FOLIA POMERANAE UNIVERSITATIS TECHNOLOGIAE STETINENSIS
Folia Pomer. Univ. Technol. Stetin. 2012, Oeconomica 298 (69), 5–14.

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THE USE OF THE DEA METHOD TO MEASURE THE EFFICIENCY OF THE PRODUCTION PROCESS BASED ON A GROUP OF FARMS

WYKORZYSTANIE METODY DEA DO BADANIA EFEKTYWNOŚCI PROCESU PRODUKCYJNEGO NA PRZYKŁADZIE GRUPY GOSPODARSTW ROLNYCH

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Streszczenie. Do metod badania efektywności produkcji, oprócz metod wskaźnikowych, zaliczane są metody parametryczne i nieparametryczne. W niniejszym opracowaniu wykorzystano nieparametryczną metodę DEA oraz w celu porównania otrzymanych wyników z danymi rzeczywistymi – elementy analizy wskaźnikowej. Do opracowania wykorzystano dane za lata 2004–2008 opracowane przez Polski FADN.

Key words: DEA method, efficiency, FADN, index analysis.
Słowa kluczowe: efektywność, FADN, metoda DEA, metoda wskaźnikowa.

INTRODUCTION

The term ‘efficiency’ is associated with a number of key conceptual categories in economics. According to Figiel, ‘Efficiency is not an explicit concept and can be understood, measured and interpreted differently, depending on the subject of analysis. Thus, the concept of efficiency used in many different problem contexts, acquires specific meaning when it refers to the economic system, market, economic entity, process or actions’ (Figiel 2011).

Among the methods for measuring efficiency of production, except for index methods, one may additionally use parametric and non-parametric methods. For the purpose of this study, the non-parametric DEA method (Guzik 2009) shall be used and in order to compare the obtained results with the actual data – some elements of index analysis shall also be used.

The non-parametric method, which is called Data Envelopment Analysis (DEA), was proposed by Charnes, Cooper, and Rhodes (Charnes et al. 1978). Using the concept of productivity, which was formulated by Debreu (Debreu 1951) and Farrell (Farrell 1957), they adapted it to a multidimensional situation. This multidimensionality means that there is more than one output and more than one input at disposal. An additional advantage of this method is that it does not require the pre-specified parameters of the model, relating inputs to outputs. The use of the DEA method will allow indication of the properly managed areas among the group of farms being studied.

Given the above, the purpose of this article, is the use of the DEA method to evaluate the efficiency of the production process in the group of farms of Pomerania and Masuria region,

specialising in field crops. For this study, data from the Polish FADN database for the years 2004–2008 was used. Broader studies are included in the dissertation (Barczak 2011).

METHODOLOGY OF THE STUDY

A starting point of the DEA method refers to the concept of productivity (which is defined as the ratio of inputs to outputs) for the multidimensional case. Given *s*-outputs and *m*-inputs, the efficiency of the object takes the form (Rogowski 1996, Rusielik 2000):

$$\text{EFFICIENCY} = \frac{\sum_{r=1}^{s} u_r OUTPUTS_r}{\sum_{i=1}^{m} v_i INPUTS_i}$$

Where:

u_r – weighted sum of outputs

v_i – weighted sum of inputs

One of the characteristics of the DEA model is a possibility to bring *m* inputs and *s* outputs to the synthetic value. This allows the calculation of the efficiency ratio, which is a maximised objective function in linear programming model. The mathematical representation of the model is as follows (Wait, Ziółkowska 2009):

$$F(u,v) = \frac{\sum_{r=1}^{s} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \rightarrow \max,$$

Where empirical data is:

x_i – inputs,

y_r – outputs.

with the restrictive conditions (Rusielik 2000):

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad for\ j = 0,1,...,n \qquad \text{and} \quad \mathbf{u_r, v_i} \geq 0.$$

This issue can be represented by a linear programming task. It takes the following form (Nykowski 1984, Rusielik 2000, Bezat 2011):

$$\max_{u,v} = u^T Y_o$$

under conditions:

$$v^T X_o = 1,$$
$$u^T Y - v^T X \leq 0,$$
$$u^T \geq 0 \ and \ v^T \geq 0,$$

whose dual task is:

$$\min_{\Theta,\lambda} \Theta$$

with restrictions:

$$\mathbf{Y\lambda} \geq \mathbf{Y_o},$$
$$\Theta \mathbf{X_o} - \mathbf{X\lambda} \geq 0,$$
$$\lambda \geq 0$$

The dual linear programming task, formulated in such a way, is solved for all the objects under study.

