

ECONOMIC AND ENERGY EFFICIENCY OF THE MINING AND QUARRYING SECTOR IN EUROPEAN COUNTRIES

Marcin WYSOKIŃSKI^a, Joanna BARAN^a, Piotr GOŁASA^a, Radim LENORT^b

^a *Warsaw University of Life Sciences, Warsaw, Poland, EU*

joanna_baran@sggw.pl, marcin_wysokinski@sggw.pl, piotr_golasa@sggw.pl

^b *VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU, radim.lenort@vsb.cz*

Abstract

The main purpose of this paper is to compare the energy and economic efficiency of the mining and quarrying sector in European countries. 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 counties. The results point out the reasons of the inefficiency and provide improving directions for the inefficient Decision Making Units.

Keywords: Efficiency, energy, mining and quarrying, Data Envelopment Analysis

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.

Rationality in allocating limited natural resources has become one of the basic challenges of 21st century economics. Just like their capital and human counterparts, natural resources have become the foundation of management [7].

The issue of utilizing natural resources was already mentioned by the founding fathers of classical economics [8], [9], [10]. It was based on the concept of paucity of natural resources, which since the beginning of 19th century dictated the assumption that the availability of such resources is limited and marks the upper bound of the economic growth rate, and hence the level of social welfare. Nowadays, the theory of resource paucity is used in numerous scientific publications in order to make long-term forecasts. A case in point is the 1972

Report to the Club of Rome that mentioned the concept of zero economic growth rate and assumed that, if the current demographic trends, use of natural resources, the rate of manufacturing food, industrial goods and services, and environmental pollution levels are sustained, within one hundred years civilization can be expected to have reached the limits of further growth [11].

An example of a natural resource is energy obtained from both renewable and non-renewable sources. In classical economics, energy occurring naturally was treated as a free resource, but such understanding does not currently meet the needs of economic practice. As a result of civilization growth and the enormous increase of production of material goods, energy has ceased to be freely available and, like almost all natural resources, became an economic good, since due to its limited availability it must be subject to management. Along with labour and capital, natural resources have been considered another important manufacturing factor [12].

Faced with the growing dependency on importing energy carriers and the limited availability of energy resources, as well as the need to impede negative climate changes, economists and scientists have become increasingly interested in the issues of economic efficiency of energy, in particular by looking for solutions that allow energy savings. The directive of the European Parliament and the Council 2012/27/EU of October 25, 2012 on energy efficiency (Energy efficiency means the ratio of output of performance, service, goods or energy to input of energy [Article 2(4) of the Directive]) notes among others that shifting to a more energy-efficient economy should also 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 related to energy efficiency (point 1 of the Directive preamble) [13]. The Directive, by establishing a common framework for a 20 % decrease of primary energy consumption in the EU, is an essential factor driving the successful implementation of the EU energy strategy until 2020. The document shows the means that allow setting up appropriate conditions to improve energy efficiency even after that date. Additionally, the Directive specifies the rules for operation of the energy market so that all irregularities hindering efficient supply can be eliminated. The act also provides for establishing national goals in energy efficiency until 2020.

Considerations on energy efficiency become even more important in light of the Ukraine crisis and the open conflict between the EU states and Russia as the largest supplier of energy resources to the Community markets. The European dependency on Russian gas and oil puts in doubt the currently prevailing commercial relations on the strategic resources market and expressly requires the undertaking of all steps for, among others, a decisive improvement of energy efficiency and seeking alternative sources of energy. This is a very difficult challenge, particularly for energy-heavy industries such as mining and extraction which have been analysed in the following sections.

2. MATERIAL AND METHODS

The main aim of research was find the economic and energy efficiency of the mining and quarrying 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 mining and quarrying sector in 22 countries in Europe. Authors kept only countries with available data for 2011 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]:

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

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

$$u_r, v_i \geq 0$$

(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].

