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European wind energy subsidy & Emission Trade System: friend or foe on the electricity market?

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PREFACE AND ACKNOWLEDGEMENTS

ABSTRACT
To combat global warming, environmental damage and fossil fuel dependency, the European Union has implemented the European Union Emission Trading Scheme (EU ETS) next to the already existing renewable energy source subsidies. As both instruments exist from 2005 onwards, the question arises what the interaction effect is of these two policy instruments and how much they affect each other. In this paper the focus is on the energy sector, wind energy subsidy and EU ETS. From theory the European Union Emission Allowances (EUA) price and wind subsidy influence the cost and prices of wind energy and CO2 emitting energy generation, via the merit order effect. Result is that effective wind subsidies increase the amount of wind energy generated and decrease the CO2 emitting generation, as in the merit order wind energy has lower marginal cost. This decreases demand for fossil fuel power and decreases demand and prices for EUAs. That could lead in the end to a lower impact on reducing CO2 emissions. The interaction is tested empirically by analyzing the effect of EUA prices on electricity prices of six European countries, from 24-06-2008 to 10-11-2011. Panel estimation results show that the high and effective subsidy countries show a less positive impact of EUA prices on the electricity price, compared to the low and less effective subsidy countries. The interaction is thus dependant on a countries' subsidy scheme and can diminish the effect of EUA prices and of EU ETS to decrease CO2 emissions.

Keywords:
EU ETS, subsidy, interaction, merit order, wind.

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1 Introduction

As global warming, environmental damage, fossil fuel scarcity and fuel dependency increase, discussions about how to combat these changes are widespread. That there is need to counteract these negative effects on the world and communities, is however less debated and reinforced by the United Nations, and international communities such as the European Union.
That global warming was to be seen as a serious issue that needed action, was initiated by meteorological scientists and the United Nations Environment Programme. Therefore in 1988, the Intergovernmental Panel on Climate Change was founded (IPCC, 2007).
According to this scientific research and review body, the reduction of greenhouse gases in the atmosphere is needed to mitigate the risk of global warming and causing further environmental damage (IPCC, 2007). In order to decrease greenhouse gas emissions and its impact on the climate, on the 21st of March 1994 The United Nations Framework Convention on Climate Change was founded. This convention was meant to stimulate its members to monitor greenhouse gas emissions, create joint policies and to share best practices.
It was in 1997 that the Kyoto protocol was adopted, an international agreement to commit countries to monitor and reduce its greenhouse gases by a certain amount. The reductions can be met by making use of national policies, but next to this there is also a market oriented approach possible, that is the carbon market. This protocol came into force on 16 February 2005 (UNFCCC).

The first approach was implemented quite early by several countries that formulated a national policy to stimulate e.g. renewable energy sources (RES) and reduce emissions by taxation on polluting firms. From feed-inn tariffs to taxation on CO2 intensive industries, an array of measures is implemented to increase/decrease the use of renewable energy sources/fossil fuels. Not solely for combating greenhouse gas emissions, but also to answer the challenge of increasing scarcity of fossil fuels and national dependency on a few fossil fuel supplying countries.

The European market for carbon or European Union Emission Trading Scheme (EU ETS), the other approach, was launched in February 2005 and should lead to a more cost effective reduction of CO2. As in this Emission Trading Scheme (ETS) it is possible to trade emission certificates from a company/country which must invest heavily to reduce the amount of CO2 to companies/countries which can decrease their emissions in a more cost effective way. In the end leading to less costs for society to reduce greenhouse gas emissions as compared to isolated companies or nations trying to reach the same goals in a less cost efficient way (Babiker et al., 2004; Betz & Schleich, 2005; Stavins, 2002; Abrell & Weigt, 2008; Hentrich et al., 2009).

As aforementioned policies exist both, from 2005 onwards, the question rises how these two mechanisms affect each other. Despite the fact that both measures are meant to solve the same problem, that is the problem of externalities (environmental pollution) that are not taken into account (internalized) as a cost factor in the price, it could be that they work in opposite direction, interact unexpectedly, or amplify one another, making it more difficult to arrive at the preferred outcome for society (e.g. Abrell & Weigt, 2008; Böhringer & Rosendahl, 2010; IEA, 2008; Sijm, 2005).

