The effects of oil price shocks on the prices of EU emission trading system and European stock returns

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Abstract

This paper examines whether oil price shocks of different origin affect the price of carbon emission allowance traded under the European Union's Emissions Trading System (EU-ETS); leading to changes in aggregate and sector specific European equity returns. The results show that positive oil demand shocks have an imminent and persistent positive effect on carbon emission price, whereas an unexpected oil supply disruption has a negative and less significant effect. These findings are economically important as positive shocks on the CO2 emission allowance price trigger a decrease on the aggregate stock return of the European equities markets, and a larger and more persistent increase on the stock return of oil-related sectors.

Keywords: oil price shocks; emissions trading system; structural VAR; European stock returns.
JEL classification: G10, G11, G12, G14.

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1 Introduction

Oil's price fluctuations and their effects in the global economic activity and the capital markets have been an important research topic over several decades (Kling, 1985; Chen, Roll and Ross, 1986; Sadorsky, 1999; Huang, Masulis and Stoll, 1996); with more recent contributions disentangling oil price shocks into oil demand and oil supply shocks (Barsky and Kilian, 2002, 2004; Kilian, 2009; Kilian and Park, 2009; Lambertides, Savva and Tsouknidis, 2017). Beyond the effects of oil-related activities on capital markets, both upstream and downstream activities of the supply chain of oil and oil products produce significant amounts of CO2 emissions. This is confirmed by Figure 1 which depicts the verified CO2 emissions in billions tonnes per industry in the EU over the period 2005-2016.[1] As observed the "Oil and Gas" industry is ranked consistently second, over the period 2005-2016, in terms of aggregate verified emissions after the industry "Power and Heat". This fact highlights the importance of emissions allowance price dynamics for the oil and gas industry.

Carbon emissions have been linked by scientists to human activities and are generally accepted to be responsible for the alarming phenomena of global warming and climate change. As a response to the global climate and environmental risks linked to the human-related emissions of CO2 in the atmosphere and in order to reduce their overall level, the 1992-signed Kyoto protocol proposed for the first time the trading of emission allowances or permits in organized financial markets. More than a decade later, in 2005, the EU introduced the emission trading scheme (ETS), which is a cap-and-trade system. After the introduction of the EU-ETS, carbon emissions in Europe are capped, traded and priced. According to this cap-and-trade system, EU allocates to each country (jurisdiction) a maximum limit on the total amount of emissions permitted to emit, which are divided into units of permitted pollution, the so-called emission unit allowance (EUA). EUA's are allocated to firms and each unit represents the right to emit one tonne of CO2 per year. Firms are required to hold EUA's (permits) equivalent to their emissions measured in tons of CO2 per year, else they pay a significant fine. In this way, EU-ETS provides financial incentives to motivate firms to reduce emissions by imposing a charge on emissions exceeding a cap (ceiling). During the initial two phases of the scheme, over the period 2005-

[1] These data on verified emissions are from the World Carbon Market database, which provides raw data for more than 11,500 installations in the EU; which can be aggregated to the firm and the industry levels.

2012, EUA's were granted to European firms free of charge; whereas in the third phase over the period 2013-2019 the majority of the EUA's are sold in auctions. Entities that chose to pollute more than the allowances they received had to purchase extra allowances in the open market from firms that used less allowances than they received. The EUA's (permits) are traded on an exchange and in this way they establish a market price associated with one unit of pollution. This led to the emergence of EU-ETS, the largest carbon market globally which accounts for about half the CO2 emissions in all EU member states and more than 11,500 installations that together emit over 2 billion tonnes of CO2 annually (World Bank, 2014). Emitting more than allowed and buying additional permits incurs cash expenses for the firms and increases their marginal production cost. In contrast, firms with lower emissions may need to buy less additional permits and in this way reduce their marginal production cost or sell in the exchange their unused given permits and benefit from additional revenues. In this way, the cost of CO2 emission allowances along with the price of oil are expected to affect directly or indirectly almost all industries and consumers. However, the relationship between oil price shocks and emissions price remains an open research question.

The extant literature on the relationship between oil price and emission allowance price is relatively thin. For example, efforts by Benz and Trück (2009) and Hammoudeh, Nguyen and Sousa (2014) explore the relationship between the two by utilizing higher frequency - daily - data and modeling potential asymmetries in oil price fluctuations. However, to the best of our knowledge, no prior study has examined the relationship between oil price and emission allowance price in a proper estimation framework, which is able to distinguish the effects of oil price shocks of different origin on emission allowance price. This paper sheds some light on the issue by investigating empirically whether oil price shocks of different origin - oil supply and oil demand shocks - affect the price of the EU-ETS carbon emission allowance. The rationale supporting the potential impact of oil supply and demand shocks on EU-ETS price is based on the structure of the global economy; that is, it is widely accepted that oil and oil products form the main source of energy for several large companies across the global manufacturing and supply chain industries. In this line, oil price shocks as introduced by Kilian (2009), are expected to affect the number of CO2 tonnes emitted by companies in the atmosphere. This will create fluctuations in the emission allowance price. The aim of this study is to test empirically this fundamental mechanism between oil supply and oil demand shocks and their impact on emission allowance price. To further investigate the economic significance derived by the oil-emission allowance price relationship, this study explores whether the identified structural shocks between oil price and EU-ETS carbon emission allowance price affect real European stock returns.[2] The economic rationale behind this argument is that high (low) emitting firms face higher (lower) costs of purchasing emission allowance units, which in turn result into higher (lower) production costs. Specifically we examine the effects of the oil-emission allowance price relationship on European stock returns in general and for a number of oil-related industries. To make the results compatible with the existing literature, we investigate the effect of oil demand and oil supply shocks on carbon emission allowance price and eventually on the European equity markets within the framework of Kilian and Park (2009).

