Do Commodities Determine the EU Emission Allowances Price?

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Abstract. This paper presents an analysis of the influence of gas, coal, electricity and Brent (crude oil) prices on the EU emission allowance price by means of a vector autoregression analysis. Statistically significant influences on the price of CO_2 emission allowances can be identified for all energy market variables examined, except electricity prices. Thus, the present analysis supports the assumptions of earlier publications that the influence of the energy market on the European Emissions Trading System (EU ETS) is decreasing and that the efforts of the European Commission are having an effect. The EU ETS is designed to stimulate the reduction of emissions by setting caps and to create monetary incentives for investment in new, low-emission technologies by trading emission allowances. However, the allocation efficiency of this system is conditional on the relative price stability of the emission allowances, as this is the only way to make reliable forecasts for risk calculations and investment decisions by companies. Using a vector autoregression model (VAR), this paper demonstrates significant influences of energy prices on the European Emission Allowances (EUA) price in the third phase of the EU ETS.

Keywords: CO_2, emission allowances, emissions trading, energy prices, vector autoregression, VAR

1 Introduction

The European Emissions Trading System (EU ETS) was implemented in all 28 EU member states on 1 January 2005. As a cap-and-trade system, it sets an upper limit for the total amount of greenhouse gas emissions permitted in industry, but allows trading of emission allowances between companies within this quota. The upper limits are set individually by the EU member states with the aim of reducing the permitted emission quantities over the course of the years [9].

The possibility of buying and selling allowances allows companies that produce particularly low greenhouse gas emissions to benefit, as they can sell surplus allowances to other, less efficient companies. In a stable trading system, this can create incentives for companies to invest in the conversion of their production facilities so that they can refrain from purchasing emission allowances in the future. In a functioning market, the prices of emission allowances thus reflect allocation-efficient investments in climate protection.

For the incentive systems described above to work, a stable market for emission allowances is necessary. This became clear when the economic crisis of 2008 abruptly reduced the CO_2 emissions of companies, which in turn led to a massive oversupply of emission allowances and caused the price of these to fall [9].

2 Trading Periods of the EU ETS

Emissions trading takes place in allocation phases lasting several years (see Fig. 1) in order to compensate for fluctuations, for example as a result of extreme weather conditions, and to create longer-term investment security. With each subsequent phase, the system was successively implemented and stabilized in the market.

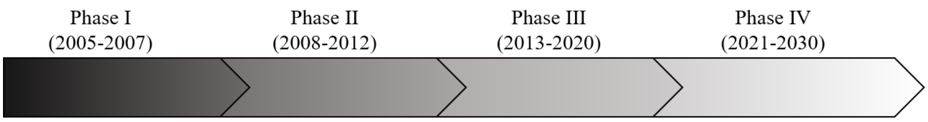

Fig 1. The phases of the EU ETS.

In Phase I, a price for carbon emissions was set that allows EU-wide trading and sanctions for exceeding the ceilings were implemented. The emission allowances were initially distributed to the companies free of charge, while at the same time an infrastructure necessary for monitoring was created. In the absence of reliable emissions data, estimates were used to determine the number of allowances to be issued. However, as these were clearly too high, the price of the emission allowances fell to zero in 2007 [9].

In Phase II, the quantity of allowances distributed free of charge was reduced, as were the emission ceilings of the countries. In addition, three new countries, Iceland, Liechtenstein and Norway joined the emissions trading scheme. The penalty price per tonne of CO_2 for exceeding the ceilings was more than doubled. However, due to the economic crisis during this period, the price of emission allowances fell significantly [9].

In the currently ongoing third phase of the EU ETS (as of March 2020), the national caps have been replaced by an EU cap. The emission allowances not distributed free of charge will be auctioned and additional industrial sectors and emission gases will be covered. In addition, the market stability reserve was introduced. As a short-term solution, the auctioning of a total of 900 million allowances in 2014-2016 was postponed to 2019 and 2020. The market stability reserve, which was implemented in January 2019, represents the long-term solution. In future, this reserve will absorb surpluses in the allowances market in accordance with defined rules and, if necessary, distribute allowances in the event of a shortage [9].

A further reduction of the ceilings and further strengthening of the market stability reserve is planned in Phase IV. In addition, from 2023 onwards, emission allowances from years prior to the previous year of the current trading period are to expire [9].

In order for the EU ETS to serve as an incentive scheme for investment in technologies to reduce greenhouse gas emissions as described above, it is necessary that the scheme provides a stable price. Only with this price as a basis can companies make conscientious investment decisions. Thus, important practical implications can be derived from this study.

