ECONOMIC-ECOLOGICAL MODEL MAXIMIZING THE PROFIT OF THE INDUSTRIAL COMPANY INCLUDING EMISSION TRADING

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Abstract

The aim of the paper is to design the model for the industrial company's profit optimization. The decision-making on the amount and structure of production is influenced by many constraints. The emphasis is put on the environmental factors including especially EU ETS system with emission trading and fees for released pollutants. These factors influence both - cost (fees that must be paid and emission permits which must be bought for covering released emissions) and revenue (from selling unused permits). Model counts with the possibility of company's choice which stock market enabling emission trading will be used for trades. The designed model is constructed as a model of linear programming and it is verified on data of the concrete steel company. The result of the paper is that environmental factors have strong influence on company total profit. Thanks to amount of permits granted to steel companies from the EU for free, it is even possible to increase the company profit. The size of this increase can be affected by choosing the most profitable stock market at the moment of making the decision.

Keywords: emissions trading, EU ETS, optimization, environmental factors, steel companies

1. INTRODUCTION

The aim of this paper is to design the profit optimizing model for steel companies in the European Union which would involve both - economic and ecological characteristics. Accept of ordinary economic constraints which are common for all manufacturing companies, heavy-industrial companies (where steel and iron sector can be also classified) must also face threats resulting from environmental legislative measures. A special emphasis is put on the European emission trading scheme (EU ETS) where carbon allowances are traded and used. The designed model should be beneficial for companies as a decision support system. The main model's purpose is to support decisions on structure and amount of production with respect to all costs associated with the manufacturing process. Designed model is primarily intended to tactical and strategic level of the management.

The paper is organized as follows. At first, a brief summary of legislative environmental factors is outlined in the Chapter 2. After that, other selected studies on economic-ecological modelling targeted to microeconomic company level are mentioned in the Chapter 3. Chapter number 4 deals with the model's design with the detail description. Formulated model is verified on the real data of one concrete anonymous company. The same chapter contains also the sensitivity analysis. The paper is concluded with the discussion of obtained results followed by suggestions for further model development and research.

2. LEGISLATIVE ENVIRONMETAL FACTORS

All companies operating on the EU market must follow many legislative restrictions related with the environment. These restrictions can be divided to two main groups - effects influencing directly costs of companies and the second one contains restrictions for the production volume.

Costs causing effects can be further divided to two other groups according to the fact whether the measure can be also the source of additional revenue or it is always only a cost. Fees paid for produced amount of pollutants (solid, liquid or an emission) induce always an expense. Within the Czech legislation are these penalties set by [1] (for solid waste), [2] (for liquid waste) and [3] (for emissions). The second group is represented by the main tool of the environmental policy of the EU - Emissions Trading Scheme (EU ETS). The EU ETS was launched in 2004 and it covers all European companies with the combustion exceeding 420 MW capacity from following fields: electricity, coke, iron, steel, cement, lime, glass, ceramics, brick, tile, refinery, paper and pulp industries and aviation [4]. The principle of this system is that each ton of CO_2 released to the atmosphere must be covered by one emission permit. This fact makes this article necessary for companies' production. Conditions within the system are not identical for all companies but it can differ [5]. For purpose of this article, only conditions for iron and steel companies are relevant and just these will be discussed. Steel producing companies belong to the group called "carbon leakage" whose firms obtain a part of required emission allowances for free from the European Commission. If a company does not use all allocated permits for one-year period it can be sold. On the contrary if there is a lack of allowances additional allowances must be purchased on the stock markets. These facts imply that the EU ETS can be a possible source of the additional profit [6]. Participating in the emission trading system brings also other (transactional) costs which are summarized by [5].

The second mentioned group of legislative environmental factors contains effects which do not bring directly the additional cost but they only create constraints for amount of the production. Emission limits and caps (ceilings) belong to this category. Emission limits are set for various types of emissions (p.e. NO_X, SO_2 or airborne dust) and they restrict the amount of released each half an hour. On the contrary, emission caps are determined as an allowable sum of year production of particular emissions. Emission limits and caps for companies in the Czech Republic can be found in [3] reflecting [7].

3. AVAILABLE PERFORMED RESEARCHES ON COMPANIES' PROFIT OPTIMIZATION INVOLVING ENVIRONMENTAL FACTORS

Thanks to the fact that the EU ETS is relatively new system, there are not many studies conducted in this field. Many of designed models involving environmental factors and especially the emissions trading are focused on the macroeconomic approach (p. e. model for effective emission permits allocation designed by [8]). Optimization models for supporting the decisions on production which include environmental factors and the EU ETS were constructed by [9], [10], [11] or [12].