The economic intuition behind the idea that oil price shocks of different origin may affect differently emissions price is explained below. For simplicity assume an oil price increase which will result in higher marginal production cost for companies using oil as an input.[3] If the observed oil price increase is due to an unexpected disruption in oil supply (shock) making extracting oil more difficult, say because of new regulation or political events, then it is expected that companies using oil as an input will face higher marginal production costs and at the same time will not face an increase in the demand for their products. The absence of an increase in the demand for their products may be attributed to the fact that the increase in oil price is merely due to the unexpected oil supply shock (lower supply) and not due to a boost in the global economic activity. In this case, oil users will not increase their level of production and thus will not increase their CO2 emissions - and not buying or using more EUAs - leading to no significant change in the price of emission allowance unit (EUA).

By contrast, if the oil's price increase is due to an unexpected increase in global economic activity, then oil users again face higher marginal production costs as they need to acquire oil at a higher price, but at the same time they face higher demand for their production output, which in turn leads into increasing their production level and emitting larger quantities of CO2 in the atmosphere, thereby increasing emissions allowance price. Finally, if the oil's price increase is due to a shock in oil-specific precautionary demand, i.e.

[2] Following this reasoning, this study does not attempt to claim an equivalent change in the systematic risk of these firms.

[3] The exact opposite rationale from the one discussed in this paragraph is expected to hold for the following cases: first, if we assume an oil price decrease instead of an increase; and second, if we assume companies using oil as their production output instead of production input.

oil users decide to buy and store oil fearing oil's future price increases, then it is expected that emissions allowance price will not be affected significantly as this oil does not reflect the intention of the companies to increase their output that would lead emission allowance price up but merely store oil for future use and in this way hedge (limit) their production costs associated with the acquisition of oil. Apart from corporations being direct oil producers or users, several industries are expected to be affected by the aforementioned oil price shocks and in this way impact emission allowance price. This is because, even if a company does not use oil directly as an input in its manufacturing process, it might be the case that it uses oil indirectly in the form of electricity power or to transport other raw materials and commodities.[4]

The empirical results of this paper are novel. First, we reveal that a positive shock on global real economic activity increases significantly the CO2 emissions allowance price as firms produce more which leads into higher emissions and higher demand for buying EUA's. Aggregate results presented in Table 1 show that in the long run, almost 74% of the variation in emission allowance price during 2005-2016 can be attributed to oil demand and oil supply shocks, making oil market fundamentals important determinants of the emission allowance price quoted in the EU-ETS. On the other hand, the results reported in this study fail to support statistically that oil price increases due to an unexpected disruption in oil supply (shock) tend to lower emission allowance price. This is consistent to our expectations that in this specification oil price increases due to oil supply disruptions will force a decrease in production levels leading to overall lower emissions. Oil-specific (precautionary) demand shocks tend to increase the emission permits prices as they can be associated with higher production levels in the near future. Finally, unexpected positive shocks on CO2 emissions allowance price lead to a small decrease on the return of the MSCI Europe equity index.

In order to explore further the economic significance of the identified relationship between oil price shocks of different origin and emissions price, we investigate the effect of the previously identified structural shocks on industry stock returns of European equity markets. Specifically, since the effect of oil price shocks on carbon emission allowances is expected to be more pronounced for oil-related industries and especially for firms using or producing oil directly, we investigate whether our findings vary within different sectors of

[4]For example, large amounts of bunker fuels - a byproduct of crude oil - are consumed by the large Capesize dry-bulk vessels which account for the largest share of dry-bulk transportation in volume terms globally; according to data by Clarksons Shipping Intelligence Network (SIN).

the European equity markets. This empirical exercise is motivated by the related literature which provides strong evidence on the leading role of industries in the equities markets in general (Hong, Torous and Valkanov, 2007) and in the oil-equity nexus in particular (Kilian and Park, 2009; El Hedi Arouri, Jouini and Nguyen, 2011; Baumeister and Kilian, 2017). Results reveal that positive CO2 emission price shocks tend to increase the stock returns of MSCI Europe indices of specific oil-related equity sectors such as Automobiles, Energy and Materials ones. The great majority (93%) of the constituents of the MSCI Europe equity index comprises by oil and gas integrated companies.[5] This may reflect the ability of firms operating within these sectors to transfer the increase on their marginal production costs associated with an increase in carbon emissions price to their customers by increasing the price charged for their production output. By contrast, for the European equity sector of industrials an unexpected increase in CO2 emissions price lowers stock returns. The industrial sector contains stocks that relate to producing goods used in construction and manufacturing.