Several papers are written on the effect that the ETS and/or RES subsidies have on electricity prices. Also several papers on this interaction effect exist, in which it is seen that the interaction effect could result in lower costs for consumers, but both instruments should be coordinated correctly to get the anticipated outcome (Linares et al., 2008). Other research concludes that both an emission pricing mechanism and a renewable energy support system could coexist, as long as they separately solve a particular market failure (Fischer & Preonas, 2010; Sijm, 2005). Most of them however analyze these aforementioned effects by using simulations of a theoretical model without investigating the empirical part of the analysis.

As the energy sector is responsible for a relatively large share of greenhouse gas emissions divided over a moderate amount of plants, this sector is most targeted and regulating this sector should result in a considerable effect on decreasing greenhouse gas emissions (Clò, 2009; Reinaud, 2004).
Wind energy is a renewable energy source which costs are relatively low compared to other RES, and can, through the merit order effect (will be explained later), reduce the costs of electricity. Therefore it is seen as one of the first renewable energy sources to become competitive and of influence on the energy market (Doherty et al., 2006; Weigt, 2008).

So when analyzing the effect two policy instruments have on a certain outcome and how they interact, in this paper the focus will be on the EU ETS, wind energy support schemes and the effect these have on the electricity prices in Europe. It should establish a more empirical understanding of the interaction of the two policies, by using a general panel model where the electricity price of the countries are used as dependant variable and the gas, coal and EUA prices as independent variables.

More exact, this paper will try to answer the following question:
What is the combined effect that EU ETS prices and wind energy subsidies have on the electricity price in Europe?

In part 2 the mechanisms of EU ETS & wind energy support schemes are described, together with the possible interactions from a theoretical point of view and gives some comparison with other literature. Section 3 will discuss the method to test the interaction empirically. Then part 4 of this paper will give the results and part 5 is to conclude and discuss the results of this research.

2 Policy instruments

2.1 EU ETS

The EU ETS is a mechanism that creates a market for carbon, on which CO2 emitting firms need to align their amount of emissions with the amount of European Union Emission Allowances (EUA) by buying or selling their allowances. The amount of allowances that is allocated towards companies is predetermined and fixed on a yearly basis by national governments, who in their turn have to seek approval from the European Union. In this way it is attempted to make the commodity traded on this market scarce. This scarcity leaves the emitters with the choice to buy allowances on the market, or to reduce their amount of CO2 emission. As there are different companies on this market, with their own cost curves and technologies, it could be that for a certain company it is cheaper to reduce its emissions than to buy allowances to comply. If it reduces the amount of emitted CO2, it will have excess EUAs which can be sold on the carbon market to firms with too little EUAs.

