EFFICIENCY OF THE METAL PRODUCTION SECTOR IN POLAND COMPARED TO OTHER MANUFACTURING INDUSTRIES

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Abstract

The main purpose of this paper is to compare the efficiency of the metal production sector with other manufacturing industries in Poland. The study applies Data Envelopment Analysis (DEA), which is a non-parametric method based on production theory and the principles of linear programming. It enables one to assess how efficiently a firm, sectors, country, or such other decision making unit (DMU) uses the available inputs to generate a set of outputs relative to other units in the data set. The analysis gives a possibility to create a ranking of sectors. The results point out the reasons of the inefficiency and provide improving directions for the inefficient Decision Making Units.

Keywords: efficiency, metal production sector, manufacturing, Data Envelopment Analysis

1. INTRODUCTION

The notion of efficiency may be defined in two ways. One of the definitions stems from neoclassical economics and the social welfare theory. This approach concerns the economy as a whole and the markets constituting its parts. The second definition concerns efficiency in a micro scale. In accordance with this meaning efficiency signifies the relation of the effects achieved to the expenditures incurred. The relation of the effects achieved to the expenditures incurred is specified in the dictionary of the Polish language as the result of economic activity and defined as economic efficiency.

Efficiency is the main criterion for a comprehensive assessment of activities of an entire industry sector [1] and individual economic operators [2]. Efficiency is considered to be one of the sources of wealth for nations and at the same time various ways of defining and measuring it are proposed. A macro-economic approach to economic efficiency refers to how well the economy allocates scarce resources to meet the needs and demands of consumers [3]. Following the microeconomic approach, the efficiency of a firm is its capacity to transform expenditures into effects, where a larger value of productivity indexes is indicative of a higher efficiency of a particular economic entity [4].

Most economists have based their theoretical and practical reasoning concerning efficiency on the universally recognized principle of rational management (cost efficiency). The principle usually occurs in two forms: as a principle of maximum productivity (assuming the achievement of maximum goals using specific means) and as a principle of cost savings (assuming the achievement of specific goals using minimum means). Following the principle of rational management leads in each case to seeking optimal solutions, i.e. ones that ensure the maximization of the adopted goal criterion. In turn, the degree to which the adopted goals are realized is precisely what is meant by efficiency [5]. According to Kulawik, rationality consists in the optimum balancing of specific expenditures while taking into account the limited scope of available resources. This limited availability is a result of either the difficulty of obtaining a particular rare material or the high costs needed to obtain it [6] [7].

Following the microeconomic approach, the efficiency is its capacity to transform expenditures into effects, where a larger value of productivity indexes is indicative of a higher efficiency of a particular economic entity [17].

Effects of activities may be estimated in various ways. One of them is to conduct a ratio analysis utilizing the available data describing various areas of material activity of the investigated entity. This analysis consists in determining the relation between expenditures and effects. It often aims at providing constituent grades. Economic efficiency of the entire industry and the selected parts thereof may be measured e.g. with the financial result and the degree of utilization of production factors used to achieve it. Such analysis may encompass the development of the values of basic ratios characterizing the quality of management in time and the dynamics of their variations within the investigated period. In order to measure efficiency in macroeconomic analysis one may utilize such economic categories as gross and net profitability ratios as well as a range of other indicators inter alia cost analysis in the company [8].

Ratio analysis is however flawed and full of imperfections, resulting from i.e., the dynamic changes in modern economy and the need for a multi-criteria approach to efficiency [9].

Alternate manners of estimating efficiency are parametric and non-parametric techniques based on efficiency curves. The parametric approach is based on the production function (it presents the technical dependence between expenditures and production and allows to determine the maximum amount of production which may be acquired with a specified amount of expenditures) and is represented by, among others, the SFA (Stochastic Frontier Approach). In this approach the model consists of an appropriately specialized function and two random elements, one of which specifies the influence of random factors and measurement errors while the second one is a model of the potential inefficiency. Parametric methods also include DFA (Distribution Free Approach) and TFA (Thick Frontier Approach). One imperfection of the parametric methods based on the production function is the complexity of methodology and the fragmentary character of analyses, taking into account only part of the efficiency category.

Another group of methods aiming at estimating efficiency are non-parametric techniques utilizing linear programming principles. This approach does not take into consideration the impact of random factors on an entity's efficiency. The primary techniques of this group are DEA (Data Envelopment Analysis) and FDH (Free Disposal Hull). The DEA method has been adopted in this article for the purposes of estimating the efficiency of sectors of the Polish processing industry.