This paper will use vector autoregression analysis (VAR) to analyse the interactions between the four most important energy prices, electricity, gas, Brent (crude oil) and coal, and the price of emission allowances. These four factors represent important economic indicators in the energy sector and are therefore suitable for examining the vulnerability of the EU ETS to minor economic fluctuations. This study covers the period from 30 September 2013 to 1 October 2019 and provides a more up-to-date analysis than the existing literature. Furthermore, existing theories for phase III of the EU ETS will be verified.

The present work is structured as follows: In the next section a short overview of the results of the existing literature is given. Based on the literature, hypotheses for the investigation are derived. In the third section the sample and the chosen methodology are presented. Then the results are discussed and a summary of the possible implications of the results is given.

3 Prior Research and Hypothesis Development

3.1 Prior Research

The literature on the dynamics and volatility of CO_2 allowances has grown rapidly during the first and second phase of the EU ETS (2005-2012) and flattened significantly with the start of the third phase of the EU ETS in 2013. This may be due to the fact that the system became established and prices have remained relatively constant since. Since 2018, however, the EUA price has risen significantly, reaching a record high in mid-August 2019, almost six times its September 2013 value. The variables influencing the price of CO_2 emission allowances identified in the literature to date are numerous and vary in their intensity from phase to phase.

Mansanet-Bataller et al. [16] concentrate in their work on the daily CO_2 price changes in 2005 in order to investigate the underlying rationality of price behaviour. For this purpose, the authors have analysed influencing factors on both the supply and the demand side of EUAs using different models. While the effects of national allocation plans on the price level of CO_2 emission allowances were not statistically significant in an intervention analysis, the influence of energy and weather variables on CO_2 price changes could be demonstrated. The authors applied OLS-regression and the Newey-West covariance matrix estimator, among other techniques.

Alberola et al. [2] have analysed the influences on the EUA price during the entire pilot phase of the EU ETS (2005-2007). Using the OLS method, the authors postulated an empirical relationship between changes in EUA prices and significant influencing factors such as commodities (Brent, coal, gas), electricity prices and weather conditions. The authors also show that the effects of the influencing factors on the EUA price changed in the period 2005-2007 after two statistically determined structural breaks in the EU ETS in April 2006 and October 2006, which were caused by the publication of new market-relevant information. According to the authors, unforeseen temperature changes in extreme weather conditions play a greater role in EUA price changes than the temperatures themselves.

Bredin and Muckley [4] have investigated the extent to which several theoretically based factors such as economic growth, energy prices and weather conditions determined the expected prices for EUAs in the period 2005-2009. Using both static and recursive versions of the multivariate cointegration probability ratio test, the authors show that the EU ETS is a functioning market driven by these factors. Creti et al [8] confirm this result in a cointegrating framework by using the Dow Jones Euro Stoxx 50 as their stock variable.

Aatola et al. [1] have investigated the pricing of EUAs under the EU ETS and its price development during the first five years (2005-2010). For this purpose, the authors first developed a market equilibrium model for the emissions trading market and then tested it empirically using time series econometrics. OLS, IV and VAR models were applied. The time series of various EUA-related commodities and other relevant market fundamentals, such as electricity, steel, paper and mineral products, were used as explanatory variables. The authors were able to show that there is a clear and stable relationship between energy prices and the EUA price. About 40% of the price changes in the EUA futures price could be explained by these fundamentals. The most important determinant of the EUA price is the price of electricity generated in Germany, which has a large and significant influence on the EUA price. Other energy prices also influence the EUA price in a statistically significant way, but to a lesser extent.

Hintermann [13] investigated the interaction between the EUA price and marginal abatement costs during the first phase of the EU ETS (2005-2007). He found that Brent (crude oil) prices, electricity and economic growth indicators are important price drivers. However, due to the shorter time span in the study, his estimates showed less statistically significant coefficients than those of Aatola et al. [1]. Hintermann [13] also classified the coal price as not significant.

Chevallier [6] has investigated the interaction between EUA, energy and macroeconomic variables by specifying and estimating several Markov-switching VAR models for the period 2005-2010, extending in particular earlier work by Benz and Trück [3] on univariate Markov-switching modelling of EUA price series. In conclusion, Chevallier [6] found that the industrial development of a country has a positive influence on the development of the EUA price. In upturns, the EUA price rises as the economy picks up; in recessions, the EUA price falls as the capacity utilisation of manufacturing companies increases. In addition, the author postulates the price of fuel as the most influential variable, which shows influences on other energy prices in addition to the EUA price.

