Stockholm School of Economics

Master Thesis in Finance

# Effects of Carbon Pricing on EU Equity Markets

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The current work examines whether the price changes of European Union Allowance (EUA) contracts for emitting carbon dioxide affect the price dynamics of the European equity markets. The author uses the Vector Autoregressive (VAR) and Vector Error Correction (VECM) models in four specifications to investigate the linkages between the EUA market and major stock indexes of 27 EU countries which are participating in the second phase of the European Emissions Trading System. The regression models, together with Granger causality testing, suggest that stock markets of several developed European countries exhibit significant negative responses to EUA price shocks. In particular, CAC 40 (France), DAX 30 (Germany), AEX (the Netherlands), and FTSE MIB (Italy) indexes have been found to react to the EUA market movements. This may serve as a hint for the growing importance of the price of carbon as an additional risk factor for businesses given that emission quotas are being consistently tightened every year.

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# Table of Contents

# List of Tables



# List of Figures

# 1. Introduction

Trading in greenhouse gas emission allowances is a relatively recent activity, which was initiated in the early 1990s as a response to the growing pressure to cut environmental pollution. One of the first successful emissions trading programs was the Acid Rain Trading initiated in 1995 by the US Environmental Protection Agency in order to reduce the amounts of $SO_2$ (sulfur dioxide) produced by the industrial companies in the United States and as a result reduce the incidences of acid rains (EPA, 2011). The program has been successful in addressing the set goal of decreasing the overall $SO_2$ emissions by 40% from the 1990 level by 2010, having stayed below the benchmark already since 2007.

Despite the fact that the US pioneered the emissions trading field, the European Union Emission Trading System (EU ETS)[1] is currently the largest and the most advanced carbon trading scheme in the world. It is designed as a cap-and-trade framework implemented in distinct phases, the first having covered the period of 2005-2007, the second spanning between 2008 and 2012, and the third scheduled to start in 2013 (a graphical representation of the EU ETS framework is provided in Appendix 2). At the beginning of each phase the EU member states agree on national emission caps. The latter are set so as to gradually reduce the total EU emissions as the system progresses. Within the national caps, the largest emitters of greenhouse gases in each country are then allocated a certain number of allowances (European Union Allowances, EUA) which is derived from their historical emission levels. At the end of each year each emitter is required to submit to the authorities the amount of EUA corresponding to its actual verified emissions during the period (which may or may not be equal to the allocated number of allowances); otherwise, large fines are imposed. The polluting entities are then allowed to exchange the EUAs privately, over-the-counter, or/and on regulated platforms (see the Data section for the list of EUA trading platforms). During the recent crisis, these carbon trading markets showed substantial resilience, with the total transaction value increasing by 18% in 2009[2], against the global equity transaction value declining by 29%[3].

[1] European Commission, 2011
[2] World Bank, 2010
[3] World Federation of Exchanges, 2011

The ultimate goal of the EU ETS cap-and-trade system is to ensure that $CO_2$ emissions are reduced in the most cost-effective way, i.e. are cut by the entities which can do it at the lowest cost. For this to be achieved, the price of the EUA contract should at all times accurately reflect the marginal cost of not emitting an additional unit of $CO_2$ (be it through lower output or investments into more efficient means of production). Since non-compliance with the EU ETS is extremely costly[4] and can be excluded from consideration in most cases, all polluters face a possibility of falling short of the needed EUAs and therefore a potential necessity to buy them on the market. This makes the polluting entities susceptible to movements in prices of emission allowances, i.e. introduces a new risk factor into their risk profiles. Emissions above the set cap may also be considered as an additional cost to the polluting corporations, which, similar to the cost of raw materials or labour, reduces the bottom line. The effects of this "carbon pricing risk factor" may vary in strength depending on the exposure of the entity, which is primarily determined by the production technologies and concentration of the business activities in carbon-intensive industries, such as coal-based power generation, refining, production of steel, aluminum, glass, paper, cement, etc. However, despite being an additional source of risk, market-based carbon pricing is ultimately the driving force of emission reduction that maintains "discipline" among the polluters and motivates a more lean approach to "dirty" operational processes (given, of course, that the pricing of emissions is sufficiently efficient).

The current study aims at investigating the effects of carbon pricing on polluting entities and the economy as a whole by searching for equity market reactions to price shocks from the European carbon trading scheme. The research question addressed by the paper is as follows: *Are price movements of European stock markets affected by the price changes on the EUA market?*

The following hypotheses have been constructed with respect to the above research question:

**Hypothesis 1:** Equity index returns in EU countries are systematically affected by the price shocks from the EUA market; stock indexes outside Europe do not exhibit any significant correlation to EU ETS carbon pricing.

[4] European Commission, 2011

**Hypothesis 2:** Such price effects are predominantly negative, as the price for emitting $CO_2$ translates into a cost and an additional source of risk for the companies, which is priced by the market.

The presence of spillovers from the carbon market into emitter share prices may serve as an indication that the pricing of emissions is becoming an integral part of the concerned industries and that the carbon market is mature enough to be taken seriously by the investors. The absence of significant effects from the EUA price movements, on the other hand, may suggest that the fears of competitiveness deterioration of the EU companies from the mandatory carbon pricing are yet to become relevant.

The rest of the paper is structured as follows: section 2 provides an overview of the existing academic literature on the topics of emissions trading and price shocks to equity markets from commodity markets; section 3 deals with data selection and preliminary data analysis; section 4 details the methodology used in the current study; section 5 describes the empirical results; section 6 follows with the discussion and analysis of the obtained results; and section 7 concludes.

# 2. Literature Review

## 2.1. Carbon Trading

Since carbon markets are still relatively young, the body of academic research examining various aspects of emissions trading is quite limited. Moreover, most of the existing studies address only the first phase of the EU ETS.

In one of the earliest works on the European carbon markets, Milunovich & Joyeux (2007) analyze the long-run relationship between the futures and spot EUA prices to find that none of the strips is priced according to the cost-of-carry model, yet they can still be used for hedging due to the stable connection between the EUA spot prices and the interest rates. The study also addresses the issue of price discovery by conducting Granger causality and volatility spillover tests, discovering that information spillovers occur both ways between the spot and futures markets and are mostly determined by returns direction rather than the magnitude of price changes. Daskalakis & Markellos (2008) look for serial correlations in the prices of EUA spot and futures contracts. They employ widely used technical analysis strategies to see if excess profits can be systematically made on the emissions market, implying its inefficiency. The authors discover that the Phase I market cannot be said to adhere to the weak-form market efficiency. Boutaba (2008), on the other hand, analyzes the degree of cointegration between the different European emissions trading platforms, finding that the markets showed sufficient degree of efficiency in this sense during the Phase I period. Miclăuş et al (2008) assess the efficiency of price reaction of EU carbon markets to significant news announcements using an event study methodology based on press releases related to the National Allocation Plans and the verification of emissions. The study produces mixed results, indicating, however, that EUA market participants displayed sufficient ability to form correct market expectations.

One of the few existing academic works studying the impacts of the EUA market on other financial markets is Bunn & Fezzi (2007), which looks into the interconnections between the UK markets for EUAs, gas, and electricity. They use a structural co-integrated vector autoregression (SVAR) model on daily data to demonstrate that the carbon market is affecting the formation of electricity and gas prices in the UK, and is in turn itself affected by the gas price dynamics. The authors also calculate the pass-through of EUA price shocks into UK electricity prices, which appears to be statistically significant (0.42% response of electricity price on a 1% shock in carbon price). Outside the EU, Simshausen & Doan (2009) examine the implications on electricity prices of an all-auction model for allocating emission rights as opposed to partially free allocation, based on the data from the Australian market. They conclude that full auctioning is expected to lead to a sharp rise in emissions prices, which in turn tends to pass through into the electricity market in the form of severe price shocks.

### 2.2. Impacts of Commodity Markets on Equity Markets

To the best of the author's knowledge, at the moment of the completion of this thesis there exist no prior academic works studying the reactions of EU equity markets on the changes in EUA prices. Despite a relatively low volume of academic research on the interconnection between the carbon market and equity markets, a different commodity has been studied much more extensively in this respect: numerous works have attempted to document and examine the influence of changes in the price of oil on the equity markets. Most of them tend to treat oil as a cost item (or revenue item, for extracting businesses) – in other words, a source of cash flow risk for companies, which in theory should lead to sensitivity of the stock markets to oil price shocks. There is no clear consensus over the existence of such relationship, yet most studies do find evidence of statistically significant responses by equity markets around the world.

One of the most cited works on this topic is Jones & Kaul (1996), which examines stock price reaction to the changes in oil prices by using a standard cash flow/dividend valuation model. The authors discover that the US and Canadian equity markets exhibit significant reaction to oil price shocks caused mainly by the changes in expected cash flows, while the UK and Japanese markets react more than would have been implied by the real cash flows or expected returns. Al-Rjoub (2005) analyzes the reaction of the US stock markets on oil price shocks using vector autoregression (VAR), Mixed Dynamic (regressing stock returns on its lags and oil prices), and Granger Causality methodologies. All three approaches indicate that oil price shocks cause immediate and negative reactions from the equity market, and that oil price movements granger cause stock market index dynamics. Park & Ratti (2007) discover linkages between oil price shocks and the equity markets of the United States and 13 European countries using an unrestricted VAR model. They find that the equity markets in the US, Austria, Belgium, Denmark, France, Germany, Greece, Italy, the Netherlands, Spain, and Sweden exhibit significant negative reactions to oil price shocks. The US market is found to display asymmetric reactions to oil price shocks, which is not characteristic of any of the European markets. Donoso (2009) also studies the sensitivities of the stock markets in the US, the UK, and Japan to oil price shocks with an unrestricted VAR model. He concludes that all three markets exhibit significant responses to oil price movements, with Japan being the least sensitive. Notably, the US and UK markets are also more influenced by negative oil price changes than by price increases. Park & Kilian (2007) go beyond the commonly used reduced-form VAR approach by treating oil prices as endogenous. They study the differences in the degree of influence of oil price changes on the US stock market depending on whether the former are caused by demand shocks or supply shocks to find that only the price changes caused by oil demand shocks have statistically significant influence on equity prices. In other words, only increases in the global demand for commodities or the forward-looking demand for oil are shown to move stock prices, as opposed to unanticipated changes in global oil supply. Arouri & Fouquau (2011) examine the long-run relationships between oil prices and equity market returns in the GCC countries using both linear and asymmetric cointegration approaches, finding that these markets are affected by oil price shocks in an asymmetric fashion.

Academic studies have also been conducted to examine stock market reactions to a broader range of commodities, including metals and agricultural goods. In particular, Johnson and Soenen (2009) study the effects of commodity prices on South American stock markets, including Argentina, Brazil, Chile, Colombia, Peru, and Venezuela. They use the VAR model and Geweke (1982) feedback ratios to discover that the Argentinean, Brazilian, and Peruvian equity markets show significant reactions to commodity price shocks on the same day as the original commodity price movement. The stock market of Chile has been found to react only to energy and metal prices, while Colombia’s market shows reactions to industrial metals and agricultural commodities. In a more market microstructure-focused work, Heaton et al (2011) examine the process of incorporation of overnight commodity and stock market information in four the Australian Securities Exchange indexes. Using a system of seemingly unrelated regressions (SUR) they discover that overnight price innovations from the energy, agricultural, and metals markets are causing significant adjustments in equity indexes during the first 15 minutes of the trading session. S&P500 price information, however, has been found to have a much more pronounced effect.

Overall, the recent academic literature on the EU ETS suggests that the complexity and efficiency of the European carbon market has been increasing and that it has already started to affect to some degree the price formation on the electricity and gas markets. In the body of literature which searches for equity market reactions on commodity prices, multiple studies have discovered statistically significant linkages between oil price dynamics and stock market returns.

