A STUDY ANALYSIS FOR THE LEVEL OF CRIMINALITY IN ALBANIA IN RELATION TO THE IMPACTS OF ECONOMIC FACTORS EXAMINED THROUGH THE MULTIPLE REGRESSION MODEL AND THE DEA METHOD

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Abstract - In the theory of recognition of the study analysis of criminality, crime is also seen under the effect of perceptions of economic factors and other influencing factors.This requires the evaluation and study of the relationships between the level of crime and these factors.This study evaluates the level of criminality in dependence on employment, economic changes within a region (district) and between regions in Albania, highlighting relevant conclusions and conclusions for each region in particular.The countries of the Western Balkans in the European region have a high level of crime indicators in relation to other countries of this region.In Albania, the coefficient of criminal proceedings per hundred thousand inhabitants for the year 2021 is 1002.Counties such as Gjirokastra and Lezha have high crime rates in 2019 and 2021, for which it is found that their economic changes are much lower than the average of the economic changes of each county in Albania (comparing the family consumption expenses of 2019, 2021 with those of year 2014).Indicators with an impact on the level of criminality are found in districts where the level of employment is low.For the study of the dependence of the number of perpetrators of criminal offenses in relation to the influencing factors, the multiple regression model and the DEA method were used as mathematical instruments.

Keywords - Criminal Offense, multiple Regression Analysis, DEA, Employment

I. INTRODUCTION

In this paper, the criminality index phenomenon is studied in relation to economic factors and other factors based on real data for 12 prefectures of Albania. This paper also brings an approach to see crime not only in the static aspect (hardened in numbers), but also in the dynamic aspect, in the variable aspect evaluated both by its size density and by its geographical regional extent. Here, the traditional study methods of this field are used, such as comparisons, percentages on statistical tables, but also methods from the field of mathematical discipline, such as the DEA method and the multiple linear regression model.

Criminology as a term was used for the first time by the French anthropologist Paul Topinard with his work Anthropology and then by Raffaele Garofalo [1] who treats the phenomenon of social crime in its individual and social causes. S. Freud [2], [3] pointed out in his studies on personality and psychoanalysis in abnormal behavior that man becomes a delinquent and a criminal when he does not find harmony in the social environment where he is and the non-fulfillment of his desires. Freud emphasizes that these symptoms appear as an internal problem in his social maladjustments learned in life, which thus lead to deviations from social balances. Enrico Ferri in the work "Sociology of crime" [4] expresses the view that the criminal is a consequence of the mutual influence of anthropological factors with social factors, public and family opinions, the educational system, industrialization, etc. Emile Durkheim [5] emphasizes how to approach social factors with a more integral perspective. He proposes two study instruments, statistical and logical reasoning.

Merton [6] explains the behavior of avoidance when there is a lack of non-fulfillment between the accepted social goals and the values of social progress.

Albania has a not very pleasant picture of the criminality coefficient.Until January 30, 2021, according to [7] the number of prisoners per 100000 inhabitants in Albania is 162.4, ranking first in the region, followed by Serbia with a value of 153.4, Montenegro with 134.7, Macedonia with 107.3 when the European average is 116.1. The average age of prisoners in Albania is 36 years and the average sentence is 15.4 years, where the European average is 12.4 years. The average index of criminality in Albania during the period 2005-2020 [8] is 143.75 per 100000 inhabitants. Dividing the period in 2005-2009, this figure is 132, in the period 2010-2014 it is 138.6 and in the period 2015-2020 it is 143.75, so there is a continuous increase.