The application of the DEA method is associated with the limitations on its use (Bezat 2011):

- When using the method, it is not possible to estimate the measurement error, resulting from the fact that the DEA is a deterministic method.
- Exclusion of significant input or output may lead to the change of the efficiency index value.
- Results of the efficiency measurement may vary depending on the orientation of the model on outputs or inputs, and depending, for example, on the degree of aggregation of units (specification of variables).
- Efficiency index is determined relatively, in relation to the best decision-making units in the analysed sample. Efficiency indexes of individual objects have a tendency to decrease the value when the number of investigated objects increases (Zhang, Bartels 1998), (Banker 1989).
- Since the DEA is a tool of measuring the relative efficiency, the results cannot be compared with the results obtained from other samples.
- Inclusion of an additional decision-making unit cannot increase the efficiency index of another unit.
- Inclusion of an additional input or output cannot result in reduction of efficiency indexes.
- By increasing the number of inputs and outputs, for a small sample, higher values of efficiency indexes can be obtained.
- Failure to take into account the impact of the external environment on the decision-making unit can lead to incorrect conclusions regarding the internal environment.

Given all of the above limitations, of the DEA models, outputs and inputs were accepted, taking into consideration, inter alia the experience of foreign authors who are engaged in agricultural research. The publications of Prasada Rao and Battese and Coelli (Battese

1992), (Prasada Rao, Coelli 1998), as well as (Lansink et al. 2002), (Aldaz, Millan 2003), (Alene et al. 2006), (Galanopoulus et al. 2006) were used herein.

Due to the fact that the literature provides many efficiency indexes, for the purpose of this article, the following indexes were selected:

The relative amount of the costs index (cost index) – the percentage ratio of the economic costs (inputs) to the value of production (gross revenues):

$$W_C = \frac{C \cdot 100}{V}$$

where:

C – Economic costs or otherwise formulated inputs,

V – Value of production or gross revenue.

When the index value is equal to 100, the production brings neither profit nor loss (Rychlik, Kosieradzki 1976, Kopeć, Nietupski 1980, Adamowski 1983). The lower the value of index, the more profitable the farm (or production) is, and the higher the value of index, the scarcer the farm is.

Profitability index (index of the relative profitability of production) – is the reverse of the previous index that is the percentage ratio of the value of production (gross revenue) to the economic costs (inputs):

$$W_O = \frac{V \cdot 100}{C}$$

When the index value is equal to 100, the production brings neither profit nor loss (Rychlik, Kosieradzki 1976, Kopeć, Nietupski 1980, Adamowski 1983). The higher the value of index, the more profitable the farm (or production) is, and the lower the value of index, the scarcer the farm is.

For the above given group, indexes of productivity of labour, land and capital were also included. Due to the fact that these inputs belong to the factors of production being studied that affect its value. Furthermore, 'the study of the relationship between the results of agricultural production and the resources of production factors involved in the manufacturing process is one of the basic methods of economic evaluation of management results' (Rychlik 1977).

Labour productivity index is calculated from the formula (Rychlik, Kosieradzki 1976, Rychlik 1977, Manteuffel 1981):

$$W_L = \frac{V}{L}$$

where:

L – input of human labour

Labour productivity is the most widely used index of technical and economic efficiency in all sectors of national economy. It denotes the value of production per unit of work used to obtain production.

Land productivity index is calculated from the formula:

$$W_A = \frac{V}{A}$$

where:

A – the area of agricultural land

It is the ratio of farm production to the area of agricultural land. The more agricultural production is obtained from 1 hectare of agricultural land, the higher is the land productivity.

Capital efficiency index is calculated from the formula:

$$W_K = \frac{V}{K}$$

where:

K – Investment

It is the ratio of the production value to the capital value, employed on the farm.

