evaluated the market efficiency and education for developing countries to provide a set of simulations in increasing productivity. Economic researchers assess productivity as the Achilles heel of the economy [4]. In this paper, the criteria (variable factors) are identified and analyzed that can have significant impacts on employment productivity with the dynamics of economic progress based on the goals set forth. In the detailed study of the analysis, two models have been formatted based on the identification of correlations between the variable factors and adapted to the practical rule of DEA which is related to the number of DMUs taken in the study as well as the total number of factors. The performance of each DMU is evaluated in particular and Cluster performance, the respective rankings and the evaluation of the overall performance. The hypotheses presented are: H1. The impact of labor productivity on the dynamics of economic progress is distinguished between the two Cluster groups as well as between DMUs. H2. The economic dynamics throughout the time period also reflect significant managerial differences between the Cluster categories and DMUs. H3. The performance of DMUs evaluated according to each model has no significant differences between them. H4. Impacts on the evaluation of the advantages and disadvantages of the performance evaluation is related to the harmonization of the correlative impact between the factors.

LITERATURE REVIEW

The assessment of performance and the determination of productivity efficiency under the influence of financial and non-financial (comparative) factors, which have significant effects, can be found in many studies and applications. [5] presents models for evaluating technical efficiency and scale inefficiency by means of DEA. [6] analyzes and studies the relationship between productive efficiency and innovative activity. The reviewed analysis is related to economic and financial data. [7] evaluates the measurement and explanation of production performance, seeing performance as a function of the state of technology and economic efficiency related to the influence of certain variables. [8] offers approaches of empirical and theoretical methods applied by researchers who study productivity issues. [9] studies and analyzes monitoring using a specific set of variables of yield and production efficiency related to the possibilities of improving results in the food industry. The process is examined in two directions, production efficiency and investment efficiency. [10] evaluates the size of the selected sample in DEA related to observations, but also to the number of inputs and outputs to increase the discriminating power of efficient and inefficient DMUs, for this they use the model of using the well-known pure DEA model, which considers either inputs only or outputs only. For the modeling of undesirable quantities, such as undesirable outputs, undesirable inputs and efficiency invariance are treated by [11]. The evaluation of the impact of each variable factor on the efficiency value as well as the evaluation of the overall efficiency on the basis of the rankings given by different models are given by [12], [13]. Models for evaluating DEA super efficiency and sensitivity analysis in DEA are given in [11]. Analysis for the improvement and evaluation of the sensitivity of the efficiency value related to the change of the limits of variable sizes is given by [15]. The evaluation of super-efficiencies for DMUs that are evaluated in the first phase as efficient are given by [14].

METHODOLOGY

DEA is a methodology, which is applied in many fields for the evaluation of relative technical efficiency and performance in a group of homogeneous decision-making units. Homogeneous decision-making units may have many inputs and many outputs, which are included in the set of production productivity [16]. T_{CCR}= { (x,y)|x $\geq \sum_{j=1}^{n} \lambda_j x_j$, y$\leq \sum_{j=1}^{n} \lambda_j y_j$, $\lambda_j \geq 0$, j=1,2,..,}. Also (x,y) can be written x= $\sum_{j=1}^{n} \lambda_j x_j + s^-$, y = $\sum_{j=1}^{n} \lambda_j y_j$-$s^+$(where the slacks are, $s^- \geq 0,\ s^+ \geq 0$). Where λ is a semi positive vector in R^n (where λ is called the intensity vector, λ= $(\lambda_1, \lambda_2, \ldots, \lambda_n)^T$. The observed activity is (x_j, y_j), (j=1,2,…,n), where the data set is given by the matrices: $[x_{ij}]_{mxn}$ and $[y_{rj}]_{sxn}$. The components of each pair (x,y) of such vectors are considered as a semi-positive point in the (m+s) dimensional linear vector space, in which the indices m and s respectively specify the dimensionality expressed in inputs and outputs respectively. DEA identifies the best practices of the evaluated efficient units; it also evaluates the inefficient units. The two basic models of DEA, the CCR and BCC models in a linear programming according to input-oriented (or output-oriented) orientation are given [16], [11]:

<u>CRS model:</u>

min θ

S.t $\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io}$, i = 1,2,…,m;

$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro}$, r = 1,2,…,s;