Hammoudeh et al. [12] use a quantile regression to investigate the effects of changes in crude oil, natural gas, coal and electricity prices on the distribution of CO_2 emission allowance prices in the United States in the period from 2006 to 2013. The authors found that an increase in the price of crude oil leads to a significant decrease in the price of CO_2 if it is very high; changes in the price of natural gas have a negative effect on the price of CO_2 if it is very low but a positive effect if it is high; the effects of changes in the price of electricity have a positive effect on the price of CO_2 in the right part of the distribution and the price of coal has a negative effect on the price of CO_2.

In summary, previous research has shown that the level of the CO_2 emission allowances price is primarily regulated by the market mechanism of supply and demand on national exchanges [6, 7, 16]. Numerous influencing factors on both the supply and the demand side have been investigated in the literature.

The supply side is determined by the number of allowances made available by the state through national allocation plans (NAPs) in consultation with the European Commission [1, 6]. A certain price or a lower or upper price limit can be set directly when the allowances are made available. Furthermore, it is possible to influence the price of CO_2 emission allowances by regulating the quantity of allowances made available [12] or by setting an upper emission limit below the usual commercial emission level [2].

The demand side is characterised by a complex interaction of various influencing factors. In addition to weather conditions (temperatures, precipitation and wind speeds) [2, 16], economic activity (economic growth and activity on financial markets) [6] and the disclosure of institutional information [2], energy prices (coal, electricity, oil and gas) are seen as the main influencing factor [1, 2, 5, 6, 12, 13, 16, 17].

The following diagram provides an overview of the main factors on the supply and demand side that influence the formation of the CO_2 emission allowances price.

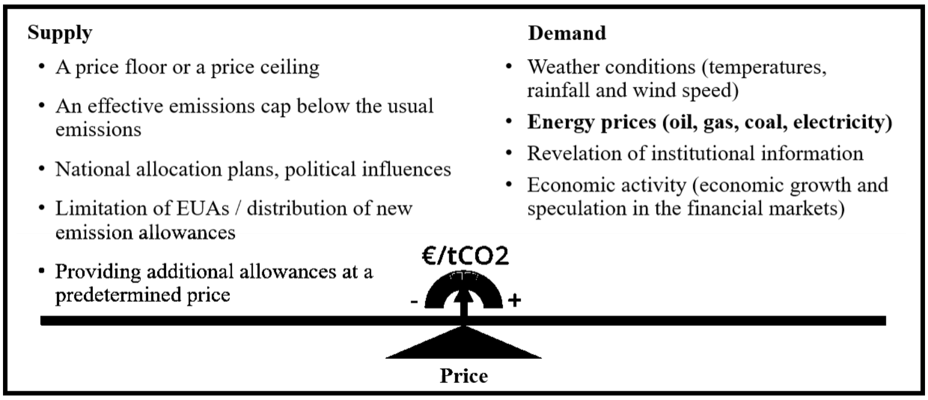

Fig. 2. Factors influencing the price of CO_2 emission allowances.

3.2 Research Gap

According to the existing scientific literature, the prices of Brent (crude oil), natural gas, coal and electricity were chosen as the most calculable price influencers on the price of emission allowances. In contrast to the existing literature, this study considers the period from 30.09.2013 to 01.10.2019. The year 2013 marks the beginning of the implementation of the third phase of the EU ETS, in which the instruments used led to a relative stabilisation of the prices for emission allowances from 2018 onwards (Fig. 4) and the interaction of the different market mechanisms.

3.3 Hypothesis Development

The following hypotheses can be derived from the results of the preceding literature:

Hypothesis I (H1): The price of Brent (crude oil) has a negative impact on the EUA price, since a high oil price reduces the demand for oil and thus greenhouse gas emissions. Consequently, an increase in the price of crude oil leads to a decrease in the price of CO_2 emission allowances [12].

Hypothesis II (H2): The coal price also has a negative influence on the EUA price [1, 2, 12]. If the coal price rises compared to other energy markets, companies have an incentive to change their energy mix to less CO_2-intensive energy sources.

Hypothesis III (H3): In the literature, the gas price is generally associated with a positive influence on the EUA price [1, 2, 16]. Hammoudeh et al. [12] differentiate further and state that an increase in natural gas prices has a negative effect on the EUA price if it is very low, while an increase has a positive effect if the EUA price is high. This effect is mainly related to the high degree of substitutability between gas and coal, which was also found in further investigations [2, 12, 16].

Hypothesis IV (H4): According to prevailing opinion, the electricity price has a positive influence on the price of EUA [1, 2]. According to Aatola et al. [1], the price of electricity produced in Germany is even the most important factor influencing the EUA price. According to Hammoudeh et al. [12], a positive influence of electricity on the CO_2 emission allowances price can only be assumed if the CO_2 emission allowances price is high, but in general a negative influence can be assumed.

