ECONOMIC AND ENVIRONMENTAL EFFICIENCY OF THE METAL INDUSTRY IN EUROPEAN COUNTRIES

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Abstract

The article specifies the economic and environmental efficiency in the metal industry in individual EU countries in 2015. 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, organization, 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 countries. The results point out the reasons of the inefficiency and provide improving directions for the inefficient Decision Making Units.

Keywords: Efficiency, environment, metal industry, Data Envelopment Analysis, Europe

1. INTRODUCTION

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]. One of the resource groups characterized by limited availability are natural resources.

The production of such huge amounts of matal products requires a correspondingly wide variety of types of input, including energy, which depletes non-renewable energy resources. On the other hand, the industry emits greenhouse gases during production processes, thus contributing adversely to climate change. Both energy consumption and greenhouse gas emissions constitute a direct burden on the environment and worsen the situation of future generations. Therefore, there is a need for effective use of limited resources and minimisation of environmental burdens, which is currently the subject of constant research.

This issue is addressed by environmental economics, defined as the field of economic theory, which studies static and dynamic conditions of optimal use of natural environment resources [7]. From the point of view of this paper, the most important elements of this theory are the issues related to limiting externalities, such as greenhouse gas emissions, and the proper rate of use of non-renewable resources.

The beginnings of the development of this trend can already be seen among the representatives of classical economic theory. Particularly noteworthy are the views of T. Malthus [8] regarding limited resources and population growth. This train of thought was continued in the 1st Club of Rome Report [9]. The authors drew attention to the barriers mankind will encounter in the near future. The most important are: the increasing level of pollution (including the rise in atmospheric CO2) and the depletion of non-renewable resources. This is particularly important within the scope of fossil fuels, which form the basis for the functioning of modern economy. This resulted in the "Peakoil" concept - a peak in extraction, after which production will decrease [10]. Due to technological progress and the unknown pace of discovering new deposits, this moment is difficult to predict. It is pointed out here that these resources are actually being depleted, but as prices rise, the world economy is switching to other energy sources [11]. This process complies with the Hotelling rule, which determines the socially appropriate rate of exploitation of non-renewable resources [12] and Nordhous's theory of "backstop technology" viewed from the point of energy carriers [13]. It defines it as a costly substitution technology with an unlimited raw material base that can lead to the replacement of raw material resources being depleted. At present, however, the topic of depletion of energy resources is slippinginto the background. The problem of climate change caused by the emission of greenhouse gases is becoming more prevalent.

2. MATERIAL AND METHODS

The main aim of research was find the economic and environmental efficiency of the metal sector in selected European countries. The data set used in this contribution is composed of information from collected in the databases of Eurostat regarding a sample of metal sector in 27 countries in Europe. Authors kept only counties with available data for 2015 year.

Based on the sample efficiency 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 [14]:

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

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

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

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 [14].

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 (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). 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 [15].

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*) [15], the BCC model providing for changing return to scale (the name derives from the authors of the model: *Banker-Charnes-Cooper* [16] [17] 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].

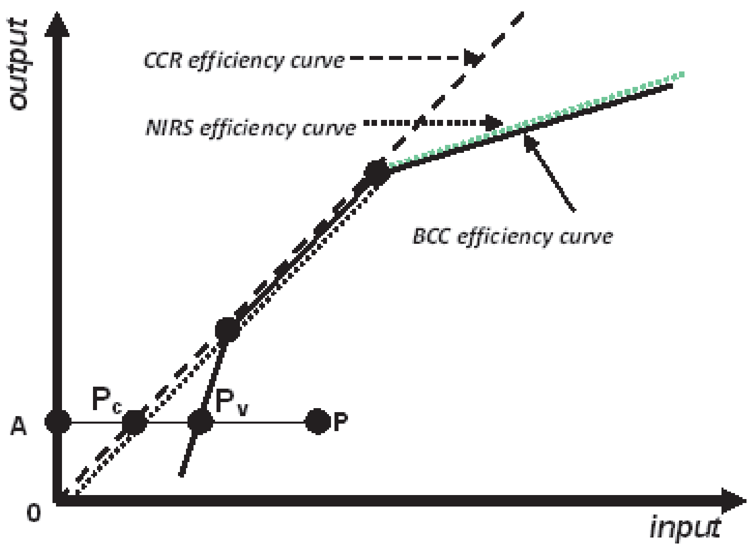

Figure 1 Scale efficiency according to the DEA method (model: 1 output and 1 input)
Source: prepared based on Coelli et al. 2005.