$\lambda_j \geq 0$, j=1,2,…,n

<u>VRS model:</u>

min θ

S.t $\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io}$ i = 1,2,…,m;

$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro}$ r = 1,2,…,s;

$\sum_{j=1}^{n} \lambda_j$ =1

$\lambda_j \geq 0$ j=1,2,..,n

The model for evaluating super efficiency is given by the Andersen-Petersen model:

$\min\theta^{super}$

S.t $\sum_{\substack{j=1 \\ j\neq 0}}^{n} \lambda_j x_{ij} \leq \theta^{super} x_{io}$, i= 1,2,…,m;

$\sum_{\substack{j=1 \\ j\neq 0}}^{n} \lambda_j y_{rj} \geq y_{ro}$, r=1,2,…,s;

$\lambda_j \geq 0$ j$\neq o$

The evaluation of the performance of the decision-making units with the relative technical efficiencies is conditioned by the factors (input-output) which have non-equivalent impacts on the inefficiencies. The evaluation of the impact of each input factor on the overall efficiency value can be evaluated with the formulas:

For inputs: $G^{I_i} = \frac{E_f^{I_i}}{\sum_{i=1}^{m} E_f^{I_i}} \cdot 100$ %, for outputs: $G^{O_r} = \frac{E_f^{O_r}}{\sum_{r=1}^{s} E_f^{O_r}} \cdot 100$ %.

For the evaluation of the overall efficiency according to the rankings in two different models, they are calculated by evaluating the values of the "distributive" function given by formulas: Z= 1- exp [- (1 - $\frac{R_i}{n}$)], (instead of n, n+1 can be set, as it avoids the zero value that Z can take for the last ranked DMU). The formula $\|E_0\| = \sqrt{Z_1 \cdot Z_2}$, where $Z_1, and\ Z_2$ are respectively evaluated for each model ranking. The construction of input/output models are formatted after investigating the Pearson correlation indicators so that the obtained efficiency values are as real as possible when we have acceptable linear relationships between the variable factors.

NUMERICAL APPLICATION

The study covers the period 2012-2022 for the countries of the European region. These countries are Albania, Bosnia and Herzegovina, North Macedonia, Serbia, Montenegro, Bulgaria, Croatia, Czechia, Estonia, Greece, Hungary, Poland, Romania, Lithuania, Latvia, Slovenia, Slovak Republic, Cyprus, Malta. The factors selected as inputs and outputs are: merchandise imports and commercial service imports (current US $) valued per capita; merchandise exports and commercial service exports (current US $) valued per capita; GDP per person employed (constant 2017 PPP $) (employment productivity); Central Government Debt, Percent of GDP; Global Innovation Index (GII); GNI per capita, Atlas method (current US$); Unemployment, total (% of total labor force) (modeled ILO estimate); Inflation, consumer prices (annual %); GDP growth (annual %); Foreign direct investment, inward, stock, us dollars at current prices per capita. The selected variable factors are in accordance with the macroeconomic literature, the correlations with the Pearson index were also evaluated. Table 1. presents the data for each factor of variable size with its minimum, average, maximum values as well as their standard deviation during the period 2012-2022. C1 represents the countries of the Western Balkans that are not members of the EU included in the study of the 19 countries of the region, while C2 represents the member countries of the EU included in the study.

Table 1. The data of variable sizes

No.	Variables	Cluster	Min. Value	Avg. Value	Max. Value	St. Dev
1	Imports (per Capita)	Total	9537.882	11955.3	17273.84	2319.706
		C1	3096.048	4061.243	6214.792	917.6937
		C2	11838.54	14774.6	21223.5	2820.424
2	Exports (per Capita)	Total	9402.5	11896.62	16570.57	2167.996
		C1	1978.726	2998.91	4751.902	794.5637
		C2	12053.85	15074.37	20791.52	2658.507
3	Investment (per Capita)	Total	45651.68	51586.72	36432.53	9427.18
		C1	3201.6	4119.309	5284.6	716.2749
		C2	60812.43	68539.37	47556.79	12538.22
4	Central Government Debt (percent of GDP)	Total	51.63947	61.63646	73.26947	6.402946
		C1	45.838	55.05636	69.118	7.126521
		C2	53.71143	63.98649	74.75214	6.144526
5	employment productivity	Total	56980.91	62098.13	68571.68	3705.223
		C1	40232.44	42995.13	45292.56	1487.667

