How Do Oil Prices Affect Emission Allowance Prices in the EU-ETS?

A study examining the relationship between oil prices and EU allowance prices from two perspectives: an overall perspective and an oil-shock perspective.
Abstract
This paper attempts to study how oil prices affect the EU allowance (EUA) price using statistical methods and economic theory. A total of five regressions were run: two regressions based on daily data for 2018-2023, to study the overall relationship, and three regressions using data for oil shocks in the same period. Overall, the results show that the correlation is weak. For all oil shocks, the absolute value of the cross-price elasticity of demand is less than 0.3, which shows weak effects. The effect is positive or negative depending on the type of shock. An oil supply shock has a positive effect while an oil specific demand shock has a negative effect. By comparison, the effect of a supply shock is smaller than its demand shock equivalent.

Keywords: Oil Shocks; EU Allowance; EU-ETS; Cross-Price Elasticity of Demand; Multiple Regression Model
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1 Introduction

Climate agreements are complex and can be difficult to achieve. With too high ambitions, the cost of minimizing pollution becomes expensive and many countries would rather stay out of them. Despite these challenges, climate agreements are extremely important for getting closer to a solution for climate change.

In “The Problem of Social Cost” (1960), Coase describes the importance of setting a price on negative externalities to make firms take responsibility for the damage they cause to their surroundings. Whether the cost of damage is not included in profit maximization, the firm will produce until the price of its last unit equals its private marginal cost. To make firms consider the cost of damage, there needs to be some kind of system that punishes them for causing the damage. Each firm that inflicts harm on others should be assigned an extra cost through property rights for instance. Property rights were not meant to affect the cost-effectiveness of an allocation but to redistribute income and wealth (Coase, 1960). The difficulty is to find the most efficient allocation. If one firm pollutes more than the other, how does the government make sure that they carry the bigger part of the burden? Governments began to create different policy systems to battle this problem. One successful example is the cap-and-trade system European Union Emissions Trading Scheme (EU-ETS), introduced in 2005.

The EU-ETS includes the EU Member States and the European Free Trade Association, EEA EFTA-states (European Commission, n.d:e). The cap for the total amount of greenhouse gases (GHGs) allowed each year is set by policymakers. Each year the cap is reduced linearly by 2.2%, following the emissions reduction plan. The goal is for the EU to reach a 55% reduction of the 1990 carbon levels in 2030 and climate neutrality by 2050.

The total amount of emissions is distributed over a number of emission allowances called EU allowances (EUAs). One allowance gives the firms the right to emit one ton of carbon dioxide or other GHG equivalents such as nitrous oxide and perfluorocarbons (European Commission, n.d:b). Allowances are mainly auctioned out on the platform European Energy Exchange (European Commission, n.d:a), also known as the EEX and the cost of an allowance is determined by its supply and demand. The number that is auctioned depends on how many allowances are already out on the market. Less is auctioned on the stock market if there are surpluses of allowances on the market as the firms can trade between themselves (European
Firms that emit more can buy allowances from firms that emit less. This type of regulation not only ensures cost-effectiveness, but also makes sure that the total amount of emissions is in line with the emissions reduction plan.

The system covers approximately 40% of EU’s emissions (European Commission, n.d:e), including the energy and manufacturing sector, aviation and maritime as of 2024. Buildings, road transportation and other additional sectors are planned to be implemented in the revised version of the trading scheme, called EU-ETS2 (European Commission, n.d:c). It is planned to be implemented around 2027/2028. Examples of activities that require emission allowances are the burning of fossil fuels. In 2022, the per capita consumption of coal in the world was approximately 18% lower than oil (Ritchie, Rosado & Rosier, 2023b; Ritchie, Rosado & Rosier, 2023c), but coal still emitted 28% more carbon dioxide than oil did (Ritchie, Rosado & Rosier, 2023a). A firm would therefore have to buy more allowances to burn coal than they would have to for the same amount of oil, all else equal.

The industry sector stood at 25.6% of EU’s final energy consumption in 2021 (Eurostat, 2023), placing third after transport and households. Of the industry’s final energy consumption, electricity stood at 33.2% and natural gas stood at 32.7%. Oil and petroleum products came in third, making up for 9.8% of consumption. While the use of oil is not high in the industry sector, it is the main fuel for air travel and maritime. In 2019, aviation made up 3.8% of EU’s total GHG emissions, while maritime stood at 4%, and these numbers are continuing to increase (European Parliament, 2022).

The main producers of oil are the United States, Saudi Arabia, Iraq, Russia and Canada (EIA, 2023). The extraction, drilling and search for new oil reservoirs is time-consuming work. This could be one of the main reasons why oil prices are volatile. They are sensitive to unexpected changes in the world economy, where an unexpected change is often presented as a shock. As oil prices fluctuate, other markets that are closely related to the oil market could be affected too. The EUA market is one of them. Fig. 1a-c show examples of the most recent oil shocks between the years 2020-2023 and how they affect the EUA market.
Fig. 1 – The development of EUA and oil prices during different oil specific shocks. All events are marked in by the arrows in the graphs a-c. a) 2020 oil price war. b) after the invasion of Ukraine. c) the Russian oil-ban.
Fig. 1a shows the effects of the 2020 oil price war. In 2020, following the economic recession during the COVID-19 pandemic, oil prices dropped due to a fall in demand. Oil producing countries faced a dilemma of either continuing to produce or cutting production. After a meeting conference in Vienna on March 5th, 2020, OPEC (Organization of the Petroleum Exporting Countries) agreed to cut oil production to help push the oil prices up (OPEC, 2020a). They proposed that non-OPEC members, among them Russia, should also cut their production. Russia refused the proposal and continued to produce as usual. On March 8th, the OPEC member Saudi Arabia hit back by increasing its production. This led to further falling oil prices, dropping by more than 24% (Stevens, 2020). The EUA price dropped as well as a result. The prices continued to fall until Russia agreed to cut down on oil production on April 9th (OPEC, 2020b).

Fig. 1b displays the effects of the Russian invasion of Ukraine, initiated on February 24th, 2022. Russia has been one of the largest European importers and stood for 31% of the oil imports for the EU in January 2022 (T&E, 2023). After the invasion, the demand for oil increased, likely due to precautionary hoarding caused by speculation of a Russian oil-ban (Enerdata, 2023; Eurostat, 2024). Only a week after the first attack, oil prices rose well over 110 dollars/barrel (Kolaczkowski, 2022) compared to the pre-war prices of around 80-90 dollars per barrel. Oil prices had increased by more than 15%. In the same period, EUA prices fell significantly, but increased again shortly after the initial oil shock.

