CDC 338.43: 519.8

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DEA METHOD FOR ESTIMATING THE OVERALL EFFICIENCY OF AGRICULTURAL ENTERPRISES OF UKRAINE

Formulation of the problem. The DEA method refers to nonparametric methods of estimating the efficiency based on the concept of the effective frontier of production opportunities [12]. One of the advantages of applying the DEA method is the possibility of integrated estimating of the level of relative efficiency of the economic entity, taking into account the influence of many input and output factors of production. The DEA method allows to finding target values for input and output parameters that will allow an inefficient economic entity to become effective. Thus, the use of DEA method as a tool to estimate the efficiency of agricultural enterprises in Ukraine is appropriate.

Analysis of recent researches and publications. The paper [11] provides an overview of scientific publications on the application of DEA method during last 30 years. Among the scientific papers of domestic scientists devoted to the theory and practice of using the DEA method, can note the papers of V.G. Andriychuk, R.V. Andriychuk [1], S.I. Demyanenko, O.V. Nivievsky [4], B.P. Dmitruk, T.B. Vitryka [5], A. Lissitsa, T. Babicheva [7] and others. An analysis of the domestic scientific papers revealed the need for further research on improving the practical use of the method.

The purpose of the article – is to determine by DEA method the overall efficiency of the production activity of agricultural enterprises in Ukraine.

Statement of the material. Depending on the units of measurement of input and output parameters and a set of output parameters characterizing the

results of production activity, distinguish technical, allocative and overall efficiency.

Technical efficiency estimates the result of the conversion of the used resources into the volume of production, presented in natural form. It reaches the maximum (unit), if for the production of a given output $Y = (y_1, y_2, ..., y_n)$ used minimal resources $X^* = (x_1^*, x_2^*, .., x_m^*)$ or at given resources $X = (x_1, x_2, .., x_m)$ the enterprise receives the maximum output $Y^* = (y_1^*, y_2^*, ..., y_n^*)$. Allocative efficiency estimates the result of the conversion of the cost of resources into the volume of production, presented in value form. It reaches the maximum (unit), if the production uses the minimum costs of resources $X^* = (x_1^*, x_2^*, .., x_m^*)$ at given volumes of production and realization of the products $Y = (y_1, y_2, ..., y_n)$ in real prices or at the given expenses on resources $X = (x_1, x_2, .., x_m)$ the enterprise reaches the maximum of production and realization of the products $Y^* = (y_1^*, y_2^*, ..., y_n^*)$ in the actual prices. The overall efficiency characterizes the result of the transformation of the cost of resources into the economic result of production activity – revenue and profit. The overall efficiency reaches the maximum (unit), if for the production uses the minimum expenses of resources $X^* = (x_1^*, x_2^*, .., x_m^*)$ at a given revenue and profit $Y = (y_1, y_2, ..., y_n)$ or at a given expenses of resources $X = (x_1, x_2, .., x_m)$, the enterprise achieves maximum revenue and profit $Y^* = (y_1^*, y_2^*, ..., y_n^*)$.

The analysis of technical efficiency reveals the efficiency of the use of resources, the analysis of allocation efficiency – the efficiency of their placement (procurement and distribution) and the analysis of the overall efficiency reveals the overall efficiency of production activity.

In this study estimated the overall efficiency of agricultural enterprises of the regions in Ukraine.

The peculiarity of estimating the efficiency of agricultural enterprises by DEA model is the use of the model VRS – input. This model assumes that the change in the cost of resources does not lead to a proportional change in the

indicators that characterize the results of production activities. Efficiency measurement using a VRS-input model is based on the solution of a linear programming problem [9]:

$$\min_{E,\lambda_1,\lambda_2,...,\lambda_k} E \tag{1}$$

$$EX_0 \geq \sum_{k=1}^{K} \lambda_k X_k , \qquad Y_0 \leq \sum_{k=1}^{K} \lambda_k Y_k \tag{2}$$

$$\lambda_k \geq 0, \quad k = \overline{1, K} \tag{3}$$

where E – input efficiency;

λ_k – coefficients of linear combination to be defined;

$X_0 = (x_{10}, x_{20}, ..., x_{m0})$, $Y_0 = (y_{10}, y_{20}, ..., y_{n0})$ – input and output vectors of the enterprise that is estimated;

$X_k = (x_{1k}, x_{2k}, ..., x_{mk})$, $Y_k = (y_{1k}, y_{2k}, ..., y_{nk})$ – input and output vectors of the k-th enterprise;

K – the number of enterprises to be compared.