In the criminal offenses registered in the average of the last two years 2019-2020, they show that 69.38% were committed by unemployed individuals, of which 90.45% are without higher education (according to the regional statistical yearbooks 2020, 2021). In Albania, according to (ILO), the informality of work for 2019 is 56.7%, the highest of any country in the region, while for the countries of the European Union this informality rate is 18%. What attracts attention is

that during the year 2005-2020, the highest crime index in Albania was found in 2019 with the number 177, among the highest in the region. Therefore, this work was done for this year. The increase in the criminality index is an obstacle to economic and social development, so in addition to the recognition of the phenomenon of criminality, the risk factors that influence its growth should be sought and recognized by presenting ideas and attitudes. This requires:

1. To identify perceptions; 2. To identify the dimensions of the extent of criminality, 3. To examine the relationships between variable factors by evaluating the value of their influence.
The component indicators of the study were perceived and evaluated in two dimensions:
the first dimension: a) the unemployment index at the prefecture level; b) the number of production economic enterprises against a previous year; c) assessment of living conditions (monthly consumption expenditures)
the second dimension: a) the index of injured of criminal offenses against the person per 10000 inhabitants at the prefecture level; b) the index of the number of prisoners per 10000 inhabitants c) the number of perpetrators of criminal offenses per 10000 inhabitants (calculated by the author according to the data of the regional statistical yearbooks).

Hypotheses that are presented:

Hypothesis 1: Criminality in Albania as a phenomenon can be evaluated in the correlative relationship between certain economic factors, which are defined as influential.

Hypothesis 2: Criminality in Albania as a phenomenon can be presented in relation to the factors and features of the regional geographical extent.

The research interest of the study is presented through research questions:

1. Can risk factors be investigated in the complexity of factors that promote criminality?
2. Why are there differences in the figures of the criminal offense according to the exposition of the features of the regional geographical extent?
3. Can the weight of the criminal offense be distinguished and determined separately for each factor in their complexity?
4. What can be the suggestions that can be brought with the aim of reducing the risk of criminality?

The study contributes to the most knowledgeable analysis of the results that appear in the behavior and attitude of the criminality phenomenon, which could serve as an incentive to increase the number of studies aimed at reducing the risk of criminality in the analysis of each factor.

II. METHODOLOGY

The methodology in the study of variable factor relationships is determined by following two steps: the first step - the application of the multiple linear regression model (with five independent variables and the index of perpetrators of criminal offenses as a dependent variable); second step - after the general trend of linear dependence has been evaluated, the DEA method is applied to evaluate the best and worst practices according to the prefectures and the weight of the influence of each variable factor on the criminality index.

For the values of each variable magnitude, in order to avoid imbalance in data magnitudes, the normalization of the data is calculated [9] because we can have large changes in values within a variable, but the measurement units of the variable values are not the same (in percentage values, in proportional values or estimated as average values or in monetary values etc.). Therefore, in order to normalize the data for each input and output, it can be done in two steps. In the first step, the average value of the column of values of each input and output is calculated, $\overline{M_i} = \frac{\sum_{n=1}^{N} M_{ni}}{N}$, where $\overline{M_i}$is the average value of each input and output column. In the second step, all column values are divided by the average value found, where the normalized value is determined, which is written$MNorm_{ni} = \frac{M_{ni}}{\overline{M_i}}$.

We consider the multiple linear regression model for n DMUs (n=12) and we have:

$Y= X\,\beta +\epsilon$ ($Y_i= \beta_0+\sum_{j=1}^{p-1} \beta_j X_{ij}+\varepsilon_i,\ i =1, \ldots, n$) [10].
$Y = (y_1, y_2, \ldots, y_n)^t$is the transposed vector accepted according to the statistical observation values.
The matrix given by the values of the independent variables can be presented

$$X = \begin{bmatrix} 1 & X_{11} & \ldots X_{1(p-1)} \\ \vdots & \vdots & \vdots \\ 1 & X_{n1} & \ldots X_{n(p-1)} \end{bmatrix}$$

The parameter vector $\beta = (\beta_0, \ldots, \beta_{p-1})^t$,where its values are given by the following equation:

$$\hat{\beta} = (\hat{\beta}_0, \ldots, \hat{\beta}_{p-1})^t = (X^tX)^{-1}X^tY$$

The application model of multiple linear regression has applications in many areas of life. This model is used to justify the truth of the linear interaction between the factors. The justification of the truth is done in two ways: from the graphical interpretation of the residuals depending on the estimated values $\hat{Y}_i$as

well as the analytical interpretation by justifying the value ofR^2, the value of the Fisher indicator [11] and as Significance F.