Fig. 1c illustrates the effect of the Russian oil-ban. After the invasion, the EU began trying to minimize its dependency on Russian oil by phasing it out of the market. On December 5th, 2022, the EU imposed final sanctions against crude oil from Russia (European Council, 2024). Oil prices increased slightly, only to plummet a short while after. When the oil prices fell, EUA prices increased. On February 5th, 2023, the EU imposed further sanctions on petroleum products from Russia.

When studying the trend lines in Figure 1a-c, a correlation between EUA prices and oil prices can be observed, though whether the correlation is constant through time or present only when there are oil specific shocks is not clear. This leads to the questions of research:

What is the relationship between the EUA price and oil price and how do oil specific shocks affect the EUA prices?
The purpose of this study is to examine how the EUA market and oil market are integrated. Knowing this can increase predictability for stakeholders of the European carbon market and their investment decisions.

This paper is divided into a total of eight sections. Section 2 presents the theoretical framework where economic terms that are used in the analysis are explained. The framework is used to predict the coefficients of shock regressions and the predictions are presented in Section 4.3. In Section 3, a literature review will be made of previous empirical studies. Section 4 focuses on explaining the choice of data and discussing data limitations. Based on the data, the regression models are set up in Section 5. The models and methods are then evaluated. In Section 6, the results are presented in two parts: 1) analyzing the overall trend and 2) analyzing the oil-shock effects on EUA prices. In Section 7, the results will be analyzed and discussed. The analysis leads to the conclusion in Section 8, where the main results and findings are presented. The reference list and appendix are presented at the end. The appendix consists of detailed derivations, boxplots to visualize data distribution and variance inflation factor analyses (VIFs).
2 Theoretical Framework

2.1 Cross-Price Elasticity of Demand

The cross-price elasticity of demand ($E_{XY}$) measures how a percentage change in the price of one good affects the quantity demanded of another good (Perloff, 2021, p. 60). Derivation of cross-price elasticity can be seen in Eq. 1 in Appendix A.1.

A positive cross-price elasticity ($E_{XY}>0$) indicates they are substitutes. Two goods are substitutes if the consumer can exchange one good for the other. When the price of one good increases, the demand for the other good increases.

A negative cross price elasticity ($E_{XY}<0$) means two goods are complements. Complementary goods are consumed together. When the price of one good increases, the demand for both goods decreases.

When the cross-price elasticity is 0 ($E_{XY}=0$), the two products do not affect each other. An absolute value greater than 1 is considered elastic ($|E_{XY}| > 1$), and if it is between 0 and 1 it is inelastic ($0 < |E_{XY}| < 1$).

In one sense, oil and emission allowances are complements; when more oil is burned, more allowances are needed. When oil prices increase, less oil will be bought, the need for allowances drops and allowance prices will fall. In this paper, it will be assumed that oil and allowances are complements. It should be noted that allowances can be bought for other reasons other than the burning of oil. Burning of other fossil fuels like coal would also lead to more allowances needed. Oil could also be substituted for coal. An increase in oil price may lead to increasing demand for coal because it is cheaper relative to oil. Because coal emits more carbon dioxide than oil, all else equal, the demand for allowances will increase, which increases its prices.

2.2 Market Shocks

The theoretical framework for market shocks can be applied to the oil and EUA markets. In the following sections, oil specific supply and demand shocks are analyzed and it is assumed that there are two actors on the market: producers (oil producers) and consumers (firms in the EU).
A supply shock affects the market due to a sudden increase or decrease in quantity produced (Perloff, 2021, pp. 48-53). It could for instance be a technological breakthrough that leads to efficiency gains in production or a sudden shortage of supply. For instance, a shortage in oil supply would mean that less oil is sold. The supply curve shifts upwards (see Fig. 2a). The quantity produced decreases from Q1 to Q2. At the same time, prices increase from P1 to P2. The market ends up in a new equilibrium Q2:P2 where the price is higher, but the quantity is lower. An oil price increase signals lower productivity and low supply on the market to the buyers as well. Assuming that this shock is temporary and that firms have little incitement to switch to other fuels like coal, higher oil prices would decrease the demand for allowances and their prices (see Fig. 2b). This means that a supply shock has a negative effect on allowance prices. In this example, a negative supply shock is used, but the same reasoning can be applied to a positive supply shock: An increase in oil supply leads to lower oil prices. It leads consumers to hoard oil while prices are low. This will increase demand for allowances, pushing the allowance price up. For both negative and positive supply shocks, the correlation is negative.

![Illustration of how a negative supply shock on the oil market (left) affects the EUA market (right).](a) Oil market (b) EUA market)

**Fig. 2** – Illustration of how a negative supply shock on the oil market (left) affects the EUA market (right). **(a)** Initial equilibrium. P1:Q1. New equilibrium: P2:Q2 (lower supply, higher price). **(b)** Initial equilibrium. P3:Q3. New equilibrium: P4:Q4 (decreasing demand and price).

The analysis of demand shocks is not as straightforward. It can be exemplified by illustrating a negative demand shock (see Fig. 3). A sudden economic recession, expectations about a recession or lower investment returns are all examples of what could cause a negative demand shock. An oil demand shock can have two effects on the EUA market.

Effect 1: A demand shock leads to price and quantity shifting in the same direction (Perloff, 2021, pp. 48-53). A negative shock shifts the demand curve down (see Fig. 3a). To meet the
new demand, oil producers supply less and prices decrease. The new equilibrium is $P_2:Q_2$. Because oil demand has now decreased, fewer allowances are needed. Decreased demand in the EUA market will lead to a price fall from $P_3$ to $P_4$. As Fig. 3b insinuates, both oil price and EUA price have decreased, hence the correlation is positive.

Effect 2: Effect 2 is a continuation of Effect 1. When oil demand falls, price of oil will also decrease. The prices decrease, and at some point, the prices will be so low that firms will eventually increase their consumption again. When oil consumption increases, demand for allowances will increase, causing allowance prices to rise, from $P_4$ back to $P_3$. A decrease in oil prices negative correlation.

When it comes to a demand shock, the total effect is ambiguous, and it depends on which one of the two effects dominates.

![Diagram](image)

**Fig. 3** – Illustration of how a negative demand shock on the oil market affects the EUA market, divided into two effects. The changes are marked by the direction of the arrows. (a) Shows the initial shock at the oil market. (b) Effect 1. (c) Effect 2.
3 Literature Review

Studying previous oil shocks and their effects on the EUA price can help stakeholders and firms make more informed investment choices. During the 1970s oil crisis and the early 2000s energy crisis, the oil prices spiked (Kilian, 2010). Both were negative oil supply shocks, but they affected the oil market differently. The 1970s crisis was a result of a real output drop during a longer period, which caused real price changes and high inflation. The effect was much stronger than for the price increase in the early 2000s. It was rather due to a sudden increase in demand of oil from industries, and there is no evidence that it was in any way affected by an overheated economy.

