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EFFICIENCY OF THE PRODUCTION SCALE OF POLISH DAIRY COMPANIES BASED ON DATA ENVELOPMENT ANALYSIS

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Abstract. This article presents evaluation of efficiency of the production scale of Polish milk processing companies in 1999–2010 performed basing on non-parametric methods. The non-parametric approach stemmed from linear programming method known as the Data Envelopment Analysis (DEA) method. The study involving a sample of 743 objects revealed increasing returns to scale observable in the Polish dairy sector. Further concentration of the dairy sector in Poland should lead to the better results of dairies. This analysis confirmed earlier conclusions of relevant literature.

Key words: production scale, efficiency, dairy sector, Data Envelopment Analysis (DEA) method

INTRODUCTION

Integration with the European Union and ongoing liberalization of international trade has been gradually leading to globalization of the diary market and expansion of the competition area. The dynamically changing environment of the Polish diary companies shows that there is a strong need for a well-thought-out and consistently implemented strategy setting clear objectives with regard to ensuring competitiveness and development. Despite significant transformations that have taken place in the Polish diary business due to market-opening, the sector still lacks sufficient international competitiveness, which results among other things from unfavourable structure (strong dispersion – both with regard to farms and processing plants) and low productivity. In the Polish milk processing sector there are approximately 200 business entities in operation. In Germany the number of diaries is similar to the Polish figures, but it should be stressed that they process over three times as much milk as in Poland with the employment level lower by

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18% [Seremak-Bulge 2009]. What is more, the Polish diary sector loses its international price competitiveness[1] basing on cheap raw material. In 2009 diaries in countries like Germany, Ireland or the Netherlands paid farmers similar prices for milk, and in Belgium the prices were even lower than in Poland [*Rynek mleka. Stan i perspektywy*... 2009].

Thus, it can be stated that there is a need to improve efficiency and competitiveness of milk processing. Processing efficiency and competitiveness may be increased through growth of production concentration, which should lead to better operational efficiency of milk processing thanks to – among other things – using scale effect and taking advantage of complementarity of resources and skills. The growth of the production scale of diary companies should affect the development of product innovations and bolster the bargaining power with regard to the sale of dairy products.

The concentration of milk processing involves a growth of the scale of production of dairy companies. It should be stressed that so far the problem of analysis and measurement of the effectiveness of the scale of production has not been handled with any common and consistent solution, either in theory or in practice. In the literature a distinction is made among i.a. classic, parametric and non-parametric approach to the analysis of scale efficiency [Pawłowska 2005, Guzik 2009].

In foreign literature it is believed that the milk processing sector exhibits increasing returns to scale [Wiendlmeier 2001, Thiele 2005]. German studies prove that it is possible to significantly reduce unit prices thanks to increasing the scale of dairy production [Wiendlmeier 2001].

The Polish specialist literature does not offer any detailed analysis on the presence of economies of scale in milk processing, either any assessment of the scope of potential benefits arising from scale effect. There is also a gap in the domestic literature with regard to the evaluation of the scale efficiency of milk processing companies basing on different variants of the production function and DEA method. Therefore, the reasons presented above illustrate that it is necessary to address the very important issue for the dairy sector.

The major purpose of the article is to define the type of returns to scale of production of Polish processing companies using non-parametric method for scale efficiency evaluation. In this article the following research hypothesis was formulated: Polish milk processing companies experience increasing returns to scale.

MATERIAL AND METHODS

The studies undertaken cover the Polish milk processing sector in years 1999–2006 (identified as group 10.5 in accordance with the Polish Classification of Activities – standing for milk processing and cheese production, ice cream production excluded). The research objects were selected taking into consideration the pre-defined criteria [Stachak 2003]. The sample included cooperatives operating in the dairy industry and companies having a different legal form which published financial statements in years 1999–2010 in

[1] As a consequence of the price increase process in Poland and reduction of prices in Europe.

the Official Journals of the Republic of Poland: "Monitor Spółdzielczy – B" and "Monitor Polski – B". Companies selected from milk processing companies which published financial statements fulfilled the following conditions:

- they prepared an account statement by nature of expenses and
- they achieved more than 70% of revenues from the sale of products.