The rest of this paper is organized as follows. Section 2 provides the theoretical background along with the research design of the paper; section 3 outlines the methodology; section 4 describes the dataset; section 5 presents the results and section 6 concludes the paper.

2 Methodology

We augment Kilian's (2009) structural VAR model in order to distinguish three oil price shocks: oil supply shock, aggregate demand shock and oil-specific demand shock; along with the carbon emission price shock and the residual shock on stock returns. Specifically, the SVAR model incorporates monthly data for the vector time series y, consisting of the percent change in global crude oil production, a measure of real activity in global industrial commodity markets, the real price of crude oil, the price of the CO2 emissions allowance and the stock return of the European equity market. The structural representation of the

[5] The main energy industry segments are the following: the petroleum industry, including oil companies, petroleum refiners, fuel transport and end-user sales at gas stations; the gas industry, including natural gas extraction, and coal gas manufacture as well as distribution and sales; the electrical power industry, including electricity generation, electric power distribution and sales; the coal industry; the nuclear power industry; the renewable energy industry, comprising alternative energy and sustainable energy companies, including those involved in hydroelectric power, wind power, and solar power generation, and the manufacture, distribution and sale of alternative fuels.

VAR model of order p is:

$$A_0 y_t = c_0 + \sum_{i=1}^{p} A_i y_{t-i} + \varepsilon_t \tag{1}$$

where $y_t = (\Delta prod_t, rea_t, rpo_t, CO2_t, ret_t)$, is a 5x1 vector of endogenous variables, A_0 refers to the 5x5 contemporaneous coefficient matrix, c_0 represents a 5x1 vector of constant returns, A_i denotes the 5x5 autoregressive coefficient matrices and ε_t stands for the 5x1 vector of structural disturbances, assumed to have zero covariance and being serially uncorrelated. $\Delta prod_t$ is the percentage change in world oil production, rea_t is the global real economic activity for all industrial commodities,[6] rpo_t are the real prices of oil, $CO2_t$ is the EU-ETS futures price and ret_t is the real stock returns for European equity markets. As discussed later in the paper we use the following stock returns series of European equity markets interchangeably as the fifth variable in the SVAR model above: the MSCI Europe - an aggregate European equity markets index and MSCI industry-specific equity indices for the following oil-related sectors: Automobiles, Energy, Industrials and Materials.

A long lag length of 24 months (p=24) is used to allow for potential delays between structural oil demand and oil supply shocks and their effect on the economy. In addition, such a long number of lags removes serial correlation effects. Kilian (2009) and Kilian and Park (2009) have shown that introducing long lags is important in structural models of the global oil market as they take into account the low frequency co-movement between the real price of oil and the global economic activity. In order to arrive to the reduced form VAR model we multiply both sides of Eq. (1) with A_0^{-1} which follows a recursive structure for the reduced form errors e_t to be linear combinations of the structural errors ε_t as follows:

$$e_t = \begin{bmatrix} e_{1t}^{\Delta \text{ global oil production}} \\ e_{2t}^{\text{global real activity}} \\ e_{3t}^{\text{real price of oil}} \\ e_{4t}^{\text{CO2 price}} \\ e_{5t}^{\text{U.S. stock returns}} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & 0 & 0 & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & 0 & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & 0 \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t}^{\text{oil supply shock}} \\ \varepsilon_{2t}^{\text{aggregate demand shock}} \\ \varepsilon_{3t}^{\text{oil specific-demand shock}} \\ \varepsilon_{4t}^{\text{CO2 price shock}} \\ \varepsilon_{5t}^{\text{other shocks to stock returns}} \end{bmatrix} \tag{2}$$

[6]The global real economic activity refers to equally weighted growth rates of freight rates for individual voyages of bulk dry cargoes. These freight rates are deflated using the US consumer price index and linearly de-trended to remove long-term trends in demand for sea transport and the effects of technological advances in ship building (Kilian, 2009).

where, $\varepsilon_{1t}^{\text{oil supply shock}}$ stands for the oil supply side shock, $\varepsilon_{2t}^{\text{aggregate demand shock}}$ denotes the aggregate demand shock, $\varepsilon_{3t}^{\text{oil specific-demand shock}}$ captures the oil market-specific demand shock, $\varepsilon_{4t}^{\text{CO2 price shock}}$ is the idiosyncratic shock to the CO2 price and $\varepsilon_{5t}^{\text{other shocks to stock returns}}$ is the residual or other shock. The economic rationale for the identifying restrictions imposed in A_0^{-1} is explained in detail in Kilian (2009).

