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The Broker Simulation Model in the Emission Allowances Trading Area

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ABSTRACT: This paper is focused on possibilities of simulations of emission allowances trading within the EU emission trading system using new designed broker simulation model which integrates different original soft computing and decision making methods. Firstly, the paper presents the background of the EU emissions trading system and an overview of different methods used in current research connected with CO_2 emission allowances trading. The key part of the paper focuses on the broker simulation model creation and application. The results are based on expert systems with fuzzy rule bases, nonlinear fuzzy rule based predictors and fuzzy rule based behavior modelling. The application part of the results has been performed in Matlab. The broker simulation model is able to make decisions connected with the traded amount, price of allowances and buy/sell actions within the time on the market.

Keywords: EU ETS; Fuzzy modelling; Broker
JEL Classifications: C44; Q48; Q58

1. Introduction

1.1 The EU Emissions Trading System Overview

The European Union established a scheme for emission allowances trading, the EU Emissions Trading System, also called EU ETS, dealing with greenhouse gas emissions. The initial EU Emissions Trading System was based on Directive 2003/87/EC, which established a fundamentally decentralized system for the pilot phase of emissions trading (2005 to 2007) and the Kyoto Protocol commitment phase (2008 to 2012). The key instrument here was the preparation of National Allocation Plans (NAPs) (Wettestad et al., 2012). Currently, based on Directive 2009/29/EC, the EU ETS has step into Phase III (2013 to 2020), the post-Kyoto commitment period.

The EU ETS is actually the largest emissions market in the world; however in comparison with energy markets it is relatively small (Conrad et al., 2012). In total, around 45% of total EU emissions are limited by the EU ETS (European Commission, 2013).

A sufficiently high carbon price promotes investment in clean, low-carbon technologies. The regulatory framework of the EU ETS was largely unchanged for the first two trading periods of its operation, however the beginning of the third trading period in 2013 brings changes in common rules[1] which should strengthen the system - from year 2013 the most important yield of the emission allowances is auctioned. Sectorial differentiation was introduced, with (initially) far more auctioning of allowances for energy producers than energy-intensive industries. In addition, free allocations were further harmonized, to be based on common state-of-the-art technology benchmarks (Wettestad et al., 2012). Policy makers give firms an incentive to move towards production that is less fossil-fuel intensive (Aatola et al., 2013).

In last years, CO_2 became a significant member of the European commodity trading market. However, there is a fundamental difference between trading in CO_2 and more traditional commodities. Sellers are expected to produce fewer emissions than they are allowed to, so they may sell the unused allowances to someone who emits more than the allocated amount. Therefore, the emissions become either an asset or a liability for the obligation to deliver allowances to cover those emissions (Benz and Trück, 2009).

The market price of the allowances is determined by supply and demand. Both in the first and in the second trading period, the EU emission allowances were traded mostly on the BlueNext trading exchange (BlueNext, 2012). In the third trading period there has only been one big exchange which can be used for emission rights trading – European Energy Exchange EEX (EEX, 2014).

EEX has offered trading of emission allowances on the basis of the EU ETS since 2005. EEX currently runs a secondary market for continuous trading on a Spot and Derivatives basis for EU ETS allowances (European Emissions Allowances - EUA, European Aviation Allowances - EUAA) and Kyoto credits (CER, ERU). In addition to the secondary market, EEX conducts large-scale primary auctions of emissions allowances on behalf of the EU Member States as well as for Germany and Poland, held four days per week. In the framework of these auctions, emission allowances are issued to the market participants for the first time (EEX, 2014).

1.2 Modeling of the EU Emissions Trading System

Since emission allowance trading has primarily started in the US, the majority of publications dealing with tradable emission allowances assess the market for SO_2 emissions under the Acid Rain Program (Benz and Trück, 2009). Regarding the EU ETS, scientists have focused mostly on modelling and forecasting the prices of CO_2 emission allowances (Benz and Trück, 2009; Li et al., 2011; Conrad et al., 2012; Garcia-Martos et al., 2013; Lecuyer and Quirion, 2013), the incidence of the carbon price (Grainger and Kolstad, 2010), the EUA price drivers (Aatola et al., 2013; Lutz et al., 2013), the marginal cost of both energy intensive companies and power sector (Lund, 2007; Chernyavska and Gulli, 2008), the influence of emission allowance trading on electricity producers (Lund, 2007; Chernyavska and Gulli, 2008; Falbo et al., 2013), its innovation impact (Rogge et al., 2011; Rentizelas et al., 2012) or economy-wide impacts of adopted and planned climate mitigation measures with a focus on energy efficiency (Lutz et al., 2014).

The authors of scientific papers have used various methods for their research connected with the EU ETS. Mainly in last years, we can find scientific studies, which describe particular models of EU ETS, created with different methods and different targets. For example, Li et al. (2011) used fuzzy

[1] Published as Directive 2009/29/EC

modelling (an interval-fuzzy two stage stochastic programming model) for planning CO_2 emission trading in industry systems under uncertainty, Conrad et al. (2012) used GARCH models for modelling the adjustment process of EUA´s[2] prices to scheduled macroeconomic and regulatory announcements. Aatola et al. (2013) created an equilibrium model of the emission trading market for the purposes of the EU ETS price determination, Falbo et al. (2013) created model based on the profit function for tracking of impacts of EUAs on the optimal policy of a competitive electricity producer. Garcia – Martos et al. (2013) used both ARIMA and VARIMA models for building a multivariate model for the afore mentioned prices and comparing its results with those of univariate ones, Lecuyer and Quirion (2013) created analytical and numerical model of the EU energy and carbon market for implications of the possibility of a nil carbon price on optimal policy instrument choice. Lutz et al. (2013) used Markov regime-switching GARCH model for examination of the non-linear relationship between the EUA price and its fundamentals.

Currently, there is a lack of scientific studies focused on national sub-models of the EU ETS, therefore we have focused our research on creation of the broker simulation model of emission allowances trading in the Czech Republic, based on the behaviour of particular agents - companies - within the EU ETS.