The DEA model is a mathematical programming model introduced for the first time by Charnes, Cooper and Rhodes [12].

In order to evaluate the efficiency with the DEA method based on the defined goals, we use the Multiplier model of oriented input [13].

$\max \theta_0 = \sum_{r=1}^{s} y_{r0}\mu_r$

Subject to: $\sum_{r=1}^{s} y_{rj}\mu_r - \sum_{i=1}^{m} x_{ij}\upsilon_i \leq 0$ (j=1, 2, …,n),

$\sum_{i=1}^{m} x_{i0}\upsilon_i = 1$,

$\mu_r \geq 0$ (r = 1, 2, . . ., s),

$\upsilon_i \geq 0$ (i = 1, 2, …, m).

The variables $\upsilon_i$and $\mu_r$are called Multipliers, so the model gets this name. For a more detailed interpretation see [14]. This model (Multiplier model) is used, according to the values of the multipliers $\upsilon_i$and $\mu_r$it can be judged about the weight of importance of each variable factor separately for each DMU.

In real life, desirable or undesirable inputs or outputs may appear.In the basic DEA models, it is accepted that inputs should be reduced in efficiency evaluation and outputs should be expanded. Therefore, in DEA, different models are applied for undesirable outputs [18], [19]. [14] presents models for both cases for undesirable output and for undesirable input.

To transform the undesirable output into the desirable output [16], [17] the desirable output is accepted as the inverse function of the undesirable output, $(O^u)^{-1}=O^D$(whereO^udenotes the output undesirable andO^Dindicates the desirable output). Even in this paper, since we have only one output (which is undesirable), the inverse values of the undesirable function are accepted.

For negative values of any variable or zero value is applied in DEA translation invariance [15], [9] by adding to each value the same value$\xi_i$according to each input or output column. Instead of the value, for example for the inputx_{ij} the value$x'_{ij} = x_{ij} + \xi_i$ is obtained [15], [9]. Considering the additive model in DEA, where each estimated slack for the input is given$\overline{s_i} = \sum_{j=1}^{n} x_{ij}\lambda_j - x_{i0} = \sum_{j=1}^{n} x'_{ij}\lambda_j - x'_{i0}$.

Thus, for the evaluation of efficiencies in DEA (in the case of translation invariance), the Additive model is used, which enables the study of efficiency and slacks [13], [15]. In the numerical application, the table of real and normalized values of each variable quantity is given.

Numerical application

For the study of the impact on the risk of criminality, the following variables were selected:independent variables: x_1- the unemployment index at the prefecture level, x_2-the calculated indicator of the change in the registered number (2019 versus 2018) of active economic enterprises that are producers of services, because we have a decrease in the number of their registration, x_3- the calculated indicator of the change in the standard of living determined by the average level of family consumption expenses (in 2019 versus 2014), x_4- the index of injured of criminal offenses against the person per 10000 inhabitants at the prefecture level, x_5- the index of the number of prisoners per 10000 inhabitants at the prefecture level.

The dependent variable y determines the number of perpetrators of criminal offenses for every 10000 inhabitants at the prefecture level. We study the estimated value of the variable y depending on the independent variables, so y = f (x_1, x_2, x_3, x_4, x_5). The source of the data is the regional statistical yearbook, 2020 and INSTAT.

The prefectures according to administrative division, which also present DMUs in the DEA application are: 1. Berat, 2. Diber, 3. Durres, 4. Elbasan, 5. Fier, 6. Gjirokaster, 7. Korce, 8. Kukes, 9. Lezhe, 10. Shkoder, 11. Tirana, 12. Vlore.

Table 1 and Table 2 present the real and normalized values of each variable factor for each prefecture.