The oil production is assumed not to respond contemporaneously to an oil demand shock within a given month due to the high adjustment costs of oil production. In contrast, oil supply shocks can influence the global economic activity, the price of oil and the emissions price within the same month. Next, the global economic activity is assumed not to be responding contemporaneously to shocks of the real price of oil within a given month because of the time that is required for the world economy to react. However, a global economic activity shock will have an immediate effect on oil prices and emission allowance price, considering the low reaction time of commodities and financial markets. In turn, real oil price innovations are not assumed to respond contemporaneously to changes in the price of CO2 emissions, but both oil supply shocks and global economic activity shocks can influence oil prices contemporaneously. As the stock returns of the emitting firms are assumed to respond with some delay to the trading of EUAs, the CO2 emissions price is assumed not to affect contemporaneously to stock returns, but reacts contemporaneously to all the aforementioned oil demand and oil supply shocks as oil is a central commodity in their production process. Finally, stock returns are assumed to react contemporaneously to all the aforementioned shocks. We do not attempt to disentangle further the shocks driving stock returns, as in this paper we only examine the impact of structural oil demand and oil supply shocks on CO2 emissions price and stock returns.

3 Data description

All data examined in this paper are obtained from April 2005, when EUA trading initiated, until December 2016. Specifically, monthly observations are utilized for world oil production, a measure of global economic activity and oil prices as the U.S. refinerś acquisition cost of imported crude oil. Both world oil production and oil prices are from the US Department of Energy. The percent change in world oil production is measured by 100 x log difference in the world oil production in millions of barrels pumped per day averaged by month. The real price of oil is the nominal price of oil deflated by the U.S. consumer price index (CPI) from the Bureau of Labor Statistics. Prices are expressed in dollars and transformed in log-returns. Global real economic activity is measured by the index constructed by Kilian (2009).[7] This index has the advantage that it incorporates activity in important emerging economies such as China and India, which are not included in conventional measures of global economic activity for OECD countries.

In addition to the oil-related series above and in line with Daskalakis, Psychoyios and Markellos (2009) and Koch and Bassen (2013), we use monthly settlement prices of EUA futures contracts for the price of EUAs obtained through Thomson Reuters Datastream. Such futures contracts are traded on the European Climate Exchange (ECX) which is owned by the Intercontinental Exchange (ICE). In line with Oestreich and Tsiakas (2015) we construct a continuous price series combining a series of futures contracts as follows. During Phase I (2005-2007) our series is equal to the price of the December 2008 contract. During Phase II (2008-2012) the series is equal to the price of the December 2009 contract until its last trading day, then switches to the December 2010 until its last trading day and so on until December 2012. During Phase III (2013-2016) we follow the same procedure and set the series equal to the futures contract with maturity on December of each year for all the trading days of the year. Figure 1 plots the constructed series of the EUA futures price in euros.

Finally, the monthly series above are matched with stock (total) returns obtained through Thomson Reuters Datastream for the following series: the aggregate stock index MSCI Europe and sector-specific stock indices by MSCI for the following sectors: Automobiles, Energy, Industrials and Materials. Real stock (log) returns are computed for the series above by subtracting from each one the Euro Area inflation rate published by the European Central Bank (ECB).

4 Empirical results

The responses of the CO2 emissions price to oil supply, global real economic activity and oil-specific demand shocks are reported in Figures 3a, 3b, 3c, respectively; whereas Figure 3d depicts the response of the cumulative real stock return of the MSCI Europe index to a structural shock on the CO2 emissions price. All shocks have been normalized as to tend to increase oil's price, i.e. the oil supply shock has been normalized to represent a negative one standard deviation shock (oil supply disruption), whereas the global real economic activity and oil-market specific demand shocks have been normalized to represent positive shocks.

[7] The data are available at Kilian's webpage: http://www-personal.umich.edu/ lkilian/paperlinks.html

The bands of one-standard and two-standard errors are depicted by dotted and dashed lines, respectively. These intervals have been computed based on a recursive-design wild bootstrap with 10,000 replications (Goncalves and Kilian, 2004). As observed, in Figure 3a an unexpected disruption in world oil supply triggers a weakly statistically significant but immediate decrease to CO2 emissions price until almost month 11. This result supports our hypothesis that, ceteris paribus, as oil price increases due to an unexpected disruption of oil supply, firms reduce their production output which results into lower emissions and lower demand for emissions allowances, thereby decreasing EUA's price. In turn, Figure 3b shows that an unexpected positive shock in the global real economic activity for all industrial commodities causes a persistent and statistically significant increase in the price of the CO2 emissions allowance for up to 16 months forward, with a notable reversal during months 2 to 4. This result confirms our research hypothesis that an oil price increase due to an unexpected positive shock on the global real economic activity increases firms' production output level and in this way the level of emissions and the price of emissions allowance. Next, Figure 3c shows that a shock in precautionary demand for oil causes a persistent increase in the price of the CO2 emissions allowance for up to 3 months, followed by a gradual reversal up to month 6, where the effect becomes insignificant. This result provides evidence that increases in oil price due to precautionary demand increase carbon emissions price in the subsequent months.

The impulse responses graphs depicted in Figure 3 indicate the timing and the magnitude of the carbon allowance price responses to one-time shocks in the supply and demand for oil. Albeit, historical oil demand and oil supply shocks may not be limited to one-time shocks as they may involve a set of shocks, often coming with different signs at different points in time. Thus, in order to understand the cumulative effect of these historical set of shocks we perform a historical decomposition of these shocks on the price of CO2 carbon emission allowance and depict the results in Figure 4. As observed, responses of the price of CO2 carbon emission allowance have been mainly driven by oil-supply and global economic activity shocks (Figs. 4a and 4b) rather than oil-specific demand (precautionary) shocks which appear to exert smaller effects. Notably, after the year 2013 oil supply shocks and global real economic activity shocks exhibit much larger effects without any particular long-run trend (positive or negative) on the price of CO2 carbon emission allowance (Figs. 4a and 4b).