3. RESULTS

The study was based on source data for 2015 collected in the databases of Eurostat regarding the metal sector in 27 European countries. The BCC models were used to determine the relative efficiency of metal sector across Europe. Models aimed at minimizing inputs (*input - oriented*) were chosen, which was based on the new UE strategy to more environmental-efficient economy.

The following variables were set for DEA models:

- output y_1 - production value
- input x_1 - persons employed - number
- input x_2 - energy consumption (all products in terajoule)
- input x_3 - CO_2 emissions (tone)

As a result of the study a ranking of countries was created according to the efficiency index for the metal sector (see **Figure 2**). The average technical efficiency of the metal sector in Europe in 2015 achieved a fairly low level. The DEA efficiency indicator in the BBC model was 0.59.

It was found that among the 27 studied countries, 6 countries (Belgium, Bulgaria, Denmark, Germany, Italy, Malta) had a metal sector that was effective, i.e. the efficiency ratio stood at 1.

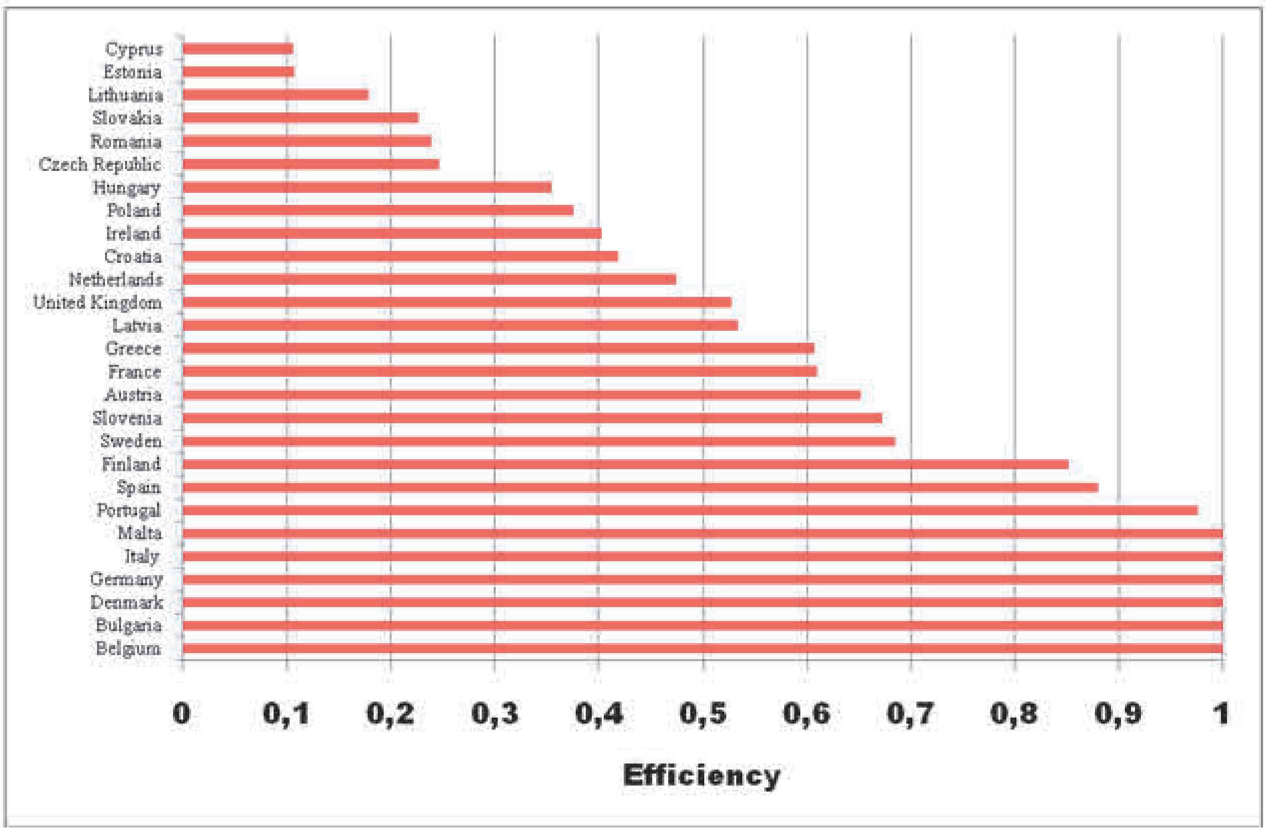

Figure 2 The technical efficiency of metal sectors in European countries in 2015

Based on the DEA method benchmarks have been defined for countries with an inefficient metal sector. 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 metal sectors. As seen in **Table 1**, results suggest how much smaller should the use of inputs be in inefficient metal 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 total number of person employed should reduce as follows: Czech Republic by about 75%, Estonia 96%, Ireland 60%, Greece 39%, Spain 12%, France 39%, Croatia 69%, Cyprus 90%, Latvia 47%, Lithuania 96%, Hungary 65%, Netherlands 53%, Austria 35%, Poland 62%, Portugal 2%, Romania 76%, Slovenia 33%, Slovakia 77%, Finland 15%, Sweden 31%, United Kingdom 47%.

With regard to energy consumption Czech Republic should reduce by about 77%, Estonia 89%, Ireland 75%, Greece 39%, Spain 12%, France 48%, Croatia 58%, Cyprus 89%, Latvia 47%, Lithuania 95%, Hungary 67%, Netherlands 81%, Austria 35%, Poland 62%, Portugal 32%, Romania 76%, Slovenia 42%, Slovakia 80%, Finland 28%, Sweden 31%, United Kingdom 47%.