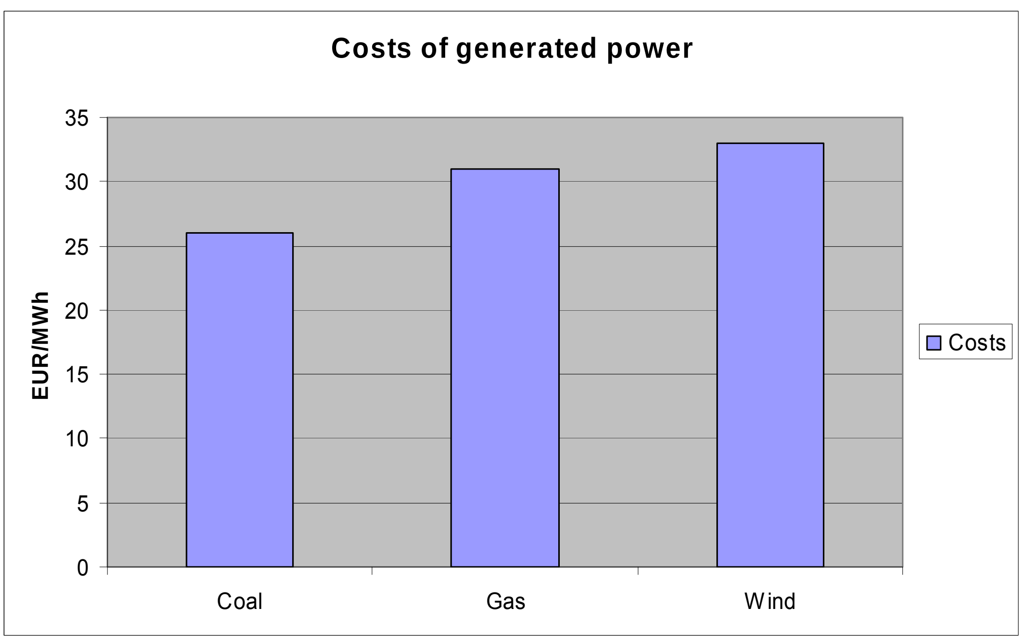
This mechanism has the potential (at least in theory) of creating a cost effective way of reducing the overall emissions in a country, as the most cost effective technologies for reducing CO2 emissions are adopted only by firms that can do this in the most cost effective way (Abrell & Weigt, 2008; Hentrich et al., 2009). These firms will reduce their emissions resulting in an overall cost advantage with the same reduction in emissions (as the amount of allowances is fixed and mostly reduced every year). This prevents all firms separately to reduce their emissions, which would result in higher costs for society, as not all firms can reduce emissions for the lowest cost possible.

Another advantage of ETS is that the market dictates where the CO2 reduction can be executed with the smallest cost impact, which saves the government the task of finding out which firm is best capable to decrease CO2 emissions at the lowest cost (Babiker et al., 2004).

Allowance scarcity of and the corresponding price for the EUA, results in opportunity costs for firms, as they can earn revenues by cutting emissions and sell the forthcoming EUAs on the market. Whether this is really the case in practice is still heavily debated between scientists in this field of research (e.g. Toke, 2007; Fischer and Newell, 2008).

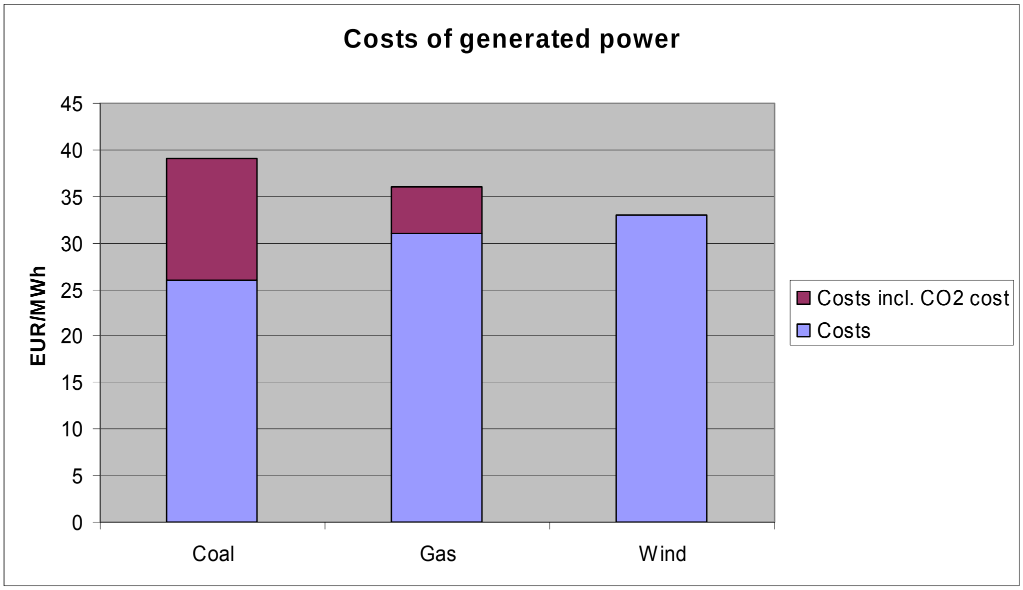
Besides EUAs, companies and thus countries can earn credits by investing in greenhouse gas reducing projects, in countries that committed to the Kyoto protocol via the Joint implementation (JI) mechanism or in countries that did not commit to the Kyoto protocol via the Clean Development Mechanism (CDM). In the JI one can earn an Emission Reduction Unit (ERU) and in the CDM one can earn a Certified Emission Reduction credits (CER), which in their turn can be used as a credit to meet the emission target (UNFCCC). This is however a research field in itself, where multiple unexpected relations come into play that distort the analysis which will be discussed in this paper. Therefore the CDM & JI will not be used in this research.