4.1 Testing the economic significance of the results

Free carbon allowances to emitting firms under a cap-and-trade scheme such as the EU-ETS imply a positive relationship between receiving the EUA's for free and stock returns. In other words, ceteris paribus, firms receiving free carbon allowances will exhibit higher stock returns. The rationale supporting this hypothesis stems from the following two mechanisms which are developed in the framework of Goulder, Hafstead and Dworsky (2010). First, a cap-and-trade system increases the marginal cost of production as the free carbon permits represent an opportunity cost for the firm. In turn, firms respond to higher marginal costs in three ways or a combination of these: increasing their output prices which are eventually paid by their customers, reducing their production level so that less carbon allowances are needed (or used) and switching to less carbon-intensive production technologies. This rationale implies that the free allocation of carbon allowances would lead to large windfall firm profits (cash flows), and to the extent these profits (cash flows) are priced by the equity market, to higher stock returns. Note that this is the case both when the EUAs are bought in the open market (an actual cost to the firm) of are received for free (an opportunity cost to the firm). The second mechanism through which free carbon allowances may lead to higher firm profits is due to the carbon risk effect. This arises due to the uncertainty firms face regarding the future price of carbon allowance, which in turn generates uncertainty regarding future cash flows. Furthermore, Weitzman (2009 and Litterman (2013) suggest that carbon emitting firms might face increased carbon risk in the future due to the higher prices of carbon allowance as a result of the ongoing climate change. Following this rationale, it is expected that, ceteris paribus, firms with higher emissions will face higher carbon risk affecting their future cash flows and for this reason equity investors will require higher expected stock returns for these corporations. However, the empirical investigation of the above economic mechanisms remains an open question in the extant literature.

The extant literature on the relationship between emission prices and stock returns documents an overall weak positive relationship between emission price increases and stock returns for European electric power utilities (Oberndorfer, 2009; Veith, Werner and Zimmermann, 2009; Koch and Bassen, 2013). In an asset pricing study, Oestreich and Tsiakas (2015) provide empirical evidence supporting that firms receiving higher free carbon allowances exhibit higher stock returns during the period 2003-2009 for the German equity market. However, the authors do not attempt to investigate the exact mechanism behind this empirical finding, i.e. whether it is a cash-flow effect or a carbon price risk effect.

Accordingly, Figure 3d reveals that an unexpected positive shock on the price of emissions causes a small and weakly significant reduction on an aggregate index of European equities markets that builds during the first 2-3 months and then drifts around the reached threshold. The results depicted in Figures 3a, 3b, 3c and 3d have important implications regarding the effects of oil demand and oil supply shocks on the European stock market. Overall, the results presented here suggest that oil demand shocks stimulate the traded price of carbon emission allowance as emissions increase due to higher production output. Thus, the stimulating effect of oil demand shocks to the US stock market and economy documented in the literature (Kilian, 2009; Kilian and Park, 2009) is shown to be transmitted to a large extent through carbon emissions price when examining the European equity markets.

In order to test whether our results vary for different industries of the equity market we also use industry-level cumulative stock returns as the fifth variable in the SVAR model described earlier in the paper. Different results are expected for oil-related sectors rather than the rest of the sectors as it is easier for investors and traders to assess the effects of oil demand and oil supply shocks along with carbon emission shocks on the stock returns of European listed companies in the oil-related sectors. Figures 5a-5d, present the impulse responses of the industry-level stock returns to an unexpected shock on the CO2 emissions price.[8] As observed in Figure 5a for the Automobile sector, CO2 emissions price shocks cause an immediate and persistent increase in the real cumulative stock return of the sector which is highly significant up to month 9. In turn, in Figure 5b for the energy sector the CO2 emission price again increases stock returns for the sector, albeit the effect is relatively small and significant only during the first 3 months; later is declines and reverses gradually. Next, in Figure 5c the stock returns for the Industrials sector decreases gradually over the whole period examined, being statistically significant for almost all the 16 months ahead examined. Finally, in Figure 5d for the Materials sector, stock returns appear to increase due to an unexpected increase in the price of CO2 emissions allowance. This effect is strongly significant for the first 6 months, whereas later it reduces both in

[8]The full set of results in this section includes the effects of oil-supply shock, global real economic activity shock, oil-specific demand shock, CO2 emissions price shock and the residual or other shock on the sector-specific stock returns, for all the sectors of the economy. However in order to preserve space we only present the results for the effect of a CO2 emissions price shock on the stock returns of oil-related European equity sectors in Figures 5a, 5b, 5c and 5d.

terms of magnitude and statistical significance and up to month 16 ahead.