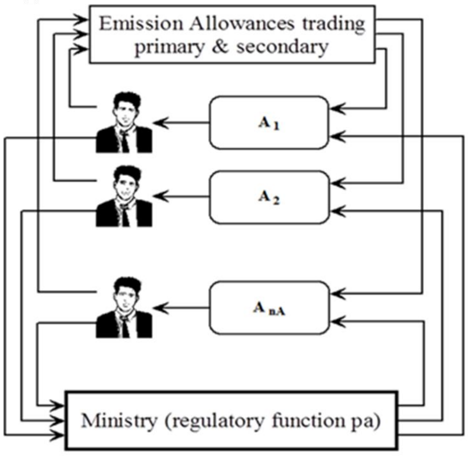
The key task of this paper is to present the first version of the broker simulation model, based on expert systems with fuzzy rule bases, nonlinear fuzzy rule based predictors and fuzzy rule based behavior modelling. The discussion part of the paper will focus on an advantages and disadvantages of proposed model; furthermore the next steps in the EU ETS research will be suggested.

2. Methodology and Data

2.1 The EU ETS system

The common problem of complex system modeling is to identify the system parts, data flows and modeling methods for the subsystems. We identified three main parts of the EU ETS system: The first one is the EUA market. The second part consists of particular agents (A_1,…, A_n) – companies. Those agents behave to optimize their business goals (dealing with the behaviour of the companies in the Czech Republic and their decision-making see Pawliczek and Piczszur, 2013). Great role in a decision making has an uncertainty caused by unknown goals of the other agents, by internal parameters of the EUA market and by external effects. The last block represents a ministerial supervision, which can have usually one year period. The following Figure 1 shows the scheme of the whole system of the EU ETS.

Figure 1. Model of the EU Emission Allowances Trading



Source: Zimmermannová and Čermák (2014).

We can see the exchange (Emission Allowances Trading, primary and secondary market), Ministry of the Environment of the Czech Republic (Ministry) and particular stakeholders involved in the EU ETS, operating on the exchange (A_1,…, A_n). Focusing on stakeholders operating on the

[2] EUA = 1 EU emission allowance

exchange and their characteristics, we can distinguish 2 main groups of stakeholders with different targets: companies – polluters and brokers.

Company – polluter tries to optimize its costs and revenues connected with the EU ETS. This stakeholder communicates both with the Ministry and with the Exchange; he also can communicate with other stakeholders. In case that his marginal abatement costs connected with decrease of 1 ton of CO_2 emissions are lower than the current EUA price on the market, he can try to decrease his pollution and to trade with redundant emission allowances on the exchange. In case his marginal abatement costs connected with decrease of 1 ton of CO_2 emissions are higher than the current EUA price on the market, he would be better to buy additional EUAs on the exchange and to cover all his CO_2 emission. On the other hand the broker operates on the exchange for the purposes of profit or the EUAs investments. Within the system, he communicates only with the exchange, he can also communicate with other stakeholders – companies or brokers. Broker can work also for the companies – polluters, for example he can trade on the exchange as representative of the particular company – polluter.

2.2 Market model

Regarding the EUA market, there are 2 possibilities of trading – agents can buy allowances at the primary spot market in auctions or at the secondary spot market in continuous trading.

Auctioning is the basic principle of allocating allowances within the EU emissions trading system (EU ETS). EEX has been awarded the role as the transitional common auction platform to auction allowances on behalf of 24 Member States. In this capacity, EEX also conducts emissions auctions for Poland during a transitional period. In addition, EEX has been selected as Germany's permanent auction platform. In these functions, EEX holds regular auctions of EU allowances (EUAs) on its spot market.

The EU emission allowances auctions are organized weekly on Mondays, Tuesdays and Thursdays, the clearing price is announced at 11 am CET. Regarding auction format, bids are submitted during one given bidding window, without seeing other participant's bids and all successful bidders pay the same auction clearing price.

The auction clearing price is determined as follows:

Bids are sorted in descending order of the price bid;

- Bid volumes are added, starting with the highest bid; the price at which the sum of volumes bid matches or exceeds the volume of allowances auctioned, shall be the auction clearing price;
- Tied bids will be sorted through random selection according to an algorithm;
- All bids with a price higher than the auction clearing price are successful; Execution of bids made at the auction clearing price depends on their ranking in the random selection;
- Partial execution of orders may be possible for the last successful bid matching the auction clearing price, depending on the remaining quantity of allowances.

The following Table 1 shows an example of setting of the auction clearing price with available quantity of EUA in the total amount of 3.461.500 (Zimmermannová and Čermák, 2014).

Regarding the secondary spot market, based on continuous trading, the EEX spot market comprises continuous trading which takes place between 8:00 am and 6:00 pm (CET) on every exchange trading day.

2.3 Agent (company) behavioral and decision making model

The proposed model must meet the following requirements:

- Use expert knowledge of domain experts from different areas;
- Adopt appropriate conclusions in case of contradictory decisions of particular experts;
- Be able to perform short term predictions;
- Overcome outside influences;
- Create or select the best strategy to achieve desired long-term goals;
- Optimizing global agent's behavior.

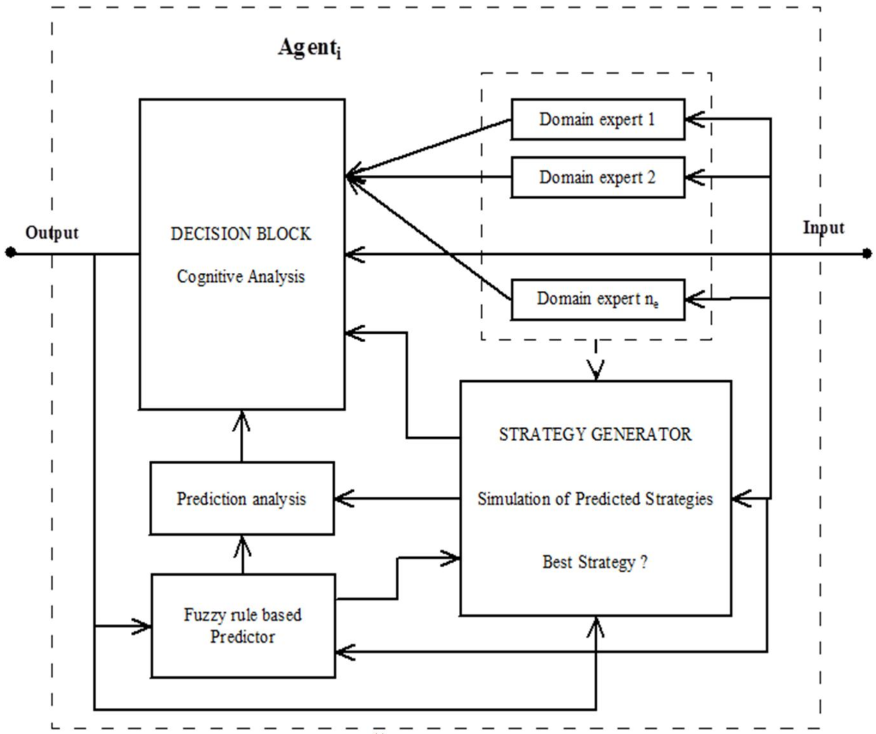
Regarding these requirements, we have created the single agent behavioral and decision making model. The following Figure 2 shows the scheme of a single agent model.