		C2	62962.51	68920.63	76885.66	4497.207
6	GII	Total	36.56368	40.8678	44.06263	2.04471
		C1	28.8	33.71018	37.3	2.398126
		C2	39.33643	43.42409	46.47786	1.918489
7	GDP growth (annual %)	Total	-4.94568	2.654841	8.260695	3.409267
		C1	-5.86489	2.436607	8.515122	3.53852
		C2	-4.61738	2.732781	8.169829	3.363105
8	GNI (per Capita)	Total	13023.16	15186.84	19234.21	1926.452
		C1	5306	6204.364	8172	886.0177
		C2	15779.29	18394.87	23185	2298.035
9	Inflation, consumer prices (annual %)	Total	-0.58142	2.528124	12.9593	3.592936
		C1	-0.03854	2.544095	11.99435	3.294927
		C2	-0.77531	2.52242	13.30393	3.699368
10	Unemployment, total (% of total labor force)	Total	7.057053	10.90784	15.77263	2.999564
		C1	12.4748	17.95596	24.214	4.042783
		C2	5.122143	8.390649	12.75786	2.626985

The evaluation of the correlation indicators with the Pearson index showed that there are significant correlations between the factors, which were used in the structuring of the two input/output models used in the study. Model 1: input 1. coefficient of coverage of imports from exports, input 2: Foreign direct investment, inward, stock, us dollars at current prices per capita, and outputs are: Output1. employment productivity; output2. Global Innovation Index, output3. GNI per capita, Atlas method (current US$). Variable quantities that are used as inputs have been processed: the coefficient of coverage of imports from exports (import over export ratio). This coefficient has a correlation (Pearson) greater than 0.68 with the variable size that was used as output in model 1. Even the outputs of model 1 have correlations between them greater than 0.73. Model 2 has as inputs: Input 1: Trade openness (import plus export in relation to GDP, concept used in macroeconomics), Input2: Central Government Debt, Percent of GDP, and as outputs there are: Output1. Inflation, consumer prices (annual %); Output 2. GDP growth (annual %); Output3. Unemployment, total (% of total labor force) (modeled ILO estimate). The indicators of the correlative relationships between these variable quantities are of significant value. Thus, trade openness to GDP growth has a value of 0.58 in the Pearson index and to Unemployment, total (% of total labor force) has a value of 0.53. These evaluations of correlations in the formatting of the models were taken into account, since the models used in DEA are linear programming models to obtain the most realistic results of the efficiency evaluation. Table 2 presents the results obtained for Model 1. These results show that for Cluster C1 grouping (in 55 observations the number of DMUs times the number of years of the period) DMUs evaluated at the efficient frontier make up 21.8% of the observations, for Cluster C2 grouping, DMUs evaluated at the efficient frontier make up 31.18% of the total number of observations. This shows that those evaluated as best practices are mostly found in Cluster C2.

Table 2. Results of model 1

Cluster	DMU	Ef_{CRS}^{H} Average	Ef_{VRS}^{H} Average	SE	RTS			Impact on efficiency (input/output) %				
					I	D	C	I_1	I_2	O_1	O_2	O_3
C_1	ALB	0.913	0.990	0.923	7	-	4	29.4	70.6	28.3	53.7	18
C_1	BIH	0.915	0.955	0.958	4	2	5	29.4	70.6	33	49.3	17.7
C_1	MKD	0.923	0.959	0.963	5	3	3	34.5	65.5	31.4	52.7	15.8
C_1	SRB	0.761	0.844	0.902	10	1	-	47.3	52.7	29.9	52.1	18.0
C_1	MNE	0.539	0.599	0.900	11	-	-	53.8	46.2	33.8	47.3	18.9
C_2	BGR	0.858	0.928	0.925	9	2	-	62.2	37.8	32.3	48.6	19.2
C_2	HRV	0.818	0.901	0.907	10	1	-	66.3	33.7	37.4	36.9	25.7
C_2	CZE	1.000(1.015)	1.000	1.000	-	-	11	78.9	21.1	35.0	35.0	30.1
C_2	EST	0.928	1.000	0.928	-	10	1	79.4	20.6	31.5	37.4	31.2
C_2	GRC	1.000(1.469)	1.000	1.000	-	-	11	47.1	52.9	33.3	33.33	33.33
C_2	HUN	0.925	0.978	0.946	11	-	-	71	29	35.2	39.3	25.5
C_2	POL	0.930	0.990	0.939	7	-	4	59.5	40.5	34.5	39.4	26.1
C_2	ROU	0.881	0.938	0.939	11	-	-	50.8	49.2	34.3	42.3	23.4
C_2	LTU	0.891	0.950	0.938	11	-	-	64.6	35.4	35.4	36.1	28.5
C_2	LVA	0.834	0.884	0.944	11	-	-	66.9	33.1	32.4	39.4	28.3