# 3. Data Description

## 3.1. Data Sources

The sample dataset for the current study contains daily data on the EUA spot prices, major stock market indexes, and short-term interest rates in 27 EU countries, as well as the price of oil over the period covered by the second phase of the EU Emissions Trading Scheme (26/02/2008-06/04/2011). The following notations will be used throughout the paper for simplicity:

*ln_eua* – natural logarithm of daily spot EUA price levels

*ln_oil* – natural logarithm of daily oil price levels

*ln_int* – natural logarithm of daily 3-month interbank interest rates in 27 EU countries (for details see table 1).

*index* – daily returns on main indexes of the largest stock exchanges of 27 EU countries (for details see table 1).

*snp* – daily returns on the S&P500 index

*nikkei* – daily returns on the Nikkei225 index

EUA contracts and therefore their derivatives are designed to be *fungible* i.e. every two units of EUA are mutually substitutable (European Commission, 2011). This implies that EUA can be viewed as a commodity and its properties should not depend on the market where it is traded. This premise has been tested and supported empirically by Milunovich & Joyeux (2007) as well as Boutaba (2008). The EU ETS carbon trading is dominated by the Netherlands-based ICE ECX exchange (www.theice.com), which is also currently the largest marketplace for emissions derivatives in the world; it accounts for over 90% of the aggregate trading volumes for EUA and CER futures[5]. Other regulated markets where the emission contracts are traded include:

- Bluenext, formerly Powernext (www.bluenext.eu; >50% of EUA spot and approx. 4.5% of EUA futures transaction volumes)
- EEX - European Energy Exchange (www.eex.com; approx. 2.5% of EUA futures transaction volumes)
- Nordpool (www.nordpool.com; <1%)

[5] ICE ECX, 2011

- Green Exchange (www.thegreenex.com; <1%)
- Climex (www.climex.com; <1%)
- Energy Exchange Austria (en.exaa.at; <1%)
- SendeCO2 (www.sendeco2.com; <1%)

Among the above, EUA spot contracts are primarily traded on the Bluenext platform, while EUA derivatives (futures and options) are most actively traded on the ICE ECX, EEX, and Nordpool. The other platforms so far have only featured spot transactions at negligibly low volumes (with the exception of Bluenext, which also lists EUA futures, yet volumes have been relatively low during its entire operating period).

The current study will use Bluenext as the primary source of data on emission allowance pricing. Despite a spread between the EUA futures and spot prices, their correlation is virtually 1, which implies that both are appropriate as a carbon pricing proxy. The spot prices are more convenient to handle since they form a continuum for the entire historical period, as compared to the futures which are split into strips which expire by years. Daily closing prices for the entire historical period of the Phase II trading are therefore retrieved from the Bluenext website.

Daily national index returns for the regarded period are obtained from the primary stock exchanges of the respective countries (see Appendix 1 for the full list of indexes and sources). Short-term interest rates are retrieved from the websites of the local central banks; in case a country has entered into the Eurozone during the considered period, the time series containing national interest rates are continued with the EURIBOR time series starting from the date of the official curculation of the Euro. This includes Slovakia, for which the BRIBOR is replaced by the EURIBOR from the 1st of January 2009 onwards, and Estonia, for which the TALIBOR is replaced by the EURIBOR from the 1st January of 2011 onwards. For the sake of consistency, all interest rates used in the paper are 3-month reference interbank borrowing rates. Table 1 provides an overview of all EU stock market indexes and interest rates used in the study:

**Table 1. Country Indexes and Rates**
The list of EU country stock market indexes and respective interest rates used in the analysis

| Country | Index | Interest rate |
|---|---|---|
| Austria | ATX | EURIBOR |
| Belgium | BEL 20 | EURIBOR |
| Bulgaria | SOFIX | SOFIBOR |
| Cyprus | FTSE/CySE 20 | EURIBOR |
| Czech Republic | PX50 | PRIBOR |
| Denmark | OMX Copenhagen 20 | CIBOR |
| Estonia | OMX Tallinn | TALIBOR |
| Finland | OMX Helsinki 25 | EURIBOR |
| France | CAC 40 | EURIBOR |
| Germany | DAX 30 | EURIBOR |
| Greece | FTSE/ATHEX 20 | EURIBOR |
| Hungary | BUX | BUBOR |
| Ireland | ISEQ | EURIBOR |
| Italy | FTSE MIB | EURIBOR |
| Latvia | OMX Riga | RIGIBOR |
| Lithuania | OMX Vilnius | VILIBOR |
| Luxembourg | LuxX | EURIBOR |
| Malta | MSE | EURIBOR |
| Netherlands | AEX | EURIBOR |
| Poland | WIG20 | WIBOR |
| Portugal | PSI 20 | EURIBOR |
| Romania | BET 10 | ROBOR |
| Slovakia | SAX | BRIBOR |
| Slovenia | SBITOP | EURIBOR |
| Spain | IBEX 35 | EURIBOR |
| Sweden | OMX Stockholm 30 | STIBOR |
| United Kingdom | FTSE 100 | LIBOR |

The current study uses Europe Brent Spot FOB as the oil price reference. Daily historical data for the sample is obtained from the website of the US Energy Information Administration (see Appendix 1 for the full list of data sources). Following the studies of the linkages between the commodity markets and equity indexes (e.g. Johnson and Soenen, 2009; Park & Ratti, 2007), the level data on prices of oil, EUA, and the interest rates are taken in the form of natural logarithms.

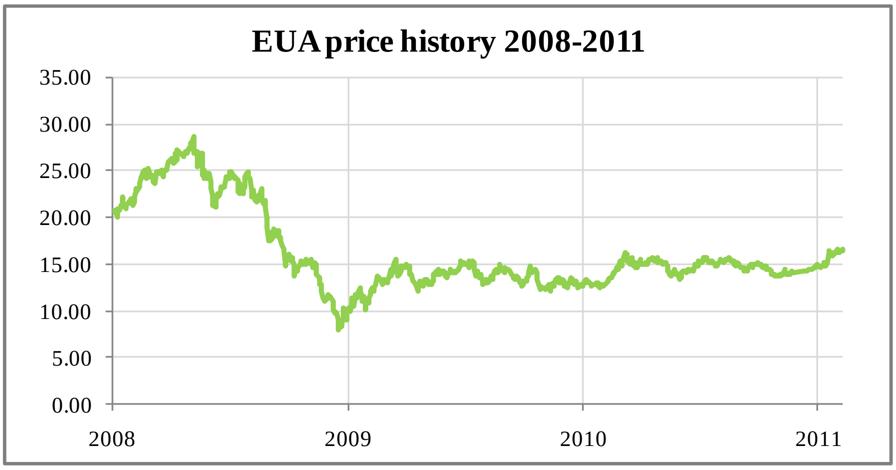
Since the EUA prices as well as the major European markets are quoted in euro, while oil is quoted in US dollars and the stock indexes as well as interest rates of the countries outside the Eurozone are denominated in currencies other than euro, all respective data is converted into euro for the purposes of the current study (for countries with floating exchange rates to the euro). The exchange rates for euro against US dollar, British pound, Czech koruna, Hungarian forint, Polish zloty, Romanian lei, Swedish krona, as well as Japanese yen, are retrieved from the European Central Bank (2011).

### 3.2. Time Series Overview

The historical price data for the period considered in the current paper contains both upward and downward trends, and is distinguished foremost by severe declines in all asset classes between July 2008 and the beginning of 2009. This bear market, triggered by the global financial crisis of 2008, was also accompanied by elevated volatility, as clearly visible from Figure 2. Like most other asset classes, the price of the EUA contract (Figure 1) posted serious declines in the second half of 2008, yet has been showing relatively modest signs of recovery in January 2009 - April 2011, as compared to e.g. the price of oil (Figure 3). In the latter period the EUA price fluctuated sideways in a corridor between 12 EUR and 16 EUR.

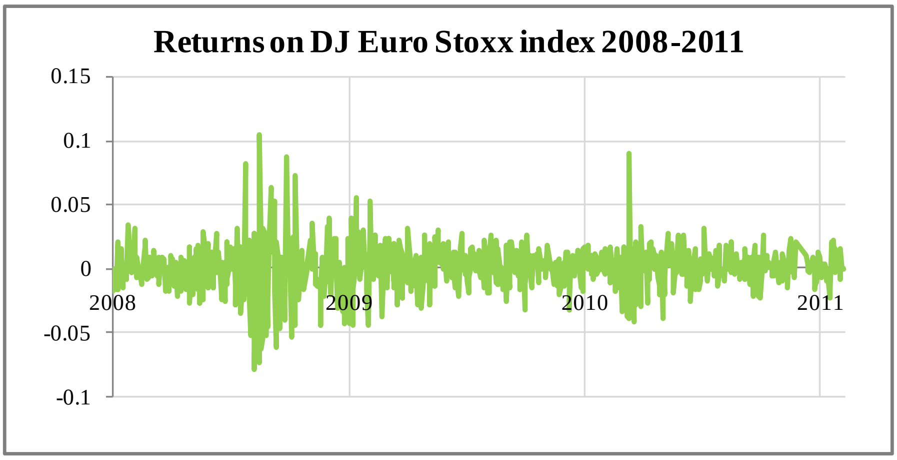
During the period under consideration the price of European $CO_2$ emission contract was relatively more volatile than the broad EU equity market as represented by the DJ Euro STOXX index (standard deviation of returns 0.024 versus 0.018 respectively), yet less volatile than that of crude oil (standard deviation 0.028). Between February 2008 and April 2011, the EUA had a total of 36 days with daily price movements of over 5% (both negative and positive), while the equity index had 18 and oil had 52 days. Notably, of the above 36 days with returns of over 5% only 12 were positive in case of the EUA market, and 31 were positive for the oil market.

Figure 1. Historical prices for EUA spot contracts (in euros), 26/02/2008-06/04/2011



As a proxy for the European stock market, we consider here the Dow Jones Euro STOXX index, which includes over 300 largest listed companies from 12 EU countries. Historical return data (Figure 2) indicates extremely uneven distribution of volatility over the regarded period. By April 2011 DJ Euro STOXX has managed to regain approximately half of the value lost during the financial meltdown, yet the post-crisis performance of individual European equity markets has been diverse. For example, Germany's DAX 30 index has reached its mid-2008 peak levels by April 2011, while Greece's ATHEX index has declined further below its end-2008 trough during the first quarter of 2011.

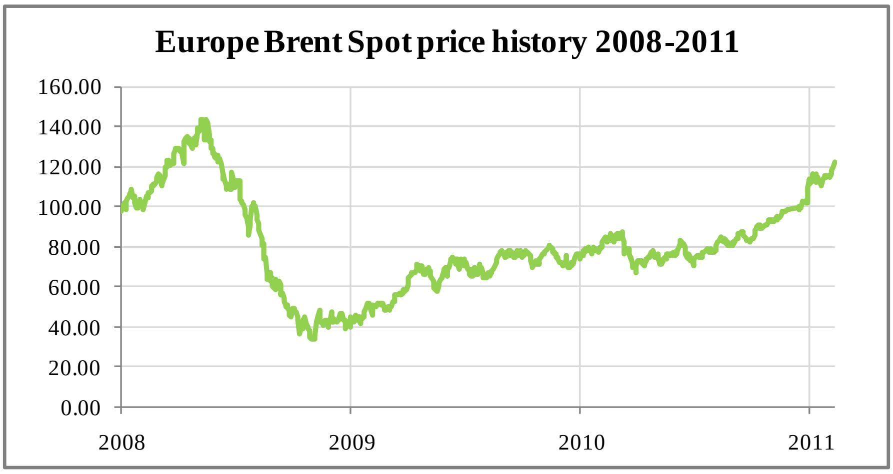
Figure 2. Historical returns on the DJ Euro Stoxx index[6], 26/02/2008-06/04/2011




Oil, as represented by the Europe Brent Spot FOB, has continued gaining in price after a plateau between the middle of 2009 and the first quarter of 2010. By April 2011 it has recovered over 80% of the decline experienced during the acute phase of the recent financial crisis. Notably, both the decline of the second half of 2008 and the subsequent recovery have been much more dramatic for oil as compared to the EUA price.