In a later study, Kilian found that demand shocks affected oil prices more than supply shocks. Political events, embargoes, and such, are major triggers to fluctuation, but changing expectations can also influence price and demand. It was stated that “anyone expecting the real price of oil to increase in the future has an incentive to store oil for future use, which in turn provides incentives to curb current oil consumption and stimulates additional oil production.” (Kilian, 2014, p. 6). Applying this type of reasoning to the EUA market, means that oil prices do not necessarily affect the EUA price, since more oil is not used simply because more is bought.

Krokida et al. (2019) studied how oil price shocks affect allowance prices and the European stock market. According to the results, 41% of the variation in the EUA between 2005-2018 can be explained by oil shocks, which stresses the importance of comprehending the effect it has on the EUA market. The study used the structural vector autoregression (SVAR) model, taking inspiration from Kilian (2009). The SVAR model can examine causal relationships between multiple variables at the same time and over time. It is useful because it captures how an interference in one variable affects other variables, which is useful when examining unexpected shocks.

The results showed that an oil supply shock had a significantly positive effect on the EUA price while an oil specific demand shock tended to have a negative effect (Krokida et al., 2019). The effect was weaker for supply shocks. The reason for the weaker effect was because there was a lag-effect between when the shock hit the economy and the market response. This delay meant that the effects of a shock may not be reflected in the economy until later. The lag-effect can be up to two years long.
To understand how oil supply shocks and demand shocks differ the following reasoning was done: A supply shock trigger is often triggered by exogenous factors like regulation changes or geopolitical conflicts (Krokida et al., 2019). The price changes with a lag. Understanding an oil demand shock is not as simple. A demand shock leads to a change in real economic activity, increasing production and demand for emission allowances. This results in a higher allowance price. Future expectations shocks of oil supply can also lead to demand shocks. Firms might want to purchase more oil if scarcity of oil resources is expected. As a precaution, firms buy oil to store, but because the oil is not burned the EUA prices will not change. This type of shock is defined as an “oil-specific precautionary demand shock”.

Zheng et al. (2021) studied the impacts of oil shocks on the EUA returns using simple regression models and found similar results as Krokida et al. (2019). The influence of different market conditions was studied as well. During periods of consumer pessimism, a negative supply or demand shock of oil had a stronger effect on the market prices of the EUA price, but it had less effect during periods of optimism. The opposite was true for positive shocks.

Previous empirical findings suggest that there is a correlation between the oil price and allowances price, but many of them argue that it is weak. Most previous studies have studied both aggregate demand shocks, oil specific demand shocks and oil supply shocks. This paper focuses on the latter two, only studying oil specific shocks. Isolating the oil shock as much as possible, helps us better understand how oil sector shocks affect EUA more specifically and separate which effects are from oil sectors and which effects are from other external factors, such as coal price and exchange rate.
4 Data

4.1 Main Variables

This study aims to find out if there is a relationship between EUA prices and oil prices. The EUA prices are based on the prices on the auction market EEX EUA and are traded in the euro. The data is extracted from Ekonomifakta (2023).

The Brent crude oil prices are extracted from Federal Reserve Economic Data (FRED, 2024) and measure the prices of Brent crude in the EU daily. Brent crude is a price benchmark for 80% of the global crude oil. Brent crude is mainly extracted from the North Sea and is one of the most traded oils in Europe (ICE, 2024). Like most other types of crude oil, it is traded in US dollars on the global investment market, which is why the prices are measured in US dollars per barrel.

4.2 Control Variables

Control variables are used in the regression models to address omitted variable bias (OVB). They help enhance internal validity by ensuring that the effect of oil price on the EUA price is isolated from other factors. The control variables for this study are coal prices and the exchange rate of US dollar per euro.

For this study, Rotterdam coal historical prices are used, with data extracted from the Dow-Jones & Company subsidiary Market Watch (2024). Rotterdam coal refers to the coal that is transshipped from the Port of Rotterdam, which is one of Europe’s largest seaports (Port of Rotterdam, n.d). Rotterdam coal is traded in US dollar, as it is the most used currency on the global investment market and is measured daily.

Coal price is used as a control variable because of two reasons – the first reason being that it is a substitute for oil. According to the data chart “Global Coal Consumption, 2000-2025” (IEA, 2023) global coal consumption reached unusually high levels in 2022 compared to the previous five to six years. In the EU, the coal consumption levels have decreased since 2017, only to increase in 2022. The invasion of Ukraine and sanctions against Russian oil exporters are part of the reasons for this switch (Greenfield, 2023). Shortages of crude oil likely incentives for firms to look for other available fossil fuels. Because coal is relatively cheaper than most other fossil fuels – being easier to find and transport – it suits as a good emergency substitute for oil. It leads us to the second reason, that coal prices are correlated with allowance prices. Coal is
more carbon intensive than crude oil. This means that more allowances are used when coal is burned and would lead to even higher allowance prices.

The exchange rate for US. dollar per euro is the second control variable and is extracted from the European Central Bank (ECB, 2024) which provides data on daily, historical changes in the exchange rate. Because EUAs are traded in euros while oil and coal are traded in US. dollars on the global investment market, US. dollar per euro becomes the most suitable exchange rate. Exchange rate is used to control for the change in purchasing power, as it affects oil consumption indirectly through aggregate demand. An increase in exchange rate means that it is cheaper for the euro area to import goods bought in US. dollars but more expensive for countries using the US. dollar to import from the euro area. For the euro area, this would mean that the demand for imported goods increases while the amount of exported goods decreases, causing domestic production to decrease. This affects the consumption of oil.

To adjust for business cycles and other macro factors that change with time, year fixed effects are used in the modeling. The data is measured daily, but the fixed effects are measured yearly. The use of years, instead of days, is because time related changes are more likely to have larger effects over longer time spans than shorter ones. Because oil supply shocks can have a lag-effect that can be up to two years (Krokida et al., 2019), years are a more appropriate measure than days or months.

4.3 Data Choice and Limitations

For this study, only data for the period 2018-2023 will be used (see grey area in Fig. 4). There are two reasons for this. The first is because the data for EUA prices have missing data between in the years 2012-2014. The prices are measured irregularly, as sometimes a few days pass between observations and sometimes a week. This could be a random error, but it could also be a systematic error which would lead to sample selection bias. Sample selection bias would affect the internal validity of the study. The data for the 2018-2023 period shows no issues with missing data.

The other reason for only working with data from 2018 has to do with the longevity of the EU-ETS system. The EU-ETS was implemented in 2005 and in the beginning, the cap was purposely set high to help the firms ease into the system, preparing them for the fact that the cap would fall every year and give them incentives to start investing in more sustainable
production. Since the cap was not binding in the beginning, the EUA prices would presumably have a quite weak correlation with other markets. This can be observed in the non-shadowed area in Fig. 4. In the years prior to 2018 the EUA price barely changed while oil prices had big fluctuations. In the period after 2018 (grey shadowed area in Fig. 4), the EUA price began to show signs of possible interrelation with oil prices.