These results reveal the existence of a relatively large - depending on the sector - and positive response of oil-related sector-specific equity returns to positive shocks on the price of CO2 emissions allowance. In this way, these results provide novel and robust evidence that oil price shocks of different origin affect CO2 emission allowance price differently; leading eventually to higher stock returns on specific oil-related sectors. Moreover, these results extend the extant literature on the issue providing strong evidence on the leading role of industries in the equities markets in general (Hong et al., 2007) and in the oil-equity nexus in particular (Kilian and Park, 2009; El Hedi Arouri et al., 2011). For instance, El Hedi Arouri et al. (2011) provide evidence that oil price changes raise U.S. stock volatilities substantially more for oil-dependent sectors, such as Automobile and Parts, Basic Materials, Industrials and Utilities rather than for non-oil-dependent sectors, such as Telecommunications.

5 Conclusion

This paper provides novel evidence that oil demand shocks and oil supply shocks affect the price of CO2 emissions allowances while traded under the EU-ETS scheme. The effects reported are large and statistically significant. Specifically, positive oil demand shocks are shown to have an imminent and persistent positive effect on carbon emission price, whereas an unexpected oil supply disruption has a negative and less significant effect. These findings are economically significant as positive shocks on CO2 emission allowance price trigger a small decrease on the aggregate stock return of the European equities markets. Sector-specific stock returns for oil-related sectors exhibit larger and more persistent increases as responses to emission price shocks.

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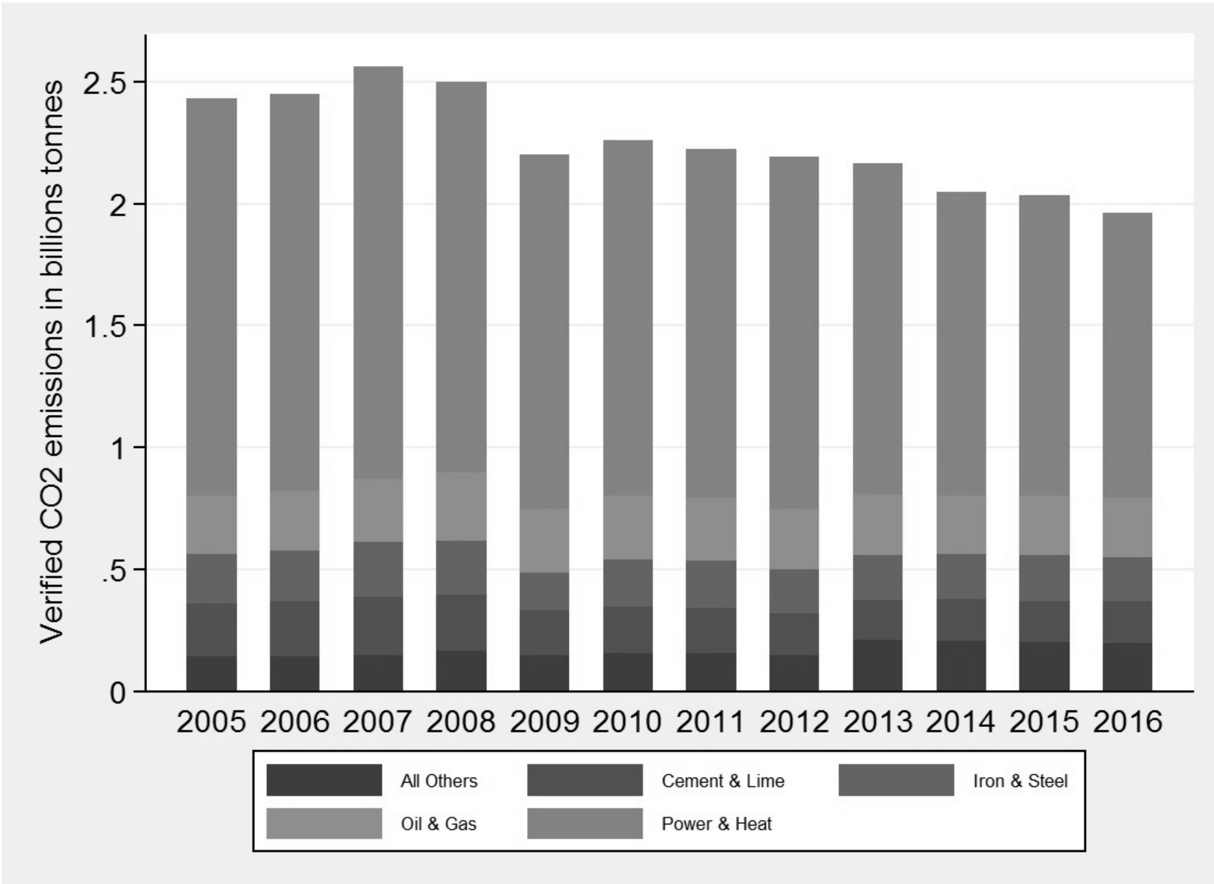


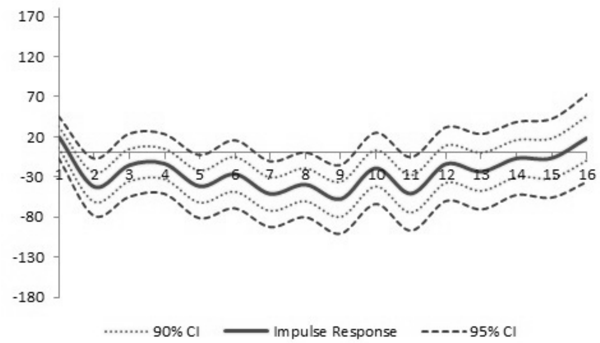
Figure 1: The verified aggregate CO2 emissions per industry are from the World Carbon Market database. The Oil and Gas sector ranks second in aggregate verified CO2 emissions throughout the period 2005-2016.

