Decision of a Steel Company Trading with Emissions

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Abstract. We formulate a Mean-CVaR decision problem of a production company obliged to cover its CO2 emissions by allowances. Certain amount of the allowances is given to the company for free, the missing/redundant ones have to be bought/sold on a market. To manage their risk, the company can use derivatives on emissions allowances (in particular futures and options), in addition to spot values of allowances. We solve the decision problem for the case of an real-life Czech steel company for different levels of risk aversion and different scenarios of the demand. We show that the necessity of emissions trading generally, and the risk caused by the trading in particular, can influence the production significantly even when the risk is decreased by means of derivatives. The results of the study show that even for low levels of the risk aversion, futures on allowances are optimal to use in order to reduce the risk caused by the emissions trading.

Keywords: CVaR, emissions trading, optimization, allowances, EU ETS

JEL classification: C61
AMS classification: 90C15

1 Introduction and the current state of art

Since its launching, the European emissions trading system (EU ETS) became the object of interest of both researchers and managers of affected companies. The system began to work in 2005 with the purpose to decrease the amount of CO_2 emissions by forcing EU industrial companies to cover their emissions by emissions allowances (1 ton of CO_2 must be covered by 1 emissions allowance).

Our paper investigates the influence of the emissions trading on profit and production portfolio plan of a steel company participating in the EU ETS. The aim of the paper is to assess the impact of the EU ETS system on the company and, also, to determine the optimal emissions management for a single one-year-long period. Because two types of emissions allowances exist (European Union Allowaces EUA, and Certified Emissions Reduction CER) and, moreover, EUA's derivatives exist (options and futures), our goal is to determine which allowance type and which financial instruments are optimal to use. The model is applied using data of one Czech steel company.

Several models optimizing the output of a company with respect to a duty of emissions trading have been already published. In [4], the deterministic models has been presented. In [9], the stochastic model has been built, but without involving any risk measure. This paper follows [8] where the single-stage single-period mean-variance model has been presented. This present contribution uses a different risk measure - Conditional Value at Risk (CVaR). In particular, a mean-CVaR model is formulated. Unlike the variance, the CVaR measure belongs to the group of coherent risk measures; moreover, it takes into account possible fat tails and an assymetry of a distribution, see e.g. [1]. CVaR has been used in both static ([6]) and dynamic (multi-stage) models, see e.g. [5]. However, the onlyapplication of the CVaR in relation to the EU ETS system has been presented by [3]; however, that paper is aimed to determine the dynamic relationship between electricity prices and prices of emissions allowances.

The core of this paper consists in the formulation of the optimization model and its verification and sensitivity analysis at the end. In order to satisfy the requirements concerning paper's length, some details about the conditions of the EU ETS have to be skipped; however, they can be found e.g. in [7]

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or [2].

The paper is organized as follows. After the introduction, the model is designed in Section 2. Section 3 presents the results of the model verification and the sensitivity analysis is done there. The last part of the paper is the conclusion where the main findings are pointed out and some proposals for further research are given.

2 The optimization model

In this section, the model assumptions are given and the Mean-CVaR optimization model is designed.

Assumptions

Production

- There is single (unit) decision period.
- There are n products produced.
- Demand for the products $d \in \mathbb{R}^n_+$, selling prices $p \in \mathbb{R}^n_+$ and the unit production costs (of final products) $c \in \mathbb{R}^n_+$ are known at the beginning of the period.
- Raw production x which is necessary for final production y is given by $x = Ty$ where $T \in \mathbb{R}^{n \times n}$ is an inverted technological matrix.
- The final production is non-zero, the limits of the raw production are given by vector $w \geq 0$, i.e.,

$$y \geq 0 \qquad Ty \leq w. \qquad (P)$$

Emissions

- The vector of CO_2 emissions resulting from raw aproduction x is given by $h^T x$ where h is a vector.

Finance

- Selling prices are collected at $t = 1$.
- The production costs are funded by a credit with (low) interest rate ι.
- Other costs are funded by loans payable at $t = 1$ with (high) interest rate $\rho > \iota$.
- If there is excess cash at $t = 0$, it may be deposited up to $t = 1$ with interest ι.
- Insufficiency of the unit of cash at $t = 1$ is penalized by constant σ (perhaps a prohibitive interest rate).