The following Figure 3 shows the influences of the four energy sources (coal, electricity, Brent and gas) on the EUA price as established in the previous literature.

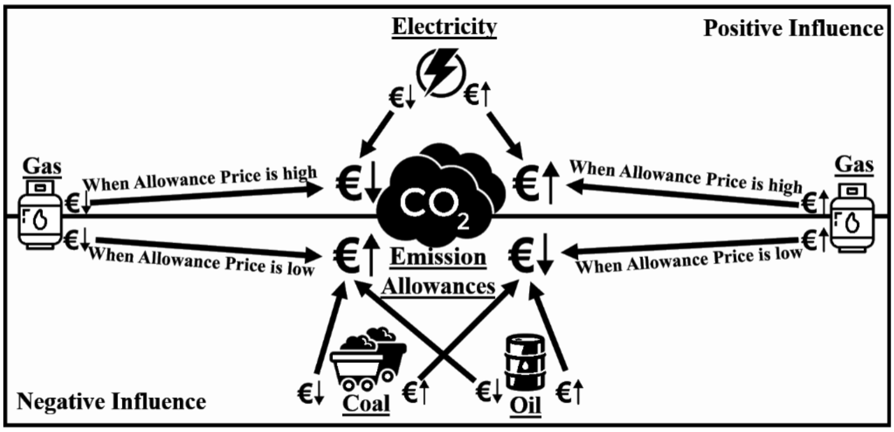

Fig. 3. Influences of energy variables on the price of CO2 emission allowances.

4 Data and Methodology

4.1 Data

In the present study, working day data from the period 30 September 2013 to 1 October 2019 are taken into account. This covers only phase III of the EU ETS, which started in 2013 and ends in 2020. The time series data were obtained from Thomson Reuters Datastream and contain 1567 observations per variable. Figure 4 shows the development of the observed prices over time. Tables 1 and 2 show basic statistics of the time series before and after the first differences were calculated. The correlation matrix on the basis of the first differences in Table 3 shows consistently positive correlations with mostly high significance.

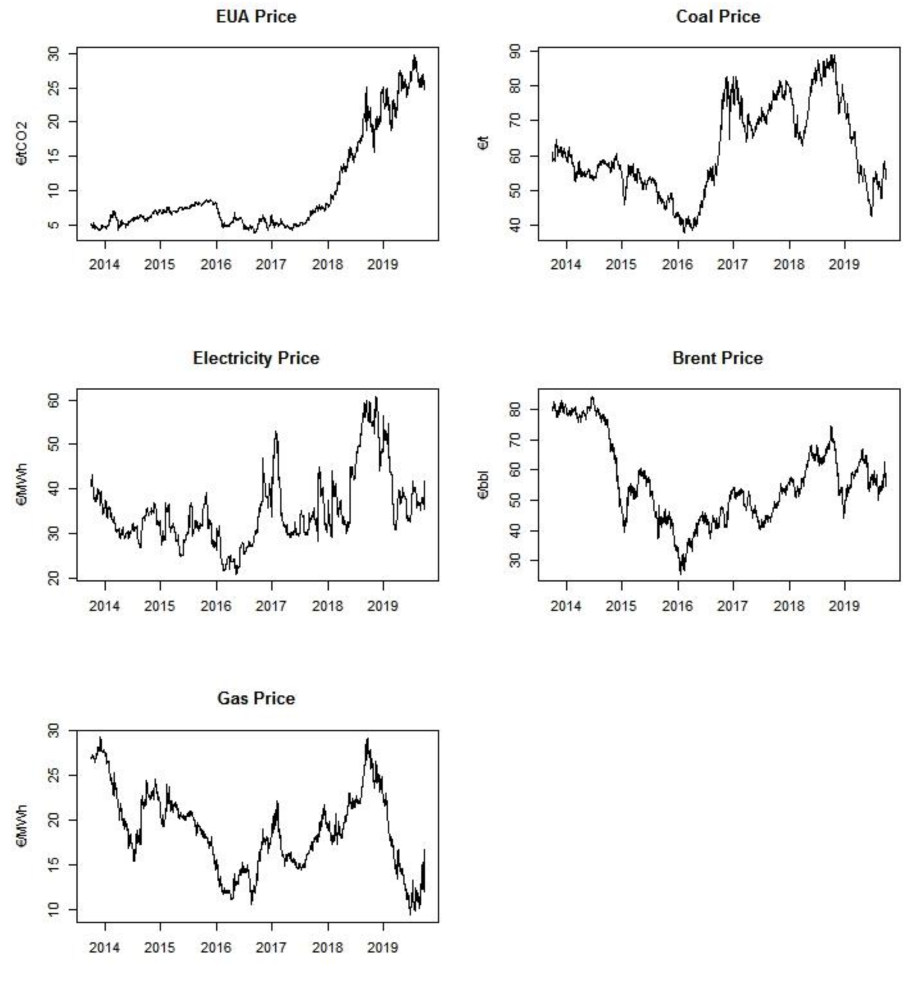

Fig 4. Time series diagrams.