[6] STOXX Limited, 2011

Figure 3. Historical prices for Europe Brent Spot FOB (in USD), 26/02/2008-06/04/2011




### 3.3. Unit-root Testing

All time series in the current study are tested for the presence of unit root by the Augmented Dickey-Fuller as well as Phillips-Perron unit root tests prior to being used in the analysis. The results of the testing are presented below:

**Table 2. Unit root testing of variables using Augmented Dickey-Fuller and Phillips-Perron tests.** The null hypothesis for both the Augmented Dickey-Fuller test and the Phillips-Perron test is the presence of a unit root in the time series; the alternative hypothesis for both tests is the time series being generated by a stationary process.

| Variable | Dickey-Fuller Z(t) statistic | Dickey-Fuller p-value | Phillips-Perron Z(rho) statistic | Phillips-Perron p-value |
|---|---|---|---|---|
| lneua | -1.368 | 0.5974 | -3.31 | 0.5839 |
| d.lneua | -19.506 | 0.0000 | -385.14 | 0.0000 |
| lnoil | -1.56 | 0.5035 | -2.42 | 0.5039 |
| d.lnoil | -22.058 | 0.0000 | -477.16 | 0.0000 |
| snp | -32.247 | 0.0000 | -747.28 | 0.0000 |
| nikkei | -24.94 | 0.0000 | -610.97 | 0.0000 |
| Short-term interest rates | | | | |
| EURIBOR | -2.996 | 0.0353 | -0.81 | 0.2261 |
| SOFIBOR | 0.515 | 0.9853 | 0.28 | 0.9855 |
| PRIBOR | -0.729 | 0.8392 | -0.38 | 0.8430 |
| CIBOR | -0.93 | 0.7780 | -0.43 | 0.7940 |
| TALIBOR | -1.088 | 0.7200 | -4.49 | 0.7132 |
| BUBOR | -0.841 | 0.8068 | -0.67 | 0.8073 |
| RIGIBOR | 1.785 | 0.9983 | 0.88 | 0.9958 |
| VILIBOR | 1.467 | 0.9974 | 0.82 | 0.9956 |
| WIBOR | -0.478 | 0.8962 | -0.41 | 0.8872 |
| ROBOR | -1.831 | 0.3654 | -8.49 | 0.1936 |
| BRIBOR | -1.525 | 0.5211 | -1.51 | 0.4756 |
| STIBOR | -1.406 | 0.5793 | -1.12 | 0.6198 |
| LIBOR | -2.124 | 0.2350 | -1.06 | 0.2685 |

| | | | | |
|---|---|---|---|---|
| European equity indexes | | | | |
| ATX | -23.00 | 0.0000 | -516.56 | 0.0000 |
| BEL 20 | -24.90 | 0.0000 | -614.79 | 0.0000 |
| SOFIX | -23.71 | 0.0000 | -596.30 | 0.0000 |
| FTSE/CySE 20 | -26.24 | 0.0000 | -594.34 | 0.0000 |
| PX50 | -19.98 | 0.0000 | -484.81 | 0.0000 |
| OMX Copenhagen 20 | -24.02 | 0.0000 | -551.89 | 0.0000 |
| OMX Tallinn | -22.38 | 0.0000 | -545.25 | 0.0000 |
| OMX Helsinki 25 | -25.40 | 0.0000 | -576.40 | 0.0000 |
| CAC 40 | -26.70 | 0.0000 | -611.51 | 0.0000 |
| DAX 30 | -26.47 | 0.0000 | -603.56 | 0.0000 |
| FTSE/ATHEX 20 | -23.33 | 0.0000 | -566.66 | 0.0000 |
| BUX | -23.81 | 0.0000 | -558.41 | 0.0000 |
| ISEQ | -24.15 | 0.0000 | -601.65 | 0.0000 |
| FTSE MIB | -25.27 | 0.0000 | -582.57 | 0.0000 |
| OMX Riga | -27.47 | 0.0000 | -645.15 | 0.0000 |
| OMX Vilnius | -23.67 | 0.0000 | -499.17 | 0.0000 |
| LuxX | -25.68 | 0.0000 | -609.17 | 0.0000 |
| MSE | -20.49 | 0.0000 | -462.35 | 0.0000 |
| AEX | -27.19 | 0.0000 | -613.73 | 0.0000 |
| WIG20 | -24.26 | 0.0000 | -543.57 | 0.0000 |
| PSI 20 | -24.13 | 0.0000 | -538.98 | 0.0000 |
| BET 10 | -23.49 | 0.0000 | -555.95 | 0.0000 |
| SAX | -26.38 | 0.0000 | -633.98 | 0.0000 |
| SBITOP | -20.54 | 0.0000 | -458.43 | 0.0000 |
| IBEX 35 | -24.77 | 0.0000 | -607.45 | 0.0000 |
| OMX Stockholm 30 | -24.76 | 0.0000 | -565.39 | 0.0000 |
| FTSE 100 | -26.53 | 0.0000 | -612.74 | 0.0000 |

The tests indicate that index returns are stationary, while the price level variables including *lneua*, *lnoil*, and the interest rates contain a unit root (integrated of order 1) and therefore must be differenced for the purposes of the current research.

### 3.4. Cointegration testing

Since the unit root tests reveal that the EUA and oil prices are integrated of order one, a need arises to check whether these time series contain a common stochastic trend. This is done by performing the Johansen cointegration test.

**Table 3. Johansen cointegration test.**
The null hypothesis states that the amount of cointegrating vectors is equal to r; the alternative hypothesis is that the number of cointegrating vectors is greater than r. The null is rejected if the trace test statistic is larger than the critical value at given confidence level of 5% (marked with an asterisk - *).

| The trace test statistics for r equal to the number of cointegrating vectors | | | |
|---|---|---|---|
| Hypothesis | exactly 0 | at most 1 | at most 2 |
| (ln_eua, ln_oil) | 10.578 * | 1.624 | |
| 5% critical value | 15.410 | 3.760 | |
| (ln_eua, ln_oil, EURIBOR) | 161.816 | 17.873 | 4.835 |
| (ln_eua, ln_oil, SOFIBOR) | 40.603 | 22.480 | 5.175 |
| (ln_eua, ln_oil, PRIBOR) | 44.747 | 23.792 | 4.638 |
| (ln_eua, ln_oil, CIBOR) | 73.269 | 21.652 | 5.263 |
| (ln_eua, ln_oil, TALIBOR) | 14.698 * | 3.465 | 0.671 |
| (ln_eua, ln_oil, BUBOR) | 22.703 * | 4.220 | 1.002 |
| (ln_eua, ln_oil, RIGIBOR) | 27.045 * | 5.893 | 0.041 |
| (ln_eua, ln_oil, VILIBOR) | 40.389 | 6.451 * | 0.926 |
| (ln_eua, ln_oil, WIBOR) | 46.638 | 19.762 | 7.714 |
| (ln_eua, ln_oil, ROBOR) | 46.102 | 12.012 * | 2.189 |
| (ln_eua, ln_oil, BRIBOR) | 41.812 | 17.400 | 4.374 |
| (ln_eua, ln_oil, STIBOR) | 58.067 | 10.920 * | 2.467 |
| (ln_eua, ln_oil, LIBOR) | 71.672 | 18.090 | 4.595 |
| 5% critical value | 29.680 | 15.410 | 3.760 |

The tests indicate that most of the national interest rates, excluding TALIBOR, BUBOR, and RIGIBOR, are displaying the signs of cointegration; VILIBOR, ROBOR, and STIBOR are cointegrated of order 1, while the rest of the variable combinations listed in Table 3 contain more than two cointegrating vectors. This implies that the appropriate setup for such time series would be a vector error correction model (VECM) rather than vector autoregression (VAR) framework, otherwise the regressions are likely to produce spurious results. The above three rates, as well as EUA prices (with respect to oil prices) do not show signs of the existence of common stochastic trends, which means they can be used simultaneously as inputs in a VAR model.

# 4. Empirical Methodology

## 4.1. VAR Model

The current work seeks to investigate the possible linkages between the price of carbon and the European equity markets by analyzing the most important equity indexes of the 27 EU member countries. The proposed methodology for estimating the possible relationship between EUA prices and equity markets is based primarily on the vector autoregression (VAR) model first proposed by Sims (1980). It has been used extensively in academic literature for discovering linkages between financial markets. For example, Donoso (2009), Johnson & Soenen (2009), Park & Ratti (2007), Park & Kilian (2007), Al-Rjoub (2005) use the VAR to examine the effects of commodity price shocks on equity markets; Singh et al (2010), Hsiao et al (2006), and Berument et al (2006) employ the VAR to find interdependencies between two or more equity markets. The author of the current study has also considered several other possible ways of addressing the posed research question, including:

1. Panel data regressions on individual companies including both polluting and non-polluting entities
2. Event study with respect to the announcements of national quotas or annual publications of verified emissions (a similar approach has been used by Miclăuş et al, 2008, to test if the EUA market reacts efficiently to the related news announcements)

However, given no prior related academic studies on which to benchmark, and given the existing data restrictions, the author has decided to employ the VAR model analysis exploring potential linkages between the broad equity indexes and the EUA price dynamics. The primary motivation for this approach is the fact that it has been widely used for testing the impact of commodity prices on the stock markets, as mentioned in the beginning of the current section. Despite having certain particularities, emission contracts can be considered as a commodity (they are fungible and represent a source of cost or revenue for the affected companies); their impact on stock returns will therefore be studied using the methodology which is being used for other commodities such as e.g. oil.

The VAR model is often used as a particularly flexible way to assess economic relationships as opposed to structural models. The VAR tests the interdependence between several time series while treating each of them symmetrically: the evolution of each variable is explained by its own lags and the lags of all other variables in the model. All n variables are arranged into a single ($n \times 1$) vector $z_t$ with $i^{th}$ element being the value of $i^{th}$ variable at time t $z_{1,t}$.

In its unrestricted form, the VAR model is specified as follows:

$$Z_t = \alpha_0 + \sum_{i=1}^{k} A_i Z_{t-i} + \varepsilon_i \qquad (1)$$

where:

- $\alpha_0$ is the intercept term
- $A_i$ is an (n x n) matrix of unknown coefficients
- k is the number of lags
- $\varepsilon_i$ is an error term with zero mean and no serial correlation. In particular, $E(\varepsilon_t)=0$; $E(\varepsilon_t \varepsilon_t')=\Omega$, and $E(\varepsilon_t \varepsilon_{t-n}')=0$

Four specifications of the above model are formulated to investigate the linkages between the EUA prices and equity markets. The specifications are distinguished by the choice of variables included into the $z_t$ vector. The basic specification contains the stock index and the EUA price i.e. has z = [*d.ln_eua, index*], similarly to the model used for the case of oil by Al-Rjoub (2005). Note that in this case and further throughout the paper the time subscript is implied yet omitted for simplicity of notation. Each specification will be tested in three modifications to allow one-, two-, and three-period responses from the equity indexes by using 1, 2, and 3 lags. The theoretically optimal number of lags using the Schwarz and Bayesian Information Criterion (SBIC) are also reported in the results.

The second specification includes the log price of oil in addition to the EUA price as a control variable, following the findings of e.g. Al-Rjoub (2005), Park & Ratti (2007), and Donoso (2009). This is done to account for energy price spillovers to equity markets which may otherwise be wrongly attributed to the carbon pricing effects. The second specification uses the variable vector z = [*d.ln_eua, d.ln_oil, index*].