Table 1. Example of determination of auction clearing price on the primary market. (Zimmermannová and Čermák, 2014).

Companies	Price	Quantity	Time	Final Distribution	Price	Quantity	Cumulative Quantity
BEZ	4,52	500000	8:32	BEZ	4,52	500000	500000
CEZ	4,51	450000	9:01	CEZ	4,51	450000	950000
ČEZ	4,51	300000	8:01	ČEZ	4,51	300000	1250000
DEZ	4,49	50000	8:15	DEZ	4,49	50000	1300000
FEZ	4,48	200000	10:30	FEZ	4,48	200000	1500000
GEZ	4,48	400000	10:55	GEZ	4,48	400000	1900000
HEZ	4,47	551000	8:10	HEZ	4,47	551000	2451000
JEZ	4,46	70000	8:09	JEZ	4,46	70000	2521000
KEZ	4,46	350000	8:25	KEZ	4,46	350000	2871000
LEZ	4,46	285000	10:59	LEZ	4,46	285000	3156000
MEZ	4,45	80500	10:00	MEZ	4,45	80500	3236500
NEZ	4,44	175000	8:08	NEZ	4,44	175000	3411500
PEZ	4,44	100000	9:10	PEZ	4,44	50000	3461500
QEZ	4,43	50000	10:10	QEZ	4,43	0	
REZ	4,42	150000	8:42	REZ	4,42	0	
SEZ	4,41	70000	8:50	SEZ	4,41	0	
TEZ	4,41	80000	9:45	TEZ	4,41	0	
VEZ	4,4	500000	9:11	VEZ	4,4	0	
WEZ	4,39	300000	8:16	WEZ	4,39	0	
ZEZ	4,38	450000	8:20	ZEZ	4,38	0	
Total		5111500				3461500	3461500

Source: Zimmermannová and Čermák (2014).

Figure 2. Single Agent Model



Source: Zimmermannová and Čermák (2014).

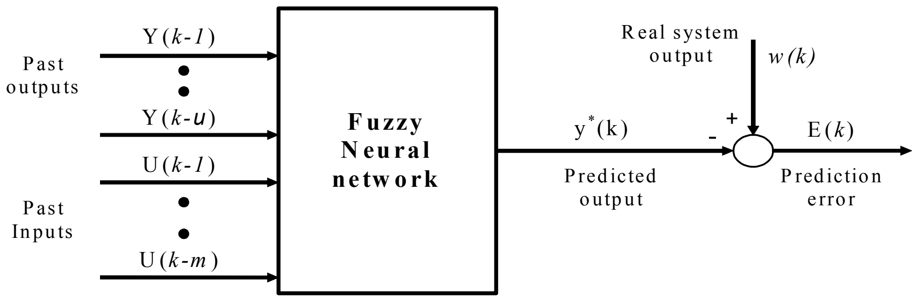
Each area is represented by single block described as “Domain expert”. In case of contradictory decisions of particular experts we apply cognitive analysis in “Decision block”. For the purposes of the prediction “sell/buy amount of allowances” together with actual price we plan to use fuzzy nonlinear regression model. This model allows us to predict short term behavior of the CO_2 allowances trade. Extracted rules can obtain information in more readable form, in comparison with neural network. In case of rapid changes on the emission allowances market or in case of great increase of RMSE error, we can adopt fuzzy nonlinear regression model. Both the RMSE error and particular rules can give information used by “Prediction analysis” block. This block gets information to the “Decision block”. Each type of company have own strategy how to achieve desired goals. If this kind of long term goal could be defined and implement as cost or fitness function, we can used evolution strategy optimizing techniques.

For the purposes of the broker model creation, we have used fuzzy rule-based systems. These systems use Takagi-Sugeno rules and Mamdani type of rules. Takagi-Sugeno fuzzy rule-based system is defined as

IF (x_1 is $A_{1,1}$) AND . . . (x_n is $A_{n,1}$) THEN ($y_2 = f(x_1, x_2, x_3, ..., x_n)$) (1)
IF (x_1 is $A_{1,r}$) AND . . . (x_n is $A_{n,r}$) THEN ($y_r = f(x_1, x_2, x_3, ..., x_n)$)

Antecedent part of each rule gives truth value of rule. The consequent part realizes function, usually linear combination of inputs. This type of fuzzy rules based system is well suited for prediction of a time series, modeling of nonlinear functions and also used for predictive control. For the purposes of determination of structure and parameters we use neural networks. The fusion variants are fuzzy neural network. More detailed description of structure and parameter identification of the fuzzy neural network is in Cermak and Pokorny (2001). This type of system is used in this research especially for predictions. The fuzzy neuro regression model (FNRM) is shown on Figure 3. The FNRM predictor is based on fuzzy-neural network and auto regression model with extended inputs.

Figure 3. FNRM predictor



Source: Cermak and Chmiel (2004).

Input vector consists of u past outputs and m past inputs of predicted system. The Result is actual predicted output value. Measurement of quality is given by Root mean square error (RMSE). The version of the FNRM with both on-line and continual learning also exists. More detailed description you can find in Cermak and Chmiel (2004) or Cermak (2005).

The second one Mamdani fuzzy rule-based system is defined as:

IF (x_1 is $A_{1,1}$) AND . . . (x is $An_{,1}$) THEN (y_1 is C_1) (2)
IF (x_1 is $A_{1,1}$) AND . . . (x is $A_{n,1}$) THEN (y_2 is C_2)
IF (x_1 is $A_{1,r}$) AND . . . (x is $A_{n,r}$) THEN (y_r is C_r)

The difference between Takagi-Sugeno rules and Mamdani type of rules is in consequent part of particular rules. These consequents are realized by terms like “The sell/buy status of allowances is quick sell”. This type of rules is well suited to develop of an expert system, definition of behavior of the agents. Those rules can be extracted with using some evolution strategies (Cermak and Chmiel, 2004).