The nonsingularity condition for solution of problem (1) – (3) is [11]:

$$K \geq \max\{m \times n; 3(n+m)\}. \tag{4}$$

To solve the problem (1) – (3) it needs to be reduced to a canonical form:

$$\min_{E,\lambda_1,\lambda_2,...,\lambda_k} E \tag{5}$$

$$EX_0 = \sum_{k=1}^{K} \lambda_k X_k + d^- , \; Y_0 = \sum_{k=1}^{K} \lambda_k Y_k - d^+ \tag{6}$$

$$\lambda_k \geq 0 \quad k = \overline{1, K} \tag{7}$$

$$d^-, d^+ \geq 0 , \tag{8}$$

where d^-, d^+ – additional variables.

As a result to solve a problem (5) – (8) for the k-th enterprise, the boundary of production opportunities $\sum_{k=1}^{K} \lambda_k Y_k$ is formed, for which an additional variable d^+ characterizes the possible additional values of the results of production activities (profit, gross output, etc.). The optimal estimates $\sum_{k=1}^{K} \lambda_k X_k$

describe the cost of resources and an additional variable d^- describe inefficiently used resources.

The Malmquist productivity index is used to analyze the dynamics of productivity opportunities for several years [9, 10]. It takes into account the shift in the production capacity boundary in each analyzed period.

In this study on the basis of statistical information for 2016 [2, 3], the DEA method by the model VRS - input estimated the overall efficiency of agricultural enterprises in 24 regions of Ukraine.

Input parameters of the model: 1) x_{1k} – labor costs, thousand of UAH; 2) x_{2k} – social transfers, thousand of UAH; 3) x_{3k} – amortization, thousand of UAH; 4) x_{4k} – other costs, thousand of UAH; 5) x_{5k} – material expenses which were included in production price (including costs for seeds and planting material, forages, other agricultural products, mineral fertilizers, fuel and lubricants, electricity, fuel and energy, spare parts, repairs and building materials for repair, payment for services and works performed by outside organizations and others material expenses), thousand of UAH. Output parameters of the model: 1) y_{1k} – gross output of agricultural enterprises, thousand of UAH; 2) y_{2k} – net profit (loss) of agricultural enterprises, thousand of UAH

In table 1 shows the values of the input parameters, and in the table 2 – the output parameters of the model.

Table 1. – Input parameters of the model for 2016

№	Regions	Input parameters				
		Labor costs, thousand of UAH	Social transfers, thousand of UAH	Amortization, thousand of UAH	Other costs, thousand of UAH	Material expenses which were included in production price, thousand of UAH
1	Vinnitsa	1181258,2	264874,3	1138436	3108875,9	17723235,9
2	Volynskyi	223361,1	50373,6	258243	458312,5	5134065,2
3	Dnipropetrovsk	972310,3	213391,2	844943,4	2861735,9	13204884,5

4	Donetsk	552806	123102,9	373460,9	1283339,7	6057368,3
5	Zhytomyr	312902,4	71471	307578,2	1076226,2	4554960,1
6	Transcarpathian	48573,7	10876,3	31393,6	62323,2	499488,1
7	Zaporozhye	700980,6	156632,3	652597,8	1790079,1	7887130,5
8	Ivano-Frankivsk	170856,1	35866,7	271614,4	390238,1	3403965,7
9	Kievsky	1566691,5	347519,1	1228773,3	4194770,8	19733879,2
…	……	…	…	…	…	…
20	Kherson	629631,1	139294,2	595787,6	1421438,1	7035589,5
21	Khmelnytskyi	580355,1	127651,6	585201,3	2366184,9	8867196,8
22	Cherkassy	1234155,6	280244,7	824698,3	3328165	15187978,5
23	Chernivtsi	97692	22263,9	112070,8	273022,6	1500052,9
24	Chernihiv	832371,8	180631,5	574202,9	2577110,1	10376814,2