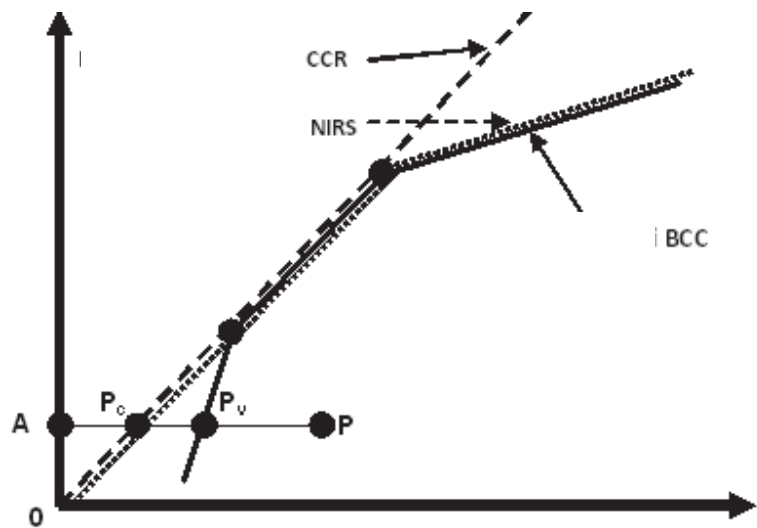


Fig. 1 Scale efficiency according to the DEA method (model: 1 output and 1 input), based on [4]

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] 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]

RESULTS

The study was based on source data for 2011 collected in the databases of Eurostat regarding the mining and quarrying sector in 22 European countries. The BCC models were used to determine the relative efficiency of mining and quarrying sector across Europe. Models aimed at minimizing inputs (input - oriented) were chosen, which was based on the new UE energy strategy to more energy-efficient economy as a result of the still ongoing economic slowdown. The following variables were set for DEA models:

- output y_1 - production value
- input x_1 - number of hours worked by employees
- input x_2 - energy consumption (all products in terajoule)

As a result of the study a ranking of countries was created according to the efficiency index for the mining and quarrying sector (see **Fig. 2**). The average technical efficiency of the mining and quarrying sector in Europe in 2011 achieved a fairly low level. The DEA efficiency indicator in the CCR model was 0.36.

It was found that among the 22 studied countries, 3 countries (Netherlands, Luxembourg, and Italy) had a mining and quarrying sector that was effective, i.e. the efficiency ratio stood at 1.

Based on the DEA method benchmarks have been defined for countries with an inefficient mining and quarrying 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 mining and quarrying sectors. Results suggest how much smaller should the use of inputs be in inefficient mining and quarrying 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 hours worked by employees should reduce as follows: Belgium by about 76 %, Bulgaria 96 %, Czech Republic 94 %, Germany 90 %, Estonia 91 %, Ireland 81 %, Spain 91 %, Croatia 85 %, Cyprus 45 %, Latvia 87 %, Lithuania 86 %, Hungary 90 %, Austria 79 %, Poland 96 %, Portugal 93 %, Romania 95 %, Slovakia 93 %, Finland 76 %, Sweden 76 %.

With regard to energy consumption Belgium should reduce by about 92 %, Bulgaria 94 %, Czech Republic 83 %, Germany 90 %, Estonia 72 %, Ireland 87 %, Spain 91 %, Croatia 53 %, Cyprus 41 %, Latvia 60 %, Lithuania 52 %, Hungary 56 %, Austria 81 %, Poland 88 %, Portugal 93 %, Romania 66 %, Slovakia 71 %, Finland 78 %, Sweden 86 %.