The first criterion was adopted due to the fact that it was necessary to obtain data needed to achieve the major study objective, i.e. to specify the type of increasing returns to scale in the milk processing sector. The second criterion allowed for evaluating the scale efficiency of companies which actually deal with milk processing, and not companies pursuing a commercial activity as their major source of revenues. The number of companies in the sample corresponded with 28–39% of the number of dairy sector entities depending on the year.

Based on the sample efficiency of the scale of production was evaluated using non-parametric methods. The non-parametric approach to the analysis of the scale efficiency relied on the linear programming methods defined as Data Envelopment Analysis (DEA). The DEA model may be presented mathematically in the following manner [Cooper et al. 2007]:

$$\max \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \qquad u_r, v_i \geq 0$$

where: s – quantity of outputs,
m – quantity of inputs,
u_r – weights denoting the significance of respective outputs,
v_i – weights denoting the significance of respective outputs,
y_{rj} – amount of output of r-th type ($r = 1, \ldots, R$) in j-th object,
x_{ij} – amount of input of i-th type ($n = 1, \ldots, N$) in j-th object ($j = 1, \ldots, J$).

In the DEA model m of inputs and s of diverse outputs come down to single figures of "synthetic" input and "synthetic" output, which are subsequently used for calculating the object efficiency index [Rogowski 1998, Rusielik 1999]. The quotient of synthetic output and synthetic input is an objective function, which is solved in linear programming. Optimized variables include u_r and v_i coefficients which represent weights of input and output amounts, and the output and input amounts are empirical data [Cooper et al. 2007].

By solving the objective function using linear programming it is possible to determine the efficiency curve called also the production frontier, which covers all most efficient

units of the focus group[2]. Objects are believed to be technically efficient if they are located on the efficiency curve (their efficiency index equals 1, which means that in the model focused on input minimization there isn't any other more favourable combination of inputs allowing a company to achieve the same outputs). However, if they are beyond the efficiency curve, they are technically inefficient (their efficiency index is below 1). The efficiency of the object is measured against other objects from the focus group and is assigned values from the range (0, 1). In the DEA method Decision Making Units (DMU) represent objects of analysis [Charnes et al. 1978].

The DEA models may be categorized based on two criteria: model orientation and type of returns to scale. Depending on the model orientation a calculation is made of technical efficiency focused on the input minimization or of technical efficiency focused on the output maximization (effects). But taking into account the type of returns to scale the following models are distinguished: the CCR model providing for constant returns to scale (the name derives from the authors of the model: Charnes-Cooper-Rhodes), the BCC model providing for changing return to scale (the name derives from the authors of the model: Banker-Charnes-Cooper and the NIRS model providing for non-increasing returns-to-scale) (Fig. 1). The CCR model is used to calculate the overall technical effi-