C_2	SVN	1.000(1.490)	1.000	1.000	-	-	11	66.9	33.1	33.33	33.33	33.33
C_2	SVK	0.827	0.928	0.891	11	-	-	70.6	29.4	33.5	35.6	30.9
C_2	CYP	0.968	0.986	0.981	3	4	4	99.1	1.0	26.3	33.5	40.2
C_2	MLT	0.992	1.000	0.992	-	4	7	99.1	1.0	34.4	31.8	33.8
Average total		0.890	0.938	0.946				61.9	38.1	32.9	40.9	26.2
Average C_1		0.810	0.869	0.929				38.9	61.1	31.3	51	17.7
Average C_2		0.918	0.963	0.952				70.2	29.8	33.5	37.3	29.3

Looking at the impact on the efficiency value of each factor, it is established for the significant impact of the first input in general for the 19 DMUs and in particular for Cluster 2. The average of relative technical efficiency (harmonic average for the entire period) for Cluster C2 is 0.918, while for Cluster C1 it is 0.810. Thus, the influence of the coefficient of coverage of imports from exports for Cluster C2 is 70.2%, compared to 38.9% of Cluster C1. This shows the significant value in the positive direction of the coefficient of coverage of imports by exports. The high value of the percentage in the influence of the efficiency value for Cluster 1 of investments, estimated at 61.1%, indicates the poor effectiveness of the use of foreign investments in increasing efficiency for these countries. The positive experience evaluated for the countries that belong to Cluster 2: Czechia, Greece and Slovenia have a better harmonization between variable sizes to increase the effectiveness of the efficiency value. In the study, it is found that in the first half of the period for Cluster 1, Albania performed well, while in the second half its performance worsened. Bosnia and Herzegovina in the first half of the period has worsened, while in the second half it has improved. Meanwhile, Serbia and Montenegro during the entire period occupy the last places in the ranking of the 19 countries included in the study. In Cluster C2, the Czech Republic, Greece, and Slovenia are evaluated at the efficient frontier during the entire period, and Malta is at the efficient frontier for 64% of the period. Thus, it can be said for Cyprus, while for the other countries in Cluster C2 it can be said that they maintain stability in the dynamics of walking. Looking at the scale efficiency values for Cluster C1, it is found that for four decision-making units their inefficiency is caused by both managerial inefficiency and unfavourable competitive conditions (E$f^{VRS} <$ SE), while in Cluster C2 the inefficiency is more related to managerial inefficiency .

Figure 1 presents the relative technical efficiency values by years for both Cluster and general groups.

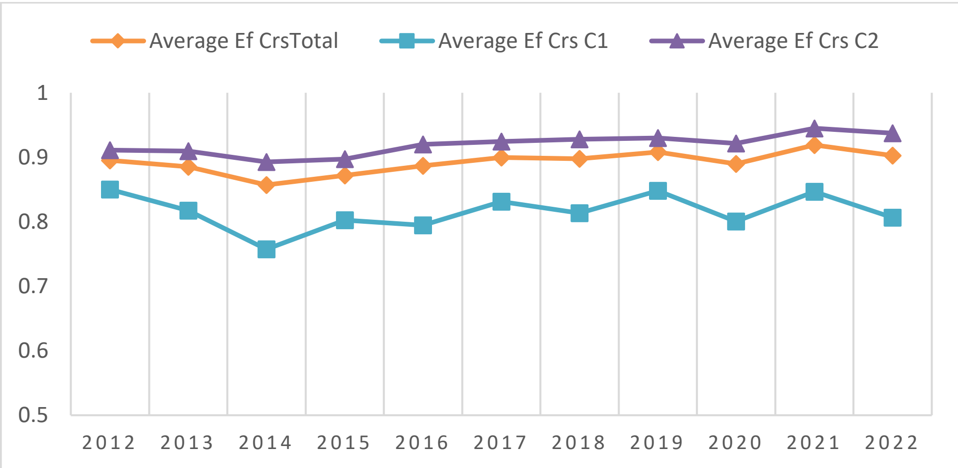

Figure 1. The results of average relative technical efficiencies according to Cluster groups during the period 2012-2022.