Figure 1a: Costs per technology



Source: own example

Figure 1b: Costs per technology (incl. CO2 cost)



Source: own example

As earlier mentioned and debated, the goal of the ETS is to reduce the emission of greenhouse gases by setting up a framework that redirects the externality costs to firms (and consumers) and create opportunity costs, as the firms have the potential to earn revenues by reducing their emissions and reselling the allowances. This will reflect in the cost and price of the sold goods by these firms, which is in this case the electricity price. Punishing those firms that have higher emissions per output of electricity, because the EUA cost increases its price, which *ceteris paribus* results in lower quantities supplied and lower profits (assuming that the price increase is not enough to make up for the lost demand). The influence on the total costs of generated power are depicted in figure 1, which shows an example of the difference in cost between a "pre-EU ETS" situation without CO2 costs (figure 1a) and one with EU ETS and CO2 costs (figure 1b). Where first the lowest cost technology is coal, and after implementation of a CO2 cost, wind has the least cost[1].

This feature and result of the ETS on the marginal cost and price of electricity will be used later to set up the empirical model and to explain the logic behind it.

[1] This is an example without referring to real costs. But the relative magnitude and the shift of wind power, after the CO2 cost effect, to become the lowest cost technology is actually broadly accepted in this research field (e.g. Reinaud, 2004).

2.2 Wind energy support

The support for wind energy is widespread among European countries. Most governments subsidize wind energy developers or utilities by means of a mark-up on the normal electricity price, so that the costs for wind energy are covered and that these energy generators earn similar profits as other non renewable energy producers. From an economic point of view, the goal of this subsidy is to let society benefit from a positive impact of wind energy on the environment and to increase the diffusion of this technology. This is necessary as a clean environment is a non excludable good from which people can freely benefit (free riding). In turn this subsidy will also result in a larger diffusion of the technology that would otherwise not be reached (Finon et al., 2003).

Some countries fix the tariff over the lifetime of the wind turbines, that is 15-20 years. Others differentiate the tariff over time, for example the first years a higher tariff is given compared to the end of the life time of the wind turbines. Another difference is the way that the support is "financed" by the state. Some countries use tax proceeds from non renewable generators to gather funds and others let the consumer pay a mark-up on their electricity bill (Butler & Neuhoff, 2004; Fischer & Preonas, 2010).

However all wind energy subsidies try to achieve the same result, which is to close the gap between the electricity market price (which does not fully cover all costs for wind energy) and the costs incurred for the generation of wind energy. In that sense it can be seen as an opposite approach as the EU ETS, where the CO2 emitting generators costs are being increased, the wind energy generators see that their costs are being decreased (by the increase in revenues from the tariff).

With this last comparison a part of the problem is revealed already, as there is some overlap of the two policy instruments. ETS results in higher costs for the non renewable generators as is depicted in figure 1a and 1b. This creates an overall higher electricity price, thus reducing the difference between the overall electricity price and the price that must be earned to cover wind energy costs.

The wind energy tariff decreases the price needed to break even, through direct support which lowers the costs that need to be covered with the normal electricity price. So both are actually favoring low carbon intensive technologies, but one via price increase (cost increase) to carbon intensive generators and the other via a cost decrease to wind energy generators.