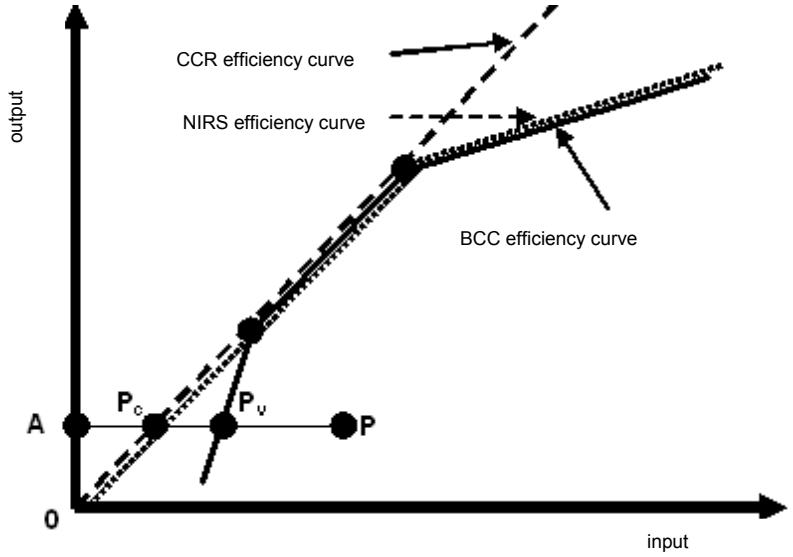

Fig. 1. Scale efficiency according to the DEA method (model: 1 output and 1 input)

Source: Prepared based on Coelli et al. 2005.

[2] The graphical presentation of the efficiency curve is possible for models: 1 input and 1 output, 2 inputs and 1 output or 1 input and 2 outputs. In case of multidimensional models the curve equivalent incorporates a few fragments of different hyperplanes linked to each other.

ciency (Technical Efficiency – TE), where TE for P object = APC/AP. The BCC model is used to calculate pure technical efficiency (Pure Technical Efficiency – PTE), where PTE for P object = APV/AP [Coelli et al. 2005].

With the overall technical efficiency and pure technical efficiency calculated, it is possible to determine the object scale efficiency (Scale Efficiency – SE) according to the formula: SE for P object = AP_C/AP_V, i.e. SE = TE/PTE. Scale efficiency (SE) calculated in this manner denotes the degree to which the object is efficient in relation to the optimum enabling the maximal use of inputs. Objects with scale efficiency at the level of 1 experience constant returns to scale. However, scale efficiency calculated in the manner described above does not make it possible to identify objects with increasing returns to scale and objects with decreasing returns to scale. The character of scale (increasing or decreasing) for a particular object may be defined by comparing the NIRS technical efficiency level with the overall technical efficiency (TE). If the figures are equal, it proves that the scale for a given object is increasing. However, if the figures are not equal, the object exhibits decreasing returns to scale [Coelli et al. 2005].

RESULTS AND DISCUSSION

At the first stage of the study a set of variables for the models of Data Envelopment Analysis models was defined. According to the literature total production is normally measured by its volume, i.e. a set of manufactured products expressed either in physical units or in fixed prices [Welfe and Welfe 1996]. In this study total production was measured by revenues earned due to the sale of products, goods and materials (in PLN thou). Due to high diversification of products in milk processing it was difficult to apply other quantitative measure of production (for example – a ton of butter is not comparable with a ton of yogurt).

Production factors are variables explaining the production volume. In the theory of economics a distinction is made of three major production factors, i.e. human labour, objectified labour (capital) and land. As a rule, in non-agricultural companies the land element does not play a vital role, and that is why it is often omitted or replaced with the raw material and material factor [Kamerschen et al. 1992, Samuelson and Marks 1998]. In connection with the above the factor of materials has been defined as costs of material and energy consumption (in PLN thou). The human labour factor is often measured in the literature as manhours or the number of workers [Keat and Young 2003]. Given the data availability the measure of the labour factor was defined in the study as labour costs, i.e. the total cost of wages and social insurance contributions and other benefits for employed people (in PLN thou). According to the literature capital represents the most diversified production factor. The factor involves own funds, acquired loans or unpaid liabilities, as well as elements represented in the form of resources (machinery, production lines, equipment, transportation means, buildings and building structures etc.) [Mercik and Szmigiel 2007]. Given the above, capital in this study was defined to be measured as the value of fixed assets (in PLN thou).

Efficiency of the production scale of dairy companies in years 1999–2010 was evaluated in accordance with the non-parametric method, based on Data Envelopment Analy-

sis (DEA) models. The applied DEA models were focused on minimization of inputs[3], and variables of the models were defined as:

- output: revenues earned due to the sale of products, goods and material (in PLN thou);
- input 1: labour costs, i.e. total costs of wages and social insurance contributions and other benefits (in PLN thou);
- input 2: costs of material and energy consumption (in PLN thou);
- input 3: value of fixed assets (in PLN thou).