Regarding multi expert system, there is a problem with making right decision of the whole system in case of opposite decisions of two or more experts. This problem could solve cognitive analysis (Cermak and Mura, 2012). This analysis computes consistence matrix and consistence histogram to determine which rules are consistent with other expert’s possible decisions. If histogram value is equal to number of experts, it is ideal case. When the histogram value decreases, belonging rules cause more inconsistent contribution to the whole system decision.

2.4 Data

For the purposes of the model creation, we have used data from EEX exchange (EEX, 2014), the leading energy exchange in Europe, particularly the following data and information: the EU emission allowances (EUAs) spot prices in particular trading days, information regarding the EEX exchange rules, trading conditions, emissions auctions, emissions allowance secondary market and other additional information regarding the EU emission allowances trading.

3. Results – The Model Description

3.1 The EUA market analysis

For the purposes of speculative intraday trading, especially Forex, commodities and other derivatives on financial markets, the brokers use fundamental and technical analysis. Our intention deals with instruments of technical analysis, because they can predict future price movements; however fundamental analysis is based on real market data (price, volume, volatility). Technical analysis would be meaningless if the markets move randomly. Regarding emissions trading, the price may be drastically affected by the policy decisions. Generally, prior to particular decision, the EUA price stagnates. After the decision, the value can increase by more than 100 %. Anticipating these characteristics, the broker's responses to particular situations are crucial in terms of profitability of the client. The following Figures 4, 5 and 6 show the EUA spot price development in the period 2012 – 2014.

Figure 4. European Emission Allowances (EUA) – 2012 (EEX, 2014).

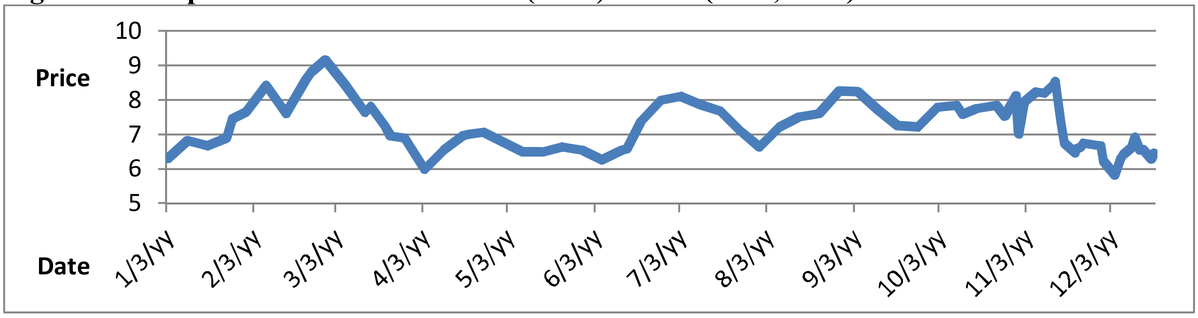


Figure 5. European Emission Allowances (EUA) – 2013 (EEX, 2014).

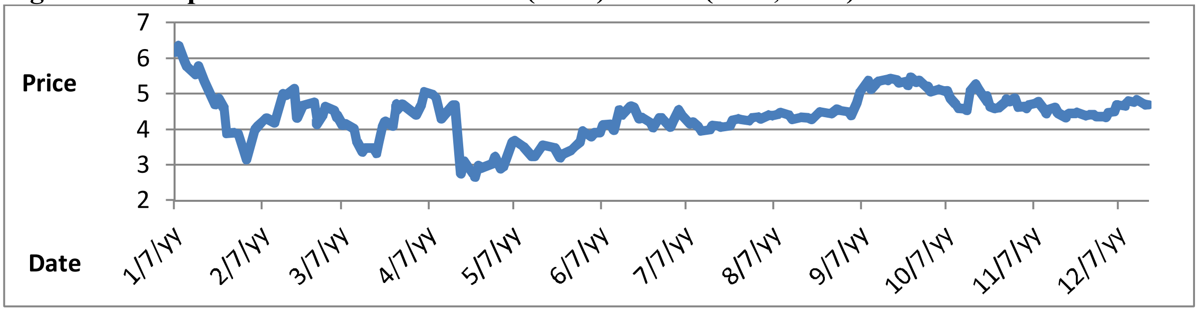
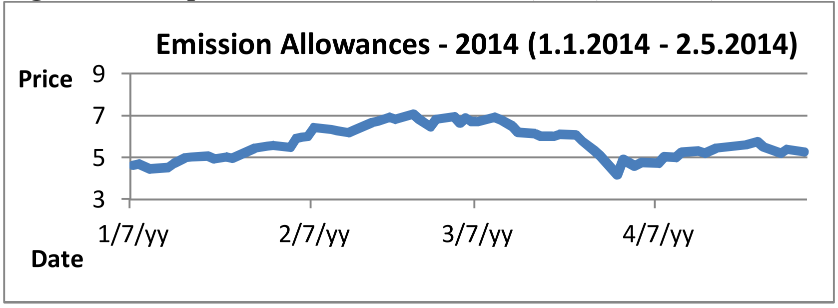


Figure 6. European Emission Allowances (EUA) – 2014 (EEX, 2014).