Many studies of the influence of oil prices on the stock markets use macroeconomic data, such as industrial production (e.g. Park & Ratti, 2007 and Donoso, 2009), as an important control variable in the VAR model to gauge the effects of the underlying economic activity, which is expected to be a driving factor for the stock markets. However, due to a relatively short time period under analysis (the second, longer stage of the EU ETS has been in existence for slightly more than 3 years) and the resulting use of daily data it does not seem practical to use macroeconomic variables as controls as they are published on a monthly or quarterly basis. In order to circumvent this and still introduce a meaningful control variable that would gauge the "core" part of the stock market returns in EU countries, the third specification therefore includes the US market index (S&P500) as a factor which exhibits significant influence on the returns of other developed and developing markets and at the same time is *not* directly affected by carbon pricing within the EU ETS. Multiple studies have shown a one-way relation to be present between the US stock markets and the European mature markets, as well as emerging markets in Europe, Asia, and Latin America. Notably, Arshanapalli & Doukas (1993) use error-correction testing to find evidence of significant impact of the US stock market on the UK, French, and German markets, with innovations response being consistent with the premise of internationally efficient stock markets. Moreover, King & Wadhwani (1990) as well as Hamao et al (1990) find evidence of returns and volatility spillovers from the US equity market to the UK and Japan markets. More recently, Berument et al (2006) use the VAR model to discover significant "centre-periphery" relations between the US equity markets and emerging markets including South America and Asia. Ozdemir et al (2009) also find that the returns of the above equity markets are Granger caused by the US market returns, but not vice-versa. Singh et al (2010) use a VAR approach to model return and volatility spillovers between the major mature and emerging equity markets around the world. They conclude that the US market has significant influence on the returns and volatility of the main European markets, including the UK, France, and Germany. Sosvilla-Rivero & Rodriguez (2010) also find significant causality relationship in the direction from the US equity market index to the UK market index. Syriopoulos (2007) goes further to discover that the emerging European markets (including Poland, Czech Republic, Hungary, and Slovakia) are also causally linked to the US market returns, both in the long run and on shorter horizons. Summing up, the US market can be expected to act as a significant factor for explaining returns of both mature and emerging European equity markets. This leads to the following expression for the variable vector of the third specification: z = [*d.ln_int*, *snp*, *d.ln_eua*, *index*]. Following Park & Ratti (2007), Donoso (2009), and Johnson & Soenen (2009), the third specification also includes the short-term interest rates (in logarithms of levels) of the respective economy as a controlling variable which has been found to exhibit significant influence on stock markets.

Finally, the fourth specification of the model includes oil prices as an additional control together with the S&P500 and short-term interest rates. The rationale behind such arrangement is to capture in one model the effects on European stock prices found to be significant on short horizons by the existing studies. The variable vector of the last specification therefore looks as follows: z = [*d.ln_int*, *snp*, *d.ln_oil*, *d.ln_eua*, *index*].

It must be noted, however, that the third and the fourth specifications are constructed primarily for the purpose of increasing the robustness of the study, rather than an end in itself, since none of the previous academic works are using both equity market index and commodity price dynamics as explanatory variables for another equity index. The first [*d.ln_eua, index*] and the second [*d.ln_eua, d.ln_oil, index*] specifications outlined above are therefore treated as the main model of reference.

For every European stock market index, a separate series of VAR estimations with 1, 2 and 3 lags will be run to determine the presence or absence of significant relationship between the EUA price shocks and the share prices. Since all variables in a VAR model need to have the same order of integration, Phillips-Perron and Augmented Dickey-Fuller unit-root tests have been conducted prior to model estimation. Following the results of the tests all price level variables (*ln_eua*, *ln_oil*, and the short-term interest rates) are differenced for the purposes of the analysis. For the first and the second specifications, the analogous regressions will be run using *snp* and *nikkei* as the dependent variables to determine if the major non-European indexes display significant reaction to the EUA prices in these models. In theory, the non-European equity indexes should not be expected to show significant responses to the EUA prices because the EU ETS only concerns the companies domiciled within the EU. In case they do, a conclusion may be made that the specifications are not as robust as desired and that the results from the EU stock indexes should also be interpreted with caution.

**4.2. VECM model**

The vector error correction model, or VECM, can be viewed as a specific case of the VAR model in which the variable vectors are cointegrated. In particular, a VAR model (1) is said to be stable if for every complex z the following condition is satisfied:

$$|I - A_1 z - \cdots - A_p z^p| \neq 0 \quad (2)$$

If the VAR is non-stable, it can still be used to produce meaningful results after certain modifications through differencing, arriving at the VECM:

$$\Delta y_t = \gamma_0 + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Phi_{\mathrm{i}} \, \Delta y_{t-i} + \epsilon_t \quad (3)$$

where:

- $y_t$ is an (n x 1) vector which is different from the $z_t$ used in (1) only by its non-stability, i.e. the variables in the vector display cointegration.
- $\Pi$ and $\Phi_i$ are (n x n) coefficient matrices
- $\gamma_0$ is the intercept term
- $\varepsilon_i$ is an error term with zero mean and no serial correlation. In particular, $E(\varepsilon_t)=0$; $E(\varepsilon_t \varepsilon_t')=\Omega$, and $E(\varepsilon_t \varepsilon_{t-n}')=0$

The equation (3) contains $\Pi y_{t-1}$, which is called the error correction term. It is based on the cointegrating vector of the underlying variables β' and an adjustment coefficient δ:

$$\Pi y_{t-1} = \beta' \delta y_{t-1} \quad (4)$$

This term acts as the "stabilizer" for the regression, allowing using cointegrated time series in a single VECM specification.

It is also worth noting that the VECM can be presented in the VAR-equivalent form as a special case of the VAR:

$$y_t = \gamma_0 + (I_k + \Pi + \Phi_1) y_{t-1} + \sum_{i=2}^{p-1} (\Phi_{\mathrm{i}} - \Phi_{\mathrm{i-1}}) \, y_{t-i} - \Phi_{\mathrm{p-1}} y_{t-p} + \epsilon_t \quad (5)$$

The VECM has been used in academic literature for examining the linkages between individual stock markets (e.g. by Syriopoulos, 2007; Arshanapalli & Doukas, 1993), which is one of the motivating factors to use it in the current paper for modelling the more complex specifications which contain the US stock market index as well as the cointegrated time series including the interest rates.

# 5. Results

The current section presents the results from the VAR and VECM model regression analysis according to the specifications proposed in the description of the methodology. The results are grouped by model specifications.

### 5.1. Basic specification

The outcome of the estimation of the simplest model specification (see Table 4.1) suggests that there are certain significant linkages between the EUA market and several major EU equity indices, in particular France, Germany, Spain, Italy, and the Netherlands. The latter have the most stable result which is significant on a 5% level. The direction of the effect is negative in all statistically significant cases, which is in line with the economic interpretation of the connection (the EUA price being a cost for the companies which are subject to the EU ETS and a risk factor for the companies which are directly and/or indirectly connected with the former). Control indexes exhibit a somewhat unexpected reaction to the EUA price changes, S&P500 showing no significant influence, yet Nikkei225 having significant coefficient with 1 and 2 lags which has a positive sign. This fact raises doubts as to the validity of this particular result: the positive sign of the coefficient would imply that an increase in the price of EUAs leads to positive returns of the equity market. This is in discord with the theoretically expected link with an opposite sign. Impulse response functions for the Dutch market (as the most significant example of linkages) are found in Appendix 3.

**Table 4.1. Results of the first specification of VAR [*d.ln_eua, index*].**
The figures indicate the coefficients for the first lags of *d.ln_eua* (the second and third lags are insignificant in all regressions). Asterisks mark the level of significance: *-significant on 10% level, **-significant on 5% level, ***-significant on 1% level. The grey shading is applied to the variables which exhibit at least 10% significance of the first lag of *d.ln_eua* in all specifications (i.e. with 1, 2, and 3 lags). The theoretically efficient number of lags using the Schwarz and Bayesian Information Criterion (SBIC) and the Hannan and Quinn Information Criterion (HQIC) is indicated in the last column.

[*d.ln_eua, index*]

| Index | Lags (1) | | Lags (2) | | Lags (3) | | SBIC | HQIC |
|---|---|---|---|---|---|---|---|---|
| ATX | 0.020 | | -0.021 | | -0.062 | | 1 | 2 |
| BEL 20 | -0.033 | | -0.026 | | -0.066 | | 1 | 3 |
| SOFIX | 0.003 | | -0.014 | | -0.112 | * | 2 | 3 |
| FTSE/CySE 20 | -0.029 | | -0.044 | | -0.039 | | 1 | 1 |
| PX50 | 0.042 | | -0.003 | | -0.099 | | 1 | 3 |
| OMX Copenhagen 20 | -0.053 | | -0.078 | * | -0.142 | ** | 1 | 3 |
| OMX Tallinn | 0.009 | | -0.035 | | -0.049 | | 1 | 3 |
| OMX Helsinki 25 | -0.028 | | -0.029 | | -0.072 | | 1 | 2 |
| CAC 40 | -0.063 | * | -0.080 | * | -0.122 | * | 1 | 3 |
| DAX 30 | -0.050 | | -0.069 | * | -0.146 | ** | 1 | 2 |
| FTSE/ATHEX 20 | -0.048 | | -0.096 | | -0.109 | | 1 | 1 |
| BUX | -0.053 | | 0.015 | | -0.123 | | 1 | 3 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ISEQ | -0.019 | | -0.064 | | -0.113 | | 1 | 1 |
| FTSE MIB | -0.070 | * | -0.084 | * | -0.135 | * | 1 | 3 |
| OMX Riga | -0.019 | | -0.047 | | -0.050 | | 1 | 1 |
| OMX Vilnius | 0.008 | | -0.021 | | -0.051 | | 1 | 1 |
| LuxX | -0.009 | | -0.008 | | -0.094 | | 1 | 1 |
| MSE | -0.001 | | 0.020 | | 0.005 | | 1 | 1 |
| AEX | -0.071 | ** | -0.093 | ** | -0.160 | ** | 1 | 3 |
| WIG20 | 0.019 | | -0.047 | | -0.266 | *** | 1 | 2 |
| PSI 20 | -0.013 | | -0.037 | | -0.054 | | 1 | 3 |
| BET 10 | -0.003 | | -0.067 | | -0.102 | | 1 | 2 |
| SAX | 0.008 | | -0.006 | | 0.003 | | 1 | 1 |
| SBITOP | -0.026 | | -0.049 | | -0.090 | * | 1 | 4 |
| IBEX 35 | -0.057 | | -0.084 | * | -0.183 | *** | 1 | 2 |
| OMX Stockholm 30 | 0.001 | | -0.011 | | -0.089 | | 1 | 3 |
| FTSE 100 | -0.040 | | -0.052 | | -0.099 | | 1 | 3 |
| Control indexes | | | | | | | | |
| S&P 500 | -0.057 | | 0.053 | | -0.059 | | 2 | 2 |
| Nikkei 225 | 0.086 | *** | 0.080 | * | 0.006 | | 1 | 2 |

For every variable which is significant in at least two specifications, a Granger causality test has been conducted in order to determine if there exists a causal link between the EUA price and the respective stock market indexes. It indicates that the EUA price changes have significant linkage with the French, Italian, Dutch, and German stock market indexes:

**Table 4.2. Granger causality test for the specification of VAR [*d.ln_eua, index*].**
The null hypothesis is the *d.ln_eua* does not Granger-cause the respective index; the alternative hypothesis is that *d.ln_eua* has significant causal relation with the index. Asterisks mark the level of significance: *-significant on 10% level, **-significant on 5% level, ***-significant on 1% level. All significant variables are highlighted in grey.

| Index | Chi2 | Prob>Chi2 | |
|---|---|---|---|
| CAC 40 | 6.9876 | 0.072 | * |
| FTSE MIB | 6.7253 | 0.081 | * |
| AEX | 9.085 | 0.028 | ** |
| OMX Copenhagen | 4.2415 | 0.237 | |
| DAX 30 | 6.3438 | 0.042 | ** |
| IBEX 35 | 3.9471 | 0.139 | |

It must be noted that the Granger test does not indicate true causality - it only implies the existence of forecasting ability with respect to the tested variables. The results of the Granger tests are therefore interpreted as one variable (in this case EUA prices) being helpful in predicting another variable (in this case the indexes).