Table 1. Basic statistics on the sample.

Variable	Mean	Median	Standard deviation	Minimum	Maximum
EUA	10.09	6.98	7.03	3.91	29.76
Electricity	35.24	33.42	8.01	20.96	60.84
Gas	18.75	18.64	4.44	9.38	29.29
Coal	61.59	57.95	12.78	37.76	88.90
Brent	56.59	53.87	13.59	25.56	84.49

Table 2. Basic statistics after formation of the first differences.

Variable	Mean	Median	Standard deviation	Minimum	Maximum
d_EUA	0.012784	0.010000	0.348067	-4.050000	2.020000
d_Electricity	0.000013	-0.010000	1.094508	-5.600000	14.070000
d_Gas	-0.006576	-0.020000	0.408956	-2.108000	4.453000
d_Coal	-0.003704	0.019540	0.940489	-7.448123	7.101688
d_Brent	-0.016202	-0.001733	1.048310	-4.778968	8.297314

Table 3. Correlation matrix with significance levels for all variables.

	EUA	Electricity	Gas	Coal	Brent
EUA	1	0.1029***	0.3045***	0.0792**	0.1187***
Electricity	0.1029***	1	0.2405***	0.0774**	0.0556*
Gas	0.3045***	0.2405***	1	0.2728***	0.1461***
Coal	0.0792**	0.0774**	0.2728***	1	0.1539***
Brent	0.1187***	0.0556*	0.1461***	0.1539***	1

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; ' ' 1

The daily spot prices (in €/t) of the European Energy Exchange (EEX) are used for the price of EUA. For the electricity prices, no intraday or day-ahead prices are considered, but daily closing prices of the next due futures contracts, in order to allow a more precise analysis of the prices in consideration of changes in industrial expectations.

For the oil price (in $/barrel), the prices of Brent crude oil were evaluated. The corresponding contracts are traded on the ICE Futures, the largest futures exchange for such futures in Europe. The price for coal (in $/t) is the currently traded contract month on the ICE Futures. It is referenced to the coal index API#2(ARA), which is published in Argus/McCloskey's Coal Price Index Report.

To ensure that all data are in the same currency, the oil and coal rates are converted into euros using the daily reference rates of the European Central Bank.

The gas price (in €/MWh) used for the analysis is the natural gas month-ahead future of the ICE Endex, the largest and most liquid gas exchange in Europe. The electricity price (in €/MWh) is the Physical Electricity Index (Phelix) future price on the EEX for the current month, shown as a Phelix baseload. This refers to the electricity base load and serves as the reference price for electricity in Germany. In this paper, the German electricity price is used because Germany is the largest economy in the EU and has the highest share of the Europe-wide auction volume among the member states [11].

The original series and the time series after the formation of the first differences, therefore prefixed with "d_...", are tested for stationarity using the Augmented Dickey-Fuller-Test. The results of the test show that none of the original time series exhibit the property of stationarity. The first differences of the time series are all stationary, which is why they were used for the test.

The basis of VAR is that the individual time series in the system influence each other. The Granger causality test is therefore used to test the relationships of the individual variables to each other before the VAR model is created. The p-values of the test show that the prices of fuels (gas, coal and Brent) have a significant influence on the EUA price. No influences of the EUA price on the four energy variables are found. The gas price also shows highly significant influence on the coal price. This justifies the VAR modelling approach for this system with several time series to be forecasted.

Table 4. Pairwise Granger causality tests with a lag of 4.

Null hypothesis	F-statistics	p-value	
Electricity does not Granger cause EUA	1.1454	0.33340	
EUA does not Granger cause Electricity	0.4856	0.74640	
Gas does not Granger cause EUA	2.8012	0.02470	*
EUA does not Granger cause Gas	0.8957	0.46570	
Coal does not Granger cause EUA	2.8933	0.02114	*
EUA does not Granger cause Coal	0.5489	0.69980	
Brent does not Granger cause EUA	5.4137	2.50E-04	***
EUA does not Granger cause Brent	1.0057	0.40330	
Electricity does not Granger cause Gas	0.3437	0.84850	
Gas does not Granger cause Electricity	4.5698	0.00114	**
Electricity does not Granger cause Coal	0.1891	0.94420	
Coal does not Granger cause Electricity	1.5844	0.17590	
Electricity does not Granger cause Brent	1.5995	0.17190	
Brent does not Granger cause Electricity	0.4453	0.77590	
Gas does not Granger cause Coal	7.3872	6.83E-06	***
Coal does not Granger cause Gas	0.5705	0.68410	
Gas does not Granger cause Brent	0.3264	0.86040	
Brent does not Granger cause Gas	1.7755	0.13120	
Coal does not Granger cause Brent	2.3207	0.05489	.
Brent does not Granger cause Coal	0.3906	0.81550	