Emissions trading

- r EUA permits are obtained for free.
- At $t = 0$, the company may buy s_0^E EUA spots and s_0^C CER spots, f futures, $\phi_1, \phi_2, \ldots \phi_k$ call EUA options with strike prices $K_1 < K_2 < \cdots < K_k$ respectively, and/or $\psi_1, \psi_2, \ldots \psi_l$ put EUA options with strike prices $L_1 > L_2 > \cdots > L_l$, respectively.
- Short sales are not allowed, i.e.

$$s_0^E \geq -r, s_0^C \geq 0, f \geq 0, \phi \geq 0, \psi \geq 0 \qquad (F)$$

- Relative margin ζ is required when holding a future, for simplicity we assume that margin calls can occur only once a month and the margin cannot be decreased (for more on futures margins, see e.g. http://www.investopedia.com/university/futures/futures4.asp).

- At $t = 1$, the company may buy s_1^E EUA spots and s_1^C CER spots, short sales are not allowed:
$$s_0^C + s_1^C \geq 0, \quad r + s_0^E + s_1^E \geq 0. \qquad (G)$$
- Banking of permits is not allowed, i.e.
$$r + s_0^E + s_0^C + s_1^E + s_1^C + f + \sum_{i=1}^{k} \phi_1 - \sum_{i=1}^{l} \psi_i = hTy. \qquad (E)$$
- Only limited number of CERs may be applied, in particular,
$$s_0^C + s_1^C \leq \eta hTy \qquad (C)$$
where $0 \leq \eta < 1$.
- The company does not speculate: in particular, they would not buy more spots than needed neither they would buy more put options than the initial number of spots, i.e.,
$$s_0^E \leq hTy, \qquad s_0^C \leq \eta hTy, \qquad \sum \psi_i \leq r, \qquad (S)$$
(an alternative to (S) would be an assumption of no arbitrage).

Summarized, the vector of the decision variables is (y, ξ) where
$$\xi = (s_0^E, s_0^C, s_1^E, s_1^C, f, \phi_1, \dots, \phi_k, \psi_1, \dots, \psi_l)$$
(note, however, that the components of ξ are dependent due to (E)).

The gross balance from financial operations at $t = 0$, excluding margins of futures, thus equals to
$$E_0 = -s_0^E p_0^E - s_0^C p_0^C - \sum_{i=1}^{k} \phi_i p_0^{c,K_i} - \sum_{i=1}^{l} \psi_i p_0^{p,L_i}$$
where p_0^E and p_0^C are EUA, CER, respectively, prices at $t = 0$, p_0^{c,K_i} and p_0^{p,L_i} are the prices of call options with strike price K_i, put option with strike price L_i, respectively, at $t = 0$.

The costs of futures maintenance amounts to fM where
$$M = \sum_{j=0}^{11} \rho_{12-j} \left[M_j - M_{j-1}\right]^+, \qquad M_j = \max\left(M_{j-1}, \left[p_0^f - (1-\zeta) P_{j/12}^f\right]\right),$$
$$j = 0, 1 \dots, 11.$$
Here, $\rho_j = (1+\rho)^{j/12} - 1$ is the $j/12$ time units interest rate, p_0^f is the future price at $t = 0$ and $M_{-1} = 0$ by definition.

The cash balance at $t = 1$ resulting from production is
$$B = p^T \min(d, y) - (1 + \iota) c^T y,$$
while the balance resulting from financial operations at $t = 1$ is
$$E_1 = -s_1^E P_1^E - s_1^C P_1^C - f p_0^f - \sum_{i=1}^{k} \phi_i \min(P_1^E, K_i) + \sum_{i=1}^{l} \psi_i \max(P_1^E, L_i).$$
Summarized, the value function is given by
$$V(y, \xi) = V(y, \xi, P_1^E, P_1^C, M_\rho) = g_{1+\sigma,1}\left(g_{1+\rho,1+\iota}(E_0) - Mf + E_1 + B\right)$$
where
$$g_{\alpha,\beta}(x) \quad = \quad \begin{cases} \beta x & x \geq 0 \\ \alpha x & x \leq 0 \end{cases}.$$
Consequently, the decision problem is formulated as
$$\begin{array}{ll} \max_{y,\xi} & (1-\lambda)\mathbb{E}V(y,\xi) - \lambda \mathrm{CVaR}_\alpha\left(-V(y,\xi)\right) \\ & \text{s.t. } (P), (F), (G), (E), (C), (S) \end{array} \qquad (1)$$
where $0 \leq \lambda \leq 1$ is a level of risk aversion.

3 Application of the model

3.1 Data

The following data sources were used for verification of the model:

- database of ICE stock exchange for data on emissions prices and related financial indeces (see theice.com);
- business data of certain Czech steel company for values related with production (i.e. margins, costs, production coefficients); these data have been slightly modified;
- database Carbon Market Data for amount of emissions and allocated allowances (see carbonmarketdata.com);
- database of Czech Steel Federation for historical data on steel market.