### 5.2. Introducing the oil component

The specification of the model with both EUA and oil prices shows less significant reactions to the carbon market among the EU stock indexes (see Table 5). In particular, only the Netherlands still displays sizeable response on all lag numbers. Other markets, including Germany, Spain, and Denmark, obtain significant coefficients in the 2-lag and 3-lag specifications. Less expectedly, Slovenia's SBITOP index also has significant coefficients on all specifications. All significant coefficients are still negative, which is in line with the expected direction of the price shocks. Control indexes are behaving quite differently from the first specification, which may suggest that the observed effects are somewhat spurious: only the *nikkei* regression with 1 lag is having a 10% significant coefficient on the first lag of *d.ln_eua*, and the sign of the coefficient is still positive (see discussion in section 5.1). The example impulse response function (IRF) graphs for this (and the previous) specification for the AEX index are provided in Appendix 4 (5). The IRF for the Dutch index illustrates graphically the significant negative response of the index returns to the upwards shocks in EUA prices. Analogous graphs for the DAX index are found in Appendix 6 (first specification) and Appendix 7 (second specification).

**Table 5.1. Results of the second specification of VAR [*d.ln_eua, d.ln_oil, index*].**
The figures indicate the coefficients for the first lags of *d.ln_eua* (the second and third lags are insignificant in all regressions). Asterisks mark the level of significance: *-significant on 10% level, **-significant on 5% level, ***-significant on 1% level. The grey shading is applied to the variables which exhibit at least 10% significance of the first lag of *d.ln_eua* in all specifications (i.e. with 1, 2, and 3 lags). The theoretically efficient number of lags using the Schwarz and Bayesian Information Criterion (SBIC) and the Hannan and Quinn Information Criterion (HQIC) is indicated in the last column.

[ *d.ln_eua, d.ln_oil, index*]

| Index | Lags (1) | | Lags (2) | | Lags (3) | | SBIC | HQIC |
|---|---|---|---|---|---|---|---|---|
| ATX | -0.001 | | -0.045 | | -0.074 | | 1 | 1 |
| BEL 20 | -0.042 | | -0.054 | | -0.068 | | 1 | 1 |
| SOFIX | -0.013 | | -0.057 | | -0.123 | * | 1 | 3 |
| FTSE/CySE 20 | -0.042 | | -0.070 | ** | -0.047 | | 1 | 1 |
| PX50 | 0.043 | | -0.013 | | -0.088 | | 1 | 3 |
| OMX Copenhagen 20 | -0.045 | | -0.076 | * | -0.129 | ** | 1 | 1 |
| OMX Tallinn | -0.002 | | -0.053 | | -0.064 | | 1 | 3 |
| OMX Helsinki 25 | -0.039 | | -0.060 | | -0.074 | | 1 | 1 |
| CAC 40 | -0.063 | * | -0.091 | * | -0.113 | | 1 | 1 |
| DAX 30 | -0.047 | | -0.075 | * | -0.130 | ** | 1 | 1 |
| FTSE/ATHEX 20 | -0.059 | | -0.114 | * | -0.136 | | 1 | 1 |
| BUX | -0.071 | | -0.021 | | -0.155 | * | 1 | 2 |
| ISEQ | -0.010 | | -0.056 | | -0.086 | | 1 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| FTSE MIB | -0.068 | * | -0.087 | * | -0.118 | | 1 | 1 |
| OMX Riga | -0.033 | | -0.062 | | -0.029 | | 1 | 1 |
| OMX Vilnius | -0.009 | | -0.044 | | -0.064 | | 1 | 1 |
| LuxX | -0.028 | | -0.046 | | -0.091 | | 1 | 1 |
| MSE | -0.005 | | 0.015 | | 0.001 | | 1 | 1 |
| AEX | -0.070 | * | -0.096 | ** | -0.143 | ** | 1 | 3 |
| WIG20 | 0.014 | | -0.060 | | -0.273 | *** | 1 | 1 |
| PSI 20 | -0.011 | | -0.036 | | -0.044 | | 1 | 1 |
| BET 10 | -0.010 | | -0.075 | | -0.072 | | 1 | 1 |
| SAX | 0.018 | | 0.020 | | -0.005 | | 1 | 1 |
| SBITOP | -0.051 | * | -0.078 | ** | -0.117 | ** | 1 | 3 |
| IBEX 35 | -0.050 | | -0.081 | * | -0.160 | ** | 1 | 1 |
| OMX Stockholm 30 | -0.010 | | -0.043 | | -0.100 | | 1 | 1 |
| FTSE 100 | -0.040 | | -0.057 | | -0.100 | | 1 | 3 |
| Control indexes | | | | | | | | |
| S&P 500 | -0.052 | | -0.047 | | -0.084 | | 1 | 3 |
| Nikkei 225 | 0.063 | * | 0.046 | | 0.021 | | 1 | 3 |

As in the first part of the current section, a Granger causality test has been performed for every variable which is significant in at least two specifications. The test shows once again that the Dutch, French, and German indexes exhibit statistically significant causal dependence from the EUA prices.

**Table 5.2. Granger causality test for the specification of VAR [*d.ln_eua, d.ln_oil, index*].**
The null hypothesis is the *d.ln_eua* does not Granger-cause the respective index; the alternative hypothesis is that *d.ln_eua* has significant causal relation with the index. Asterisks mark the level of significance: *-significant on 10% level, **-significant on 5% level, ***-significant on 1% level. All significant variables are highlighted in grey.

| Index | Chi2 | Prob>Chi2 | |
|---|---|---|---|
| AEX | 10.618 | 0.014 | ** |
| SBITOP | 4.111 | 0.250 | |
| CAC 40 | 7.578 | 0.056 | * |
| OMX Copenhagen | 3.585 | 0.167 | |
| DAX 30 | 6.914 | 0.032 | ** |
| IBEX 35 | 3.552 | 0.169 | |

### 5.3. Introducing the S&P500 component

The third specification employs the VECM framework, which can be considered a special case of the VAR model for the situations when the variables are cointegrated. Adding the variables representing the short-term interest rates and the world’s dominant equity market does change the picture to a certain extent (see Table 6), despite the fact that now S&P500 accounts for a large part of the variance in European national index dynamics. All lags of *snp* tend to be significant in all regressions. Denmark, Germany, Italy, and Spain are exhibiting certain hints on linkages to EUA prices. However, in this specification many other indexes, including Hungary, Belgium, Greece, Poland, Portugal, and Slovenia become significant with 1, 2, and 3 lags, which raises doubts as to the robustness of this particular specification.

**Table 6. Results of the third specification of VECM [*d.ln_int*, *snp*, *d.ln_eua*, *index*].**
The figures indicate the coefficients for the first lags of *d.ln_eua* (the second and third lags are insignificant in all regressions). Asterisks mark the level of significance: *-significant on 10% level, **-significant on 5% level, ***-significant on 1% level. The grey shading is applied to the variables which exhibit at least 10% significance of the first lag of *d.ln_eua* in all specifications (i.e. with 1, 2, and 3 lags). The theoretically efficient number of lags using the Schwarz and Bayesian Information Criterion (SBIC) and the Hannan and Quinn Information Criterion (HQIC) is indicated in the last column.

| [*d.ln_int*, *snp*, *d.ln_eua*, *index*] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Index** | **Lags (1)** | | **Lags (2)** | | **Lags (3)** | | **SBIC** | **HQIC** |
| ATX | -0.065 | | 0.014 | | 0.016 | | 2 | 3 |
| BEL 20 | -0.126 | *** | -0.080 | *** | -0.083 | *** | 2 | 3 |
| SOFIX | -0.035 | | -0.033 | | -0.033 | | 1 | 2 |
| FTSE/CySE 20 | -0.059 | ** | -0.023 | | -0.032 | | 2 | 3 |
| PX50 | -0.085 | ** | -0.020 | | -0.022 | | 1 | 2 |
| OMX Copenhagen 20 | -0.117 | *** | -0.061 | ** | -0.075 | ** | 1 | 2 |
| OMX Tallinn | -0.015 | | -0.020 | | -0.004 | | 1 | 1 |
| OMX Helsinki 25 | -0.119 | *** | -0.053 | | -0.061 | * | 2 | 3 |
| CAC 40 | -0.125 | *** | -0.041 | | -0.056 | * | 2 | 3 |
| DAX 30 | -0.134 | *** | -0.056 | * | -0.058 | * | 2 | 3 |
| FTSE/ATHEX 20 | -0.172 | *** | -0.117 | *** | -0.113 | *** | 2 | 3 |
| BUX | -0.192 | *** | -0.134 | *** | -0.107 | ** | 1 | 2 |
| ISEQ | -0.150 | *** | -0.085 | ** | -0.087 | | 2 | 3 |
| FTSE MIB | -0.129 | *** | -0.061 | * | -0.072 | ** | 2 | 3 |
| OMX Riga | 0.013 | | 0.010 | | 0.019 | | 2 | 2 |
| OMX Vilnius | -0.047 | * | -0.029 | | -0.026 | | 1 | 2 |
| LuxX | -0.074 | ** | -0.042 | | -0.038 | | 2 | 3 |
| MSE | 0.017 | | 0.015 | | 0.015 | | 2 | 3 |
| AEX | -0.126 | *** | -0.037 | | -0.050 | | 2 | 3 |
| WIG20 | -0.167 | *** | -0.089 | ** | -0.089 | ** | 2 | 2 |
| PSI 20 | -0.107 | *** | -0.069 | ** | -0.074 | *** | 2 | 3 |
| BET 10 | -0.138 | *** | -0.048 | | -0.033 | | 2 | 5 |
| SAX | 0.038 | | 0.031 | | 0.034 | | 1 | 2 |
| SBITOP | -0.056 | *** | -0.038 | * | -0.039 | ** | 1 | 3 |
| IBEX 35 | -0.134 | *** | -0.080 | ** | -0.081 | ** | 1 | 3 |
| OMX Stockholm 30 | -0.115 | *** | -0.045 | | -0.053 | | 1 | 2 |
| FTSE 100 | -0.113 | *** | -0.027 | | -0.038 | | 1 | 2 |

## 5.4. Combining all components

The combined VECM regression model with both the S&P 500 index and the price of oil produces several statistically significant results in terms of the linkages with the EUA market: Belgium, Greece, Hungary, Poland, and Spain are still significant with 1, 2, and 3 lags. Other markets, including Denmark and Italy, obtain significant coefficients only in the case of two out of three specifications.

**Table 7. Results of the third specification of VEC [*d.ln_int, snp,* d.*ln_oil, d.ln_eua, index*].**
The figures indicate the coefficients for the first lags of *d.ln_eua* (the second and third lags are insignificant in all regressions). Asterisks mark the level of significance: *-significant on 10% level, **-significant on 5% level, ***-significant on 1% level. The grey shading is applied to the variables which exhibit at least 10% significance of the first lag of *d.ln_eua* in all specifications (i.e. with 1, 2, and 3 lags). The theoretically efficient number of lags using the Schwarz and Bayesian Information Criterion (SBIC) and the Hannan and Quinn Information Criterion (HQIC) is indicated in the last column.