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; ' ' 1

4.2 Methodology

In order to model the interactions between the EUA price and energy prices, a VAR model is used for the econometric analysis in this study. In contrast to conventional autoregressive models, this type of time series analysis model does not assume a unidirectional relationship, i.e. that the target variable is influenced by the influencing variables, but not vice versa. In the following VAR model, therefore, the feedback relationships of all variables to be investigated are taken into account; formally expressed, all variables are treated as endogenous:

$$\begin{pmatrix} d\_EUA \\ d\_Electricity \\ d\_Gas \\ d\_Coal \\ d\_Brent \end{pmatrix} = \mathbf{c} + \boldsymbol{\beta}_{t-1} \times \begin{pmatrix} d\_EUA_{t-1} \\ d\_Electricity_{t-1} \\ d\_Gas_{t-1} \\ d\_Coal_{t-1} \\ d\_Brent_{t-1} \end{pmatrix} + \boldsymbol{\beta}_{t-2} \times \begin{pmatrix} d\_EUA_{t-2} \\ d\_Electricity_{t-2} \\ d\_Gas_{t-2} \\ d\_Coal_{t-2} \\ d\_Brent_{t-2} \end{pmatrix} + \cdots + \boldsymbol{u} \quad (1)$$

Where c is the column vector of the regression constants, β_(t-n) is the 5x5 matrices of the regression coefficients with lag n and u is the residuals of the VAR model. Before estimating the model, it has to be determined how many lags should be included. Here it is important to weigh up the pros and cons, because too few lag values may leave valuable information of the more distant values unnoticed or explanatory parameters may be missing, while too many lag values may lead to over-specification of the model. The model includes four lags, based on the Akaike information criterion.

Impulse response functions (IRF) are derived from the VAR model, which indicate how changes in one variable affect other variables. For this purpose, the variables under investigation are subjected to an isolated shock (impulse) in the amount of one standard deviation and its effects over time are determined. For the analysis of the IRF their plots including the bootstrap confidence intervals are used. If the 95% confidence level at a given time includes the zero line, there is no significant effect.

5 Results and Discussion

Figure 5 shows the impulse-response functions and Figure 6 shows the cumulative impulse-response functions of the energy prices under consideration: Brent (crude oil), natural gas, coal and electricity. These functions show the reactions of the EUA price to an impulse from a standard deviation of each energy price.

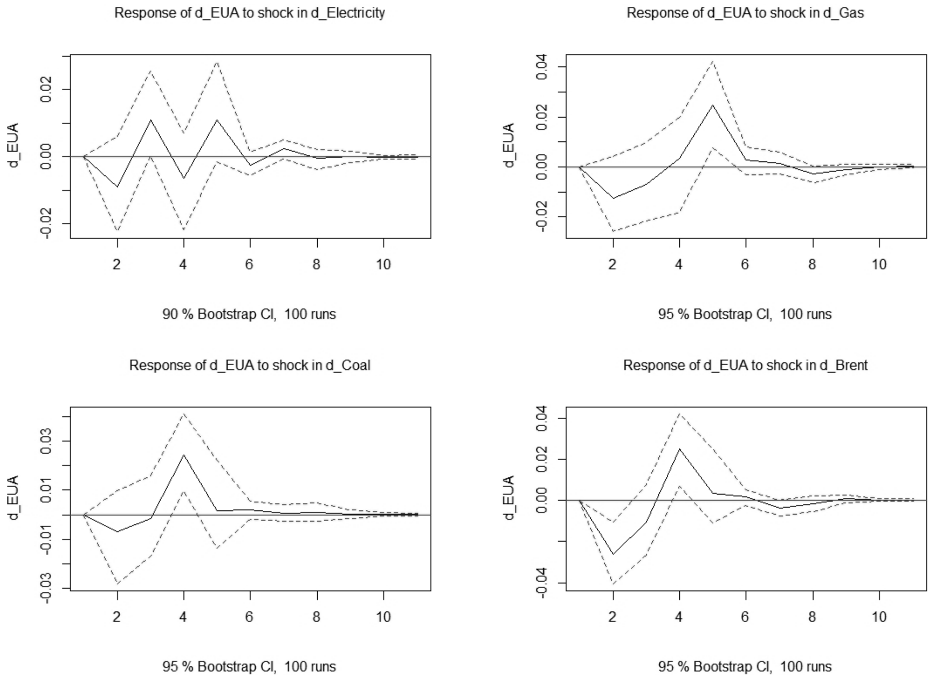

Fig. 5. Excerpts of the impulse response function plots from the 4-Lag VAR-Model.