Table 1: Percent contribution of demand and supply shocks in the crude oil market to the overall variability of EU-ETS futures price and European real stock returns

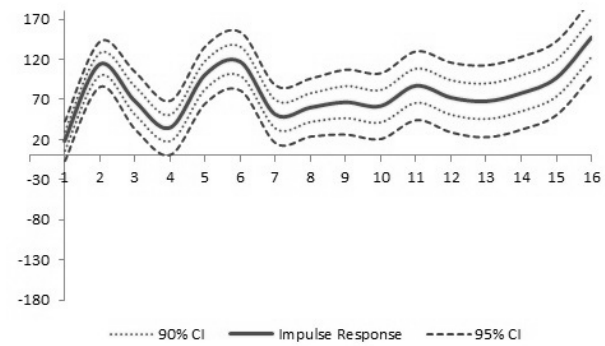
Horizon	Oil Supply Shock	Aggregate Demand Shock	Oil-specific Demand Shock	Other Shocks
1	1.06	1.98	2.00	94.96
2	2.37	19.62	24.48	53.54
3	8.56	27.08	30.04	34.32
12	15.35	25.29	29.08	30.29
∞	24.39	24.49	25.37	25.75

Notes: Based on variance decomposition of the SVAR model (1).

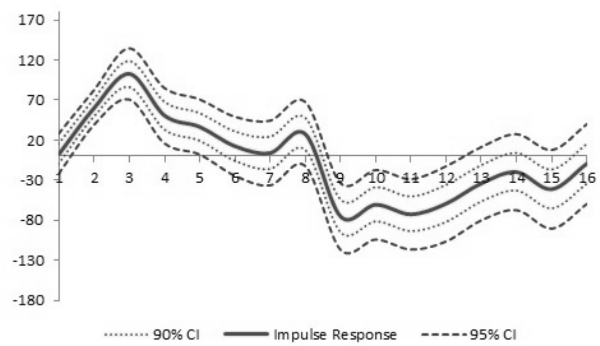
Figure 2: The price of one European Union Allowance (EUA) over time. The series depicted plots in euros the futures price of one EUA, i.e. the price of the right to emit one CO2 tonne per year. The series depicted is constructed as follows. During Phase I (2005-2007) our series is equal to the price of the December 2008 contract. During Phase II (2008-2012) the series is equal to the price of the December 2009 contract until its last trading day, then switches to the December 2010 until its last trading day and so on until December 2012. During Phase III (2013-2016) we follow the same procedure and set the series equal to the futures contract with maturity on December of each year for all the trading days of the year. Y-axis is in euros.



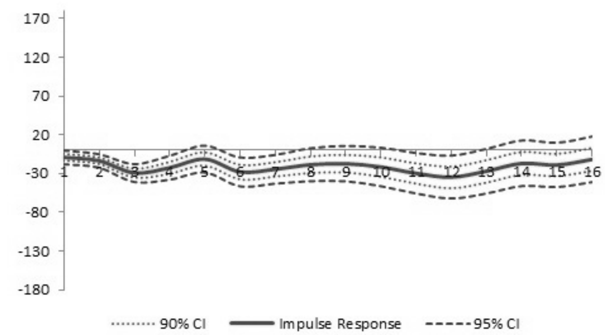
(a) Oil supply shock on CO2 emissions price