2.3 EU ETS & wind energy subsidy interaction

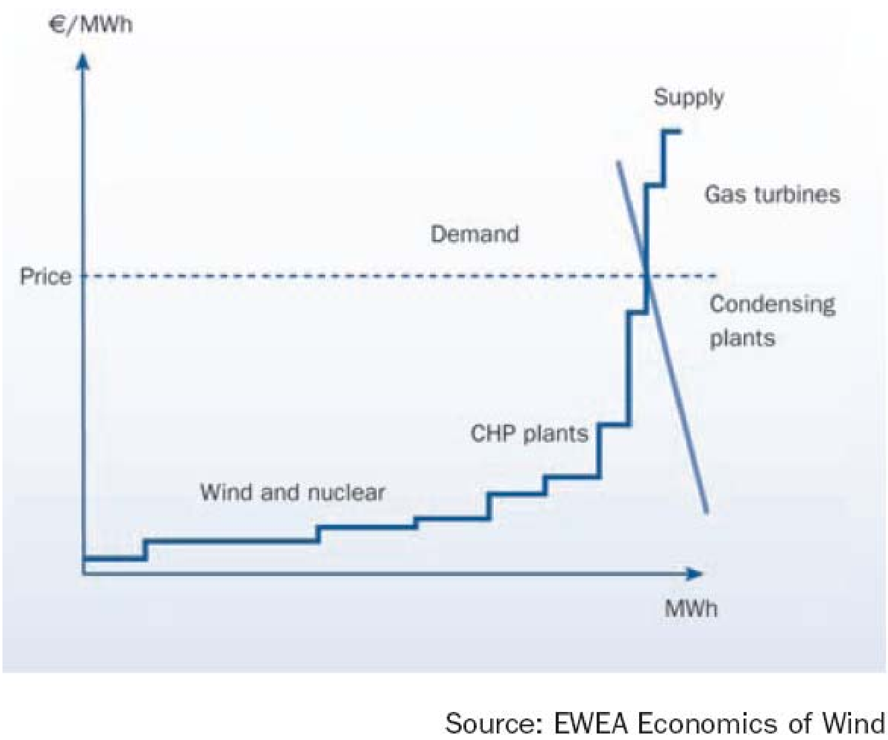
As described earlier, the two mechanisms influence the costs and the price of the good “electricity”. That is why on the energy market the ETS & wind energy support programs will show interaction. In order to analyze their possible interaction, the energy market and its special features will be described.

The European electricity market has been liberalized in 2007 (Heinzow et al., 2006), resulting in more competition and less monopolistic behavior. Although the market is still far from perfect, the normal demand and supply mechanism with competing suppliers is at play. One difference however compared to normal consumption goods, is that “electricity” cannot be stored and therefore there should always be an exact equilibrium in supply and demand. This balance is reached via a constant selling and buying of electricity in ever increasing international trading on the day-ahead-market (spot market), where quantities of electricity is sold, to be delivered between 12 or maximum 24 hours later. As not all these day-ahead contracts fully materialize and actual supply/demand may differ from what was expected, the regulating power market equals any imbalances on the demand side by an independent transmission system operator (TSO) who “chooses” which generated electricity is bought at which price (EWEA, 2010).

As the demand side of this regulating market (TSOs) wants to have the lowest price option for the electricity system, it will choose the least cost or lowest offered electricity supply price for a certain point in time. The demand is thus served almost solely on the ground of each technology’s marginal cost, as this is the main driver for the “marginal/average” price. A wind farm has lower marginal costs than a combined cycle gas turbine plant and will therefore supply (is asked to supply by the TSO) a larger part of the total demand compared to the gas fired plant (Genoese et al., 2008).

Important for the analysis, is that the electricity generated at the lowest cost is used as a base price for all the electricity producers in that particular region, so that low price supply is stimulated (Genoese et al., 2008; Weigt, 2008). This characteristic is important to take into account in the analysis of policy instruments and their effect on price and energy technologies as is described in more detail below. Especially when knowing the product on this market, electricity, is produced by making use of a range of technologies with different cost functions.