Even though sustainability and environmental work have been topics of discussion ever since the early 1990s, only in recent years has sustainability become a norm and more new regulations have been carried out (Winston, 2022). This could be why there is a rapid price increase in this period, especially after 2020.

**Fig. 4** – The development of EUA prices and oil prices from 2012 to 2023. The grey shadowed area shows data from 2018 to 2023.

### 4.4 Defining the Shocks

Because this study is limited to the period 2018-2023, the shocks that can be studied are also limited to this period. Three major oil shocks are studied. They are: The 2020 oil price war, the Russian invasion of Ukraine and the Russian oil-ban (see Section 1: Fig. 1a-c). To make the results comparable to previous studies and the theoretical framework, it will be necessary to study the origins of the shocks.
4.4.1 The 2020 Oil Price War

The 2020 oil price war (Fig. 1a) can be defined in two different ways: as a negative demand shock or as a positive supply shock. It is also possible that the demand shock following the COVID-19 pandemic triggered the supply shock or that they worked together. This negative demand shock led to a drop in overall market activity and lower production, causing both oil prices and the EUA prices to decrease (see Fig. 3a-b). The correlation is positive. A positive supply shock also leads to falling oil prices but the oil demand would increase as a result. That would increase the need for allowances and increase EUA prices. The correlation would then be negative. Since the disagreement between Russia and Saudi Arabia led to a pure increase in oil supply, it will be defined as a positive supply shock.

4.4.2 The Invasion of Ukraine

The Russian invasion of Ukraine led to a positive demand shock on the oil market. There was a specific increase in the oil demand as there were speculations about a Russian oil-ban. The increased oil demand leads to more EUAs being demanded. Both oil price and EUA price increase, and a positive correlation should be observed. However, there is a second possible effect of a demand shock in which the correlation could be negative as well (this effect is analyzed in detail in Section 2.2). Whether the coefficient will be negative or positive depends on which of the two effects is larger.

4.4.3 The Russian Oil-Ban

The sanction of Russian oil products (Fig. 1c) has caused the EU to lose one of its largest importers of crude oil. While the demand for crude oil was still high, the sanctions caused a decrease in supply, at least within the EU, which is why it is defined as a negative supply shock. A negative correlation should be observed for a negative supply shock (see Fig. 2a-b).

4.4.4 Table of Coefficient Predictions

The predictions of the coefficients are based upon the analysis above, the theoretical framework presented in Section 2.2 and through observing the trend lines in Fig. 1a-c in Section 1. In Table 1 below, the names of the shocks, how they are defined, and the predicted direction of the coefficient (positive or negative) are presented.
<table>
<thead>
<tr>
<th>Shock name</th>
<th>Definition</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>The 2020 oil price war</td>
<td>Positive supply shock</td>
<td>Negative (-)</td>
</tr>
<tr>
<td>Invasion of Ukraine</td>
<td>Positive demand shock</td>
<td>Negative (-) or positive (+) depending on which effect dominates</td>
</tr>
<tr>
<td>Russian oil-ban</td>
<td>Negative supply shock</td>
<td>Negative (-)</td>
</tr>
</tbody>
</table>

Notes: Predictions are based on the analysis in 4.4.1-4.4.3, the theoretical framework in Section 2.2 and the Fig. 1a-c in Section 1.
5 Methodology

5.1 Model Specification

In previous studies, common methods to use are the SVAR model and the ordinary least-squares multiple regression model. This study uses a multiple regression model inspired by Zheng et al. (2021). The multiple regression model is useful because of its simplicity and ability to be powerful enough to provide insightful conclusions. The model is set up in Eq. 1:

\[ lneuap_t = \beta_0 + \beta_1 lnolp_t + \beta_2 lncoa_t + \beta_3 lnxchange_t + \epsilon_t \] (1)

where the dependent variable is the logged EUA price, the independent variable is the logged oil price, and the control variables are the logged coal price and logged US. dollar per euro exchange rate. The index \( t \) stands for daily prices. \( \beta_0 \) is the intercept of the curve, \( \beta_1, \beta_2 \) and \( \beta_3 \) respectively are the coefficients of each variable. The term \( \epsilon \) is the error term.

To study the effect of the control variables, each variable is progressively integrated into the regression model. As the interest lies in studying the cross-price elasticity of demand for the variables, all variables are logged in the model. The cross-price elasticity can be derived through the logged model (see Appendix A.2). The interpretation of the coefficient is: “a percentage change in oil prices leads to an “x” percentage change in EUA prices”. It is similar to the interpretation of cross-price elasticity. The only difference in the interpretation between the theoretical cross-price elasticity and that the model takes it a step further:

\% change in oil prices → \% change in quantity demanded of EUA → \% change in EUA prices

Extra step

The model interpretation

Further in this paper, cross-price elasticity is used as the term to describe the coefficients in the regressions and \( E_{XY} \) is used as the denotation.

It is also of interest to study whether time-related factors affect Eq. 1. An adjustment for yearly changes is made by adding the term \( \mu \) to the model. When running the regression for all data, it is run first without year fixed effects (see Eq. 1) and then with year fixed effects (see Eq. 2).

\[ lneuapl_t = \beta_0 + \beta_1 lnolp_t + \beta_2 lncoa_t + \beta_3 lnxchange_t + \mu_y + \epsilon_t \] (2)
where $\mu$ is a constant for fixed effects and the index $y$ stands for year. $\mu$ has a unique value for each year.

The study is separated into two parts: Part 1) running a regression for all data between 2018-2023 with Eq. 1 and Eq. 2, and Part 2) studying the oil shocks with Eq. 1. Eq. 2 is not needed for the shock-analysis. Since the shocks cover periods shorter than a year, adjusting for year effects is not required. When deciding upon the period length for each shock, the oil shocks were isolated as much as possible from other shocks that could disrupt the results. The 2020 oil price war has clear set dates, as it was between March 8th and April 9th that the actual “price war” between Russia and Saudi Arabia took place. For the two other shocks, pre-shock effects and potential lag-effects should be considered when running the regressions.

5.2 Assumptions

The assumptions for multiple regression models are the same as for the ordinary least squares-regression models (OLS model), with an added condition, making it a total of five assumptions. As long as these assumptions hold, the models in Section 5.1 can produce reliable estimates. Each assumption is presented and evaluated below.

Firstly, a zero conditional mean is assumed. This means that the expectation of the value of the error term, $\epsilon$, does not vary with the X-variables (the regressors). There should be nothing else in the error term that explains the model. Control variables are a way to make sure this assumption holds.

Secondly, the variables in an OLS model should be independently and identically distributed to avoid measurement error and bias in the estimates. This means that the sample must be random, which makes it important to analyze and validate the dataset before processing it.