In this study the notion of "industry" is understood as three primary areas of economic activity which, pursuant to the Polish Classification of Activity (PKD) utilized among others for the purposes of statistic documenting their economic results, are formed by the following sections: - Mining and extraction, - Processing industry, - Electricity, gas and steam manufacturing and supply. The research encompasses 24 sectors classified as industrial processing which formed 16.7% of the GDP in Poland in 2013. Processing industry is 84% of industrial production sold, 55% of the gross value of tangible assets in industry and 83% of employment in industry. The metal industry sector is part of the processing industry and in the Polish Classification of Activity (PKD) it is present in two sections: Manufacture of basic metals and Manufacture of metal products. Both sections in total reflected over 10% of industrial production sold in Poland, around 7% of the gross value of tangible assets in industry and 12% of employment in industry in 2013.

Against the backdrop of the economic slowdown observed in recent years, it is necessary to increase productivity of the manufacturing industry and associated services in order to support economic growth and a favorablelabor market situation, as well as to restore the sound condition and sustainable development of the EU economy. Industry is therefore in the foreground of the new growth model for the EU economy, which has been unveiled in the "Europe 2020" strategy. [10] [18]. Only strong and competitive economy can overcome the economic crisis without destructive consequences [11]. The development and use of emerging business opportunities depends on the ability of companies to respond quickly to changes in the environment and build effective strategies, supported by the use of solutions which can be quickly deployed and implemented. A major difficulty is the fact that the business environment is currently characterized by very high volatility and unpredictability [12] [16].

2. MATERIAL AND METHODS

The main aim of research was find the efficiency of the manufacturing sectors in Poland. The data set used in this contribution is composed of information from collected in the databases of Central Statistical Office of Poland regarding a sample of 24 manufacturing sectors in Poland. Authors kept only available data for 2013 year.

Based on the sample efficiency was evaluated using non-parametric methods. The non-parametric approach to the analysis of the efficiency relied on the linear programming methods defined as Data Envelopment Analysis (DEA). The DEA model may be presented mathematically in the following manner [13]:

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

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

$$u_r, v_i \geq 0 \tag{2}$$

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,…,R) in j-th object,
x_{ij} – amount of input of i-th type (n =1,…,N) in j-th object; (j =1,…,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. 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 [13].

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[1]. Objects are

[1] 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.

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 favorable 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 [14].

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*) [14], the BCC model providing for changing return to scale (the name derives from the authors of the model: *Banker-Charnes-Cooper* [15] and the NIRS model providing for non-increasing returns-to-scale) (drawing 1). The CCR model is used to calculate the overall technical efficiency (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 [4].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 [4].

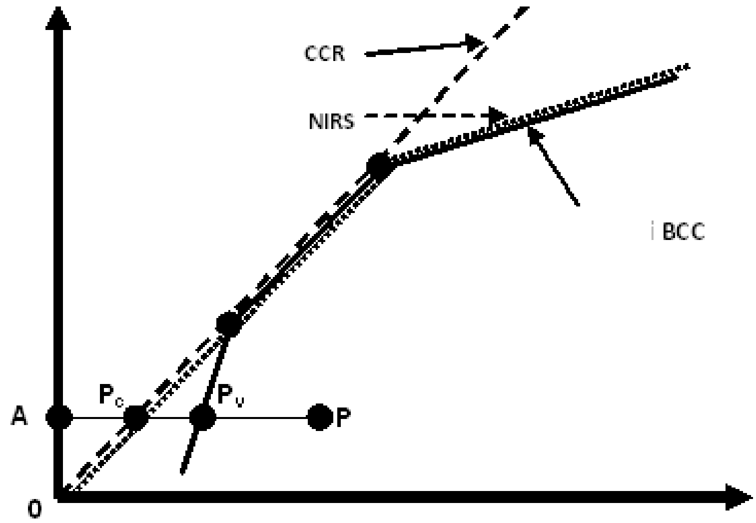

Fig. 1 Scale efficiency according to the DEA method (model: 1 output and 1 input), based on [4]

3. RESULTS

The study was based on source data for 2013 collected in the databases of Central Statistical Office of Poland regarding the 24 manufacturing sectors in Poland. The DEA models were used to determine the relative efficiency of manufacturing sectors in Poland in 2013. Models aimed at minimizing inputs (input - oriented) were chosen, which was based on rational management where we minimize expenditure at a given level of effects. The following variables were set for DEA models:

- output y_1 – sold production in mln PLN
- input x_1 – average paid employment in thous.
- input x_2 - gross value of fixed assets in mln PLN

As a result of the study a ranking of sectors was created according to the efficiency index for the sectors (see Figure 2). The average technical efficiency of the manufacturing sectors in Poland in 2013 achieved a fairly middle level. The average DEA efficiency indicator was 0.61.

