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EVALUATION OF THE EFFICIENCY OF NATIONAL DEFENSE, THROUGH THE DATA ENVELOPMENT ANALYSIS METHOD

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Abstract: *This paper highlights certain possibilities for measuring the efficiency and performance of organizations, of economic processes or labor productivity, based on a set of input and output values, through the Data Envelopment Analysis (D.E.A.) method. The method is used in many fields of activity, especially in the medical system, education, finance, logistics, military, etc. The model is flexible and can be used for a wide range of activities and areas, allowing organizations to observe the aspects that can be improved and track the progress of the analyzed decision units to achieve the set objectives. The paper presents relevant studies by some prestigious authors who applied the D.E.A method in the defense sector, thus demonstrating that the method is a valuable tool that can be used in the evaluation of the efficiency of the defense sector. The last part of the paper is devoted to the pragmatic presentation of how to use the method.*

Keywords: efficiency, defense as a public good, Data envelopment analysis

1. Introduction

Efficiency research has developed two broad currents of thought such as: the parametric model based on the stochastic frontier analysis (SFA) method, and the non-parametric model, which includes the Data Envelopment Analysis (DEA) method. The non-parametric model was highlighted for this paper, a method that measures the efficiency of the estimation model, through the optimal level of outputs conditioned by the amount of inputs. The method is often used in international studies and research, but very little used in studies in our country, which gives a novelty and originality to the application of this method.

2. Review of specialized literature

2.1. The important literature of the DEA method

The concept of the efficiency frontier appears for the first time through the work of Farrell (1957) and is based on the simple notion, according to which an organization that uses less inputs than another organization to produce the same amount of outputs (output/production/services), can be considered more efficient. The resulting "frontier" by drawing segments between the most effective observations thus "frames" or "wraps" all the analyzed observations.

William W. Cooper, is one of the pioneers of the Data Envelopment Analysis (DEA) method, being the one who made significant contributions to the development and popularization of the method. Cooper co-authored the first DEA paper, Programming and Data Analysis in Management Science (1978), which helped highlight DEA as a tool for evaluating efficiency in a decision-making system.

Lawrence M. Seiford is another important

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researcher who made significant contributions to the development, extension and refinement of this method, the most representative work being "*Data Envelopment Analysis: A Comprehensive text with models, applications, references, and DEA-Solver Software*" (1996). Another important author who made important contributions to the development and improvement of the accuracy of the DEA method is *Russell L. Rapanos*, through the paper "*Data Envelopment Analysis in Financial and Insurance Services*" (1998).

Joe Zhu is another author who made major contributions to the DEA method. His contributions in the paper "*Data Envelopment Analysis and its Applications: In Production, Finance, and Environment*" (2004) focused on the development of DEA models for use in environmental and resource analysis, integrating the DEA method with other methods and tools.

2.2. The literature that uses the DEA method in the field of defense sector

*Charnes A,*et al., in his studies, he followed for a period of seven months, maintenance and upkeep efficiency for aircraft of some units in the service of the US Air Force, developing a four-output, four-input indicator system; in another study, Pareto-Koopmans analysis was used, for determining the efficiency of the production function in the defense industry. Bowlin, carried out studies using the DEA analysis method, to determine the operational efficiency of the internal maintenance activities of air commands in specific trainings, using a system of three inputs and four outputs. In addition, Bowlin, used the DEA method to determine the financial performance of some companies in the defense industry, over a period of ten years, using three outputs and two inputs.

Clarke, used the DEA method to evaluate the productivity of 27 military vehicle maintenance and service units over a four-year period.

Hanson, used the input-oriented DEA method, using a four-input, three-output system, analyzing a sample of 11 units over a 4-year period.

DEA is an important tool for researchers, practitioners and decision makers who are interested in evaluating and improving the efficiency of organizational and economic systems. Although DEA is not without its limitations and criticisms, it remains a method that can be used to analyze production processes and identify opportunities for improvement.

3. Research methodology and data used

The Data Envelopment Analysis (DEA) method involves the application of linear programming techniques in establishing the efficiency frontier, determined only on the basis of extreme observations. The method is based on the simple notion that an organization that uses fewer inputs than another organization to produce the same amount of outputs is more efficient. The resulting "frontier" by drawing segments between the most effective observations thus "frames" or "wraps" all the analyzed observations. In Figure no. 1, observations A, B, C, and D are considered effective given the characteristics of the data. The position of observation E is indicated as inefficient, either by the vertical or horizontal distance from the "frontier" – because it uses more inputs to produce a similar level of output as observation B, despite using a similar amount of input as observation C while producing a smaller output.

