ENVIRONMENTAL EFFICIENCY OF STEEL SECTORS OF THE VISEGRAD FOUR COUNTRIES WITHIN THE EU ETS SYSTEM

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Abstract

In order to increase efficiency in production with respect to emissions production, the European trading system with emissions of CO_2 has been established at the beginning of this millennium. The impact of this system on participating companies, even after one decade of its functioning, has been questioned many times in published studies. This paper devotes to the analysis of efficiency of steel sectors in the countries of the Visegrad Group, i.e. the Czech Republic, Poland, Slovakia and Hungary. In particular, the fact how efficiently steel producers in the countries are transforming their inputs into ouputs is researched. Moreover, relationships (dependency) between inputs and outputs are identified and discussed. The analysis is made at national level, not at the level of steel producers/companies. The PROMETHEE method is used. To perform the analysis, the data on inputs (number of allowances allocated for free and structure of companies' size) and outputs (amount of production and CO_2 emissions and amounts of production) are used.

Keywords: Steel sector, efficiency, PROMETHEE, GAIA, Visegrad four

1. INTRODUCTION

A state of being efficient in production means an ability to avoid wasting materials and other production inputs when achieving a desired result (output). A pressure on efficiency in production still increases regardless a field of business. In the European steel sector, an effort to reach the efficiency must be especially emphasized due to its importance for many other heavy industrial sectors and also because a strong competitive pressure by non-european companies. A competitive position of steel companies in the EU has been even worsen by a new environmental-legislative constraint in the form of emissions trading in Europe since 2004. Under the direction [1], the European Union Emissions Trading Scheme (EU ETS) which obliged all steel companies (with energy consumtion exceeding 420 MW per year [1]) doing their business within the EU to cover their emissions of the carbon dioxide by emissions permits (allowances) has been launched. Many studies have been already devoted to assessing the impact of the EU ETS on companies, see e.g. [2] or [3]. That studies have confirmed a significance of EU ETS's possible influence on companies. This research provides a different approach to assess the performance of European steel companies under the EU ETS because an amount of CO_2 emissions (as output) and a number of emissions permits allocated to companies for free (as input) are involved in multicriteria decision making on efficiency of selected national European steel sectors.

There are many possibilities how to assess the performance or efficiency of decision-making units. For example, a Data Envelopment Analysis (DEA) or a Stochastic Frontier Approach (SFA) in many forms is very popular nowadays, see e.g. [4] or [5]. The interesting idea was to use some principles of the project management, see [13]. In this contribution, a different method was used. In particular, the PROMETHEE methods (Preference Ranking Organization METHod for Enrichment Evaluation) are used. The reason for this choice is simple. PROMETHEE provides, except of a ranking of alternatives, also many useful lateral facts, it can reveal new (non-apparent) links and relationships and, last but not least, many graphical interpretations when using a specialized software are available, see [6] or [7].

In analyses within this research, one unit which is assessed is equal to the national sector. That means that values of considered indicators for each country under evaluation are aggregated values by all steel companies doing their business in that country. For the sake of simplicity, only the countries of Visegrad Four are evaluated. Moreover, these countries are highly comparable (they are of a similar economic strength) and a steel sector has a long and strong position there. The aim of the paper is to assess the efficiency of steel sectors in the Czech Republic, Hungary, Poland and Slovakia with regard to the European emissions trading in 2014. Apart of the plain fact regarding if a particular national steel sector is efficient or not (under the given set of criteria), a dependency of criteria considered as well as a similarity of units' profiles will be investigated too.

This study can be considered as very innovative because such an analysis has not be performed anytime before (at least to the best of conscience of the authors). Despite the fact that many scientific studies concerning the efficiency in connection with the EU ETS have been published, those studies are really different - mostly the efficiency of the allocation of permits within the system is investigated (see [8]), or the efficiency of the EU ETS as a whole is analyzed, see [9]. Furthermore, studies on steel sectors efficiency have also been done. For example, [10] and [11] explore the efficiency connected with energy consumption in the steel sector. And, in [12] the overall technical efficiency of steel companies from all over the world is assessed by using the SFA approach, but no environmental factors are included there and very old data are used there. Those are the facts why it can be concluded that the study like this one is very novel.

2. A METHODOLOGY OF THE PROMETHEE METHODS

The PROMETHEE is a set of multi-criteria decision making methods based on special preference functions [6]. The core idea is that the final evaluation of each alternative is calculated using the preference degrees which express "how much" is that alternative better in (pair-wise) comparison with all other alternatives regarding all criteria one by one. Let *k* and *n* be a number of criteria and alternatives, respectively. Then, let us have the weight w_j for each of *k* criteria and $P_j(a,b)$ which stands for the preference degree given by a pairwise comparison of the alternative *a* with the alternative *b* using the criterion *j*. A value of the preference degree ranges from 0 ($a \nsucc b$) to 1 (*a* is absolutely preferred to *b*). The choice of preference functions for each criterion depends on a decision-maker and it can vary for different criteria. But, generally, it should be non-decreasing, see [7]. The overall evaluations of the alternatives is done using the measures of the positive ϕ^+, negative ϕ^- and net ϕ flows, see the equations (1) and (2).