Figure 2 presents the values of employment productivity (estimated in thousands of dollars) according to groups and according to years.

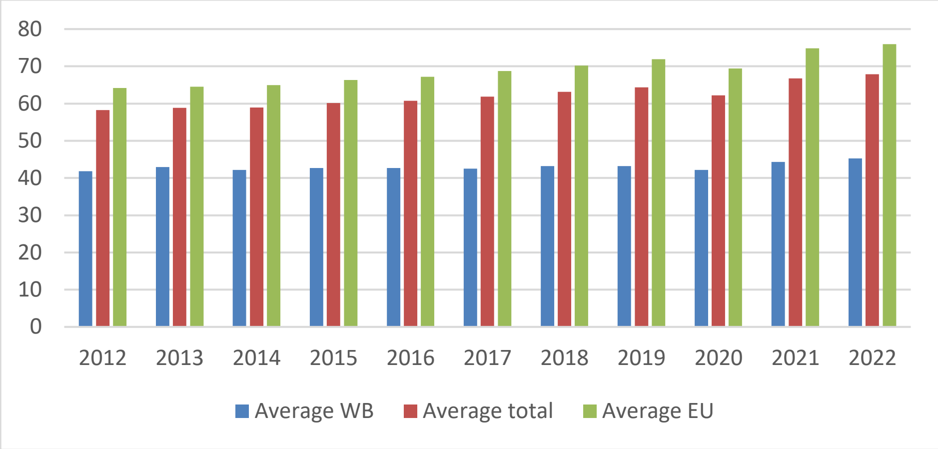

Figure 2. Employment productivity (estimated in thousands of dollars) by groups and by years.

Table 3. Gives summary results obtained from the application of model 2.

Table 3. Results of model 2.

Indicator	Ef_{CRS}^{H} Average	Ef_{VRS}^{H} Average	SE	RTS (%)			Impact on efficiency (input/output) %				
				I	D	C	I_1	I_2	O_1	O_2	O_3
Total	0.853	0.908	0.940	26.4%	36.8%	36.8%	63.4%	35.6%	34.8%	36.1%	29.1%
Cluster C_1	0.820	0.895	0.909	60%	-	40%	65.9%	34.1%	40%	43.2%	16.8%
Cluster C_2	0.865	0.913	0.951	14.3%	50%	35.7%	62.5%	37.5%	33%	33.6%	33.4%

From the results of Table 3, it is found that trade openness has a greater impact on the value of efficiency than input number 2, which is debt, both in mitigating inflation, mitigating unemployment and increasing the percentage of GDP. Trade openness in Cluster C2 is 62.5% of the impact on the efficiency value from 37.5% of the debt impact. Even in Cluster C1, the values of 65.9% of the impact of trade openness to 34.1% of debt show the same conclusion. While, seeing the impact on the efficiency value of the outputs where the increase in GDP has a more significant impact on Cluster 1, but the 16.8% assessment of the impact of reducing unemployment in Cluster C1 shows the poor effectiveness of both inputs, while in Cluster C2 almost the same value of the influence of each output in the evaluation of the relative technical efficiency is found (33%; 33.6%; 33.4%).

Figure 3. presents the progress of inflation, GDP Growth and unemployment throughout the period.