FINDINGS

Figures 1–4 present a graphic image of a combination of the most efficient use of inputs using the DEA method for a group of farms specialising in field crops. In order to illustrate the results in a better way, the volume of output and input of production factors have been compared with actual values.

The DEA method showed the volume of production to be effective in 2004–2005 and in 2007. At other times, the method generated higher values – by 62 841 28 zł in 2006 and by 11 100 31 zł in 2008 (Fig. 1).

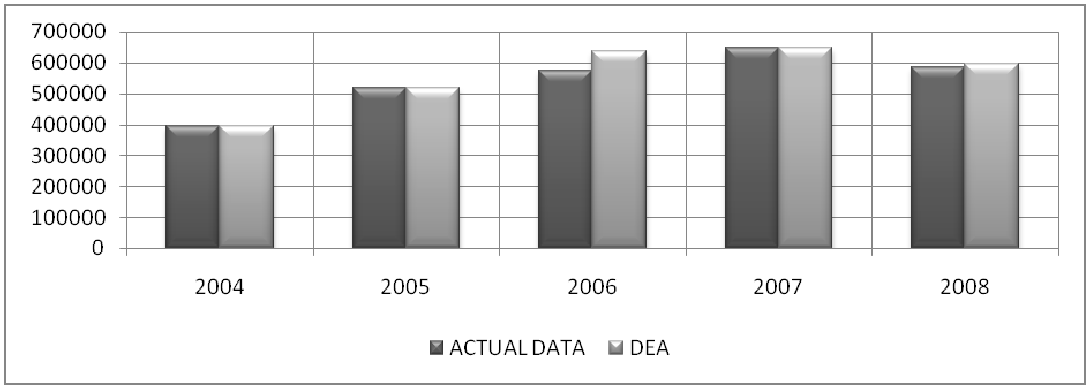

Fig. 1. The value of production of the group of farms specializing in field crops, actual and determined using the DEA method
Source: Own elaboration based on FADN data.

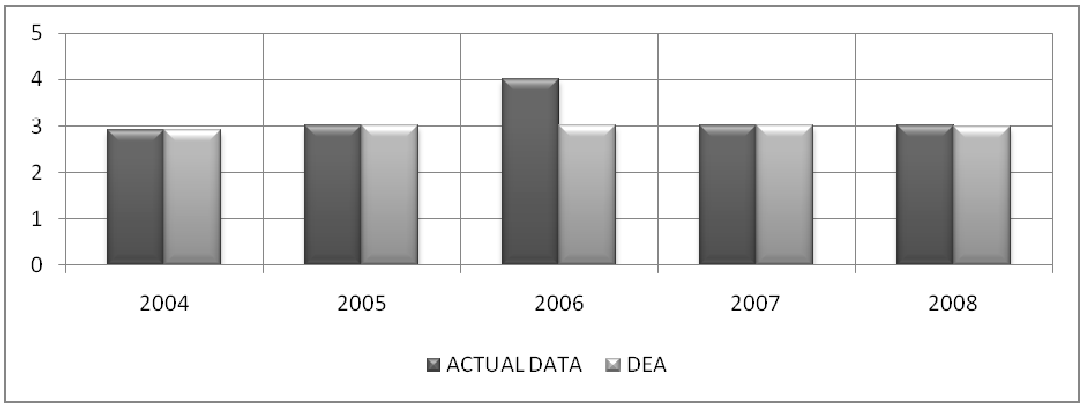

Fig. 2. Labour input in the group of farms specialising in field crops, actual and determined using the DEA method
Source: Own elaboration based on FADN data.