[*d.ln_int*, *snp*, *d.ln_oil*, *d.ln_eua*, *index*]

| Index | Lags (1) | | Lags (2) | | Lags (3) | | SBIC | HQIC |
|---|---|---|---|---|---|---|---|---|
| ATX | -0.033 | | 0.027 | | 0.027 | | 1 | 2 |
| BEL 20 | -0.096 | *** | -0.071 | ** | -0.078 | ** | 1 | 2 |
| SOFIX | -0.016 | | -0.020 | | -0.023 | | 1 | 1 |
| FTSE/CySE 20 | -0.036 | | -0.013 | | -0.028 | | 1 | 2 |
| PX50 | -0.043 | | 0.004 | | -0.003 | | 1 | 1 |
| OMX Copenhagen 20 | -0.079 | ** | -0.042 | | -0.064 | ** | 1 | 1 |
| OMX Tallinn | -0.001 | | -0.016 | | 0.001 | | 1 | 1 |
| OMX Helsinki 25 | -0.081 | ** | -0.036 | | -0.056 | * | 1 | 2 |
| CAC 40 | -0.083 | ** | -0.020 | | -0.043 | | 1 | 2 |
| DAX 30 | -0.084 | ** | -0.031 | | -0.038 | | 1 | 2 |
| FTSE/ATHEX 20 | -0.133 | *** | -0.097 | ** | -0.098 | ** | 1 | 1 |
| BUX | -0.156 | *** | -0.131 | *** | -0.117 | *** | 1 | 2 |
| ISEQ | -0.112 | *** | -0.059 | | -0.072 | * | 1 | 2 |
| FTSE MIB | -0.086 | ** | -0.040 | | -0.056 | * | 1 | 2 |
| OMX Riga | 0.030 | | 0.017 | | 0.029 | | 1 | 2 |
| OMX Vilnius | -0.030 | | -0.020 | | -0.017 | | 1 | 1 |
| LuxX | -0.038 | | -0.025 | | -0.023 | | 1 | 3 |
| MSE | 0.019 | | 0.018 | | 0.015 | | 1 | 2 |
| AEX | -0.084 | ** | -0.017 | | -0.039 | | 1 | 2 |
| WIG20 | -0.122 | *** | -0.073 | * | -0.087 | ** | 2 | 2 |
| PSI 20 | -0.077 | *** | -0.054 | * | -0.065 | | 1 | 1 |
| BET 10 | -0.102 | ** | -0.034 | | -0.034 | | 2 | 2 |
| SAX | 0.043 | | 0.045 | * | 0.045 | * | 1 | 1 |
| SBITOP | -0.042 | * | -0.030 | | -0.033 | | 1 | 1 |
| IBEX 35 | -0.097 | ** | -0.060 | * | -0.069 | ** | 1 | 1 |
| OMX Stockholm 30 | -0.070 | * | -0.029 | | -0.040 | | 1 | 2 |
| FTSE 100 | -0.073 | ** | -0.010 | | -0.027 | | 1 | 2 |

# 6. Discussion and Analysis

The search for linkages between the price of carbon under the EU ETS and the European stock market has produced mixed results. On the one hand, very few national indexes of the total of 27 countries which are obliged to follow the rules of the EU ETS exhibit substantial reactions on price shocks from the EUA market. Moreover, different specifications of the model using the VAR and VECM frameworks produce non-identical results – some of the index coefficients are significant only in one model specification or in models with a certain number of lags. Nevertheless, several equity indexes representing mostly large developed markets tend to show significant effects and causal links in the main representations of the model – the first [*d.ln_eua, index*] and the second [*d.ln_eua, d.ln_oil, index*] specifications. In particular, the Dutch (AEX), the French (CAC 40), the German (DAX 30), and the Italian (FTSE MIB) indexes have consistently displayed significant coefficients – and the respective Granger causality tests.

The reason why smaller and emerging markets show lower significance in the models might stem from the low concentration of listed companies in carbon-intensive industries in the respective countries; this particularly concerns power generators in Eastern Europe. Another explanation might be the higher awareness among market participants on mature stock markets (such as e.g. the NYSE Euronext exchanges) about the European carbon trading mechanisms and their current and prospective influences on the local corporations. Moreover, the non-industrial participants, including hedge funds and institutional investors which purchase emission contracts exclusively for investment purposes, are more likely to be acting on mature markets rather than on the "periphery" of the region (e.g. Eastern and Southern Europe). The above factors may collectively or individually result in the following paradox: despite being considerably more carbon-efficient (per unit of economic value output), developed markets may tend to be more responsive to the changes in $CO_2$ emission prices, as hinted by some of the results of the current study.

The third [*d.ln_int, snp, d.ln_eua, index*] and the fourth [*d.ln_int, snp, d.ln_oil, d.ln_eua, index*] auxiliary specifications of the model which employ the VECM methodology display substantially different results from the basic specifications. This is probably influenced by at least two important factors: the change in the estimation procedure from VAR to VECM (introduction of the error-correction component), as well as the inclusion of the S&P 500 index as the additional variable into the regressions. The latter is deemed as a more significant "disturbance" to the results of the models and is carried out primarily for the purpose of comparison, with the aim of ensuring that no important influencing factors have been omitted. It can be observed that the inclusion of the S&P index (and the interest rates) as additional variables makes most of the developed market indexes insignificant, while raising the significance of the developing market indexes (such as e.g. BUX, SBITOP, and WIG). This may be due to the fact that the former are much more coupled ("synchronized") with the globally dominant markets such as the US stock market, which raises the explanatory power of the S&P 500 index; the latter, on the other hand, contain a larger proportion of idiosyncratic price movements, which results in less explanatory power of the S&P 500 and consequently more significant coefficients on the EUA prices.

Overall, it is possible to outline at least three potential reasons as to why some countries' equity markets do seem to exhibit significant reactions to EUA price changes:

1). EUA prices indeed have a direct effect on certain developed equity markets

2). EUA prices and equity prices are driven by the some common factors, which creates the illusion of a causal linkage

3). The effect of linkage is a completely spurious result stemming from the construction of the model itself

Starting from the bottom of the list, it must be stressed that the results of the models used in the current study have been at least partially confirmed by the Granger causality testing, thus it might be overly pessimistic to conclude that none of the findings has an underlying reasoning. On the other hand, however, the current study presents a small and definitely insufficient evidence to close the discussion once and for all. Conducting more studies on carbon pricing spillovers into equity markets, preferably using other models, timeframes, and/or entity sample pre-selection, is currently the author's best recommendation concerning future development of the topic.

Referring to the second item on the list above, one can argue that it is the EUA price that is affected by the same risk factors as do the stock prices (e.g. by oil prices, gas prices, etc), which leads to a false inference of direct causality. For example, Bunn & Fezzi (2007) find that EUA prices are affected by gas prices – this could mean that gas (and oil, for that matter) affects both the stock market returns and the EUA returns, leading to false conclusions on the causal links of the latter. This explanation is definitely a possibility, yet only as one of the components of the true mechanism – the same arguments apply as with the previous alternative, motivating to develop the remaining perspective.

Finally, considering the most aggressive assumption at the top of the list, the “true” effect of carbon pricing on equity returns, if it does exist, may stem from the fact that equity market participants adjust their valuations of concerned businesses given the price changes of the EUA (seen in this respect as an additional cost item). This would imply that the industries and countries which are systematically experiencing lack of allowances at the end of compliance periods due to tight caps and scarce allocation would be more prone to react to EUA price movements – because they regularly face the need to purchase the allowances from the market and therefore expose themselves to price risks. In order to investigate the possibility that the reactions to EUA prices are determined by the relative scarcity of the emission allowances among the local businesses, the current study uses the data on European emitters of $CO_2$ from the World ETS Database compiled by Carbon Market Data (2011). The database contains the full list of polluting entities and the respective account holders in all EU countries, together with data on their verified $CO_2$ emissions and EUA allocations/submissions starting from 2005. According to the database, the UK, Germany, and Denmark have had the highest allowance deficits in the submission periods of 2008, 2009, and 2010 (the former two mostly due to a large share of coal-based power generation and developed heavy industry, and the latter owing to extremely strict self-imposed quotas). The Netherlands have tended to be close to zero emissions-to-cap ratios over the years, while Italy and France have mostly been over-allocated (see Appendix 7 for full data). The notion of supply scarcity may therefore not be the most probable candidate for explaining the linkages between carbon and equity markets.

Another point of view on explaining the carbon-equity market linkages is to assume that equity investors are gradually starting to systematically track the price development of EUAs - in a similar fashion as it is being done with the key commodities - and adjust their market actions accordingly. The materials which have significant influence on the revenues and costs of large businesses – such as e.g. oil, gas and metals, have the propensity to move equity markets given large enough commodity price jumps. This way of reasoning implies that carbon pricing is seen by investors as a significant driver of the competitiveness of certain sectors or even entire economies.

Since the price of EUAs is determined by both economic factors such as industrial production volumes (which drive the collective demand for emitting $CO_2$), as well as policy-related factors like the yearly allocation of carbon credits to corporations under the EU ETS (which determines the supply of emission allowances in any given year), the relation between EUA prices and the value of businesses from carbon-intensive industries is probably anything but straightforward - and might even not exist in direct form at all. The hints of certain reactions of the stock markets to price shocks from the EUA market show the possibility of such linkages becoming clearer and more pronounced in the future.

# 7. Conclusion

The current paper investigated the possibility of causal linkages between the price shocks from the European carbon market and the country equity markets. The research question posed by the study - "*Are price movements of European stock markets affected by the price changes on the EUA market?*" – cannot be answered completely positively. However, the evidence from the VAR and VECM modeling suggests that neither of the hypotheses on the existence and direction of the influence of EUA prices on stock market returns can be rejected for all European markets. The price of carbon is currently very far from being as influential on the global markets as the oil price; however, continuous growth in the world's population and weakly controlled depletion of natural resources may well change this situation. Despite modest results, the current work hints on the possibility of causal links from the carbon trading systems to equity markets, which may be the first stage on the way to a more efficient environmental compliance through rigorous market discipline.

Louis Redshaw, the head of environmental markets at Barclays Capital, likes to put it[7] much more aggressively: “Carbon will be the world's biggest commodity market, and it could become the world's biggest market overall”.

Future research on this topic will definitely benefit from the longer time frames as the market matures. This could bring more clarity as to the temporal evolution of the linkages between the carbon and the equity markets, while increasing the reliability of the results. Moreover, the EU ETS Phase III will be a very interesting period for studying the effects of the transition to auctioning of the EUA instead of free allocation based on historical performance, which should theoretically increase the importance of the carbon market pricing. It may also prove enlightening to consider other equity market gauges such as e.g. industry indexes and all-share indexes in order to generate further material for inferences on the underlying reasons of the reactions of stock markets on carbon prices. Finally, different contracts may also be considered by future research on the topic, such as e.g. the CERs (Certified Emission Reductions) and the ERUs (Emission Reduction Units), which represent tradable carbon contracts based on reductions of emissions outside the European Union. Despite being closely correlated with the EUAs in terms of price dynamics (so far), these alternative contracts my reveal additional channels through which the price of $CO_2$ emissions feeds into the equity markets across Europe, and in the future – possibly across the world.