For each analyzed year a calculation was made of models providing for constant returns to scale and models providing for variable returns to scale. In the next step a scale efficiency index was determined as a quotient of overall technical efficiency and pure technical efficiency.

In years 1999–2010 the analyzed milk processing companies experienced a growth of an average level of the scale efficiency index (SE) from 0.80 to 0.96 (a median from 0.82 to 0.98) (Fig. 2), which shows that in the period under investigation the average scale of production of the companies reached the optimum level. It should be stressed that a systematic improvement of scale efficiency of dairy companies had been observed since 2002, which can be attributed to the intensification of merger and acquisition processes [Pietrzak and Dworniak 2010].

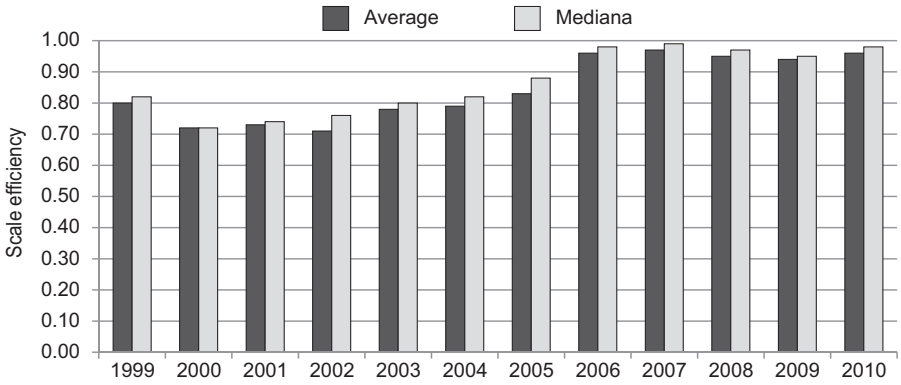

Fig. 2. Scale efficiency index of dairy companies in years 1999–2010

Source: Own work.

[3] In the dairy sector there are administrative restrictions of production volume under the milk quotas system. Given this, milk processing companies striving to maximize outputs (production/revenues, and indirectly also processing) may encounter some problems in this respect. Therefore, the application of the output-oriented DEA model which maximizes results keeping consumed inputs at the same level seems not to be fully justified. The second argument against the DEA models focused on the maximization of outputs and providing for a specific level of inputs arises due to the fact that the domestic demand for dairy products is stable, and it can be even noticed that in the examined period of 1999–2010 it displayed a downward trend. Thus, taking into consideration the above, the potential for the growth of production and sales in milk processing is limited, and so is the possibility to maximize sales revenues. According to the author it is more appropriate to use an input-oriented model. The model minimizes inputs of an object so as to make it efficient, keeping at least the same level of achieved results.

Based on the scale efficiency index (SE) objects operating in the range of constant returns to scale were identified, i.e. objects with SE index equaling 1. The percentage of dairy companies achieving constant returns to scale in the sample amounted on average to 9% (Fig. 3). Calculation of the scale efficiency index for remaining objects allowed only for determining the degree of efficiency of a particular company in terms of scale in relation to companies with an efficient production scale.

Dairy companies with increasing and decreasing returns to scale were identified using a method based on non-increasing returns to scale. The NIRS model indices were compared to pure technical efficiency value (calculated based on the BCC model). The analyses conducted proved that in years 1999–2010 on average 69% of examined dairy companies experienced increasing returns to scale, and 22% – decreasing returns to scale (Fig. 3).