Due to the limited length of the contribution, it is not possible to present the complete set of input data. The same input values as in [8] have been used for corresponding parameters (e.g. data on demand or production) with the difference that a longer period of permit prices was used. Prices of EUA's and CER's spots at the beginning of the period are $p_0^e = 5$ EUR and $p_0^c = 0.38$ EUR. For the sake of simplicity, only 5 call and put options have been involved with different strike prices ($K = L = \{3, 4, 5, 6, 7\}$ EUR). Prices of those options are shown in Tab. 1.

Type of option/strike price	3	4	5	6	7
Call option	2.31	1.95	1.12	0.77	0.53
Put option	0.15	0.56	1.06	1.71	2.48

Table 1 Prices of EUA options with different strike prices [EUR] (source: theice.com)

The distribution of the emissions prices at the end of the period was assumed to be log-normal; in the actual computation more than 1000 scenarios were used with the following mean values: $p_1^e \doteq 5.29$ EUR, $p_1^c \doteq 0.43$ EUR and $M \doteq 0.78$ EUR.

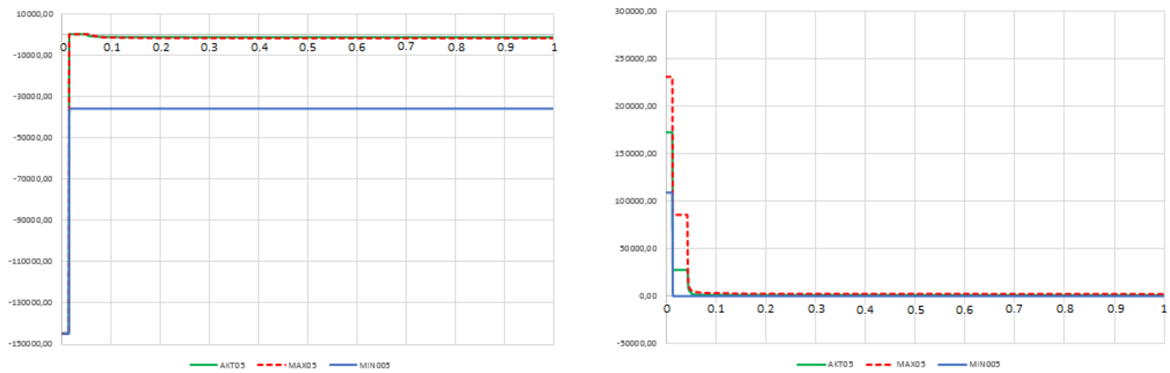
Unfortunately, no precise data on interests rates ι, ρ, σ were available. Therefore, their values are just estimated to be meaningful and to satisfy the assumptions listed in Section 2. In particular, $\iota = 0.01$, $\rho = 0.1$, $\sigma = 1$ were set (essentially, σ rate should be prohibitive enough). For the future research, those values will be surveyed and set more accurately.

It is reasonable to expect that the portfolio of financial instruments on allowances will depend on the fact if a company needs some additional allowances to purchase or if the amount of EUA's received for free is sufficient to cover all CO_2 emissions. That is why three different scenarios of the demand for production are considered. The first one $S1$ corresponds to the current level (i.e. level of 2014), when the company has a "slight" shortage of allowances. The second scenario $S2$ counts with the values of demand corresponding to production capacities of the company (i.e. the state when the company needs the maximum number of additional allowances). And the last scenario ($S3$) supposes the demand at the level of 50% of production capacities (in this case, the company has a surplus of permits).

The last parameter whose value left to be set is the risk aversion parameter λ. In order to avoid setting a particular range of values, the model will be run with all possible values, i.e. for $\lambda \in [0, 1]$. CVaR will be computed at 5% level of α.

3.2 Results

The model is solved using GAMS software. Similarly to other studies mentioned in the introduction (e.g. [8]), emissions trading does not influence the amount of the production. Moreover, the amount of production of all products is equal to the levels of demand considered, regardless a degree of risk-aversion. Thus, the only matter to analyze is the optimal portfolio of financial instruments for emissions allowances. In none of the three scenarios considered under any value of λ, EUA options are traded. All the remaining variables of allowances type differ with scenarios and a value of risk-aversion coefficient.