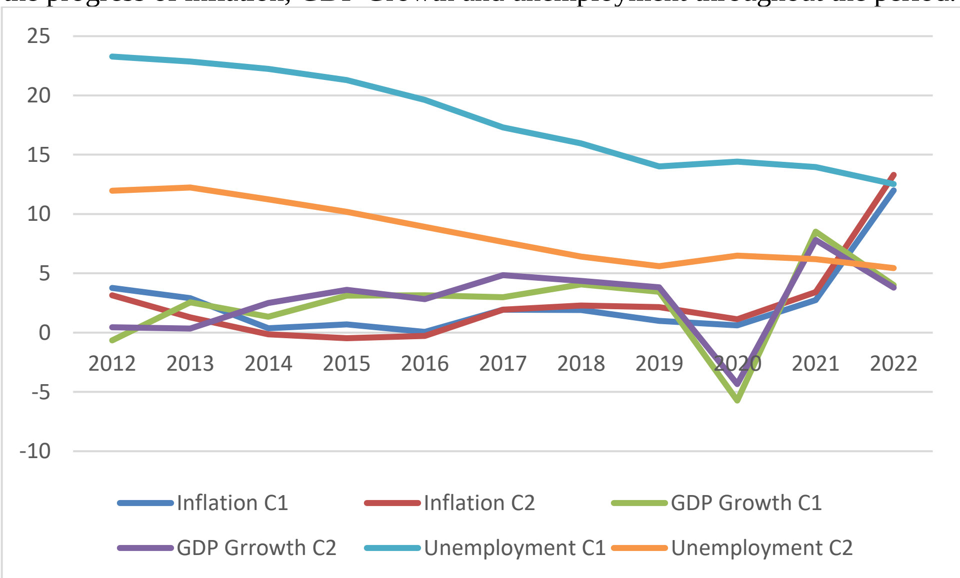

Figure 3. The progress of inflation, GDP Growth and unemployment throughout the period.

Based on the conclusions of both models according to the ranking obtained and the evaluation of the general performance evaluated with the formula $\|E_0\| = \sqrt{Z_1 \cdot Z_2}$, ku $Z_1, and\ Z_2$ are evaluated according to the formula given in the methodology. The results obtained for the evaluation of the general performance and the rankings according to the Cluster groups are given in table 4.

Table 4. Results of overall performance and rankings by Cluster

Cluster	DMU	Z_1	Z_2	$\|E_0\|$	Evaluation of OP (Rank)	
					a	b
C_1	ALB	0.50341	0.42305	0.46149	2	5
C_1	BIH	0.61326	0.41778	0.50617	1	2
C_1	MKD	0.18127	0.42042	0.27606	3	15
C_1	SRB	0.13929	0.11550	0.12684	4	18
C_1	MNE	0.32968	0.48771	0.12680	5	19
C_2	BGR	0.55067	0.30169	0.40759	6	8
C_2	HRV	0.45119	0.19236	0.29460	12	14
C_2	CZE	0.29531	0.55877	0.40621	7	9
C_2	EST	0.59343	0.42827	0.50413	2	3
C_2	GRC	0.47795	0.60076	0.53585	1	1
C_2	HUN	0.04877	0.41778	0.14274	13	16
C_2	POL	0.32968	0.47319	0.39497	8	10
C_2	ROU	0.57259	0.32968	0.43448	4	6
C_2	LTU	0.25918	0.35362	0.30274	11	13
C_2	LVA	0.39347	0.24215	0.30867	10	12
C_2	SVN	0.22120	0.60076	0.36454	9	11
C_2	SVK	0.09516	0.20691	0.14032	14	17
C_2	CYP	0.52763	0.48032	0.50342	3	4
C_2	MLT	0.36237	0.51457	0.43182	5	7

DISCUSSIONS AND CONCLUSIONS

The result of this study based on the applications of the DEA method evaluates the economic dynamics with the efficiency chain and the ranking of the DMUs of the countries of the European region (19 countries of the region) during the period 2012-2022. For the evaluation of the macroeconomic dynamics, a grouping of variable sizes with an impact on the examined macroeconomics and the correlative relationships between them were used for two Cluster categories, as well as for the evaluation of the performance of each DMU. The hypotheses presented in the objectives of the study proved that we have an impact of labor productivity on the distinct dynamics of economic progress between the two Cluster groups and DMUs. Also, the evaluation and argumentation of inefficiencies for each cluster grouping and as a whole reflects significant managerial differences in economic dynamics. The performance of DMUs evaluated according to the two models does not have significant tangible differences between them in the cluster evaluations and between DMUs. The effects on the advantages and disadvantages in the evaluation of the performance is also related to the effects of variable sizes. Thus the impact of the global innovation index was quite distinct. Cluster 1 countries according to the Global Innovation Index have unfavorable evaluations in the ranking. According to the global innovation index for 2022, the ranking of the countries of the Western Balkans is from the 55th to the 84th place, while the EU member countries are ranked from the 18th to the 49th countries (this ranking was evaluated with the participation of 132 countries). Thus, throughout the period 2012-2022, the ranking of Cluster 1 countries in the global innovation index is in a more unfavorable ranking position than that of Cluster 2. Distinct influences on economic dynamics appear in labor productivity, trade openness, inflation and unemployment figures. This study is an alternative that can be applied in DEA when we have a large number of variable factors.