It was found that among the 24 studied sectors, 3 of them (Manufacture of coke and refined petroleum products, Manufacture of computer, electronic and optical products, Repair and installation of machinery and equipment) was effective, i.e. the efficiency ratio stood at 1.

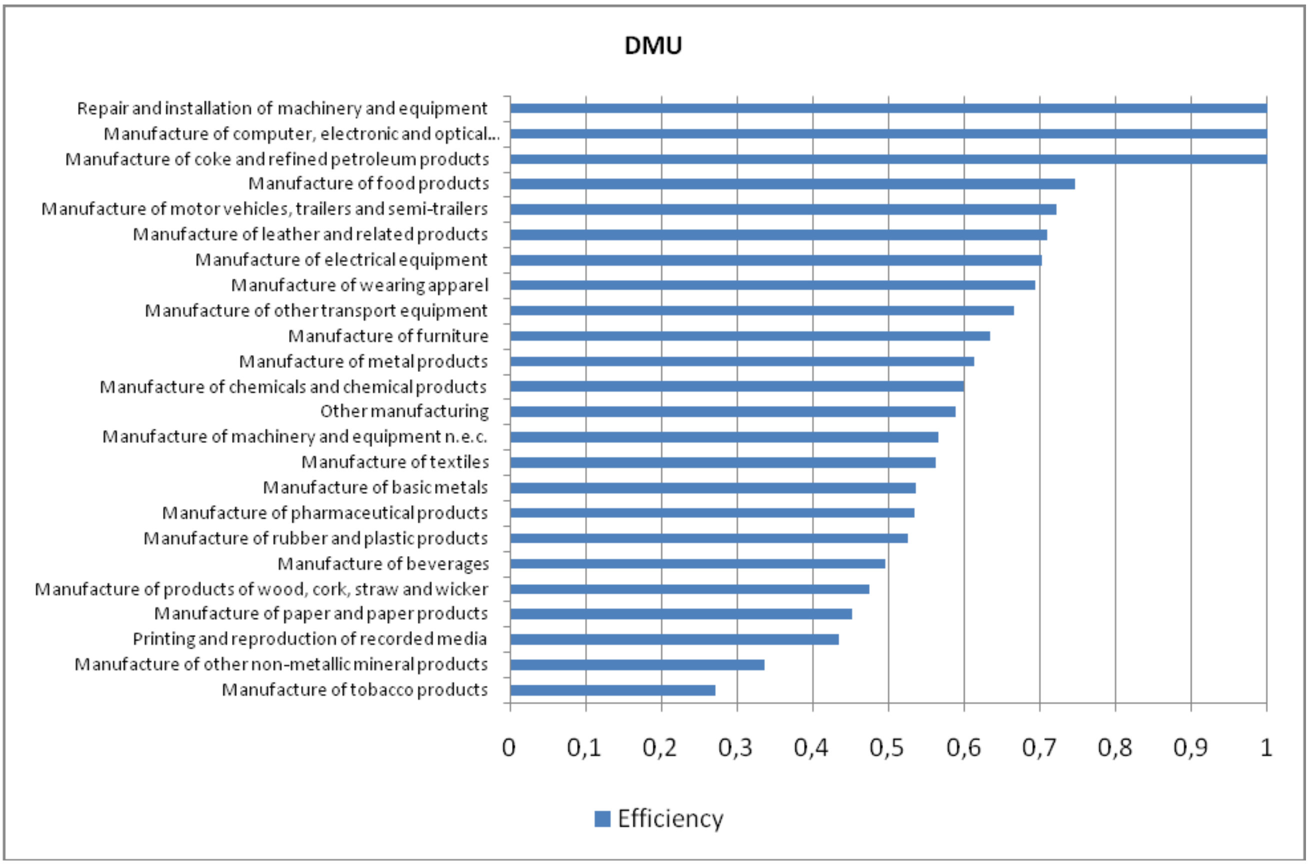

Fig. 2 The technical efficiency of manufacturing sectors in Poland in 2013

Based on the DEA method benchmarks have been defined an inefficient sectors. On the basis of these benchmarks for inefficient sectors (DMU), it is possible to determine a combination of technologies that allows the same results to be achieved with less input.