No.	Prefecture	x_1	x_2	x_3	x_4	x_5	y
1	Berat	7.1	-189	7232	19.7	13.0	127.28
2	Diber	10.1	-88	-278	20.6	15.3	120.27
3	Durres	14.7	-450	7697	22.7	23.1	131.12
4	Elbasan	5.4	-442	15890	18.7	11.2	115.33
5	Fier	9.5	-549	10178	13.9	22.9	88.33
6	Gjirokaster	7.7	-137	-1370	39.1	28.6	220.36
7	Korce	7.5	-173	24591	22.7	18.7	131.66
8	Kukes	7.2	-30	10140	13.9	17.76	121.17

9	Lezhe	7.7	-294	-2833	29.5	27.4	216.87
10	Shkoder	9.4	-494	-214	11.7	21.84	147.48
11	Tirana	15.0	-221	16751	27.4	12.3	181.99
12	Vlore	15.2	-571	15160	41.9	19.0	185.49

Table 1. Real data for each variable and prefecture (for the year 2019)
Source: Regional Statistical Yearbook 2020 and INSTAT (author processing $x_3$and y)

No.	Prefecture	x_{1Norm}	x_{2Norm}	x_{3Norm}	x_{4Norm}	x_{5Norm}	y_{Norm}
1	Berat	0.677	2.06	0.877	0.839	0.675	0.855
2	Diber	0.958	3.04	0.233	0.877	0.794	0.807
3	Durres	1.39	3.06	0.917	0.967	1.2	0.88
4	Elbasan	0.512	3.3	1.62	0.796	0.582	0.774
5	Fier	0.901	2.44	1.13	0.592	1.189	0.93
6	Gjirokaster	0.731	2.9	0.226	1.665	1.485	1.479
7	Korce	0.712	1.22	2.366	0.967	0.971	0.884
8	Kukes	0.683	1.47	1.127	0.592	0.922	0.813
9	Lezhe	1.679	5.7	0.014	1.256	1.423	1.456
10	Shkoder	0.892	4.5	0.239	0.498	1.134	0.99
11	Tirana	1.423	0.41	1.694	1.167	0.639	1.221
12	Vlore	1.442	5.05	1.557	1.784	0.987	1.245

Table 2. Normalized values (from table 1) for each variable size

In Table 1, the values of the variablex_3 before normalization, since negative values also appear by means of the "invariance" transformation, the value ξ_i=3000 is added to each value to convert all the values of the variable $x_3$into positive values, then they are determined normalized values.

By applying the multiple linear regression model with five independent variables and one dependent variable, the equation $\hat{y}_i$= 0.38114 + 0.1299 x_1- 0.02174x_2 – 0.07336x_3 + 0.39059 x_4 + 0.26323 $x_5$was determined. The value $\hat{y}_i$is the estimated value of the variable Y for a given X, which is evaluated for the 12 prefectures. The regression results are given in Figure 1 and Table 3.

Regression Statistics	
Multiple R	0.88949331
R Square	0.791198348
Adjusted R Square	0.617196971
Standard Error	0.157644
Observations	12

Figure 1.Regression results for 12 prefectures

ANOVA

	df	SS	MS	F	Significance F
Regression	5	0.565011883	0.113002	4.547081	0.046311868
Residual	6	0.149109784	0.024852		
Total	11	0.714121667			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.381142336	0.264023954	1.44359	0.198964	-0.264901005	1.027185678	-0.264901	1.027185678
x1	0.129900556	0.148861834	0.87262	0.416418	-0.234351229	0.494152341	-0.2343512	0.494152341
x2	-0.021741525	0.040142794	-0.5416	0.6076	-0.119967403	0.076484352	-0.1199674	0.076484352
x3	-0.073362004	0.087243994	-0.8408	0.432641	-0.286840342	0.140116342	-0.2868404	0.140116342

	22		8		85			
x4	0.390586083	0.139577891	2.798338	0.031232	0.049051288	0.732120878	0.049051289	0.732120878
x5	0.263228995	0.205684447	1.279771	0.24788	-0.240062715	0.766520706	-0.240062715	0.766520706