Source: Department of Statistics in the Ukraine [2]

Table 2. – Output parameters of the model for 2016

№	Regions	Output parameters	
		Gross output of agricultural enterprises, thousand of UAH [3]	Net profit (loss) of agricultural enterprises, thousand of UAH [2]
1	Vinnitsa	13794600	7868840,5
2	Volynskyi	2572200	982906,8
3	Dnipropetrovsk	9145900	4938865,6
4	Donetsk	4374400	1992536,1
5	Zhytomyr	4309700	2371627,9
6	Transcarpathian	355300	173275,1
7	Zaporozhye	5451400	4537547,6
8	Ivano-Frankivsk	1807000	-152990,8
9	Kievsky	10264800	6017469,1
…	……	…	…
20	Kherson	8864700	5324727,7
21	Khmelnytskyi	5782700	4243352,4
22	Cherkassy	7540300	3579681
23	Chernivtsi	11372800	6038252,6
24	Chernihiv	917600	94349,6

Source: Department of Statistics in the Ukraine [2, 3]

For the solution of the linear programming problem (5) - (8), it is necessary to fulfill the condition of non-negative variables. Since the activities of the agricultural enterprises of Ivano-Frankivsk region in 2016 were not profitable, we will exclude this region from estimating.

Thus the number of objects under consideration: $K = 23$; the number of input parameters: $m = 5$, and the number of output parameters: $n = 2$. Condition (4) is performed.

According to calculations, in 2016 agricultural enterprises of Vinnitsa, Volyn, Zhytomyr, Transcarpathian, Kirovograd, Lugansk, Lviv, Odesa, Poltava, Rivne, Kherson, Khmelnytsky, Cherkasy regions had the overall efficiency equal to 1. Among the 24 studied regions, the listed regions had an efficiency rank equal to 1. Estimates of the overall efficiency of agricultural enterprises of other regions of Ukraine and their rank of efficiency are in table 3.

Table 3. – Overall efficiency of the agricultural enterprises of the regions of Ukraine in 2016 and their rank by level of efficiency

№	Regions	Efficiency score	Rank
1.	Sumy	0,9793	2
2.	Kharkiv	0,9229	3
3.	Chernihiv	0,9219	4
4.	Zaporozhye	0,9184	5
5.	Chernivtsi	0,8779	6
6.	Nikolayevsky	0,8752	7
7.	Dnipropetrovsk	0,8533	8
8.	Donetsk	0,8451	9
9.	Ternopil	0,7899	10
10.	Kievsky	0,6577	11
11.	Ivano-Frankivsk	–	12

Source: own calculations

Table 4 shows the values of parameters characterizing the overall efficiency of activity of agricultural enterprises of regions of Ukraine in 2016.

Table 4. – Parameters characterizing the overall efficiency of the agricultural enterprises of the regions of Ukraine in 2016

№	Parameters	Values
1	Average overall efficiency	0,94
2	Standard deviation of overall efficiency	0,09
3	Maximum overall efficiency	1
4	Minimum overall efficiency	0,6577
5	Share of agricultural enterprises with overall efficiency >0,6 and <0,8, %	8,7
	>0,8 and <1, %	34,7
	=1, %	56,52

Source: own calculations

Thus, in 2016, the share of the regions having the maximum overall efficiency of agricultural production was 56,5%, 43,5% of the regions can improve production performance by reducing resource costs. The applied method allows to finding the target values of the input parameters, which will allow an inefficient enterprises to become 100% effective. For the regions listed in Table 3 we calculate the values of the input parameters that will allow them to become effective (see Table 5).