With regard to CO_2 emission Czech Republic should reduce by about 75%, Estonia 90%, Ireland 81%, Greece 44%, Spain 114%, France 60%, Croatia 76%, Cyprus 89%, Latvia 49%, Lithuania 82%, Hungary 65%, Netherlands 69%, Austria 65%, Poland 66%, Portugal 2%, Romania 82%, Slovenia 32%, Slovakia 77%, Finland 47%, Sweden 31%, United Kingdom 61%.

Table 1 Projections values

DMU	Persons employed - number	Energy consumption - terajoule	CO2 emission - tone
Czech Republic	-75.378	-76.502	-75.378
Estonia	-95.644	-89.306	-90.432
Ireland	-59.675	-74.803	-81.854
Greece	-39.215	-39.215	-44.018
Spain	-11.969	-11.969	-13.532
France	-39.012	-48.496	-60.488
Croatia	-69.135	-58.045	-76.376
Cyprus	-90.355	-89.412	-89.412
Latvia	-46.65	-46.65	-49.249
Lithuania	-96.367	-94.645	-82.13
Hungary	-64.538	-67.133	-64.538
Netherlands	-52.522	-80.817	-69.497
Austria	-34.813	-34.813	-65.365
Poland	-62.415	-62.415	-66.241
Portugal	-2.408	-32.419	-2.408
Romania	-76.136	-76.136	-82.59
Slovenia	-32.743	-42.028	-32.743
Slovakia	-77.333	-80.051	-77.805
Finland	-14.83	-27.699	-46.586
Sweden	-31.465	-31.465	-31.465
United Kingdom	-47.253	-47.253	-60.823

4. CONCLUSIONS

Considering the tightening EU climate policy, it seems that the best approach to monitoring efficiency is a comprehensive approach to both economic and environmental aspects. The conducted studies present such an approach and make it possible to indicate countries with the highest economic and environmental efficiency of the metal industry.

More environmental-efficient economy should accelerate the spread of innovative technological solutions and improve the competitiveness of industry in the Union, boosting economic growth and creating high quality jobs in several sectors.

The paper presents the application of the DEA methodology to the evaluation of efficiency of the metal sector in European countries. 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.

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

- The countries with the most efficient of the metal sector are Belgium, Bulgaria, Denmark, Germany, Italy, Malta.
- 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.

The obtained results provide the foundation for further in-depth studies, in which it is necessary to identify the main factors that have had an impact on the economic and environmental efficiency of the metal industry in individual EU countries.

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