$$\phi^+(a) = \frac{1}{n-1}\sum_{b\neq a}\sum_{j=1}^{k} w_j \cdot P_j(a,b), \qquad \phi^-(a) = \frac{1}{n-1}\sum_{b\neq a}\sum_{j=1}^{k} w_j \cdot P_j(b,a) \tag{1}$$

$$\phi(a) = \phi^+(a) - \phi^-(a) \tag{2}$$

The PROMETHEE I (a partial ranking) set the preference relations between two alternatives (*a* and *b*) using the equation (3) - there *a* is preferred to *b*, and (4) - there *a* is equal to *b*. For all other cases, *a* and *b* are incomparable.

$$a \succ b \Leftrightarrow \phi^+(a) \geq \phi^+(b) \wedge \phi^-(a) \leq \phi^-(b) \text{ (and at least one of the relations is sharp)} \tag{3}$$

$$a = b \Leftrightarrow \phi^+(a) = \phi^+(b) \wedge \phi^-(a) = \phi^-(b) \tag{4}$$

The PROMETHEE II (a complete ranking) set the preference relations between two alternatives (*a* and *b*) using the equation (5).

$$a \succ b \Leftrightarrow \phi(a) > \phi(b), \quad a = b \Leftrightarrow \phi(a) = \phi(b) \tag{5}$$

It can be seen that PROMETHEE II guarantee the comparability between all pairs of criteria. On the other hand, PROMETHEE I enables the decision-maker to distinguish directions of flows which can serve for the identification of strengths and weaknesses of alternatives.

A very useful tool for a graphical representation of the results of PROMETHEE analysis is GAIA (Graphical Analysis for Interactive Aid) which also works with flows. But those flows are not calculated for all criteria together (like for PROMETHEE I, II) but for each criterion individually. Then, using the equation (6), each alternative can be identified by a k-dimensional vector $a = (\phi_1(a), \ldots, \phi_k(a))$ in the k-dimensional space. To be able to display the space, PCA (Principal Component Analysis) method is used to reduce the dimensionality to 2 (to a plane), for more information see e.g. [7].

$$\phi_j(a) = \frac{1}{n-1} \sum_{b \neq a} (P_j(a,b) - P_j(b,a)) \quad (6)$$

In order to keep the length of the paper reasonable, a reader can find more details about the PROMETHEE methods in [6] or [7].

3. THE STRUCTURE OF THE PROBLEM AND INPUT DATA

A crucial step is the choice of criteria for an evaluation. Because of the mentioned novelty of the analysis, following 5 criteria are considered at the discretion of the authors (the important role for that selection played the fact that the influence of the EU ETS has to be involve):

- **Number of allowances obtained by the EU authority for free** - this number was set regarding the amount of CO_2 emissions released in past years. An amount of obtained allowances decreases year by year. This indicator is considered as the input of a company/sector.
- **Number of very big companies (with emissions exceeding 10^6 tons of CO_2 per year)** - this number gives the information about the structure of the national steel sector. It can be expected that very big companies (very often supra-national) reach higher efficiency. This indicator is considered as the input of a sector. The share of very big steel companies in the whole EU is equal to approximately 15 %.
- **Share of small companies (with emissions not exceeding 10^5 tons of CO_2 per year) -** this is the second indicator on the market structure. This indicator is considered as the input of a sector. The share of small steel companies in the whole EU is equal to approximately 55 %.
- **Amount of CO_2 emissions -** emissions (in tons) are regarded as an undesirable output of a company/sector. The less emissions the better efficiency.
- **Amount of production -** the most reasonable (classical) output of each manufacturer is an amount of production. Because the efficiency of whole national steel sectors is evaluated, a simplification of this indicator is done. The products are not diversified and only the total amount of production (in tons) regardless a production type is used for each country.

It can be summarized that 3 inputs and 2 outputs are involved in the analysis. The data on the first four criteria have been taken from the Carbon Market Data database, see www.carbonmarketdata.com. The data on amounts of production have been derived from statistical yearbooks of the World Steel Association (available online on www.worldsteel.org).

The choice of the criteria is discussable. Definitely, an energy consumption would be reasonable to pick. Unfortunately, corresponding data are not available for the authors of this paper. Anyway, the set of criteria can be possible to modify or extend in some further studies.

4. THE RESULTS OF ANALYSES

Due to the very restrictive limit for length of a contribution, no partial calculation or values of the input data are provided. The emphasis is put on the results of the analysis and their discussions. All the analyses have been performed using the Visual PROMETHEE application software. For all criteria, the "usual" preference function has been used (i.e. the function which returns the preference degree of one for each preference relationship regardless the value of difference). No reason for using any different function has been identified (and also, any different choice would be difficult to justify). Weights for criteria have been set to equally (at 20 %).