No.	Prefecture	$\hat{Y}_i$	$e_i = Y_i - \hat{Y}_i$
1	Berat	0.865340273	-0.010340273
2	Diber	0.973947298	-0.166947298
3	Durres	1.121473604	-0.241473604
4	Elbasan	0.721163709	0.052836291
5	Fier	0.906440567	0.023559433
6	Gjirokaster	1.437690289	0.041309711
7	Korce	0.906824425	-0.022824425
8	Kukes	0.829149470	-0.016149470
9	Lezhe	1.339442588	0.116557412
10	Shkoder	0.874656795	0.115343205
11	Tirana	1.056818824	0.164181176
12	Vlore	1.301052158	-0.056052158

Table 3. The residuals

$\sum_{i=1}^{n} e_i$ = -7.21645E-15 = 0

The regression analysis can be given in two ways: a) graphical representation, b) statistical analytical interpretation. For graphical interpretation, the estimated residuals $e_i = Y_i - \hat{Y}_i$can be presented as a function $\hat{Y}_i$.

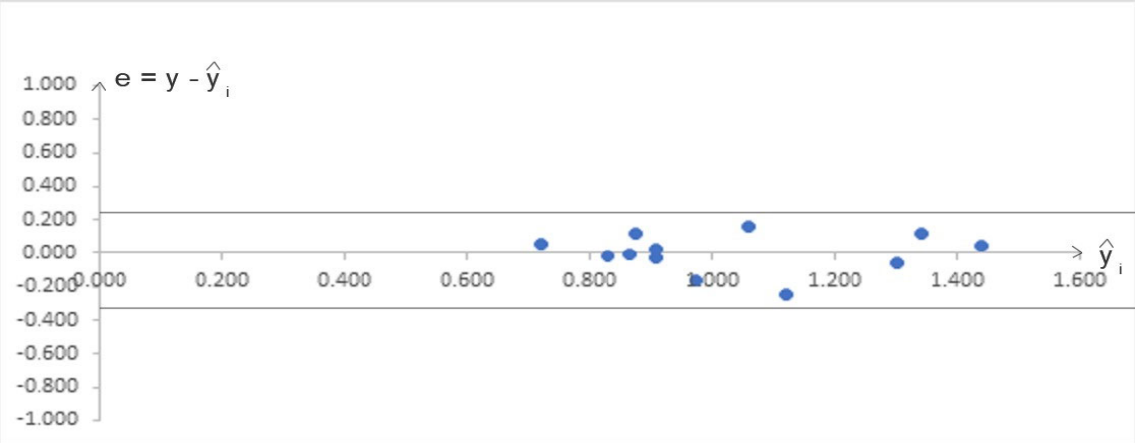


Figure 2. Graph of residuals

From the graph, it can be seen that all the distributed residues are located within a narrow horizontal band (part of the coordinate plane) between two lines parallel to the abscissa axis. This graphical presentation approach verifies the validity of the multiple linear regression model.From the statistical analytical interpretation given in Figure 1. the Fisher indicator, F = 4.547081 is greater than the critical value indicator$F_{0.05,5,6}$= 4.39. Also, Significance F = 0.046311868 < 0.05. This regression analysis given in both ways: a) graphic presentation, b) statistical analytical interpretation creates the conviction of the final reasoning that we have the general tendency of a multiple linear dependence. In the second step applied with the DEA method, the best and worst practices can be evaluated in assessing the risk of increased crime at the prefecture level for the 12 prefectures. The DEA (Multiplier Model) method evaluates the multiplier variables υ_i and μ_i, which indicate the weight of the influence of each variable on the efficiency values. This was used for the two groups, for the influence of economic factors$[(I_1, I_2)$ x O]; $[(I_1, I_2, I_3)$ x O]as well as for evaluating the impact of other factors on the determined dependent variable, which are the perpetrators of criminal offenses ($[(I_4, I_5)$ x O]) $(I_1, I_2, I_3, I_4, I_5$ respectively represent variable quantities x_1, x_2, x_3, x_4, x_5 and O represents quantity y). From Table 4, it is clearly noted that the economic factors that have influenced the increase in

criminality appear in the prefectures of Lezhe, Vlore, Gjirokaster, Shkoder and Durres.