An approach of Tang and Song [11] is completely different from the others. This paper solved the production planning problem by defining the production function of company's profit and then that function was maximized without using any method of optimization (just through the first derivative of the function). Other studies used optimization methods. Lemanthe and Balakrishnan [9] designed the model of linear programming came with their model very early after the EU ETS launching. The biggest disadvantage of this study is the fact that it combines a both - European and American emissions trading scheme and their conditions which makes using of these models more complicated for European companies. Tang and Song [11] and Zhang and Xu [12] designed models of stochastic optimization. This method allows to cover an uncertainty into models. On the other hand, problems come with determining the probability distribution function of stochastic variables. Then it is supposed that the future development of these uncertain variables follows the past trends. Advantages of models designed in this paper are as follows:

- Selling and purchasing prices are distinguished.
- Current conditions of the EU ETS system are included.
- Models contain also other environmental factors as model constraints.

All mentioned papers also contain a note that there is a need to extend conducted studies and to explore the field itself. They find the current state of knowledge to be insufficient.

4. PROFIT OPTIMIZING MODEL FOR STEEL COMPANIES INCLUDING ENVIRONMENTAL FACTORS

At first, a structure of the model will be presented followed by the discussion.

$$\sum_{i=1}^{n} m_i y_i + \left(R_{EUA} - \sum_{i=1}^{n} e_i x_i\right)^{+} \cdot (p^{max} - q^{VC}) - \left(R_{EUA} - \sum_{i=1}^{n} e_i x_i\right)^{-} \cdot (p^{min} + q^{VC}) \rightarrow \max \quad (1)$$

$$\text{s.t. } y_j = \sum_{i=1}^{n} (\varepsilon_{ji} - a_{ji}) x_i, \quad j = 1,2,\dots,n \quad (2)$$

$$x_i \le V_i, \quad i = 1,2,\dots,n \quad (3)$$

$$D_i^c \le y_i \le D_i^e, \quad i = 1,2,\dots,n \quad (4)$$

$$\sum_{i=1}^{n} h_{ki} x_i \le S_k, \quad k = 1,2,\dots,m \quad (5)$$

$$\sum_{i=1}^{n} h_{ki} x_i \le 17520 \cdot L_k, \quad k = 1,2,\dots,m \quad (6)$$

$$x_i, y_i \in R_0^+ \quad (7)$$

where m_i is a margin per unit of the *i*-th product, x_i is an amount of production for each of *n* products and y_i sales for *I*-th product. R_{EUA} stands for number of free allocated permits for modelled company, e_i amount of CO_2 emissions released by production of one unit of *i*-th product, p^{min}/p^{max} is the lowest/highest available price of emission allowance, q^{VC} variable cost for purchased/sold emission permit. Constraints of the model contain following variables: a_{ji} is a technological coefficient expressing an amount of the *j*-th product required for production of 1 unit of the *i*-th product, ε_{ji} represents an element of the identity matrix, V_i is a production capacity for the *i*-th product, D_i^c stands for current demand and D_i^e for expected demand, S_k is the emission cap for the *k*-th emission, h_{ki} is an amount of the *k*-th pollutant released by manufacturing of one unit of the *i*-th product and L_k is an emission limit for the *k*-th pollutant.

The objective function (1) can be divided into two parts – the first one ($\sum_{i=1}^{n} m_i y_i$) counts the total margin from selling the products and the rest of the equation stands for the additional profit/loss caused by the emission trading. A presumption is that the company enters the stock market only once during the modelled period (1 year), respectively in the end of this period. When a company has a lack of permits, there is a need to purchase additional allowances. On the contrary, when company has any redundant permits remaining from the free allocated amount, the rest can be sold on any of stock markets. In a case of purchase, companies choose the lowest possible price available on the market and selling is realized for the highest available price. Accept of the permit's price companies have to count even with the variable cost associated with a realization of the trade (this is a reason why variable costs of EU ETS are added to permit's price in (1).

The first constraint (2) is defined to ensure the consistency between sales (*y*) and production (*x*).It comes from input output Leontief model and its equilibrium, see p. e. [13]. An amount of production of the *i*-th product is restricted by upper bounds as well as by a lower bound. The first upper restriction of this type is given by the production capacities and the second one is determined by the expected demand in the modelled period (3) and (4). The reason of the second mentioned constraint is that the volume of production exceeding the demand does not bring the profit in the modelled period (only cost) to a company. Lower bound for production is determined by the rest of (4) constraint that means a restriction given by the current demand (concluded contracts at the moment of using the model). (5) and (6) are constraints determined by environmental factors – emission ceilings and emission limits (in the case of emission limits, the constant on the right side of the equation is multiplied by 17 520 what is a number of half-hours per one year).

A period of modelling is set at one year which is also one period for the EU ETS system's cycle.