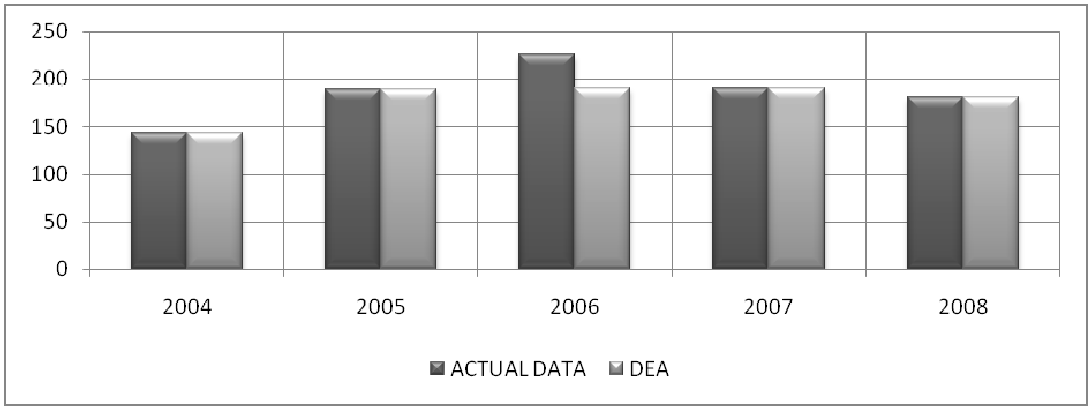

Fig. 3. Land input in the group of farms specialising in field crops, actual and determined using the DEA method
Source: Own elaboration based on FADN data.

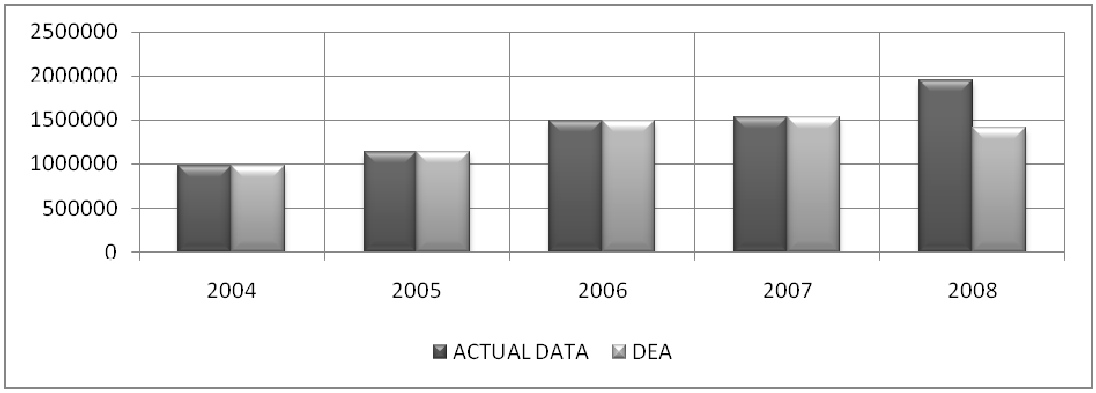

Fig. 4. Capital input in the group of farms specialising in field crops, actual and determined using the DEA method
Source: Own elaboration based on FADN data.

According to the results generated by the DEA method, in 2006, production which is higher by 62,841.28 zł can be achieved by reducing the workforce by 1 AWU, which is an increase by 33.33% (Fig. 2) and land input by 35.09 ha – 18.38% (Fig. 3).

In 2008, the effective process which enables achieving production which is higher by 11 100 31 zł presupposes the reduction in employment by 0.021 AWU – 0.70% (Fig. 2), and at the same time reduction of capital input by 539 667 20 zł, that is by 38.11% (Fig. 4).

Figures 5–9 present the development of indexes of production factors efficiency and indexes of the relative amount of the costs and profitability.

In case of the labour productivity index, in 2004–2005 and in 2007, it is at the same level in case of actual data and the results obtained by means of the DEA method. In 2006, labour productivity for the DEA method is 47.89% higher than for the actual data, and in 2008 – higher by 2.61% (Fig. 5).