Table 1 contains the improvements required in order to make inefficient sectors. Results suggest how much smaller should the use of inputs be in inefficient sectors in order to achieve the current value of effects (production value). Having this information, managers or governments should concentrate their efforts in enhancing the performance.

Projections suggest that the average paid employment should reduce for example: Manufacture of tobacco products 73%, Manufacture of wearing apparel 68%, Manufacture of other non-metallic mineral products 66%, **Manufacture of basic metals** 46%, **Manufacture of metal products** 39%, Manufacture of machinery and equipment n.e.c. 44%,.

With regard to gross value of fixed assets Manufacture of tobacco products should reduce by about 73%, Manufacture of wearing apparel 31%, Manufacture of other non-metallic mineral products 66%, **Manufacture of basic metals** 46%, **Manufacture of metal products** 39%, Manufacture of machinery and equipment n.e.c. 44%.

Table 1 Projections values

DMU	Average paid employment	Gross value of fixed assets
Manufacture of food products	-25,34%	-25,34%
Manufacture of beverages	-50,45%	-50,45%
Manufacture of tobacco products	-72,80%	-72,80%
Manufacture of textiles	-43,68%	-43,68%
Manufacture of wearing apparel	-68,08%	-30,69%
Manufacture of leather and related products	-38,33%	-29,07%
Manufacture of products of wood, cork, straw and wicker	-52,52%	-52,52%
Manufacture of paper and paper products	-54,77%	-54,77%
Printing and reproduction of recorded media	-56,52%	-56,52%
Manufacture of chemicals and chemical products	-40,10%	-40,10%
Manufacture of pharmaceutical products	-46,58%	-46,58%
Manufacture of rubber and plastic products	-47,40%	-47,40%
Manufacture of other non-metallic mineral products	-66,43%	-66,43%
Manufacture of basic metals	-46,34%	-46,34%
Manufacture of metal products	-38,63%	-38,63%
Manufacture of electrical equipment	-29,68%	-29,68%
Manufacture of machinery and equipment n.e.c.	-43,47%	-43,47%
Manufacture of motor vehicles, trailers and semi-trailers	-27,78%	-27,78%
Manufacture of other transport equipment	-33,42%	-33,42%
Manufacture of furniture	-36,53%	-36,53%
Other manufacturing	-41,13%	-41,13%

CONCLUSIONS

The paper presents the application of the DEA methodology to the evaluation of efficiency of manufacturing sectors in Poland. From the methodological point of view the proposed approach for ranking and benchmarking of DMU has a universal character and can be applied in different industries. It allows comparing relative efficiency of DMU by determining the efficient DMUs as benchmarks and by measuring the inefficiencies in input combinations in other units relative to the benchmark.

One of the main tasks was to compare the efficiency of metal sector with other sectors of industrial processing in Poland. The metallurgical industry in Poland is an important branch of the economy, which is proven by its 10 percent share in sold production of general industry in 2013. There are about 1300 companies (with over 49 employees) in the field of metals and metal products production present on the Polish market. Therefore it is important whether the individual production factors (labour, capital) are being used efficiently to achieve a specific magnitude of production from the point of view of the entire national economy as well as of the individual enterpreneurs.

From the practical point of view the results of this analysis can be summarized as follows:

- The most efficient sectors are Manufacture of computer, electronic and optical products, Manufacture of coke and refined petroleum products, Repair and installation of machinery and equipment.
- The worst efficiency in the study group were sectors: Manufacture of tobacco products, Manufacture of other non-metallic mineral products.
- Manufacturing and machining metals have demonstrated similar effectiveness to the average in the whole group. Whilst it was proposed, decrease expenditures to improve efficiency to the level of the leaders of the group. Higher efficiency index achieved Manufacture of metal products than Manufacture of basic metals.
- Detailed analysis of the efficient DMUs as a benchmark for other evaluated units point out the reasons of the inefficiency and provide improving directions for the inefficient DMU.

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