Prefecture	Efficiency and Optimal Multipliers $[(I_1, I_2)\ x\ O]$				Efficiency and Optimal Multipliers $[(I_4, I_5)\ x\ O]$				Efficient Input Target$[(I_1, I_2, I_3)\ x\ O]$		
	Eff.	υ_{n1}	υ_{n2}	μ_n	Eff.	υ_{n1}	υ_{n2}	μ_n	I_1	I_2	I_3
Berat	0.886	1.089	0.127	0.757	0.838	0.875	0.394	0.717	0.68	1.35	0.71
Diber	0.656	0.761	0.089	0.529	0.822	0.810	0.365	0.663	0.78	1.34	0.46
Durres	0.452	0.572	0.067	0.398	0.617	0.663	0.299	0.543	0.72	1.23	0.42
Elbasan	1.000	1.114	0.130	0.774	1.000	0.945	0.426	0.774	0.51	3.30	0.62
Fier	0.630	0.843	0.099	0.586	0.874	1.689	0.000	0.813	0.68	1.16	0.40
Gjirokaster	0.439	0.934	0.109	0.649	0.237	0.428	0.193	0.351	0.43	0.73	0.25
Korce	1.000	0.328	0.628	0.884	0.660	0.712	0.321	0.583	0.71	1.22	0.42
Kukes	1.000	0.618	0.393	0.813	1.000	0.993	0.447	0.813	0.68	1.47	0.89
Lezhe	0.204	0.426	0.050	0.296	0.297	0.527	0.238	0.432	0.43	0.74	0.26
Shkoder	0.495	0.705	0.082	0.490	0.976	2.008	0.000	0.966	0.64	1.09	0.38
Tirana	1.000	0.453	0.868	1.221	0.577	0.000	1.565	0.705	1.42	0.41	0.59
Vlore	0.275	0.492	0.058	0.342	0.367	0.000	1.013	0.456	0.51	0.87	0.30
Average	0.670	0.695	0.225	0.645	0.689	0.804	0.438	0.651	0.68	1.24	0.48

Table 4. Evaluation results with the DEA method.

These prefectures have an efficiency value lower than the average efficiency value (0.66962). Overall, the factor with the greatest impact, based on the values of the multiplier variables, is the first variable x_1, as the average value of υ_1= 0.6946 and the average value of υ_2 = 0.22507. For the assessment of the impact of other (non-economic) factors on the increase in the risk of criminality, it is found that the highest risk appears in the prefectures of Gjirokaster, Lezhe and Vlore, it is also found here that both factors and the indicator of injured of criminal offenses as well as the indicator of prisoners for every 10000 inhabitants have both impacts, but the biggest impact appears in the first factor, as the weight of the first factor $\upsilon_1 > \upsilon_2$.

In the application of the DEA method, considering that in its basic models, the reduction of inputs and the increase of outputs is assumed, and since we have a single output, for the output values, its inverse function was taken (according to the presentation given in the methodology).

For the grouping $[(I_1, I_2, I_3)\ x\ O]$, the slack model was used (based on Translation Invariance given in the methodology) according to the evaluation given in the Efficient Input Target evaluation, the contractions of the respective input values for each prefecture are given. The biggest "shrinkage" is input I_2, which in percentage terms is 42% (the calculated indicator of the change in the registered number (2019 versus 2018) of active economic enterprises that are producers of services). From Table 4, it is noted that the prefectures evaluated as best practices for the impact of dealing with the risk of increased crime are the prefectures of Elbasan, Korce, Kukes, Berat, and in dealing with the risk from other factors, the prefectures of Elbasan and Kukes are noted, followed by Fier and Berat. In the prefectures of Shkoder, Tirana, Durres, there are large differences in the impact of economic factors in relation to other factors.