Because of drastic changes in political decisions during the analysed period, it is difficult to predict the EUA spot price. Based on this situation, we propose the basic system of the trend line analysis, polynomical two period moving averages, for the short-term trading predictions based on data from March 17th, 2014 - April 14th, 2014. Polynomical two period moving average is defined as:

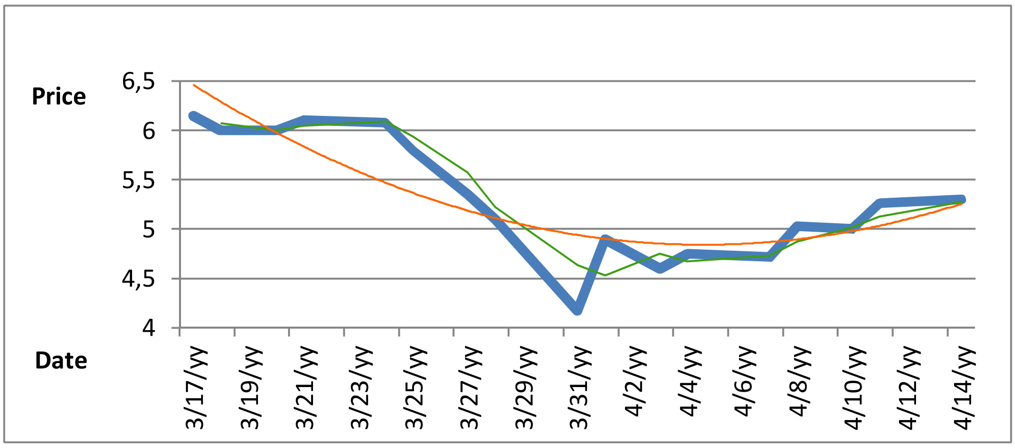
$x = 2 / (n + 1)$, (3)

$MA = (p-1) + [x * (p - (p - 1)]$,

whereas n = number of days, p – 1 = price of the previous day, p = current price

The results are shown on Figure 7.

Figure 7. Emission Allowances – Trendlines - Polynomical, Two period moving average



We can see the circular trend and therefore when the large radius of the circle waits to achieve lower bottom, we recommend to buy emission allowances and to wait for the achievement of the expected minimum 5 % increase in the level of 5.75. For the chosen strategy the broker can get higher returns over a longer time interval.

For two periods it would be better to use moving average proposed by the following scenario. As we can see from Figure 7, shopping is optimal to implement at the trend line located under the main line graph, we call this level of resistance. For the chosen strategy the broker can get lower valuations for a shorter time interval.

From the available historical data of the years 2012, 2013 and 2014, we put together a business charts and graphs candles on the basis of software intended for trading determined the individual zones and border designs for trade and sale (see Table 2).

Table 2. Emission Allowances – zone (Clarity ©, 2014).

Zone	Trend		Result	
			Buy	Sell
Zone 1	-2	+2	0,651	0,085
Zone 2	>2		0,372	1,794
Zone 3	<-2		1,906	0,119

By identifying those areas, we decided to create fuzzy rules model. For more accurate decision-making criteria, we have introduced even zones 4 and 5, it is a boundary zone of growth and decrease of more than 4 %.

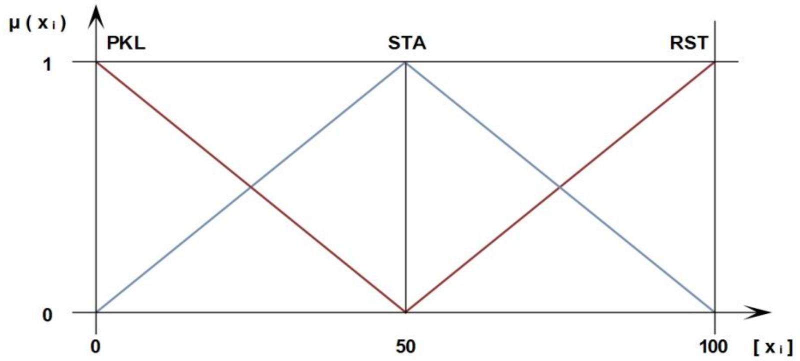
3.2 BROKERv2 – the fuzzy rule-based model

The linguistic fuzzy rule-based model works with the price development trend (TVC), the gross domestic product (HDP), the economy development (VEK), the commodities price (CKO) presenting the four input linguistic variables and with the broker behaviour (CHA) serving as the one output linguistic variable. The input variables always have 3 linguistic values and the output one has always 5 linguistic values. The input variables universes are normed <0, 100>. The input variables linguistic values names are identical.

Decrease	PKL	[0, 0, 50]
Stagnation	STA	[0, 50, 100]
Increase	RST	[50, 100, 100]

According to the Figure 8, the linguistic values are formalized by the fuzzy sets with the triangular membership functions.

Figure 8. The membership functions of the fuzzy sets input variables linguistic values (authors).

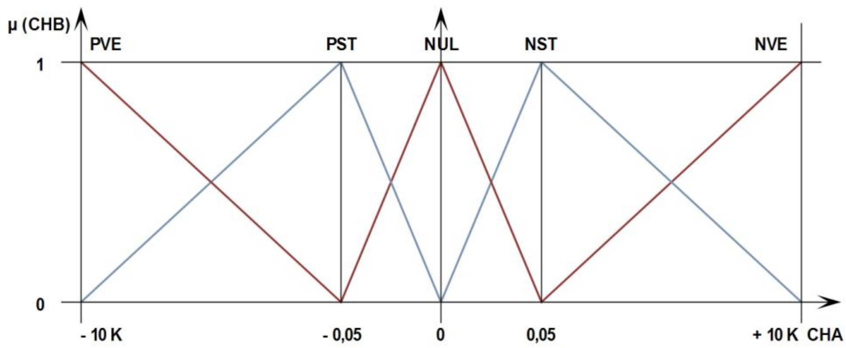


The Broker behaviour output linguistic variable is defined on the <-1.10e4, +1.10e4> universe with the following linguistic values:

Big purchase	NVE	[5.10e2, 1.10e4, 1.10e4]
Standard purchase	NST	[0, 5.10e2, 1.10e4]
No action	NUL	[-5.10e2, 0, 5.10e2]
Standard sale	PST	[-10.10e4, -5.10e2, 0]
Big sale	PVE	[-1.10e4, -1.10e4, -5.10e2]

The membership functions shapes of the output linguistic values are illustrated by the Figure 9.

Figure 9. The membership functions shapes of the output linguistic values (authors).



3.3 BROKERv2 model input values data preparation

The current input variables values are the following:

1) TVC – the EUA price development trend[3]
2) HDP – gross domestic product[4]
3) VEK – economy development[5]
4) CKO – commodities price[6]

A variable "economy development" can be calculated as

VEK = HDP + INF + USA + EUS + WIN (4)

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[3] For more information see www.eex.com
[4] For more information see www.partia.cz
[5] For more information see www.partia.cz
[6] For more information see www.partia.cz

Whereas HDP = gross domestic product, USA = interest rate, EUS = forex course development EUR/USD, WIN = world inflation.
A variable "commodities prices" can be calculated as:

$$CKO = PXE + KOV\ (AL + CU + PB + NI + ZN + PD) + SKO\ (BA + SB + PS + KU + KA + CU) + FKO\ (AU + SG + PT) \quad (5)$$

Whereas PXE = Prague energy stock market index Praha, KOV = metals, SKO = soft commodities and FKO = fix metals; the individual commodities consist of the following items: AL (aluminium), CU (copper), PB (lead), NI (nickel), ZN (zinc), PD (palladium), BA (cotton), SB (soya beans), PS (wheat), KU (corn), KA (cacao), CU (sugar), AU (gold), SG (silver), PT (platinum).