REFERENCES:

[1] Kim, Young Eun and Loayza, Norman, Productivity Growth: Patterns and Determinants Across the World (May 10, 2019). World Bank Policy Research Working Paper No. 8852, Available at SSRN: https://ssrn.com/abstract=3386434

[2] Alistair Dieppe, Global Productivity: Trends, Drivers, and Policies, World Bank Publications (2020) ISBN-10: 1464816085, ISBN-13 : 978-1464816086

[3] Young Eun Kim, Norman V. Loayza, Productivity Growth: Patterns and Determinants across the World, (2019), Economia, Vol. 42, Issue 84, 36-93, ISSN 2304-4306, DOI: 10.18800/economia.201902.003

[4]S.Xhepa, O.Liperi Produktiviteti: Thembra e Akilit e Ekonomise Shqiptare (2020), Friedrich-Ebert-Stiftung, https://library.fes.de/pdf-files/bueros/albanien/18303.pdf
[5] R.D.Banker, A.Charnes and W.W.Cooper, Some models for estimating technical and scale inefficiencies in data envelopment analysis.Manag.Sci.30 (1984) 1078-92
[6] L.D-Balteiro, A.C.Herruzo, M.Martinez, J. González-Pachón An analysis of productive efficiency and innovation activity using DEA:An application to Spain's wood based industry. Forest Policy and Economics, Volume 30, Issue 7 (2006) 762-773
[7] Harold O. Fried (ed.), C. A. Knox Lovell (ed.),Shelton S. Schmidt (ed.), The measurement of productive efficiency and productivity change, Oxford University Press(2008), Print ISBN: 9780195183528, Online ISBN: 9780199870288 https://doi.org/10.1093/acprof:oso/9780195183528.001.0001
[8] R.C Sickles, V. Zelenyuk**,** Measurement of productivity and Efficiency-Theory and practise, Cambridge University Press,(2019) DOI: 10.1017/9781139565981 ISBN: 9781107036161
[9] M.Flegl, C.A. Jiménez-Bandala, I. Sánchez-Juárez, E.Matus, Analysis of production and investment efficiency in the Mexican food industry: Application of Two-stage DEA,Czech journal of Food Sciences, (2022) Vol.40.No.2, 109-117 DOI: 10.17221/172/2021-CJFS
[10] V.Charles, J. Aparacio, J.Zhu, The curse of dimensionality of decision-making units: A simple approach to increase the discriminatory power of data envelopment analysis, European Journal of Operational Research (2019), Volume 279, Issue 3, 929-940, https://doi.org/10.1016/j.ejor.2019.06.025
[11] J.Zhu, Quantitative models for performance evaluation and benchmarking, Data Envelopment Analysis with Spreadsheets, third Edition, International Series in Operations research &management science, (2014), ISSN 0884-8289, ISBN 978-3-319-06646-2, DOI 10.1007/978-3-319-05547-9
[12] 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.
[13] 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, Volume 21, 2024. pp. 169-185, Doi: 10.37394/23209.2024.21.17
[14] P.Andersen and N.C.Petersen, A procedure for ranking efficient units in data envelopment analysis, Management Science, vol.39,pp 1261-1264, 1993
[15] Thompson, R., Dharmapala, P.S., Thrall, R.M. (1994). Sensitivity Analysis of Efficiency Measures with Applications to Kansas Farming and Illinois Coal Mining. In: Data Envelopment Analysis: Theory, Methodology, and Applications. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-0637-5_20
[16] W.Cooper, L.Seiford, K.Tone, Data Envelopment Analysis, A comprehensive Text with Models, Applications, References and DEA-Solver Software (2002), Kluwer Academic Publishers, New York, Boston, Dordrecht, London,Moscow, ISBN 0-7923-8693-0