Thirdly, homoscedasticity is assumed. The variance of the error in all regressor variables should be constant. However, oil prices are greatly affected by both sectorial shocks and economic shocks and tend to fluctuate with them. Assuming homoscedasticity when the actual data is heteroscedastic can lead to inaccurate estimates. To avoid this problem, heteroscedasticity robust standard errors are used in all regressions.

Next, it is assumed that large outliers are unlikely. Large outliers can distort the estimates, even if the outliers are few, especially if they exist because of measurement errors. In some cases,
outliers can be interesting to analyze if they carry information that shows some kind of randomized bias in the sample that is out of the researcher’s control, sudden market shocks for instance. To check for outliers, the boxplots in Appendix A.3 were made to visualize the distribution of the data. How outliers are solved in the models of this paper is further discussed in Section 5.4.

Lastly, no multicollinearity is assumed. Multicollinearity means that two or more explanatory variables are highly correlated with each other, which could happen in a multiple regression model. When variables are highly correlated, it is harder to distinguish the effects of each variable. This causes problems for the causality of the analysis because it makes estimation and interpretation of the parameters harder. The problem can occur when too many variables are added, so some variables are excluded. To test for multicollinearity, a variance inflation factor analysis (VIF) was conducted for each of the five regressions that were run. The VIFs are presented in Tables 8-12 in Appendix A.4.

5.3 Method Critique

Causal relationships are extremely difficult to establish. Although a multiple regression model can be powerful, it has the same limitations and weaknesses as an OLS model. Reversed causality is one of them. Causality is established if only one variable affects the other. But if both variables affect each other simultaneously, it could diminish the internal validity of the results. This should not pose as a problem for this study, because EUA prices are likely not very influential on oil prices. The EU-ETS regulates carbon emissions, not the oil usage itself. An increase in EUA prices would therefore have little to no effect on oil prices, which makes reversed causality less of a threat.

Omitted variable bias (OVB) can also be a problem for the causal relationship. Even if control variables are used, there could still be factors in the error term that affect the results but are omitted. Even so, to include all variables that are slightly correlated with the main variables is not the solution either. It would make the regression model very cluttered and cause problems with interpretation and multicollinearity. This is why a trade-off between more variables and clarity of the model should be done. A thumb rule would be to include only the variables that are the most relevant to the research. The control variables that have the most significant effects
on the results are the most important ones for the model.

5.4 Sensitivity Analysis

To test the stability and reliability of the results, a sensitivity analysis is modeled by removing outliers. Descriptive statistics in Table 2 and boxplots in Appendix A.3 show how data is distributed. To test for the model’s sensitivity to outliers, the overall regression will be done with all available data, and then run again after outliers have been removed. Here, it should be emphasized that outliers are removed only in Part 1. Outliers do not need to be removed in Part 2 because shorter periods are used for the shock regressions. Moreover, the aim when studying the shocks is to study possible outliers.

Table 2. Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Obs</th>
<th>Mean</th>
<th>Sd</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUA price</td>
<td>1210</td>
<td>44.69</td>
<td>27.42</td>
<td>7.58</td>
<td>97.42</td>
</tr>
<tr>
<td>EUA price (Log.)</td>
<td>1210</td>
<td>3.59</td>
<td>0.67</td>
<td>2.03</td>
<td>4.58</td>
</tr>
<tr>
<td>Oil price</td>
<td>1210</td>
<td>71.29</td>
<td>20.28</td>
<td>9.12</td>
<td>133.18</td>
</tr>
<tr>
<td>Oil price (Log.)</td>
<td>1210</td>
<td>4.22</td>
<td>0.33</td>
<td>2.21</td>
<td>4.89</td>
</tr>
<tr>
<td>Coal price</td>
<td>1210</td>
<td>122.83</td>
<td>85.65</td>
<td>41.75</td>
<td>459.80</td>
</tr>
<tr>
<td>Coal price (Log.)</td>
<td>1210</td>
<td>4.61</td>
<td>0.60</td>
<td>3.73</td>
<td>6.13</td>
</tr>
<tr>
<td>Exchange rate</td>
<td>1210</td>
<td>1.13</td>
<td>0.06</td>
<td>0.96</td>
<td>1.25</td>
</tr>
<tr>
<td>Exchange rate (Log.)</td>
<td>1210</td>
<td>0.12</td>
<td>0.05</td>
<td>-0.04</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Notes: The table shows descriptive statistics for the variables EUA price, Oil price, Coal price, the Exchange rate and the logged versions of each of these variables. EUA prices are measured in euros, oil prices are measured in US. dollar per barrel, coal prices are measured in US. dollar, and the exchange rate is the US. dollar per euro-exchange rate.
6 Empirical Results

6.1 Part 1: Overall Results

Two tables are presented here. Table 3 shows the overall results where all available data for 2018-2023 are used. Table 4 shows the results of the sensitivity analysis.

Table 3. Regression Model: Daily Prices for 2018-2023

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil price (Log.)</td>
<td>1.056***</td>
<td>-0.145***</td>
<td>0.822***</td>
<td>-0.00436</td>
<td>0.379**</td>
<td>0.285***</td>
<td>0.405**</td>
<td>0.324**</td>
</tr>
<tr>
<td></td>
<td>(0.0487)</td>
<td>(0.0411)</td>
<td>(0.0338)</td>
<td>(0.0423)</td>
<td>(0.133)</td>
<td>(0.0491)</td>
<td>(0.146)</td>
<td>(0.123)</td>
</tr>
<tr>
<td>Coal price (Log.)</td>
<td>0.840***</td>
<td>0.645***</td>
<td>0.201</td>
<td>0.158</td>
<td>0.0222</td>
<td>(0.0235)</td>
<td>(0.134)</td>
<td>(0.135)</td>
</tr>
<tr>
<td>Exchange rate (Log.)</td>
<td>-5.136***</td>
<td>-3.040***</td>
<td>-1.245</td>
<td>-0.910</td>
<td>(0.293)</td>
<td>(0.323)</td>
<td>(1.899)</td>
<td>(1.890)</td>
</tr>
<tr>
<td>Observations</td>
<td>1210</td>
<td>1210</td>
<td>1210</td>
<td>1210</td>
<td>1210</td>
<td>1210</td>
<td>1210</td>
<td>1210</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.275</td>
<td>0.484</td>
<td>0.430</td>
<td>0.527</td>
<td>0.126</td>
<td>0.182</td>
<td>0.174</td>
<td>0.205</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.570</td>
<td>0.480</td>
<td>0.505</td>
<td>0.460</td>
<td>0.162</td>
<td>0.157</td>
<td>0.158</td>
<td>0.155</td>
</tr>
<tr>
<td>Year FE</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Columns 1-4 are based on Eq. 1. Columns 5-8 are based on Eq. 2. Control variables are progressively added in both models. Heteroscedasticity robust standard errors are shown in the parentheses. *=10% significance. **=5% significance. ***=1% significance.