III. CONCLUSIONS

From the conclusions of the evaluations obtained with the above application, it must be accepted that the phenomenon of criminality can be studied by identifying as clearly as possible the risk factors that can promote or mitigate the index of criminality. The study showed the impact of each economic factor as well as other factors. The three economic factors presented show their significant impact as a whole and according to the prefectures in particular. Both hypotheses were verified in the paper: Hypothesis 1- Criminality in Albania as a phenomenon appears in the relationship between certain economic factors, which are defined as influencing.
Hypothesis 2: Criminality in Albania as a phenomenon has its own characteristics even with regional extensions, both from economic factors and from other factors.

The study provided answers to the research questions presented in the Introduction. As a conclusion, we can say that as a methodology in the study of criminality, the methods of integrated models can be widely used, such as the multiple linear regression model with the DEA method. This is a contribution brought by such studies, which analyze the behavior and attitude of the phenomenon of criminality in

relation to different variable factors treated analytically with mathematical methods.

REFERENCES

[1] M.Beqaj, Kriminologjia, https://www.scribd.com/document/246606441/120568839-Kriminologji-rtf#

[2] S.Freud, A general introduction to Psychoanalysis, HorageLiveright, 1920,

[3] S.Freud, Civilization and its Discontents,: Norton, 2005, ISBN: 0393059952

[4] E..Ferri, Criminal Sociology, Hard Press Publishing, 2010, ISBN-10 : 1407628364

[5] E.Durkheim, The rules of Sociological Method and Selected Texts on Sociology and its Method, First American Edition 1982, ISBN 0-02-907930-6

[6] Robert K. Merton, Social Theory and Social Structure. (1968) New York: The Free Press

[7] Xh.Deda, https://siu.scan-tv.com/te-burgosurit-shqiperia-rekord-ne-rajon-regjistrojme-163-persona-te-denuar-per-100-mije-banore-denimi-mesatar-deri-ne-15-4-vite/

[8] Open Data Albania, Koeficientiikriminalitetit ne Republiken e Shqiperise 2004-2021, 25 shkurt 2023

[9] J.Sarkis, Preparing your Data for DEA, In book:Modeling Data Irregularities and Structural Complexities in Data Envelopment Analysis (pp.305-320), June 2007 DOI:10.1007/978-0-387-71607-7_17

[10] Y.Dodge, The concise Encyclopedia of Statistics, Springer New York, NY, 2008, ISBN 978-0-387-31742-7, DOI https://doi.org/10.1007/978-0-387-32833-1

[11] S.RonaldA.Fisher, The design of Experiments, Hafner Press, 1971

[12] A.Charnes, W.W.Cooper and E.Rhodes, Measuring the efficiency of decision-making units, European Journal of Operational Research 2 (1978) 429-444

[13] 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, 2017, https://doi.org/10.1007/978-0-387-45283-8

[14] J.Zhu Quantitative Models for Performance Evaluation and Benchmarking. Data Envelopment analysis with spreadsheets, 2017, Springer, Third Edition, DOI https://doi.org/10.1007/978-3-319-06647-9

[15] A. Iqbal Ali, L.M.Seiford, Translation Invariance in Data Envelopment Analysis, Operations Research Letters,Volume 9, Issue 6, November 1990, Pages 403-405,https://doi.org/10.1016/0167-6377(90)90061-9

[16] B.Golany, Y.Roll, An application procedure for DEA, Omega, Volume 17, Issue 3, 1989, Pages 237-250, https://doi.org/10.1016/0305-0483(89)90029-7

[17] H.Scheel, Undesirable outputs in efficiency valuations, European Journal of Operational Research, Volume 132, Issue 2, 16 July 2001, Pages 400-410, https://doi.org/10.1016/S0377-2217(00)00160-0

[18] P.Korhonen, M.Luptacik, Eco-efficiency analysis of power plants:An extension of data envelopment analysis, European Journal of Operational Research, Volume 154, Issue 2, 16 April 2004, Pages 437-446, https://doi.org/10.1016/S0377-2217(03)00180-2

[19] L.M.Seiford, J.Zhu, Modeling Undesirable factors in efficiency evaluation, European Journal of Operational Research, Volume 142, Issue 1, 1 October 2002, Pages 16-20 https://doi.org/10.1016/S0377-2217(01)00293-4

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