[7] Kanter, 2007

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# Appendix 1: Variables

**Table 8. Sources of data for variables**

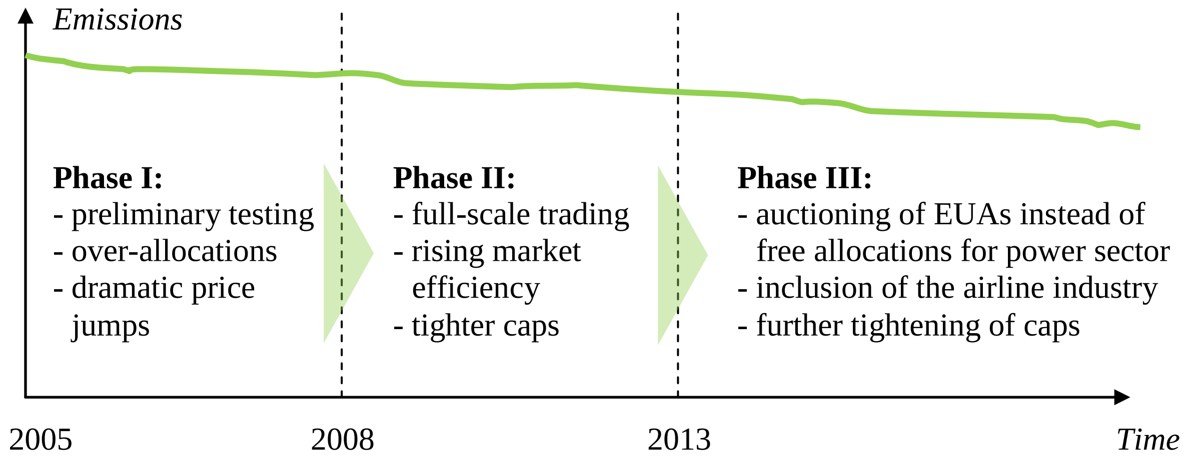
The following list contains the data sources for all variables used in the current paper

| Variable | Organization | URL |
|---|---|---|
| lneua | Bluenext exchange | http://www.bluenext.eu/ |
| lnoil | US Energy Information Administration | http://www.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RBRTE&f=D |
| snp | Standard & Poor's Financial Services | http://www.standardandpoors.com/indices/sp-500/en/us/?indexId=spusa-500-usduf--p-us-l-- |
| nikkei | Nikkei | http://e.nikkei.com/e/app/ac/market/historical.aspx |
| Short-term interest rates | | |
| EURIBOR | Euribor-EBF | http://www.euribor-ebf.eu/euribor-org/euribor-rates.html |
| SOFIBOR | Bulgarian National Bank | http://www.bnb.bg/FinancialMarkets/FMSofibidAndSofibor/index.htm?toLang=_EN |
| PRIBOR | Czech National Bank | http://www.cnb.cz/en/financial_markets/money_market/pribor/daily.jsp |
| CIBOR | NASDAQ OMX | http://www.nasdaqomxnordic.com/obligationer/danmark/cibor/ |
| TALIBOR | Bank of Estonia | http://www.bankofestonia.info/pub/en/dokumendid/statistika/ |
| BUBOR | Magyar Nemzeti Bank | http://english.mnb.hu/Statisztika/data-and-information/mnben_statisztikai_idosorok |
| RIGIBOR | Bank of Latvia | http://www.bank.lv/en/monetary-policy/monetary-policy-instruments/market-operations/money-market-indexes-rigibid-and-rigibor |
| VILIBOR | Bank of Lithuania | http://www.lb.lt/statistics/statbrowser.aspx?group=7222 |
| WIBOR | Money.pl | http://wibor.money.pl/ |
| ROBOR | National Bank of Romania | http://www.bnro.ro/Interactive-database-1107.aspx |
| BRIBOR | National Bank of Slovakia | http://www.nbs.sk/en/statistics/data-categories-of-sdds/interest-rates/interest-rates-of-the-nbs/en-bribor-bribid-za-mesiac-po-dnoch |
| STIBOR | Sveriges Riksbank | http://www.riksbank.com/templates/stat.aspx?id=17186 |
| LIBOR | British Bakers' Association | http://www.bbalibor.com/rates/historical |
| European equity indexes | | |
| ATX | Wiener Boerse | http://en.wienerborse.at/indices/ |
| BEL 20 | NYSE Euronext | http://www.euronext.com/trader/summarizedmarket/stocks-2634-EN-BE0389555039.html?selectedMep=3 |
| SOFIX | Bulgarian Stock Exchange | http://www.bse-sofia.bg/ |
| FTSE/CySE 20 | Cyprus Stock Exchange | http://www.cse.com.cy/en/marketdata/downloads.asp |
| PX50 | Prague Stock Exchange | http://www.pse.cz/dokument.aspx?k=Exchange-Indices |
| OMX Copenhagen 20 | NASDAQ OMX | http://www.nasdaqomxnordic.com/index?languageId=1 |

| | | |
|---|---|---|
| OMX Tallinn | NASDAQ OMX | http://www.nasdaqomxbaltic.com/market/?pg=charts&lang=en |
| OMX Helsinki 25 | NASDAQ OMX | http://www.nasdaqomxnordic.com/index?languageId=1 |
| CAC 40 | NYSE Euronext | http://www.euronext.com/trader/summarizedmarket/stocks-2549-EN-FR0003500008.html?selectedMep=1 |
| DAX | Yahoo Finance | http://finance.yahoo.com/q/hp?s=^GDAXI+Historical+Prices |
| FTSE/ATHEX 20 | Yahoo Finance | http://finance.yahoo.com/q/hp?s=FTASE.AT+Historical+Prices |
| BUX | Budapest Stock Exchange | http://www.bse.hu/menun_kivuli/dinportl/downloadable/nonrealtimehistdata |
| ISEQ | Irish Stock Exchange | http://www.ise.ie/Prices,-Indices-Stats/ISEQ%C2%AE-Benchmark-Index-Data/IndexHistory/ |
| FTSE MIB | Yahoo Finance | http://finance.yahoo.com/q/hp?s=FTSEMIB.MI+Historical+Prices |
| OMX Riga | NASDAQ OMX | http://www.nasdaqomxbaltic.com/market/?pg=charts&lang=en |
| OMX Vilnius | NASDAQ OMX | http://www.nasdaqomxbaltic.com/market/?pg=charts&lang=en |
| LuxX | Luxembourg Stock Exchange | http://www.bourse.lu/application?_flowId=IndiceTauxHistoFlow&cdVal=45&cdTypeVal=IND |
| MSE | Malta Stock Exchange | http://www.borzamalta.com.mt/index.php?option=com_jotloader&view=categories&cid=2_715207dda5b50f86dd461507946e1833&Itemid=93 |
| AEX | NYSE Euronext | http://www.euronext.com/trader/summarizedmarket/stocks-2634-EN-NL0000000107.html?selectedMep=2 |
| WIG20 | Money.pl | http://www.money.pl/gielda/archiwum/indeksy/ |
| PSI 20 | NYSE Euronext | http://www.euronext.com/trader/summarizedmarket/stocks-2634-EN-PTING0200002.html?selectedMep=5 |
| BET 10 | Bucharest Stock Exchange | http://www.bvb.ro/IndicesAndIndicators/indices.aspx?t=1&p=BSE&i=BET&m=&d=5/20/2011 |
| SAX | Bratislava Stock Exchange | http://www.bsse.sk/obchodovanie/indexy/_IndexHistoria.aspx?LANG=EN&Idx=SAX |
| SBITOP | Ljubljana Stock Exchange | http://www.ljse.si/cgi-bin/jve.cgi?doc=2069 |
| IBEX 35 | Yahoo Finance | http://finance.yahoo.com/q/hp?s=^IBEX+Historical+Prices |
| OMX Stockholm 30 | NASDAQ OMX | http://www.nasdaqomxnordic.com/index?languageId=1 |
| FTSE 100 | Yahoo Finance | http://finance.yahoo.com/q/hp?s=^FTSE+Historical+Prices |

# Appendix 2: The European Union Emission Trading Scheme

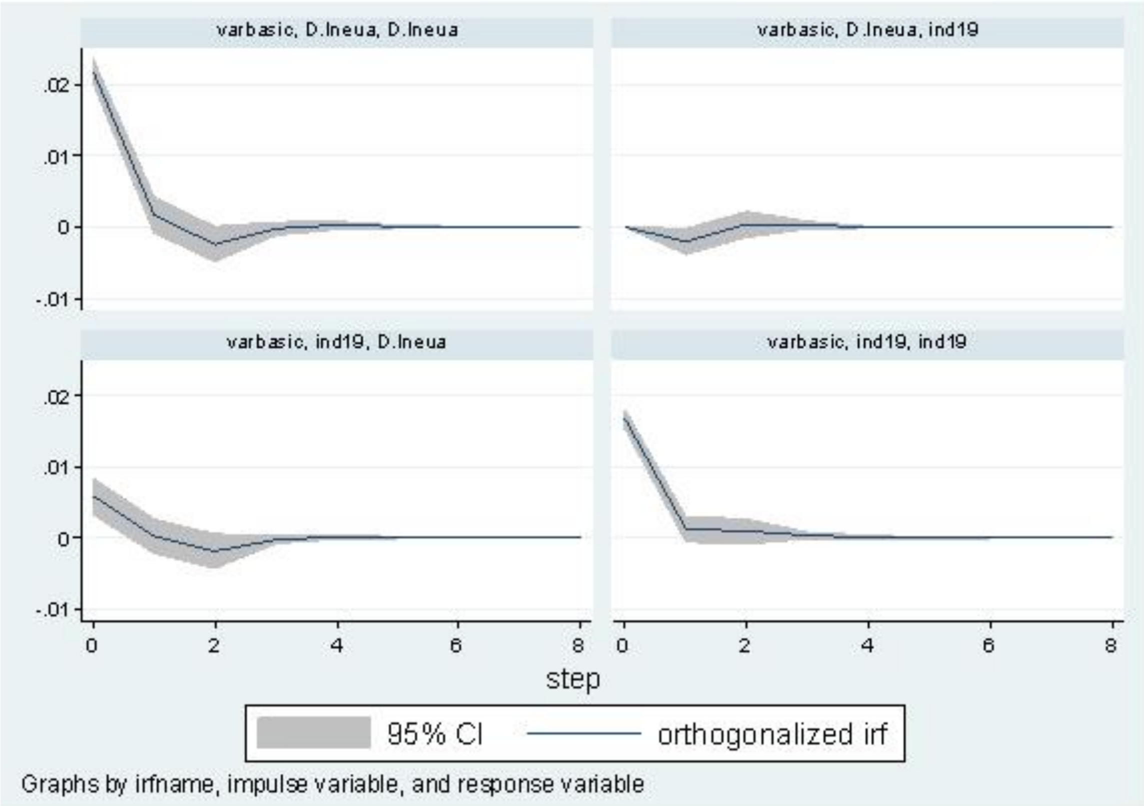
**Figure 4. Development of carbon trading in the EU**
An illustrative representation of the EU ETS evolution. The volatile green line is an illustration of the falling emission levels as the trading scheme progresses.
*Source: European Commission, 2011*