In Column 1, oil prices have a statistically significant and positive effect on EUA prices, with a value over 1, indicating the cross-price elasticity of demand is elastic. The estimate decreases when control variables are added in Columns 2 and 3. The effect in Column 1 is overestimated and the cross-price elasticity is inelastic. The estimates shift between positive and negative, depending on the control variables. Coal has a significantly positive effect while exchange rate has a negative effect. In Column 4, the estimate for oil prices becomes insignificant. The R-squared values increase with control variables from 0.275 (Column 1) to 0.527 (Column 4). A higher R-squared value indicates that the model fits the data better. The mean standard errors (RMSE) decrease slightly, from 0.570 to 0.460. The lower RMSE the better, as it means that the model’s predicted estimates are closer to the actual values.

When year fixed effects were added all estimates became positive (Columns 5-8). They are also less volatile compared to estimates in Columns 1-4. The values range between 0.285 and 0.405. The control variables have no significant effect on the model. The RMSE is also lower and varies less compared to the RMSE for Columns 1-4. The same can be concluded when
observing the adjusted R-squared values; they are lower, but more consistent. Column 8 shows the final estimation, which is statistically significant at the 5%-level and positive effect.

When the sensitivity analysis is run, the results change again (see Table 4). After the outliers have been removed the values of the significant estimates are about the same as in Table 3 and the estimate directions are unchanged. Only the level of significance has changed for some. The estimate in Column 4 becomes statistically significant at the 1%-level and negative. Similar to the results of those in Table 3, when fixed effects are added, the estimates become more stable. This can also be observed through the adjusted R-squared values and RMSE. The estimate in Column 8 that was significant at 5% in Table 3 is not statistically significant at all in Table 4. By comparing Tables 3 and 4, it is noticeable that outliers affect the results. When discussing the overall results, both Tables 3 and 4 will be referred to.

Table 4. Regression Model: Outliers Removed

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil price (Log.)</td>
<td>2.185**</td>
<td>-0.0708</td>
<td>0.826**</td>
<td>-0.484**</td>
<td>0.648</td>
<td>0.381</td>
<td>0.394**</td>
<td>0.253</td>
</tr>
<tr>
<td></td>
<td>(0.0657)</td>
<td>(0.139)</td>
<td>(0.0334)</td>
<td>(0.145)</td>
<td>(0.361)</td>
<td>(0.227)</td>
<td>(0.130)</td>
<td>(0.262)</td>
</tr>
<tr>
<td>Coal price (Log.)</td>
<td>0.858**</td>
<td>0.812**</td>
<td>0.195</td>
<td>0.140</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0427)</td>
<td>(0.0442)</td>
<td>(0.120)</td>
<td>(0.156)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exchange rate (Log.)</td>
<td>-5.610**</td>
<td>-4.187**</td>
<td>-1.687</td>
<td>-1.932</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.317)</td>
<td>(0.377)</td>
<td>(1.999)</td>
<td>(2.180)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>1034</td>
<td>1034</td>
<td>1184</td>
<td>1008</td>
<td>1034</td>
<td>1034</td>
<td>1184</td>
<td>1008</td>
</tr>
<tr>
<td>Adjusted R2</td>
<td>0.344</td>
<td>0.448</td>
<td>0.427</td>
<td>0.512</td>
<td>0.105</td>
<td>0.153</td>
<td>0.199</td>
<td>0.235</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.560</td>
<td>0.513</td>
<td>0.507</td>
<td>0.484</td>
<td>0.167</td>
<td>0.163</td>
<td>0.155</td>
<td>0.155</td>
</tr>
<tr>
<td>Year FE</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Same regressions as Table 3, but outliers have been removed from the dataset with the help of boxplots in Appendix A.3. There were 176 outliers for logged oil price (Columns 1-2 and 5-6) and 26 outliers for logged exchange rate (Columns 3 and 7). In total, 202 outliers were removed (Columns 4 and 8). Heteroscedasticity robust standard errors are shown in the parentheses. *=10% significance. **=5% significance. ***=1% significance.
6.2 Part 2: Effect of Oil Shocks

The following three tables, Tables 5-7, are put in the same order as presented in Section 4.4.

**Table 5. Positive Supply Shock (The 2020 Oil Price War)**

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil price (Log.)</td>
<td>0.360***</td>
<td>0.314***</td>
<td>0.207***</td>
<td>0.191***</td>
</tr>
<tr>
<td></td>
<td>(0.0520)</td>
<td>(0.0446)</td>
<td>(0.0504)</td>
<td>(0.0370)</td>
</tr>
<tr>
<td>Coal price (Log.)</td>
<td>-1.688***</td>
<td>-1.507***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.373)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exchange rate (Log.)</td>
<td>3.887***</td>
<td>3.256***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.932)</td>
<td>(0.774)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** The models use daily data from March 2nd to April 9th, 2020. Control variables have been progressively added. Based on Eq. 1. Heteroscedasticity robust standard errors are shown in the parentheses. * = 10% significance. ** = 5% significance. *** = 1% significance.

**Table 6. Positive Demand Shock (the Invasion of Ukraine)**

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil price (Log.)</td>
<td>-0.785***</td>
<td>-0.334***</td>
<td>-0.678***</td>
<td>-0.294***</td>
</tr>
<tr>
<td></td>
<td>(0.175)</td>
<td>(0.0988)</td>
<td>(0.158)</td>
<td>(0.0942)</td>
</tr>
<tr>
<td>Coal price (Log.)</td>
<td>-0.272***</td>
<td></td>
<td>-0.329***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0417)</td>
<td></td>
<td>(0.0689)</td>
<td></td>
</tr>
<tr>
<td>Exchange rate (Log.)</td>
<td>2.325***</td>
<td></td>
<td>-1.166</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.600)</td>
<td></td>
<td>(0.976)</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** The models use daily data from February 21st to April 21st, 2022. Control variables have been progressively added. Based on Eq. 1. Heteroscedasticity robust standard errors are shown in the parentheses. * = 10% significance. ** = 5% significance. *** = 1% significance.