Figure 2: Merit order

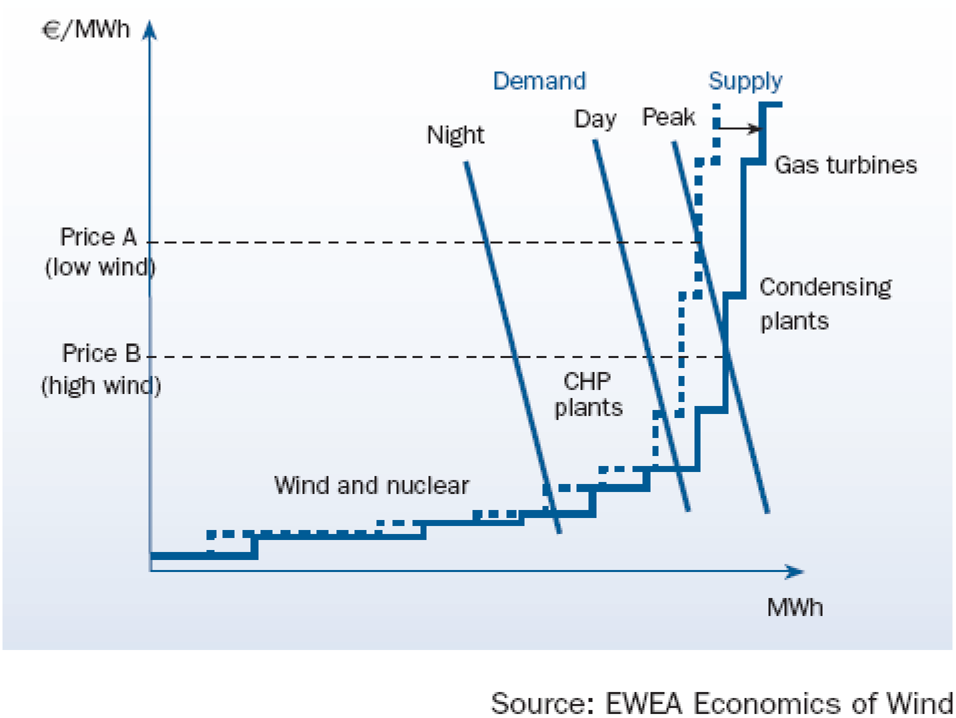


Source: EWEA, 2009

So because there is a low price based supply together with a certain mix of electricity generating technologies available in a country or region, a technology which has relatively lower marginal costs has more chance of supplying a large part of total demand. As can be seen in figure 2, without any ETS or wind support, here wind and nuclear shall supply their full potential and other technologies shall not fully supply their full capacity. It is mostly that this cheapest form of electricity (dependant on fuel prices and other operating costs) will supply the first part of electricity demanded and that then the second lowest marginal cost technology will follow etcetera. In literature on electricity markets, this phenomenon is called the “merit order” effect.

The influence both policy instruments have on the cost of these technologies, as described earlier, is directly affecting this so called merit order.
At first, wind energy’s low marginal cost compared to other more “CO2 intensive” energy sources (wind does not use fuel, which is a large cost component for fossil fuel generators), creates an advantage for wind energy over fossil fuel (more CO2 intensive) generated electricity. Even to a possible larger extent, as at the same time EU ETS induces extra CO2 cost to the fossil power generated electricity producers. Theoretical interaction of these two policies thus seems not that ineffective after all and can even reinforce one another in the right way, resulting in more wind energy supplied and less fossil fuel demanded.
Secondly however, another effect of the wind power increase is that an increase in wind power (or high wind versus low wind) results in a price decline (De Miera et al., 2008). This effect can be seen in figure 3, where an increase in wind generated power as a result of high winds (which is similar as if there is an increase in installed wind power) creates an increase in the supply of low cost electricity, which lowers the overall electricity price and shifts the supply curve to the right (Genoese et al., 2008). This in its turn shall show up in an overall less CO2 intensive energy production, suppressing the EUA prices as there is less demand for them (less opportunity cost). Which in the end again shall be followed by a lower wholesale electricity price (as CO2 prices are put through to the end customers) (Rathmann, 2005).