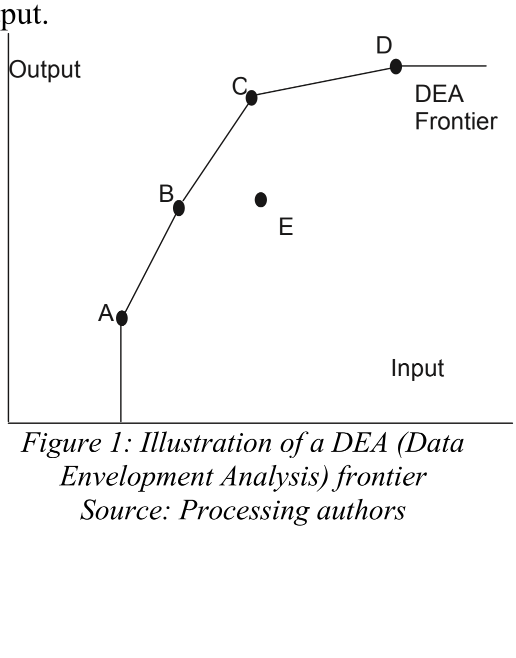

Figure 1: Illustration of a DEA (Data Envelopment Analysis) frontier
Source: Processing authors

Assuming that only one input (input, X) is used, for each observed unit (A, B, C, D, E), to produce a single output, unit E, follows with respect to each observation (DMU), to find based on a set of weights (importance/specific weight w^{O} and an efficiency score θ_{O}) ratio to maximize outputs (Y, output).

$$\theta_{O} = \frac{\sum_{r=1}^{s} y_{rO} w_{r}^{o}}{X_{o}} \qquad (1)$$

$$\frac{\sum_{r=1}^{s} y_{rj} w_{r}^{o}}{X_{j}} \leq 1, j = 1, \dots, n \qquad (2)$$

where w^{O} is the weight, which maximizes the apparent performance of organization O, subject to the imposition that, using that set of weights, no organization has an efficiency greater than 1. In other words, it searches among the targeted organizations, which of them produces the same amount (or more) of output, but at the lowest cost (a fraction $1/\theta_{O}$ from the costs X_{O} of the organization O).

4. Results, discussions and interpretations

As presented, the measurement of efficiency is generally determined by the ratio of total outputs to total inputs (eq 3). This principle is also used in the DEA method.

Efficiency =output/input (3)

4.1. The case of a single input and a single output

Based on the two measurement indicators, an input measure (budget - expressed in million €), and an output measure (Maneuver (land warfare): tanks and combat vehicles - operational (2021); - expressed in points (IISS Military Balance 2021)we believe that the performance of military units (A, B, C, D) can be determined, as shown in table no. 2.

Table 2 Input output indicators

UNIT	A	B	C	D
Input (budget) – mil.€	8,6	2,2	15,6	31,6
Output (maneuver) - pct.	1,8	0,2	2,8	4,1

Source: processing authors

It is observed that units absorb different amounts of inputs and produce different levels of outputs. Given this data, however, how can performance be measured? The easiest approach is by relating the outputs to the inputs, according to eq. 3. Since in this case, there is only one input and one output, the calculation of this ratio is simple. These data are shown in table no. 3.

Table 3: Performance comparison by output / input ratio

UNIT	A	B	C	D
Input (budget) – mil.€	8,6	2,2	15,6	31,6
Output (maneuver) - pct.	1,8	0,2	2,8	4,1
Output/Input	0.209	0.091	0.179	0.130

Source: processing authors

It is observed that unit A, recorded the highest efficiency (added value) compared to the committed budget, while unit B recorded the lowest efficiency among the four units. Since drive A has the highest ratio, we can compare the performance of the other drives relative to that of drive A. Through the stability of the fact that the performance of unit A is 100% efficient, the relative efficiency obtained by the other units can be calculated, in relation to the performance obtained by unit A, as shown in table no. 4.