The input variables values are acquired from the stated webpages. Then the input variables are further normalized to the <0,100> range. The procedure of the input data ranges normalization is the following:
The x_i input data values normalization to the <0, 100> range is performed by the following common relation:

$$x_{i,NORM} = \frac{x_i - \min(x_1,...,x_i)}{\max(x_1,...,x_i) - \min(x_1,...,x_i)}(I_{\max} - I_{\min}) + I_{\min} \quad (6)$$

Whereas $x_{i,NORM}$ = input variable normalized value, x_i = variable initial value, I_{min} = normalized interval lower limit and I_{max} = normalized interval upper limit.

3.4 BROKERv2 model rules structure - knowledge base

The linguistic values complete combination of the all input variables presents the fuzzy model consisting of the $R = 3^4 = 81$ conditional IF-THEN rules. The fuzzy model was structurally optimized following the expert consequents declaration (6) as this optimization led to the rules reduction to the final rules number R = 17. Their verbal interpretation are the following:

1) IF development_trend IS decrease AND commodities_price IS decrease THEN behaviour_on_the_market IS big_purchase
2) IF development_trend IS decrease AND commodities_price IS stagnation THEN behaviour_on_the_market IS big_purchase
3) IF development_trend IS decrease AND commodities_price IS increase AND economy_development IS decrease THEN behaviour_on_the_market IS big_purchase
4) IF development_trend IS decrease AND commodities_price IS increase AND economy_development IS stagnation THEN behaviour_on_the_market IS big_purchase
5) IF development_trend IS decrease AND commodities_price IS increase AND economy_development IS increase THEN behaviour_on_the_market IS standart_purchase
6) IF development_trend IS stagnation AND commodities_price IS decrease THEN behaviour_on_the_market IS standart_purchase
7) IF development_trend IS stagnation AND commodities_price IS stagnation AND economy_development IS decrease THEN behaviour_on_the_market IS standart_purchase
8) IF development_trend IS stagnation AND commodities_price IS stagnation AND economy_development IS stagnation THEN behaviour_on_the_market IS standart_purchase
9) IF development_trend IS stagnation AND commodities_price IS stagnation AND economy_development IS increase THEN behaviour_on_the_market IS no_action
10) IF development_trend IS stagnation AND commodities_price IS increase THEN behaviour_on_the_market IS no_action
11) IF development_trend IS increase AND commodities_price IS decrease THEN behaviour_on_the_market IS standart_sale
12) IF development_trend IS increase AND commodities_price IS stagnation AND economy_development IS decrease AND HDP IS decrease THEN behaviour_on_the_market IS standart_sale
13) IF development_trend IS increase AND commodities_price IS stagnation AND economy_development IS decrease AND HDP IS stagnation THEN behaviour_on_the_market IS standart_sale
14) IF development_trend IS increase AND commodities_price IS stagnation AND economy_development IS decrease AND HDP IS increase THEN behaviour_on_the_market IS big_sale

15) IF development_trend IS increase AND commodities_price IS stagnation AND economy_development IS stagnation THEN behaviour_on_the_market IS big_sale
16) IF development_trend IS increase AND commodities_price IS stagnation AND economy_development IS increase THEN behaviour_on_the_market IS big_sale
17) IF development_trend IS increase AND commodities_price IS increase THEN behaviour_on_the_market IS big_sale

3.5. Broker model implementation in the MATLAB system

The language model implementation was made within the Fuzz Toolbox programming environment of the MATLAB system. Deduction is performed by the Mamdani's deduction method. Defuzzyfication is provided by the COG method. Figures 10, 11, 12, 13, 14 and 15 show the MATLAB interactive screens with presentations of the program editing and model function simulation.

Figure 10. AGENT – BROKER model main screen (authors).

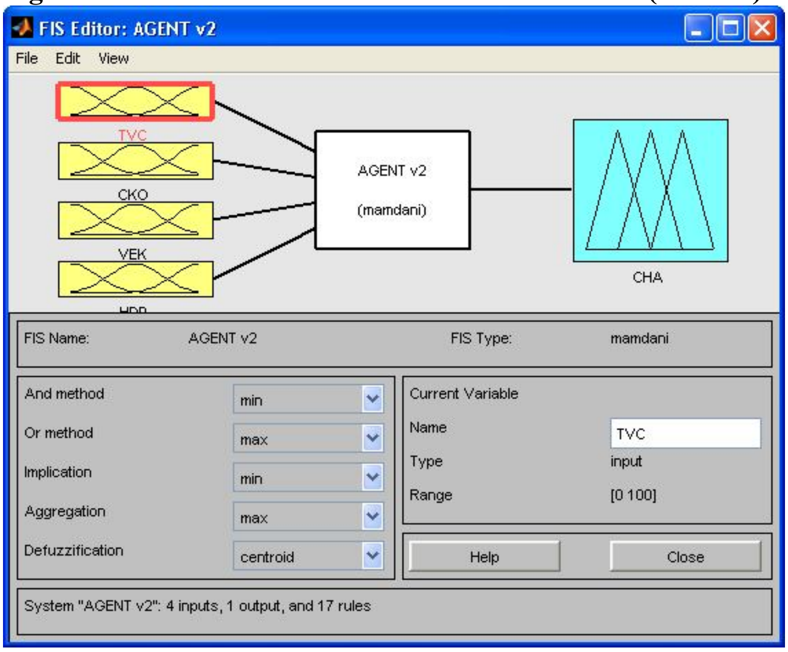


Figure 11. Input variable language values (authors).