Table 5. – Recommended input parameters for agricultural enterprises of regions of Ukraine

№	Regions	Recommended input parameters				
		Labor costs, thousand of UAH	Social transfers, thousand of UAH	Amortization, thousand of UAH	Other costs,, thousand of UAH	Material expenses which were included in production price, thousand of UAH
1	Dnipropetrovsk	771690,4	172447,4	720995,9	2441938,8	11267817,8
2	Donetsk	320412,6	73117,4	315593,5	1084487,3	4713056,4
3	Zaporozhye	630649,2	140539,3	599371,4	1644078,9	7243849,9
4	Kievsky	941284,1	210927,7	808109,6	2758714,5	12978096,4

5	Nikolayevsky	471785,5	107244,8	469375,5	1525777,3	6603845,1
6	Sumy	583686,9	130845,5	525933,4	1876038,9	8106094,7
7	Ternopil	324346,4	73916,9	319188,2	1123191,2	4736297,5
8	Kharkiv	776781,9	173317,9	700911,7	2427858,2	10897874,7
9	Chernivtsi	85772,0	19315,1	77128,9	239709,5	1154642,2
10	Chernihiv	722551,2	163224,3	529369,5	2191252,4	9012230,7

Source: own calculations

From table 5 it follows, that, for example, to ensure 100% effective of agricultural enterprises of the Kyiv region, it was recommended to cut down the following costs: 1) labor: by 39,9%; 2) social transfers: by 39,3%; 3) amortization: by 34,2%; 4) other costs: by 34,2%; 5) material expenses which were included in production price: by 34,2%.

Findings. The paper investigates the practical use of DEA method in order to determine overall efficiency of agricultural enterprises. In the study estimates values of the overall efficiency of agricultural enterprises of the regions of Ukraine in 2016 and has calculated the target values of the input parameters, that will allow an inefficient enterprises to become 100% effective.

Долгіх Я.В.

Метод DEA при оцінці загальної ефективності діяльності сільськогосподарських підприємств України

Ціль статті – визначити за методом DEA загальну ефективність діяльності сільськогосподарських підприємств України.

Дослідження виконано методами економіко-математичного моделювання.

Проаналізовано теоретичні та методологічні аспекти визначення загальної ефективності сільськогосподарського виробництва за методом DEA. На основі статистичної інформації за 2016 р. оцінені рівні загальної ефективності сільськогосподарських підприємств регіонів України. Розраховані значення ресурсних показників, що дозволять неефективним

сільськогосподарським підприємствам регіонів України стати 100% ефективними.

Бібліогр.: 12.

Ключові слова: вхідні та вихідні показники, загальна ефективність, метод DEA, сільськогосподарські підприємства.

Долгих Я.В.

Метод DEA при оценке общей эффективности сельскохозяйственных предприятий Украины

Цель статьи – методом DEA определить общую эффективность сельскохозяйственных предприятий Украины

Исследование проведено методами экономико - математического моделирования.

Проанализированы теоретические и методологические аспекты определения общей эффективности сельскохозяйственного производства методом DEA. На основе статистической информации за 2016 г. оценена общая эффективность сельскохозйственных предприятий регионов Украины. Рассчитаны значения ресурсных показателей, позволяющие неэффективным сельскохозяйственным предприятиям регионов Украины стать 100% эффективными.

Библиогр.: 12.

Ключевые слова: входные и выходные показатели, общая эффективность, метод DEA, сельскохозяйственные предприятия.

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DEA method for estimating the overall efficiency of agricultural enterprises of Ukraine

The purpose of the article – is to determine by DEA method the overall efficiency of the production activity of agricultural enterprises in Ukraine.

The study was conducted by methods of economic and mathematical modeling.

The author has analyzed theoretical and methodological aspects of DEA method to estimate overall efficiency of the agricultural production.

In the study estimates values of the overall efficiency of agricultural enterprises of the regions of Ukraine in 2016 and has calculated the target values of the input parameters, which will allow inefficient enterprises to become 100% effective.

Bibliography: 12.

Keywords: inputs and outputs parameters, overall efficiency, DEA method, agricultural enterprises.

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