The results of the PROMETHEE I and II are displayed in **Figure 1**. All alternatives are comparable using both methods with following results:

$$Poland \succ Czech\ Republic \succ Slovakia = Hungary.$$

	Car	Phi	Phi+	Phi-
1	Poland	0,5333	0,7333	0,2000
2	Czech Rep	0,4000	0,6667	0,2667
3	Slovakia	-0,4667	0,2000	0,6667
4	Hungary	-0,4667	0,2000	0,6667

Figure 1 The values of net/positive/negative flows

In **Figure 2**, the profiles of all countries are shown. Criteria below the *x* axis (with negative value of flows) can be considered as the weaknesses and positive flows as the strengths of an alternative in comparison with other alternatives. A bar heights express the size of such weakness/strength. The interesting fact is that the Czech Republic does not have any weakness. But, on the other hand, the sizes of all strengths are not so big and thus, in overall, Poland is preferred to the Czech Republic**. Figure 3** shows the GAIA output (the quality of the projection to the 2-D space is 99 %, i.e. excellent). If a pair of alternatives is close to each other, their profile is similar. And, if a pair "alternative + criterion" is close to each other, it means that that alternative reaches a "good" value regarding the "paired" criterion. The last output (see **Figure 4**) reveals the fact about the efficiency of alternatives. It can be seen that both, Poland and the Czech Republic are efficient. That means that Slovakia and Hungary are dominated (the same amount of outputs is reached with less inputs or vice versa).

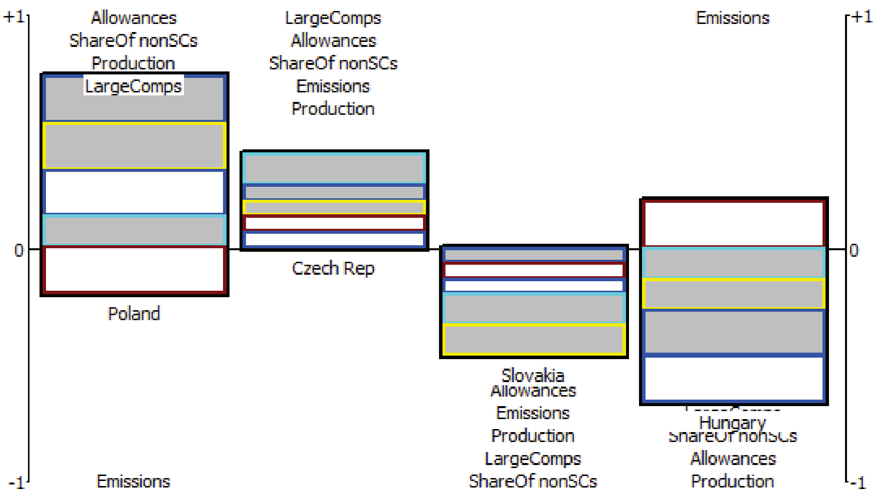

Figure 2 Profiles of the alternatives

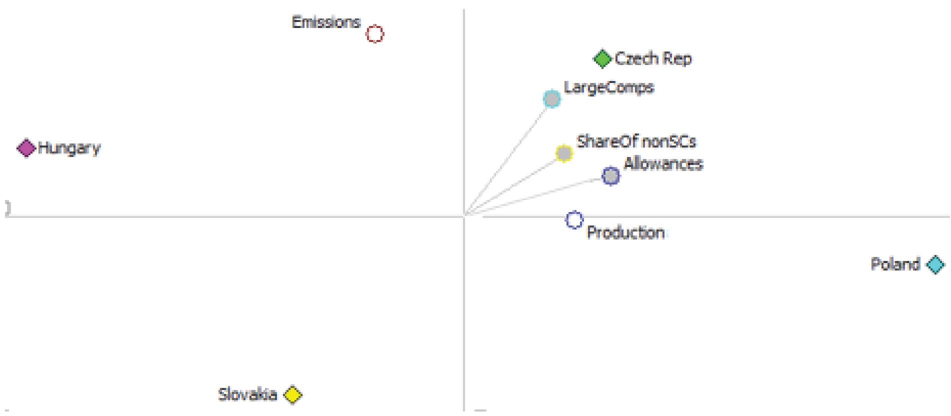

Figure 3 GAIA output

Figure 4 Non-dominated alternatives

5. CONCLUSIONS

Using the PROMETHEE family methods, the efficiency of national steel sectors of Visegrad Four countries regarding the CO_2 emissions has been investigated. Two countries (Poland and the Czech Republic) has been proven to be efficient and they dominate the remaining two countries (Hungary and Slovakia). The non-dominated pair achieves its position mainly due to the “good” steel sector structure and because of the amount of total production and free allocated allowances. The GAIA analysis proved the dependency among those four factors. The fact which might be found interesting is that in the GAIA amount of emissions released and amount of allowances do not lie next to each other (i.e. they are not as dependent as it could be expected on the basis of how the amount of granted allowances is set). On the other hand, it must be reminded that the factor of a total production is aggregated for whole national sectors and differences between related CO_2 burdens was ignored. The analysis can be extended by other factors or countries in the future research.

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