**Table 7. Negative Demand Shock (Ban of Russian Oil)**

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil price (Log.)</td>
<td>0.187**</td>
<td>0.268***</td>
<td>0.191**</td>
<td>0.290***</td>
</tr>
<tr>
<td></td>
<td>(0.0859)</td>
<td>(0.0807)</td>
<td>(0.0848)</td>
<td>(0.0792)</td>
</tr>
<tr>
<td>Coal price (Log.)</td>
<td>-0.0503**</td>
<td></td>
<td>-0.0731**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0204)</td>
<td></td>
<td>(0.0309)</td>
<td></td>
</tr>
<tr>
<td>Exchange rate (Log.)</td>
<td>0.143</td>
<td></td>
<td>-0.513</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.297)</td>
<td></td>
<td>(0.410)</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** The models use daily data from November 24th, 2022, to July 21st, 2023. Control variables have been progressively added. Based on Eq. 1. Heteroscedasticity robust standard errors are shown in the parentheses. * = 10% significance. ** = 5% significance. *** = 1% significance.
All the estimates for the oil shocks are statistically significant, most at the 1%-level and some at the 5%-level. Table 5 shows the regression for the positive supply shock. During a positive supply shock, a one percent decrease in oil prices leads to a decrease in EUA prices by 19.1%. Table 6 shows that during a positive demand shock, a one percent increase in oil price leads to a decrease in the EUA price by 29.4%. The magnitude of the effect is larger than for the positive supply shock. There is also a large drop in estimate value in Table 6, from 78.5% (Column 1) to 33.4% (Column 2) when coal prices have been controlled for, dropping with more than half of their initial value.

Table 7 shows that during a negative supply shock, oil prices affect 29% of the oil prices. Table 7 indicates that a negative oil supply shock has an effect that is near the same magnitude as a positive demand shock. For both Tables 5 and Table 6 an overestimation of the effect is observed, and the coefficient decreases with added control variables. The regression for Table 7 shows an initial underestimation, as the coefficient increases from 18.7% to 29%.

Studying the “goodness-of-fit” measures, the adjusted R-squared for all shocks increases when both control variables are added and the RMSE decreases. The adjusted R-squared for Table 7 are low compared to Table 5 and Table 6. The control variables have the largest effect on Table 5, the positive supply shock, as the RMSE shrinks from 0.110 to 0.0687. For the other two regressions, Tables 6 and 7, the control variables have less effect, even though the RMSEs for all shock regressions are considered low.
7 Discussion

The overall results from Tables 3 and 4 indicate that the correlation is mostly positive, but it changes under different statistical conditions. The oil price is likely not the only factor that affects the demand for allowances. This should not come as a surprise, as EU-ETS is a system that regulates the amount of GHG emissions, not oil usage itself. Several other factors could affect the EUA price, which is why adding the control variables as well as adding year fixed effects leads to drastically lower estimates from what they initially were.

When year fixed effects are added, the results become less significant. The oil price is sensitive to changes in the macro environment, which could explain why adjusting for yearly changes makes a significant difference. Another statistical modification that affected the results was when the outliers were removed. It is not clear why the estimate became insignificant, but one possible explanation could be that after removing outliers, some of the shock observations were removed. This would cause the correlations to become less significant.

The analyses of control variables are also of interest, as they tell us more about how the EU-ETS works as a system. Beginning with coal prices, something that both the overall regressions have in common is that coal prices and oil prices have the opposite effect on EUA prices (see Column 2 in Tables 3 and 4). The estimates show that coal prices have a larger effect than oil prices, which means that the EUA price is more sensitive to changes in the coal price than the oil price. The reason for this could be that coal emits more carbon dioxide than oil. Increasing consumption of coal generates a greater need for EUAs. While coal prices have a positive effect on EUA prices, oil prices have a negative one, which supports the fact that coal and oil act as substitutes.

Next is the exchange rate variable. The exchange rate has a large, negative effect on EUA prices in the overall regressions. This was slightly unexpected because two outcomes were possible: a positive coefficient and a negative coefficient. The outcomes are presented below, and the analysis is based on what would happen if the euro appreciates:

1) When the euro appreciates, oil becomes cheaper for the euro area. Oil demand increases and oil prices increase. At the same time, more consumption of oil means that more EUAs are bought, and the allowance price would increase. The coefficient would then be positive. This is the direct effect.
2) An appreciation of the euro could also mean that fewer domestic goods are demanded and aggregate demand falls. As a response, production activity in the EU would decrease and oil demand would decrease. The price of oil would fall. Simultaneously, fewer EUAs are needed, and a lower demand causes the EUA price to decrease. The coefficient would be negative. This is the indirect effect.

Both these scenarios can happen at the same time, the total effect depends on which one dominates. While the direct, positive effect seemed to be more likely to dominate, the results show that the effect of the exchange rate is highly negative. The indirect effect of a change in the exchange rate is larger than the direct one. Aggregate demand changes hit the economy harder than the oil specific demand shocks. Once again, this shows that EUA prices depend on the overall production activity and how much the firms emit, not as much on oil consumption itself.

Meanwhile, the oil-shock regressions showed more correlation between the oil price and the EUA price. All three regressions show statistically significant results, and the effect is different depending on whether it is a supply or demand shock. The positive demand shock has a negative effect of 29.4% on EUA prices. In contrast, the positive supply shock only leads to a 19.1% increase. EUA prices seem to be more elastic during a demand shock than a supply shock equivalent. Both supply shocks produced results that were unexpected and one reason for this could be because oil prices are not the sole factor that affects EUA prices.

In Table 5, the estimates for the positive supply shock were different from what was predicted (see Table 1 for predictions). In short, theory suggests that a positive supply shock should lead to more oil sold at a lower price. This led to an increase in demand for EUAs and therefore an increase in EUA prices, which in turn should result in a negative correlation. Instead, the results show a positive and highly significant effect. The positive supply shock in March 2020 led to a decrease in both the oil price and the EUA price. This could be because there was a negative demand shock at the same time. The restrictions during the COVID-19 pandemic caused most market activity to pause, so even if the oil price decreased, demand did not increase. Because of this, both demand for oil and demand for EUAs were low, hence both of their prices dropped, resulting in a positive correlation as they move in the same direction.
The results for the positive demand shock in Table 6 generated results that were more in line with the theoretical predictions. Theoretically, a positive demand shock increases oil demand which should lead to more allowances being bought which should result in a positive correlation. However, if firms expect oil to become scarcer, then prices will eventually increase, which can incentivize firms to hoard oil so that the demand for oil increases even more. Prices would then continue to rise to even higher levels and at some point, it will reach a point when oil becomes too expensive, and demand would plummet. This seems to be what happened during this shock, as firms speculated that the EU would possibly impose sanctions against Russia. This could explain why the results show a negative coefficient for this shock. As previous studies concluded, more oil being bought does not mean that more oil will be used (Kilian, 2014; Krokida et al., 2019). Increased oil demand does not have to affect EUA prices, but in this case, it seems to have had significant effects.

Demand shocks are usually driven by macroeconomic changes and future expectations, both can be controlled through monetary policy. In this way, real prices are affected, including oil prices, making the effect of a demand shock easier to see and predict. The demand shock initially had a negative effect, changing from -78.5% (Table 6, Column 1) to -29.4% (Table 6, Column 4). It is hard to discern why the effect was reduced as control variables were added, as there are often several factors that influence the characteristics of an oil demand shock. In this case, it could be a combination of several factors: speculation about sanctions against Russian oil caused firms to hoard oil and increase demand for coal; high post-COVID 19 production activities caused demand for oil and other fossil fuels to increase; surging inflation rates led to higher overall prices.