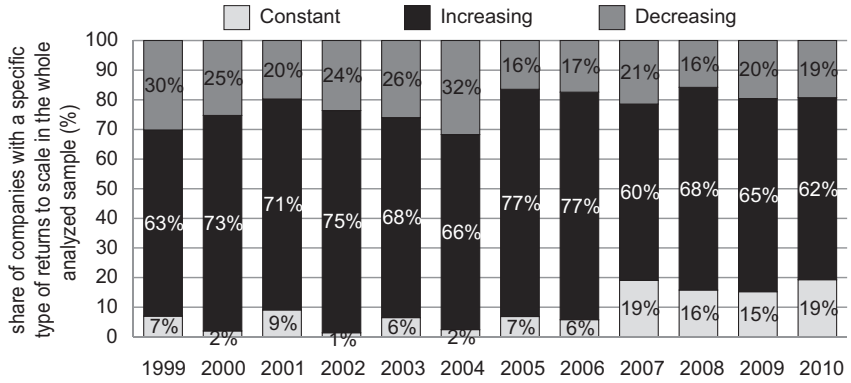

Fig. 3. The type of returns to scale of milk processing companies evaluated based on the DEA method

Source: Own work.

Relying on non-parametric methods it can be assumed that the Polish milk processing sector in years 1999–2010 was characterized by increasing returns to scale, which is in line with the present conclusions presented in relevant literature [Pijanowski and Gaweł 1986, Guba 2000, Pietrzak 2007, Baran 2009]. It means that in most analyzed dairy companies (on average above 70%) the pace of production growth was higher in percentage terms than the growth pace of inputs (production factors). In consequence, the companies achieved increasing returns to scale and falling long-term average costs. Thus, it can be assumed that further growth of the production scale of these companies will contribute to bringing them in the area of constant returns to scale, and thus, to the improvement of their efficiency[4].

[4] Confirmation of higher efficiency of companies experiencing constant returns to scale was presented among other things in an article by J. Baran "The returns to scale in relation to economic-financial results of dairy companies in 2004–2006", Zeszyty Naukowe SGGW, EiOGŻ 76/2009, 95–108.

CONCLUSIONS

The studies conducted for the purpose of this article allow for drawing the following conclusions:

1. The gap between the Polish milk processing and leading European countries implies that there is a need for improved efficiency and international competitiveness. One option leading to the improvement of competitiveness may entail concentration of milk processing and resulting growth of the scale of production.
2. Based on non-parametric methods it was concluded that there are increasing returns to scale in the Polish milk processing sector. Given the above, it must be admitted that this conclusion confirms the hypothesis and is in line with the conclusions presented in the relevant literature.
3. Given the fact that most Polish dairy companies experience increasing returns to scale, it is justified to accept the postulate recommending milk processing companies to intensify actions aimed at increasing the scale of production. It should lead to the improvement of their efficiency, and in consequence improvement of international competitiveness. The chance may be used both by companies striving for external growth via mergers and acquisitions and by companies which initiate dynamic internal growth of their own potential.

EFEKTYWNOŚĆ SKALI PRODUKCJI POLSKICH PRZEDSIĘBIORSTW PRZETWÓRSTWA MLEKA BAZUJĄCA NA METODZIE DATA ENVELOPMENT ANALYSIS

Streszczenie. W artykule, bazując na metodzie nieparametrycznej, dokonano oceny efektywności skali produkcji polskich przedsiębiorstw przetwórstwa mleka w latach 1999–2010. Podejście nieparametryczne bazowało na metodzie programowania liniowego określanej jako metoda Data Envelopment Analysis (DEA). Przeprowadzone badania na próbie 743 obiektów wskazały na występowanie rosnących korzyści skali w polskim sektorze mleczarskim. Dalsza konsolidacja polskich przedsiębiorstw przetwórstwa mleka powinna zatem sprzyjać poprawie efektywności tych podmiotów. Badania te potwierdzają wcześniejsze wskazania literatury.

Słowa kluczowe: skala produkcji, efektywność, branża mleczarska, metoda DEA

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