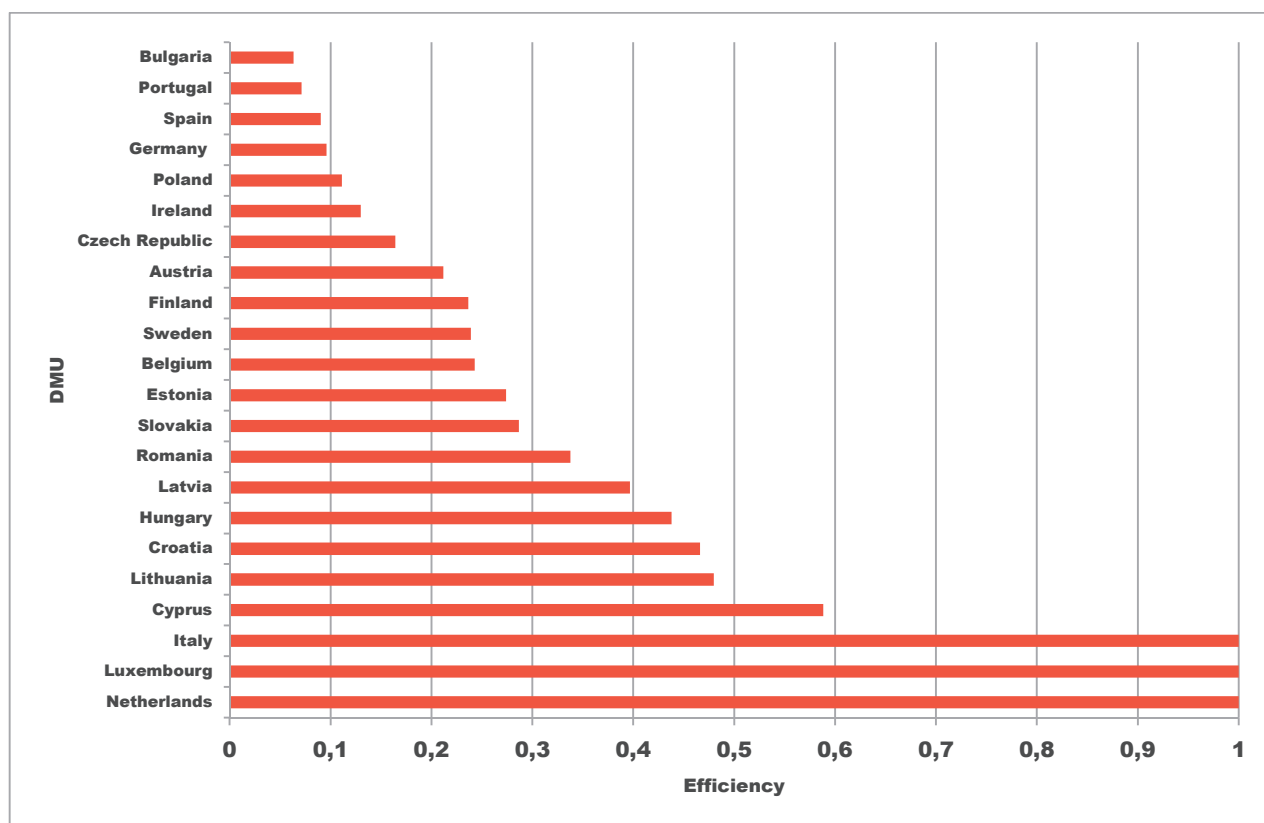


Fig. 2 The technical efficiency of sectors mining and quarrying in European countries in 2011

Table 1 Projections values

DMU	Number of hours worked by employees	Energy consumption
Belgium	-75.72 %	-92.18 %
Bulgaria	-95.97 %	-93.67 %
Czech Republic	-93.88 %	-83.58 %
Germany	-90.41 %	-90.41 %
Estonia	-91.35 %	-72.62 %
Ireland	-87.02 %	-87.18 %
Spain	-90.96 %	-90.96 %
Croatia	-85.58 %	-53.40 %
Cyprus	-45.02 %	-41.16 %
Latvia	-87.40 %	-60.34 %
Lithuania	-85.99 %	-52.01 %
Hungary	-89.81 %	-56.21 %
Austria	-78.82 %	-81.45 %
Poland	-96.25 %	-88.89 %
Portugal	-92.87 %	-92.87 %
Romania	-95.17 %	-66.24 %
Slovakia	-92.74 %	-71.33 %
Finland	-76.33 %	-77.81 %
Sweden	-76.10 %	-86.32 %

CONCLUSIONS

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, 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. In the context of energy efficiency it is necessary restructuring of the energy-intensive industries (mining and quarrying sector for example). More energy-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 related to energy efficiency.