Table 4: The relative efficiency of the units compared to the efficiency achieved by unit A

UNIT	A	B	C	D
Output/Input	0.209	0.091	0.179	0.130
Relative efficiency %	100.0	43.4	85.8	62.0
Output/Input	0.209	0.091	0.179	0.130

Source: processing authors

The main assumption underlying the relative efficiency calculation, is that,
if a given unit, say unit A, is able to produce Y(A) amounts of output using X(A) amounts of input, then the other units (B, C, D) should be able to do the same, if they were operating as efficiently.

Thus, performance targets can be established for inefficient units (B,C,D),in order to enable them also to reach 100% relative efficiency compared to unit A, the most efficient of them. If unit A operates in a similar environment to the other units, it can be stated as a realistic assumption that the performance recorded by this unit can be used as a benchmark.

The input target, for unit B, is the committed budget that will allow the unit to have the same maneuver-to-budget ratio as unit A.

Input target = (relative efficiency* actual input)/100 (4)

For the unit B,

Input target B = $\frac{2,2 \times 43,4}{100}$ = 0,95 mil€.

This means that if unit B operates using only €0.955 million as an input, and still produces 0.2 pts of maneuver, this unit can be considered as efficient as unit A.

For units whose performance has been determined to be ineffective, an entry target needs to be established. This target will necessarily be lower than the actual input used. The resulting difference between the actual input and the input target is called Input slack (excess input, or unused input), and is given by the equation:

Excess input = Actual input – Target input (5)

Input slack B= 2.2 – 0.955

= 1.245 mil. €.

Excess input can also be expressed as a percentage using the following formula:

Percent Surplus Entry = (Input slack/ actual input)*100(eq 6)

Slack input percentage B

$= \frac{1.245}{2.2} \times 100 = 56,6\%$

Thus, if for unit B it is desired that its performance be as high as for unit A, unit B should produce the same amount of output using 56.6% less input. For all other units, Input Targets and Excess Inputs can be determined in a similar manner.

Applying similar logic, both output targets and output slack (Output Slack, or unused output) can be determined.

Output target = **(**actual output / actual output) *100 (eq7)

Output Slack = Output target - Actual output

Output Slack B = 0.46 – 0.2

= 0.26 pct.

The percentage of Output Slack = (Output Slack / actual output)*100 (eq8)

The percentage of Output Slack B =

$= \frac{0.26}{0.2} \times 100 = 130\%$

Thus, if unit B is to achieve the same level of performance as unit A, unit B should increase its maneuverability score by 0.26 points or 130% for the same input level (budget).

4.1. The case of two inputs and one output

In practice, a large amount of resources are used in the production process, and no organization consumes only one input to produce one output. Thus, to the previous data, another set of input data will be added - the number of employees (hundreds of military personnel), as shown in table no. 5.

Table 5: Adding an extra entry for the four units

Unit	*A*	*B*	*C*	*D*
Input 1 Budget- mil.€	8,6	2,2	15,6	31,6
Input 2 Number of employees - thousands of military personnel	1,8	1,7	2,6	12,3
Output Maneuver - pct.	1,8	0,2	2,8	4,1

Source: processing authors

The question arises: How can the performance of organizations now be compared? Can the output to input ratio method still be used? If so, in this situation, there would be two reports. The calculations are presented in table no. 6.

Table 6: Comparing efficiency by reporting the indicator of. output at each input

Unit	*A*	*B*	*C*	*D*
Output /Input1	0,209	0,091	0,179	0,130
Output /Input2	1,000	0,118	1,077	0,333

Source: processing authors

It is worth noting that unit A produced the highest value for the Output/Input1 ratio, while unit C produced the highest value for the Output/Input2 ratio. Since it is not known which of the ratios is more important, we cannot consider unit A to be more efficient than unit C or vice versa. What can be concluded, however, is that units B and D are less efficient than units A and C, as the output-input ratio results are lower.

5. Conclusions

The paper mainly presents the method of non-parametric analysis of the D.E.A. efficiency, based on the simple notion, according to which an organization that uses less inputs than another organization to produce the same amount of outputs (output/production/services), can be considered more efficient. The paper described the concepts of efficiency measurement in two cases. The case of efficiency measurement when there is only one input and only one output, and the case where there are two inputs and only one output were analyzed. Efficiency or inefficiency was estimated for the decision units in the model, depending on the results of the output-input ratios.

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