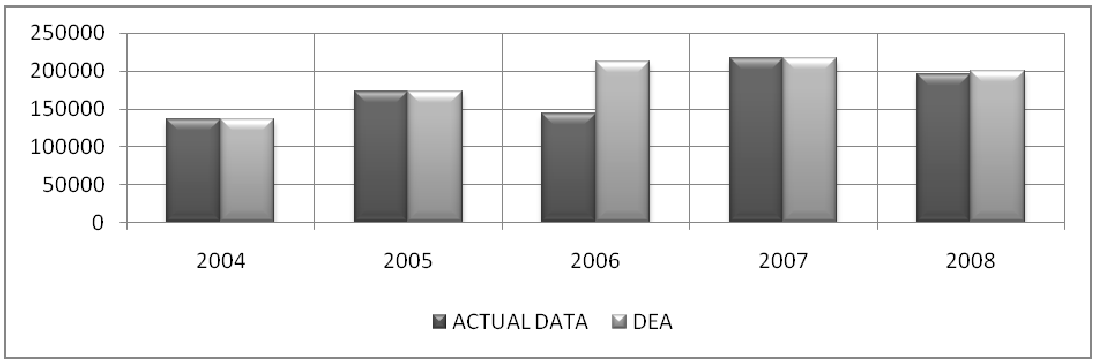

Fig. 5. Labour productivity indexes in the group of farms specialising in field crops, for the actual data and values determined using the DEA method
Source: Own elaboration based on FADN data.

In the case of the land productivity index, in 2004–2005 and in 2007 the actual data is at the same level as the results obtained by means of the DEA method. In 2006, land productivity for the DEA method is by 31.31% higher than for the actual data and in 2008 higher by 1.89% (Fig. 6).

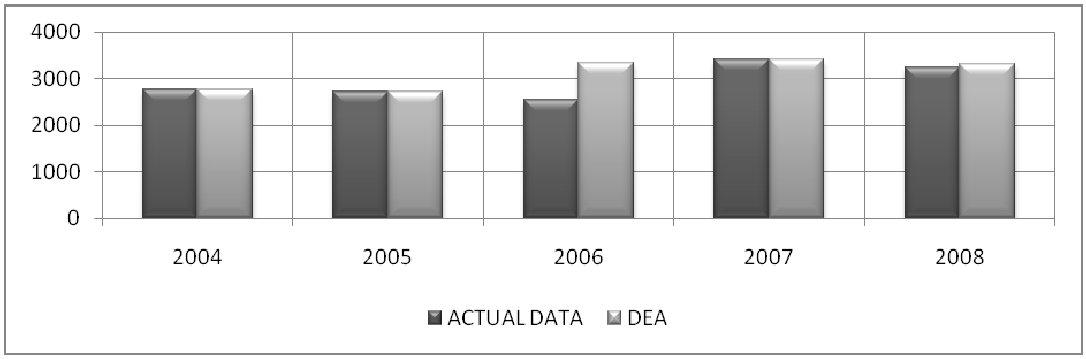

Fig. 6. Land productivity indexes in the group of farms specialising in field crops, for the actual data and values determined using the DEA method
Source: Own elaboration based on FADN data.

A similar situation can be observed with the capital productivity index, in which actual data for the years of 2004–2005 and in 2007 is at the same level as the results obtained by means of the DEA method. In 2006, capital productivity for the DEA method is by 10.92% higher than for the actual data and in 2008 – it is higher by 40.73% (Fig. 7).

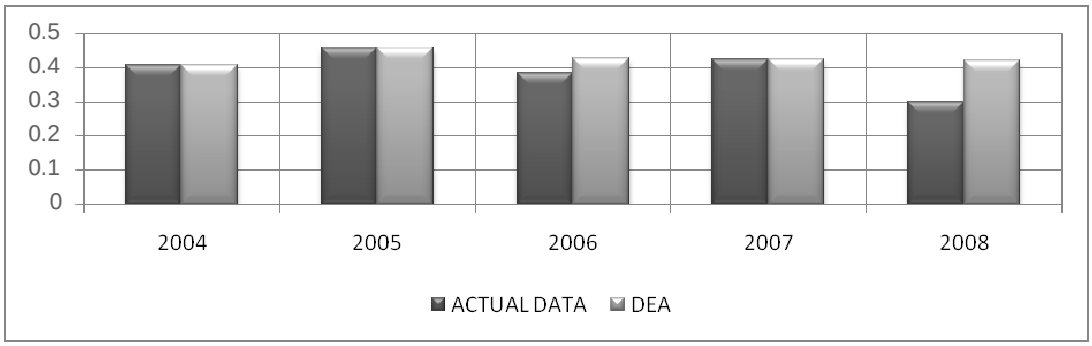

Fig. 7. Capital productivity indexes in the group of farms specialising in field crops, for the actual data and values determined using the DEA method
Source: Own elaboration based on FADN data.