(a) p_0^e (b) p_1^e

Figure 1 EUA's traded at the beginning and end of the period

Most of the allowances are traded in a form of EUA spots. Optimal numbers of EUA spots traded at the beginning and the end of the period are shown in Fig. 1a and Fig. 1b, respectively. It can be seen that the company would sell all the allowances obtained for free (i.e. value of r) in all three scenarios for very low values of risk-aversion (for λ from 0 to values of around 0.02). The reason is, that the mean value of EUA price at the end of the period is slightly higher than the current (certain) value. With values of λ greater than 0.02, the company prefers higher certainty given by the current price of EUA and it sells the EUA spots only when no additional EUA's have to be bought (i.e. $S3$). At the end of the period, for small values of λ, all EUA's needed for the whole period are bought, when a risk-aversion increases, optimal values of p_1^e drops to zero (let us remind the expected increase in EUA price till the end of the period again).

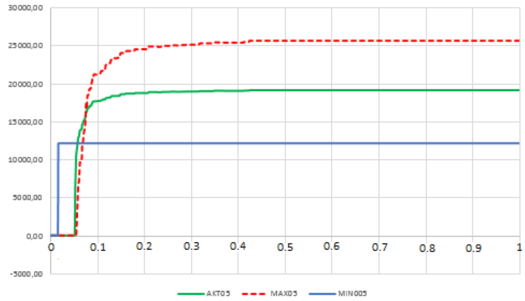
Due to very low prices of CER's in comparison with EUA's, the highest possible amount of CER's (given by $\eta = 10\%$) is always used by the company. The higher value of λ, the more CER's are bought at the beginning of the period and the less at its end, see Fig. 2a and Fig. 2b.

Out of all the EUA derivatives, only the futures are possibly used by the company. The optimal values of f when changing λ parameter are depicted in Fig. 2c. Under the scenario $S3$, no futures should be purchased at all. There is no reason for this because no additional EUA's are needed due to the low level of demand. The results differ when the number of allowances allocated to the company for free (r) is not sufficient to cover all CO_2. When assuming a lack of allowances $S1$ and $S2$, no futures should still be bought for $\lambda < 0.046$. But, for stronger risk-aversion, futures are used to decrease the risk related with emissions trading. In scenario $S1$, the amount of around 15% of all allowances needed should be purchased in the form of futures, meanwhile, under the scenario $S2$, the share of the futures goes even up to one third.

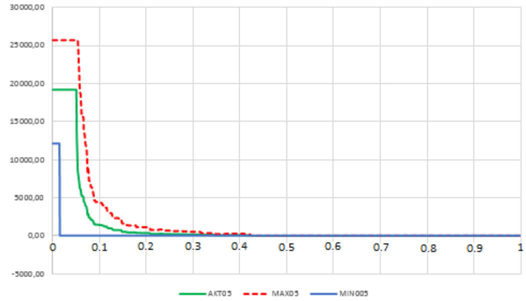
4 Conclusions

This paper was devoted to the effects of emissions trading within the EU ETS system on steel companies. The single-stage mean-CVaR optimization model has been formulated. The model has been applied using the data of the real steel company. For the sake of better understanding the modeled system, different scenarios of demands have been considered and all possible values of the decision-maker's risk aversion have been investigated. In the line with past studies, emissions trading does not affect the amount of production. The emphasis has been put on the analysis of optimal portfolio of financial instruments on emissions allowances. EUA options (both, call and put) have been considered to be inefficient to use. The optimal strategy regarding EUA spots differ with the value of risk-aversion coefficient. The company would always use 10% limit for CER allowances. When the number of allowances allocated to company for free is not sufficient, EUA futures should be used to decrease the risk.

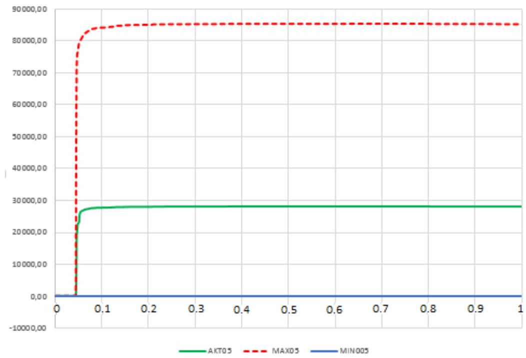
Two ways how to extend the model to the future are expected. The first lies in improvement of the presented model (e.g. data on interest rates could be further investigated and other sensitivity analyses could be performed) and the second one consists in the extension to the multi-stage (dynamic) version.



(a) p_0^c



(b) p_1^e



(c) f

Figure 2 CER's traded at the beginning and end of the period and amount of futures purchased

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