5. INPUT DATA FOR MODEL'S VERIFICATION

All data on the EU ETS system were collected from the databases (carbonmarketdata.com, IRZ.cz), from directives [14] and [15] and from websites of particular stock markets (EEX, SendeCO2, ICE, KBB). Required company data were acquired from one anonymous enterprise (these data were gently modified to keep this company in secret). Some of necessary data like price of allowances or expected demand are random. That can be solved either by statistical estimations or by using the historical data. The second possibility were chosen for purposes of this paper – data on sales for the year 2013 will be used. Prices of emission allowances will be counted as an average of daily prices of four stock markets (EEX, ICE, SendeCO2 and KBB) for the whole year 2013. Respectively, the highest price (p^{max}) is an average value of maximal daily prices of all four mentioned stock markets and p^{min} is an average value of minimal daily prices of same markets. Data are shown in **Table 1 – Table 3**. Thanks to the fact that emission ceilings are always stricter than emission limits, constraint (6) will be skipped for the verification (a necessary presumption is that the production process is homogenous during the entire modelled period).

Table 1 Data on modelled company

	Production capacity/year [t]	Expected demand [t]	Current demand [t]	Margin per ton [EUR]
1 Raw iron	680 000	0	0	0 (iron is not sold)
2 Brams	900 000	20 000	8 000	19.67
3 Plates	750 000	510 000	154 000	43.67
4 Profiles	120 000	90 000	30 000	110.23
5 Cut shapes	30 000	28 000	10 000	231.89

Table 2 Data on the EU ETS system

p^{max} [EUR]	p^{min} [EUR]	R_{EUA} (2012) [t]	R_{EUA} (2013) [t]	q^{VC} [EUR]
4.49	4.45	210564	191670	0.0085

Table 3 Emission caps for pollutants

Type of emission	NOX	CO	Airborne dust
Emission cap [kg]	200 000	3 200 000	12 000

6. MODEL VERIFICATION

Results of the verification of the model designed in chapter 4 on data from chapter 5 are summarized in **Table 4**. The model was implemented in GAMS software. A form of the objective function (1) is piecewise linear (it means surely convex) so it can be solved by any method of nonlinear programming. The linear programming can be used after some gentle modifications.

Results show that the modelled company should produce an amount of products equal to the expected demand. That is not really surprising fact because of the current recession of steel industry and very low production capacity utilization. The total margin of the company is 39 077 135 EUR, and the company has a lack of permits (it must purchase allowances) but only an insignificant amount in the total price 125 EUR. When fixed costs are subtracted to obtain the total profit of the company (in the amount of 42 963 970 EUR) it is found out that the company is in loss 3 886 835 EUR. Just for a comparison, if the model would be optimized with the value of R_{EUA} from the year 2012, the loss would be lower (3 802 001 EUR) because it would be partly covered by profit from selling permits (84 708 EUR).

The model was also tested for the case when the company would be able to sell all production in any amount (constraint given by the expected demand was skipped). Results are as follows: total margin 52 530 610 EUR including the loss causing by purchasing additional permits 473 726 EUR and the total profit of the company would be 9 566 640 EUR. Optimized values of decision variables are shown in Table 4.

Theoretically, it is possible that a price of emission allowance would be high enough to influence the structure or an amount of production. For this purpose, parametric analysis were performed (the model was optimized with changing the p^{max} value (by 0.5 EUR by each step) until the selling price was beneficial enough to affect the production. Analysis showed that an amount of production would be influenced by allowances price only at price 169 EUR/EUA or higher.

Table 4 Model results

[tons]	Raw iron	Brams	Plates	Profiles	Cut shapes
Production (including expected demand)	357 303	477 707	551 832	90 000	28 000
Sales (including expected demand)	0	20 000	510 000	90 000	28 000
Production (without expected demand)	563 785	753 767	729 994	120 000	30 000
Sales (without expected demand)	0	147 222	685 174	120 000	30 000

CONCLUSIONS

Designed model showed that environmental factors have notable impact on steel companies. Changing conditions place high requirements on analytic and heuristic knowledge of managers. It was shown that in one period these factors can bring an additional significant profit and in immediately following period same factors can be a source of loss. Under current conditions and state of researched market, companies produce only an amount of products equal to the expected (or current) demand. When the all iron and steel market raises, companies would use more of their production capacity and the emission trading system would have significantly stronger influence on companies. By distinguishing the selling and purchasing price of allowance, company can earn (save) extra 0.04 EUR for each bought (sold) permit on average. The current price of permit is not high enough to influence an amount and structure of companies' production. Price would have to rise up 169 EUR per permit which is highly improbable.

The model can be further extended. It would be very beneficial to replace the historical data with stochastic variables with estimated probability distribution (or at least make the point estimates of these variables) to be able to reflect the uncertainty in better way. It is also possible to extend the model for more numbers of periods (to design a dynamic model) however, lower accuracy for next periods would have to be expected. It would be also possible to include more types of emission allowances (p. e. CER or ERU allowances) or other types of financial instruments (accept of considered spots their derivatives also exist).

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