The values of the relative amount of the costs index for the years of 2004–2005 and 2007 are at the same level for both the actual data and the results obtained by means of the DEA method. In 2006, the index value for the DEA method is 10.39% lower than for the actual data, and in 2008, it is lower by 2.01% (Fig. 8).

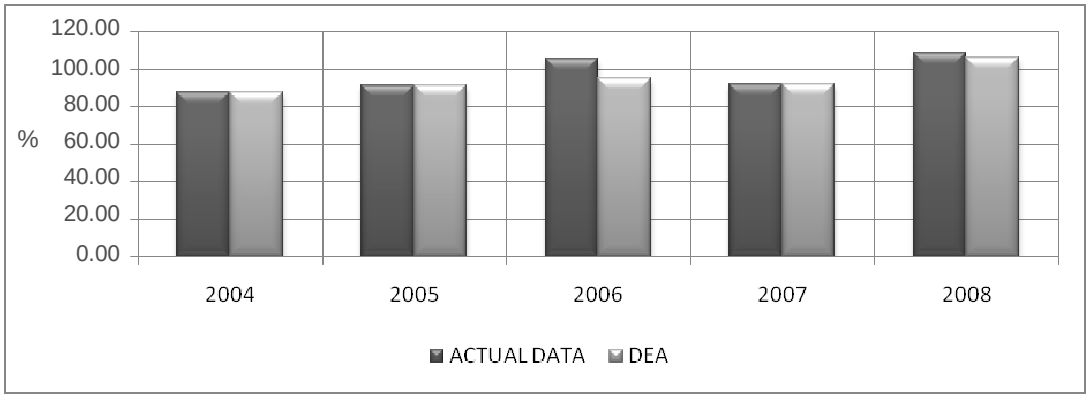

Fig. 8. Relative amount of the costs indexes in the group of farms specialising in field crops, for the actual data and values determined using the DEA method
Source: Own elaboration based on FADN data.

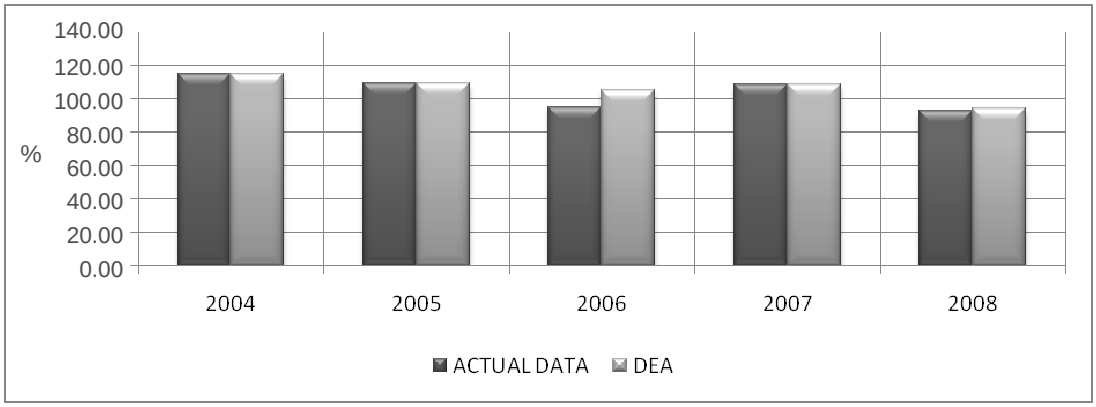

Fig. 9. Relative profitability of production indexes in the group of farms specialising in field crops, for the actual data and values determined using the DEA method
Source: Own elaboration based on FADN data.

Similarly, as in the case of other indexes, the values of the relative profitability of production index in 2004–2005 and 2007 are at the same level for actual data and the results obtained by means of the DEA method. In 2006, the index value for the DEA method is 10.35% higher than for the actual data and in 2008, it is higher by 1.75%.

The index analysis shows that both indexes of efficiency of inputs of production factors and the profitability and relative amount of costs index, confirm greater a efficiency of results obtained using the DEA method.

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