The paper presents the application of the DEA methodology to the evaluation of efficiency of the mining and quarrying 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 mining and quarrying sector are Italy, Netherlands and Luxemburg.
- 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.

ACKNOWLEDGEMENTS

The work was supported by the specific university research of Ministry of Education, Youth and Sports of the Czech Republic No. SP2014/81.

REFERENCES

- [1] POMYKALSKI P., BAKALARCZYK S., SAMOLEJOVA A. Benchmarking polish basic metal manufacturing companies, *Metalurgija*, Vol. 53, No. 1, pp. 139-141.
- [2] SANIUK A., SANIUK S., WITKOWSKI K. Using activity based costing in the metalworking processes. In *METAL 2011: 20th Anniversary International Conference on Metallurgy and Materials*, Ostrava, Tanger, 2011, pp. 1328-1333.
- [3] KAMERSCHEN D., MCKENZIE R., NARDINELLI C. *Ekonomia*, Wydawnictwo Fundacja Gospodarcza NSZZ „Solidarność”, 1991.
- [4] COELLI T. J., PRASADA RAO D. S., O'DONNELL C. J., BATTESE G. E. *An Introduction to Efficiency and Productivity Analysis*, Springer, New York, 2005.
- [5] SZYMAŃSKA E. *Efektywność gospodarstw wyspecjalizowanych w produkcji żywca wieprzowego w Polsce*, Wydawnictwo SGGW, Warszawa, 2011, pp. 57.
- [6] KULAWIK J. *Analiza efektywności ekonomicznej i finansowej przedsiębiorstw rolnych powstałych na bazie majątku WRSP*, Wydawnictwo IERiGŻ-PIB, Warszawa, 2008, pp. 114.
- [7] PIASECKI R. *Ekonomia rozwoju*, PWE, Warszawa 2011, pp. 232.
- [8] MILL JSt. *Zasady ekonomii politycznej (tom I i II)*, PWN, Warszawa 1965-1966.
- [9] MALTHUS T. *Prawo ludności*, Warszawa, 1925.
- [10] RICARDO D. *Zasady ekonomii politycznej i opodatkowania*, PWN, Warszawa, 1957.
- [11] MEADOWS D. H., MEADOWS D. L., RANDERS J., BEHRENS W. B. *Granice wzrostu*, PWE, Warszawa, 1973.
- [12] RECHUL H. *Zasoby naturalne - jak bliska jest bariera dostępności*, *Wokół Energetyki*, Kwiecień 2004, pp. 1.

- [13] Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, Brussels, 25 October 2012.
- [14] COOPER W. W., SEIFORD L. M., TONE K. Data Envelopment Analysis, A Comprehensive Text with Models, Applications, References and DEA-Solver Software, New York, Kluwer Academic Publishers, 2007.
- [15] CHARNES A., COOPER W. W., RHODES A. Measuring the Efficiency of Decision Making Units, European Journal of Operational Research, 2 (6), 1978, pp. 429-444.
- [16] BANKER R. D., CHARNES A., COOPER W. W. Some Models for Estimating Technical and Scale Inefficiency in Data Envelopment Analysis, Management Science, 30, 1984.
- [17] BARAN J. Efficiency of the production scale of Polish dairy companies based on Data Envelopment Analysis, Acta Scientiarum Polonorum Oeconomia, 12 (2) 2013, pp. 5-13.