The results in Table 7, like in Table 5, are different from what the theory predicts. While it was predicted that a negative supply shock should have a negative coefficient, the results show a positive one. It could be because this shock was more linked with geopolitical changes rather than macroeconomic changes. The control variables that were used were better suited for controlling economic shocks, which could be why the results did not comply with the theoretical predictions. The R-squared values were also continuously very low in this regression, which suggests that the model may not have been ideal for studying this type of shock. Other control variables could have been used, but it would require finding ways to measure exogenous factors like politics. These are more difficult to capture in numbers than economic ones and because of this, the supply shock effects were less predictable.
While the sanctions might have shocked the economic system, they were not entirely unexpected, thus not affecting the economy as a negative supply shock theoretically would. During the time leading to the sanctions, stakeholders speculated about what would happen. Combined with the fact that the EU was progressively phasing out the usage of Russian oil (European Council, 2024), firms were likely already preparing for the drop in oil supply, either by buying from other oil producing countries (Enerdata, 2023; Eurostat, 2024) or by substituting oil for coal (Eurostat 2023:a; Greenfield, 2023). An effect that is expected might level out during a longer period rather than hitting all at once on the day the sanctions are first announced. This would also explain why the coefficient in Column 1 in Table 7 was underestimated. Perhaps another shock should have been chosen in its place to provide more useful results.
8 Conclusion

In this study, statistical methods were used to establish how the EUA market and the oil market are integrated. A multiple regression model was used to determine the causal relationship between EUA prices and oil prices. The study was then separated into two parts: an overall analysis and an oil shock analysis.

The overall analysis indicates that there is a statistically significant relationship, but that it gets less significant as the model becomes more complex. When outliers are removed, control variables added and year effects adjusted for, oil prices have no significant effect on EUA prices. The overall results are merely an average value that has been made to fit the data as well as possible, which is not an easy task when the effect seemingly switches under different statistical conditions. Analyzing different shocks over shorter periods proved to give more insightful results.

In the three oil-shock regressions, it is found that the absolute value of the cross-price elasticity of demand ranges between 0 and 0.3. Oil prices seemingly have a weak effect on EUA prices. While an oil supply shock has a positive effect, an oil specific demand shock has a negative effect on EUA prices. The supply shocks also proved to be less predictable because of exogenous factors, which was why the effect of a supply shock was smaller than its demand shock equivalent.

The multiple regression model is a relatively simple model that is easy to interpret, but it lacks some complexity and does not cover all aspects needed to accurately study all of the shocks. For future studies, other statistical methods could be used to study more shocks. To strengthen the validity of the study, it is also advisable to research other cap-and-trade systems in other unions or countries as it could help enhance the understanding of the oil and GHG markets.

In conclusion, the relationship between oil prices and EUA prices appears to be constantly shifting between being positive and negative depending on macroeconomic, environmental and geopolitical conditions. In turn, these conditions also change with time, making it difficult to determine the exact direction of the relationship. What can be assured is that as the cap continues to be lowered and as the scheme is expanded to cover more sectors, the EU-ETS will become of even greater interest. Tracking developments through studies like this will be an important part of navigating major climate agreements in the future.
Reference list


Eurostat (2024). *Oil import dependency at its highest in 2022.*


Appendix

A.1 Cross-Price Elasticity of Demand Derivation

Derivation is shown in Eq. 3 below:

\[ E_{XY} = \frac{\frac{dQ_x}{dP_Y}}{\frac{Q_x}{P_Y}} = \frac{\frac{dQ_x}{dP_Y}}{\frac{Q_x}{dP_Y}} = \frac{dQ_x}{dP_Y} \frac{P_Y}{Q_x} \]

(3)

where \( E_{XY} \) stands for cross-price elasticity of demand, \( Q \) stands for quantity and \( P \) for price. The indexes \( X \) and \( Y \) represent two different goods. A negative cross-price elasticity indicates two products are complements (the first factor in Eq. 1 \( \frac{dQ_x}{dP_Y} \) is negative). A positive cross-price elasticity indicates two products are complements (the first factor in Eq. 1 \( \frac{dQ_x}{dP_Y} \) is positive).

A.2 Deriving cross-price elasticity through the log-function

Derivation is shown in Eq. 4-6 below:

\[ \ln Y_i = \beta_j \ln X_i \]

\[ \rightarrow \frac{dY_i}{Y_i} = \beta_j \frac{dX_i}{X_i} \]

\[ \rightarrow \beta_j = \frac{\frac{dY_i}{Y_i}}{\frac{dX_i}{X_i}} = \frac{dY_i}{dX_i} \frac{X_i}{Y_i} = E_{XY} \]

(4)

(5)

(6)

where \( E_{XY} \) is the cross-price elasticity of demand, \( Y \) is the dependent variable, \( X \) is the independent variable. The index \( i \) stands for the observation, \( j \) is the corresponding number (1, 2, 3…) to each coefficient (\( \beta \)) in Eq. 1 and Eq. 2 (see section 5.1). At the right-hand side in Eq. 4, the functional form for an elasticity is shown.
A.3 Boxplots

The boxplots show the distribution and eventual outliers of each of the logged variables that are included in the regression models (Eq. 1 and 2).

Fig. 5 – Boxplot of logged EUA price distribution during the years 2018-2023.

Fig. 6 – Boxplot of logged oil price distribution during the years 2018-2023.
A.4 VIF values and interpretation

Tables 8-12 show the VIF values for the regressions of each of the five regressions in this paper. Each table is titled with which regression table it corresponds to. The lowest VIF value is 1, where 1 means there is no correlation between the variables. A value between 1 and 5 means that there is correlation, but multicollinearity does not affect the results. A value over 5 indicates multicollinearity that may need to be adjusted for.
### Table 8. VIF for Table 3

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<td>Coal price (Log.)</td>
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<td>Exchange rate (Log.)</td>
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Observations 1210

Notes: Based on regression model in Column 4.

### Table 9. VIF for Table 4

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<td>Oil price (Log.)</td>
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</tr>
<tr>
<td>Coal price (Log.)</td>
<td>4.51</td>
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<td>Exchange rate (Log.)</td>
<td>1.32</td>
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Observations 1008

Notes: Based on regression model in Column 4.

### Table 10. VIF for Table 5

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<tr>
<td>Coal price (Log.)</td>
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<td>Exchange rate (Log.)</td>
<td>1.73</td>
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Observations 26

Notes: Based on regression model in Column 4.

### Table 11. VIF for Table 6

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Observations 38

Notes: Based on regression model in Column 4.

### Table 12. VIF for Table 7 Regression Model

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Observations 139

Notes: Based on regression model in Column 4.