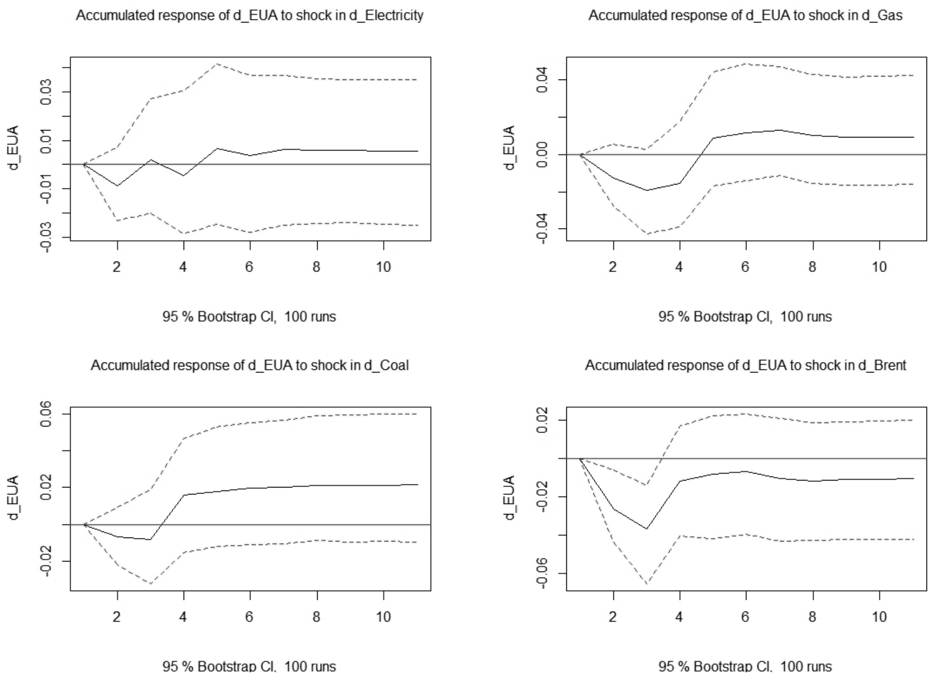

Fig. 6. Excerpts of the accumulated impulse response function plots from the 4-Lag VAR-Model.

The impulse-response function from the EUA price by entering a gas standard normal distribution leads to a decrease of the EUA price after one day. This is followed by a stronger increase in the price. Cumulated, a positive influence can be determined. This correlation between natural gas prices and EUAs could be due to the fact that there is a high degree of substitutability between coal and gas in electricity production. Rising prices in the gas sector therefore lead to a stronger demand for coal. Since a coal-fired power plant for the generation of one kilowatt hour of electricity emits almost twice as much carbon dioxide as a gas-fired power plant, this leads to a rising demand for CO_2 emission allowances and thus to a price increase [14].

The EUA price shows high volatility when the electricity price is stimulated. Overall, an increase in the electricity price leads to a marginal increase in the EUA price. This reaction can be explained by the fact that the companies need electricity for production and a marginal change in the electricity price does not immediately lead to a reaction on the part of the companies, which ultimately leaves the EUA price virtually unaffected. In addition, the electricity price is influenced by production-related factors, especially by the impact of coal and gas prices, so that these two energy prices already absorb the influence of the electricity price on the EUA price [15].

In the event of a shock in the coal price, the impulse response function shows an overall positive correlation with the EUA price. In this way, an impulse in the coal price after one day initially leads to a decline and from day three to a relatively strong increase in EUA prices. This reaction can be explained by the substitutability of coal and gas as described above. Thus, an increase in coal prices could ceteris paribus lead to a fuel switch from coal-fired power plants to gas-fired power plants. As a result, emissions will decrease and with it the demand for and price of CO_2 emission allowances. The reaction that the price of EUA rises despite this can be explained by the fact that particularly energy-intensive industries are using this situation to expand their production [10], which means that more electricity is produced by gas-fired power plants, which in turn increases the price of EUAs.

The impulse-response function for the EUAs price shows a negative correlation on the first day in the event of a shock in crude oil, which, with a weaker positive reaction, ultimately leads to a lower EUA price. This reaction can be due to a decreasing demand for crude oil, which is why emissions are lower and therefore the decreasing demand for EUAs leads to a lower price.