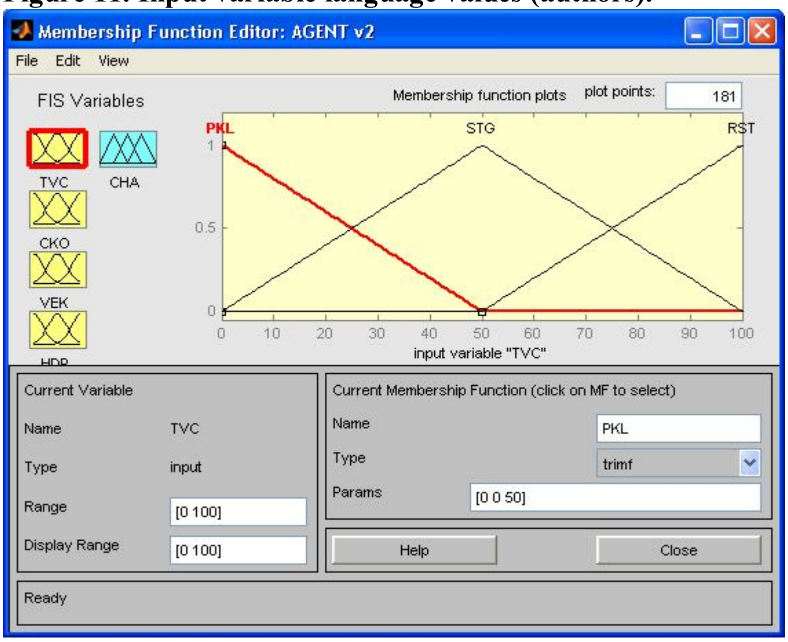


Figure 12. Output variable language values (authors).

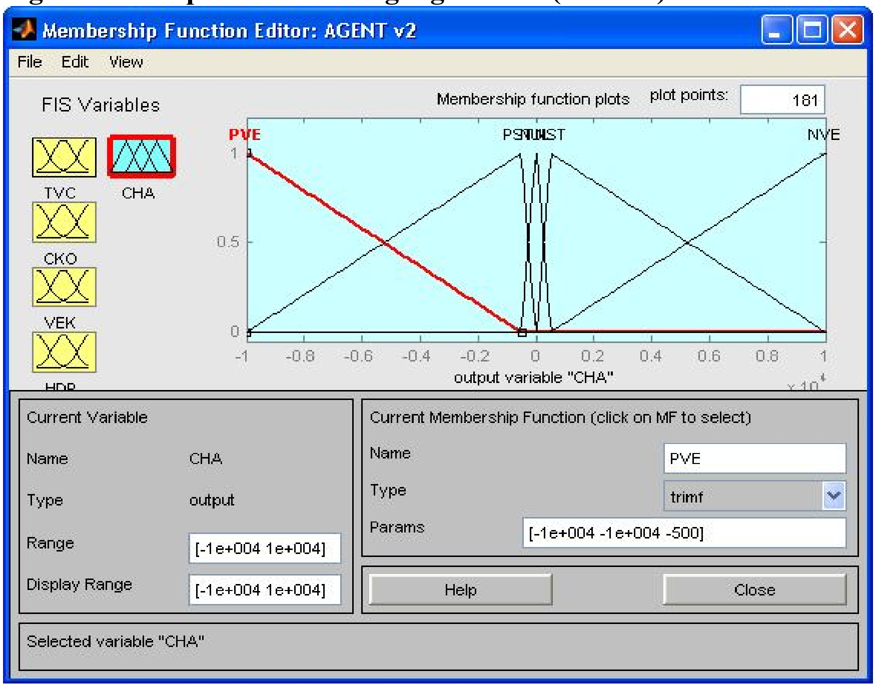


Figure 13. Model rules editing screen (authors).

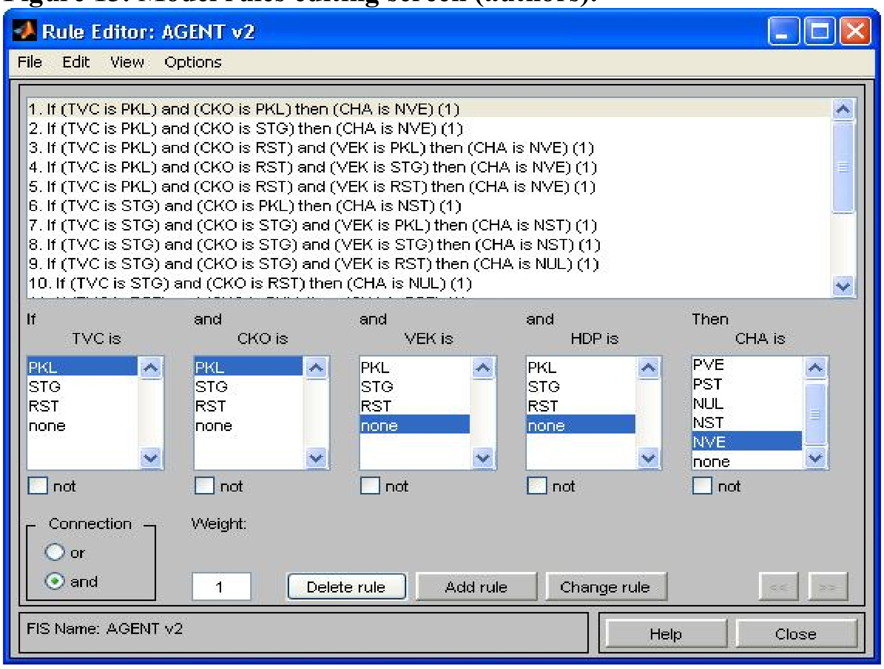


Figure 14. Example of the outputs functional dependence on the inputs (authors).