(b) Aggregate demand shock on CO2 emissions price

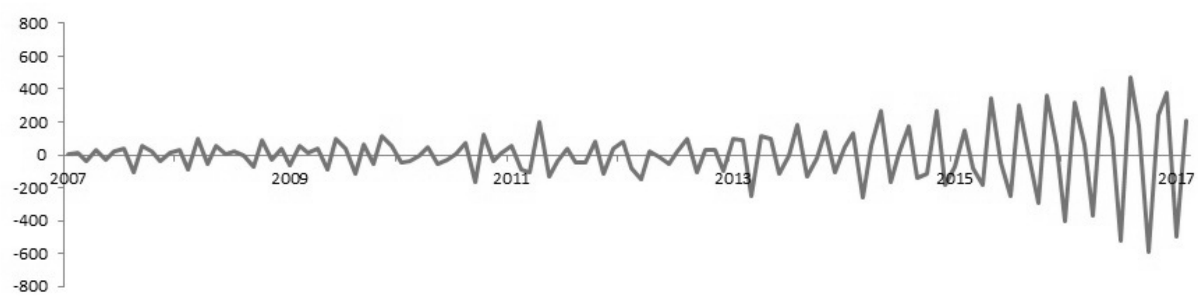


(c) Oil-specific demand shock on CO2 emissions price

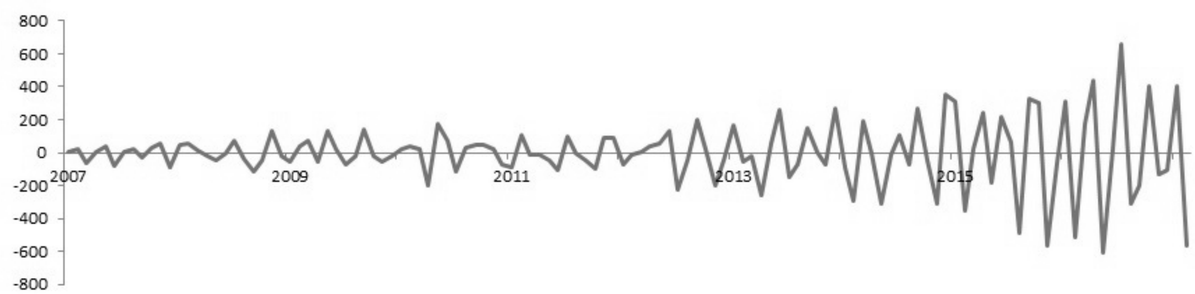


(d) CO2 emissions shock on cumulative stock return

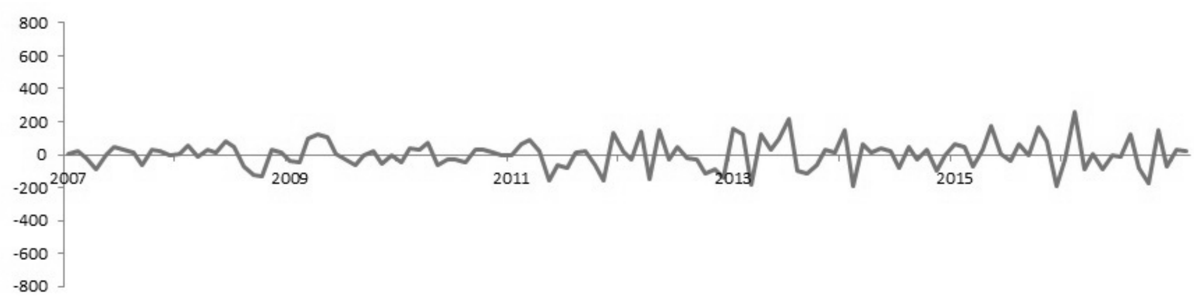
Figure 3: Oil shocks on CO2 emissions price; and CO2 emissions price on cumulative stock return. Y-axis in percentage, X-axis in months.



(a) Cumulative Effect of Oil supply Shock on CO2 emissions



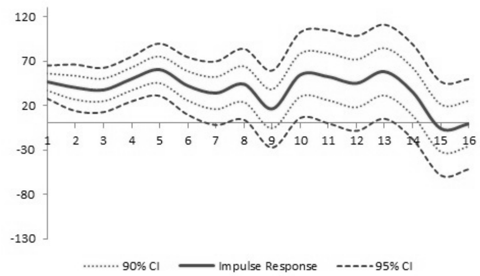
(b) Cumulative Effect of Aggregate Demand Shock on CO2 emissions



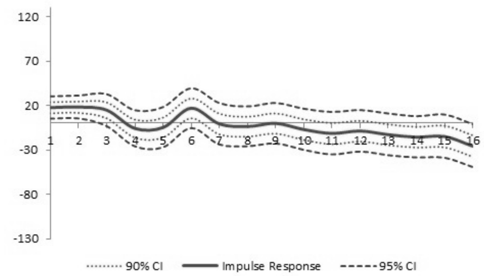
(c) Cumulative Effect of Oil-Market Specific Demand Shock on CO2 emissions

(d) Cumulative Effect of CO2 Shock on CO2 emissions

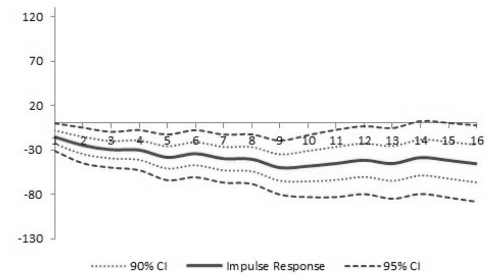
Figure 4: Historical decompositions: 2005:4 to 2016:12.



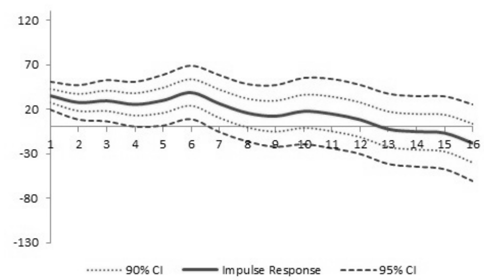
(a) Automobiles Sector Stock Returns response to a shock on CO2 emissions



(b) Energy Sector Stock Returns response to a shock on CO2 emissions



(c) Industrials Sector Stock Returns response to a shock on CO2 emissions



(d) Materials Sector Stock Returns response to a shock on CO2 emissions

Figure 5: CO2 emissions price shock on cumulative industry stock returns. Y-axis in percentage, X-axis in months.