The impulse response functions were described and explained in the previous section. In the following, the results are assessed according to their significance, the significance level being used as a measure. The regression parameters of the estimated model with respect to d_EUA are presented in Table 5.

Table 5. Estimation results for equation d_EUA:

	Estimate	Std. Error	t value	Pr(>|t|)	
d_EUA.l1	0.0393667	0.0267497	1.472	0.14131	
d_EUA.l2	0.0207154	0.0268060	0.773	0.43977	
d_EUA.l3	-0.0705162	0.0268289	-2.628	0.00866	**
d_EUA.l4	-0.0685827	0.0267998	-2.559	0.01059	*

d_Electricity.l1	-0.0052224	0.0083499	-0.625	0.53178	
d_Electricity.l2	0.0118200	0.0083570	1.414	0.15745	
d_Electricity.l3	-0.0087327	0.0083586	-1.045	0.29630	
d_Electricity.l4	0.0054170	0.0083522	0.649	0.51671	
d_Gas.l1	-0.0228549	0.0239048	-0.956	0.33918	
d_Gas.l2	-0.0089361	0.0254117	-0.352	0.72515	
d_Gas.l3	-0.0154623	0.0253897	-0.609	0.54262	
d_Gas.l4	0.0531368	0.0254377	2.089	0.03688	*
d_Coal.l1	-0.0041975	0.0098785	-0.425	0.67096	
d_Coal.l2	0.0006287	0.0098928	0.064	0.94934	
d_Coal.l3	0.0259646	0.0098904	2.625	0.00874	**
d_Coal.l4	0.0009338	0.0098027	0.095	0.92412	
d_Brent.l1	-0.0255580	0.0085772	-2.980	0.00293	**
d_Brent.l2	-0.0116378	0.0086117	-1.351	0.17677	
d_Brent.l3	0.0237124	0.0086044	2.756	0.00592	**
d_Brent.l4	0.0026161	0.0086028	0.304	0.76109	
const	0.0138457	0.0087713	1.579	0.11465	

Signif. codes: 0; '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; ' '

Residual standard error: 0.3447 on 1541 degrees of freedom
Multiple R squared: 0.03404,
F-statistic: 2.715 on 20 and 1541 DF, p-value: 6.466e-05

A special focus in this presentation is on the differentiation between significant and non-significant values. The coefficients for Brent (crude oil) show a significant value on the first and third day. The significance level is below 1%. The absolute value of the negative coefficient is marginally higher in comparison and provides a point of reference for forecasting the future development of the EUA price. According to Hammoudeh et al. [12], an increase in the price of crude oil leads to a sharp decline in CO_2 emission allowances prices and this reaction reflects the present result of the vector autoregression analysis carried out, according to which H1 of this study can also be confirmed in phase III of the EU ETS.

The coal price shows a positive influence on the EUA price on the third day with a significance level of less than 1%. Consequently, the assumed negative influence of the coal price in the context of H2 is not confirmed. As described above, the reasons for this counterintuitive result could be the high degree of substitutability between coal and gas.

The reciprocity between the price of natural gas and the price of EUAs shows a significantly positive influence on the fourth day, as assumed in H3, which has also already been determined by Alberola et al [2].

For the influence of d_Electricity no significant coefficients are found. Therefore, in the present model, in contrast to the existing literature (H4), no correlation between the electricity price and the price of emission allowances can be established. This result can be explained by the fact that the energy prices of coal and natural gas implicitly reflect the influence of electricity anyway, since these are used for electricity generation, among other things.

6 Conclusion

The results of this work show that the price of EUAs is significantly influenced by the prices of fuels (Brent, coal, gas) in the third phase of the EU ETS. The extent of the influence is less pronounced for the individual energy variables than was observed in the previous phases. Furthermore, the influence of the electricity price on the EUA price cannot be determined in the third phase. While the negative influence of Brent and the positive influence of gas are confirmed, a positive influence on the EUA price is observed for coal, contrary to the existing literature. This shows that the market influences in phase III of the EU ETS have changed compared to the previous phases. One reason for this may be that fossil fuels are gradually being pushed out of the energy market by renewable energies. Electricity can also be produced with much lower emissions than it was the case in the first phases of the EU ETS. The influence of the individual energy sources on the EUA price has fallen accordingly over time. The present results could therefore be an indication that the pricing of EUAs as an EU instrument is no longer effective. The tendency for EUA prices to rise also indicates that this effect will continue to increase in the coming years and that even lower-emission technologies will be focused on the European area.

Accordingly, this work offers the opportunity for further research to investigate the forecasting capabilities of the EUA, taking into account other factors such as weather or economic activity in the EU.

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