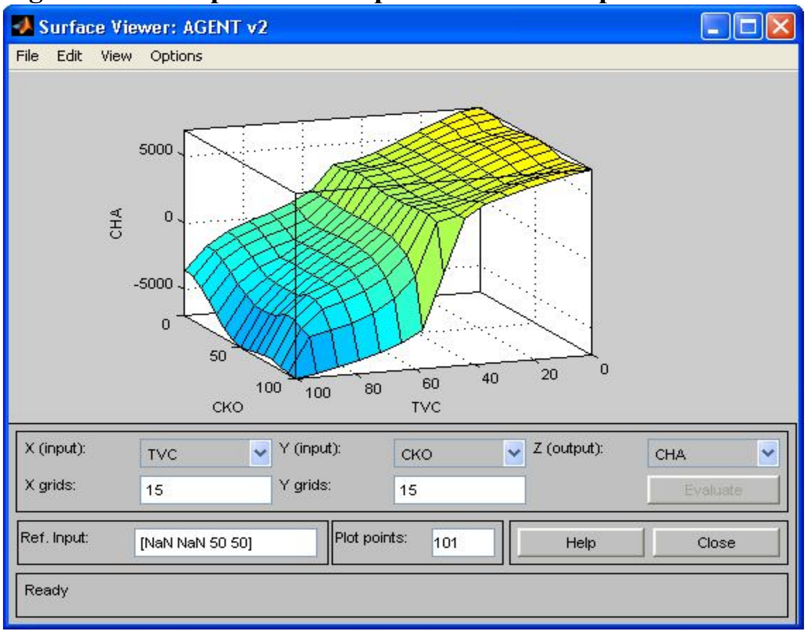
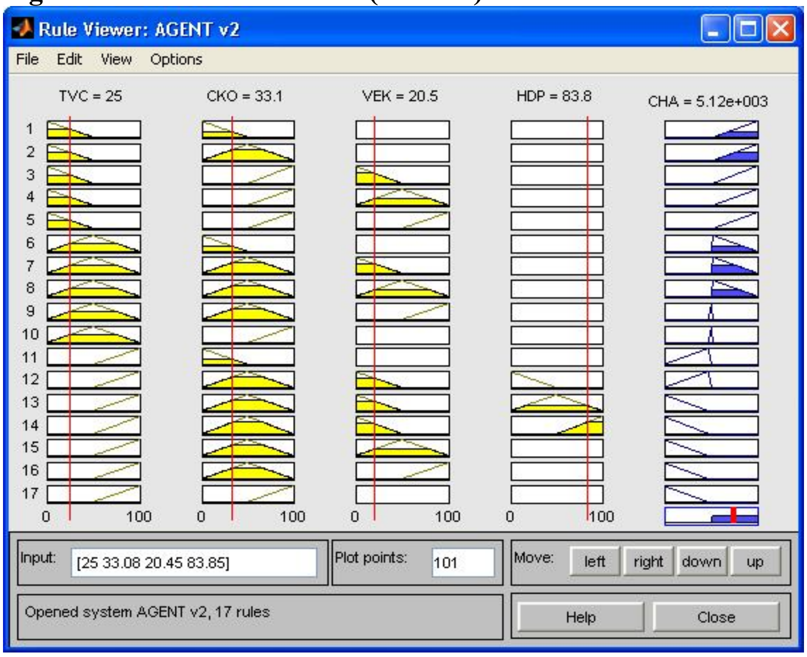


Figure 15. Simulation screen (authors).



4. Discussion

Regarding proposed broker simulation model and his significance in a decision making process, it should be mentioned, that this instrument can serve both as an important additional source of information and as a significant tool for particular strategies simulations. The model can simulate different development of the EU ETS, for example different development of prices of one emission allowance on the spot market and consequent impacts of these changes on particular broker (company) behavior.

Generally, the broker simulation model can serve as an experimental EU ETS space, where we can track changes in behavior of the broker. The possibility to extend the one-agent broker model to the multiagent one should be discussed. The individual brokers can have for example the following specifics:

1. Basic Agent – Broker
   - purchases on the primary and the secondary market;
   - sells on the secondary market;
   - cooperate if it is beneficial to him.
2. Quantity Agent – large bank, institution
   - purchases in a large amounts on the primary and the secondary market;
   - sells on the secondary market;
   - cooperate if it is beneficial to him;
   - sells already purchased allowances on the secondary market for a higher price than was their purchasing price on the primary market.

3. Agent, that failed on the auction market – institution or broker that wanted to buy in auction, but it offered too low price so that it failed. The allowances are really necessary for him.

- purchases on the primary market, it fails there, purchases on the secondary market;
- its rules will be similar to the broker 1, considering the fact that he will purchase the allowances for the higher price than the broker 1;
- it can cooperate, e.g. make an agreement with some of the other agents that they will join the allowances amount requirements on the secondary market to achieve a lower price;
- purchases only.

4. Agent paid by company – an institution or broker that should purchase the certain amount of allowances for the XY company (it really require the given allowances amount).

- purchases on the primary and the secondary market;
- the XY company really needs the certain XY amount of allowances and buys them even for a higher price (we can set the particular limit or we can set the arbitrarily high price), i.e. the broker purchases by the company request;
- it can cooperate, e.g. make an agreement with the Quantity Agent that the last mentioned will purchase the higher allowances amount for lower price and then to sale part of it to the Agent paid by company;
- only purchases on the market.

5. Agent paid by company – an institution or broker that should purchase the certain allowances amount for the ZZ company (the company that wants to invest).

- purchases on the primary and the secondary market;
- the ZZ company does not necessarily need the certain amount of allowances but wants to invest in it, i.e. the broker purchases by the company request;
- it can cooperate in the same way as the previous agent – e.g. make an agreement with the Quantity Agent that the last mentioned will purchase the higher allowances amount for lower price and then to sale part of it to the Agent paid by company;
- a difference in comparison with the previous Agent – the Agent purchases even for the disadvantageous price for the XY company, the Agent purchasing for the ZZ company buys only if the price is good.

There can be the following options for cooperation of particular agents: the first one is that the agents can make an agreement with the Quantity Agent that the last mentioned will purchase the higher amount of allowances for the preferable price and then to sale part of it at a profit to them. The second one is that some agents purchasing on the auction market can agree on (regarding the increasing price of the allowances) that they will buy up the auction market – i.e. they will offer a higher price and buy up the large amount of the allowances. They can sell these allowances at a profit on the same day or on the following days as to the allowances price is increasing.

5. Conclusions

This paper is focused on possibilities of simulations of emission allowances trading within the EU emission trading system using new designed broker simulation model which integrates different original soft computing and decision making methods. The paper presents the background of the EU emissions trading system and an overview of different methods used in current research connected with CO_2 emission allowances trading.

The key part of the paper focuses on the broker simulation model creation and application. The results are based on expert systems with fuzzy rule bases, nonlinear fuzzy rule based predictors and fuzzy rule based behavior modelling. The application part of the results has been performed in Matlab. The broker simulation model is able to make decisions connected with the traded amount, price of allowances and buy/sell actions within the time on the market. In the next steps, the given system will be further extended by the other types of agents and also by the agent internal structure.

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