# Appendix 3: Impulse Response Functions – AEX Index [1]

**Figure 5. IRS for AEX index**

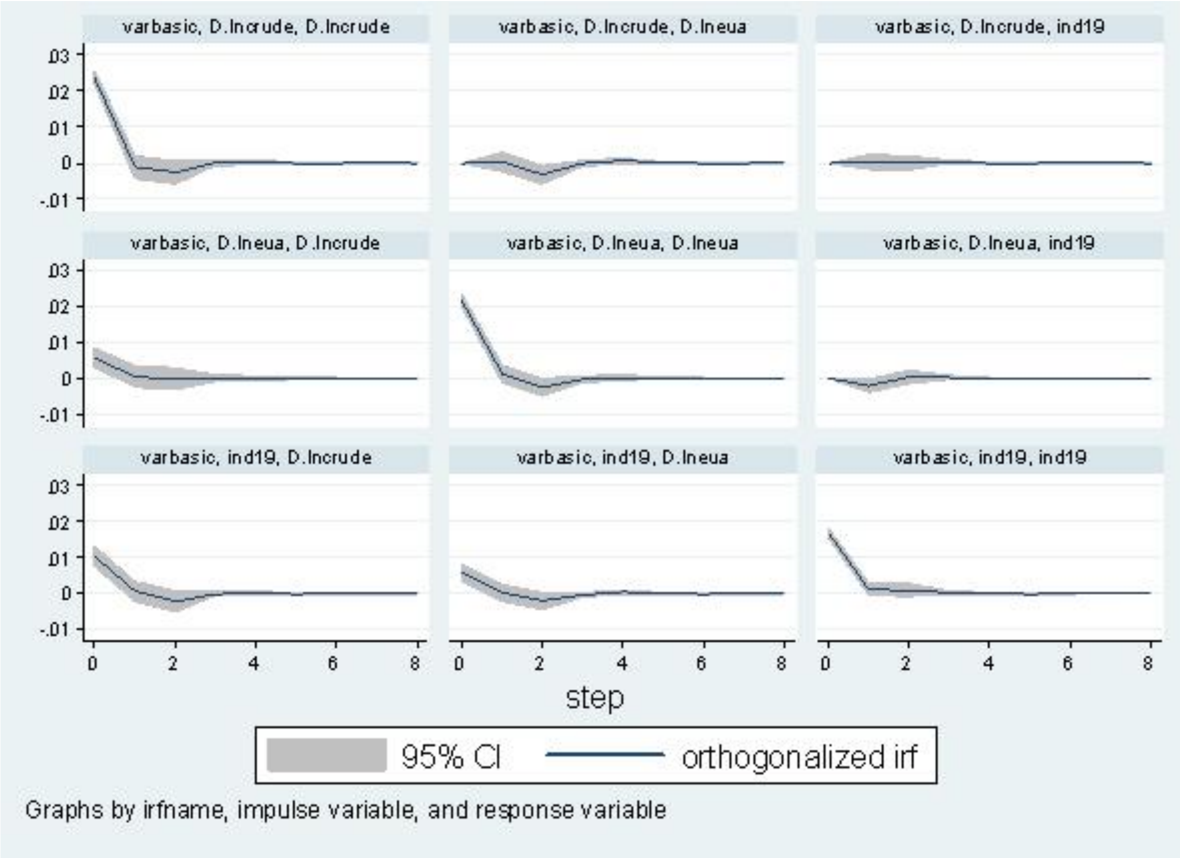
Impulse response functions for the VAR specification: [*d.ln_eua*, *index*], where index is the AEX, the gauge of the largest and most liquid companies on Amsterdam Stock Exchange (part of Euronext). This particular index has been chosen for the stable significance of its results in VAR model estimations.



# Appendix 4: Impulse Response Functions – AEX Index [2]

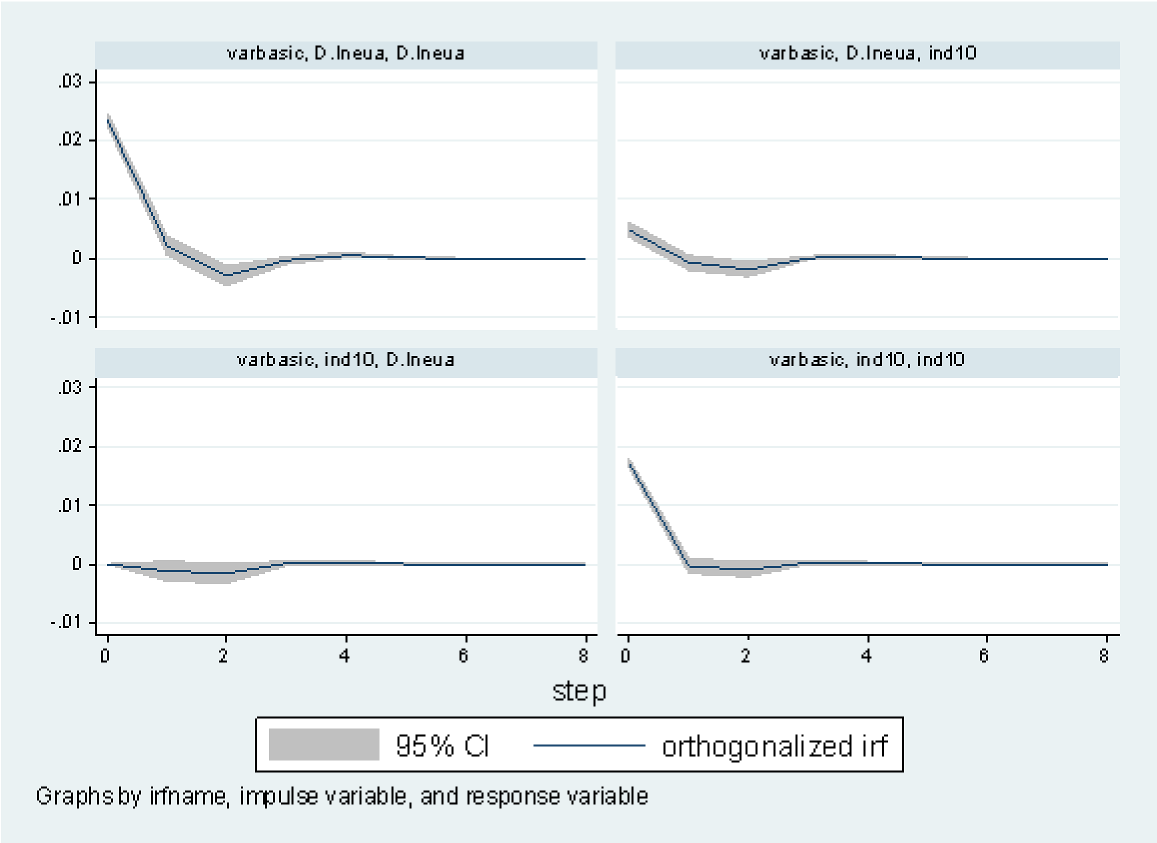
**Figure 6. IRS for AEX index**

Impulse response functions for the VAR specification: [*d.ln_eua, d.ln_oil, index*], where index (ind19) is the AEX, the gauge of the largest and most liquid companies on Amsterdam Stock Exchange (part of Euronext). This particular index has been chosen for the stable significance of its results in VAR model estimations.



# Appendix 5: Impulse Response Functions – DAX Index [1]

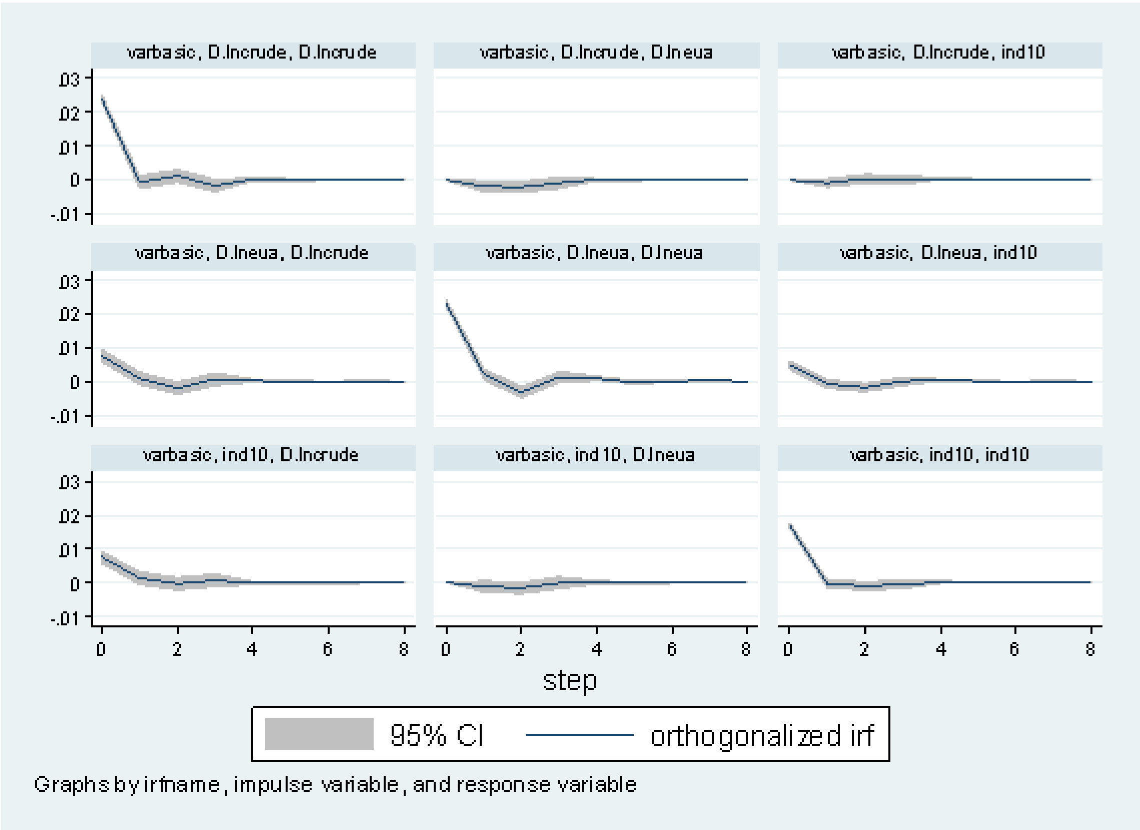
**Figure 7. IRS for DAX index**
Impulse response functions for the VAR specification: [*d.ln_eua*, *index*], where index is the DAX, the gauge of the largest and most liquid companies on Frankfurt Stock Exchange. This particular index has been chosen for the stable significance of its results in VAR model estimations.



# Appendix 6: Impulse Response Functions – DAX Index [2]

**Figure 8. IRS for AEX index**

Impulse response functions for the VAR specification: [*d.ln_eua*, *d.ln_oil*, *index*], where index (ind10) is the DAX, the gauge of the largest and most liquid companies on Frankfurt Stock Exchange. This particular index has been chosen for the stable significance of its results in VAR model estimations.



# Appendix 7: Emissions-to-Cap

**Table 9. Emissions-to-cap ratios for EU countries**

The table below provides data on the ratios of verified emissions per country over the allocated caps in particular years. A green figure means that the country had excess EUAs at the end of the regarded year, while the red color of the data implies that the aggregate allocated amount of EUAs has been insufficient to cover the emissions by the country's industrial sectors.

| Country | Emissions-to-cap, as % of cap | | |
|---|---|---|---|
| | 2008 | 2009 | 2010 |
| Austria | 6.39 | -14.39 | -5.15 |
| Belgium | 0.14 | -18.63 | -10.45 |
| Bulgaria | 0.00 | -21.13 | -4.74 |
| Cyprus | 15.82 | 5.36 | 0.00 |
| Czech Republic | -6.03 | -14.12 | -12.20 |
| Denmark | 10.68 | 6.48 | 5.69 |
| Estonia | 15.95 | -12.93 | 23.49 |
| Finland | -1.00 | -7.40 | 8.91 |
| France | -4.25 | -13.66 | -10.59 |
| Germany | 21.58 | 9.40 | 13.38 |
| Greece | 9.69 | 0.66 | -7.27 |
| Hungary | 8.61 | 6.29 | -10.48 |
| Ireland | 2.06 | -13.72 | -17.49 |
| Italy | 4.04 | -11.51 | -4.22 |
| Latvia | -6.66 | -29.52 | -7.89 |
| Lithuania | -18.72 | -23.59 | -21.65 |
| Luxembourg | -15.65 | -12.32 | -9.33 |
| Malta | -4.23 | -10.57 | -13.02 |
| Netherlands | 8.80 | -3.30 | -0.45 |
| Poland | 1.56 | -5.35 | -2.73 |
| Portugal | -1.87 | -8.57 | -25.93 |
| Romania | -10.71 | -33.62 | -36.79 |
| Slovakia | -21.23 | -32.81 | -32.92 |
| Slovenia | 7.86 | -1.81 | -1.00 |
| Spain | 6.22 | -9.09 | -19.12 |
| Sweden | -3.30 | -16.97 | -3.61 |
| United Kingdom | 23.81 | 7.12 | 7.71 |