Figure 3: Wind power effect



Source: EWEA, 2009

At a certain point in time, in the extreme case, wind energy is producing an increasing larger percentage of the energy because of effective wind subsidies. This will result, through substitution, to an even larger decrease in demand for fossil generation and a lower CO2 price, and the most CO2 intensive technology will be favored or used first to meet the demand of electricity. This is caused by the effect that cheap CO2 allowances will be used first for the most CO2 intensive technology (there is a greater benefit of using them in high CO2 emitting technologies than in a less CO2 intensive technology). Thus in the extreme case the wind increase or increase in installed wind power can cause more CO2 intensive electricity generation compared to a state where there was no wind support (Böhringer & Rosendahl, 2010).

In order to see whether this is a mechanism in practice and whether this interaction is actually occurring, the next section shall describe a method to test the interaction and possible effect on the price of electricity.

3 Method & data

3.1 Method

EU ETS does not have a direct impact on non CO2 emitting technologies, such as wind energy. Therefore it is tried to analyze this interaction effect on the common "playing field" where both instruments meet: the electricity market. Because the two policy mechanisms affect prices and costs of electricity generation technologies as has been explained, it can be seen as a correct basis for the analysis.

By estimating the effect that the EUA price and the wind energy subsidy have on electricity prices, the interaction shall be analyzed. However, the lack of wind energy subsidy data prevents the use of it as a direct variable in the model. Instead a proxy could be used, but most proxies create correlation problems and are difficult to define in the case of wind energy subsidy. Therefore it is chosen to follow a different route, where two countries analyzed in an exact same manner. The only difference between the two is that one has a relatively high subsidy level and a more efficient subsidy scheme, and the other group a relatively low level and less efficient subsidy scheme. The parameter estimates of both will be compared, and a conclusion will be drawn on the different effects the EUA price has on the overall electricity price and thus on the strength of this EUA – subsidy interaction effect.

Because comparing 2 countries, could give a too narrow and biased view on the mechanism (-s) at work and as little data points are inherent to such approach, instead 2 groups of countries shall be used. A panel data set is created which includes data for different countries over time that are necessary for the analysis. Electricity, EUA, gas and coal prices are pooled together for the two groups of countries. The gas and coal prices are included as they are used as a predominant fuel resource in energy plants.

In the next part it shall be elaborated on what kind of panel data estimation shall be used, a random effects or a fixed effects model. It is however expected that there could be correlation between the error term and the explanatory variables, and that thus the “fixed-effects” model is safer to use as this model allows for aforementioned correlation (Pindyck & Rubinfeld, 1998).

The general model specification is as follows:

$$Pe_{it} = \alpha + \beta Peua_{it} + \beta Pg_{it} + \beta Pc_{it} + \varepsilon_{it} \qquad (1)$$

Where Pe is the day ahead base load electricity price (EUR/MWh), α is the intercept, Peua the European Emission Allowance spot price (EUR/mT (metric ton)), Pg the gas index price (EUR/MWh), Pc the coal index price (EUR/MWh) and ε the error term. All prices are given on a daily basis (mostly 5 days per week) for each country *i*, at time *t.*

As certain countries do not have their own market for the variables mentioned, a respective general market price is used instead, which will be discussed later in this paper.

3.2 Analysis reasoning, groups chosen & data

By using two groups of countries, one with a substantial high level of wind subsidy (very subsidy efficient) and the other with substantial low subsidies (not subsidy efficient), it is expected that the former “high” subsidy estimation result has a less positive effect of the EUA price on the overall electricity price.

This is caused by the fact that this group of countries has more energy generated by wind compared to the other group, which will lower the electricity price and in the end will cause the EUA effect to diminish for several reasons. A direct effect of the low generation cost technology wind power is that it will lower overall electricity prices, but the increase in wind energy will also reduce the demand for EUAs and thus reduces indirectly the positive effect that the EUA would have if there were no subsidies in place.

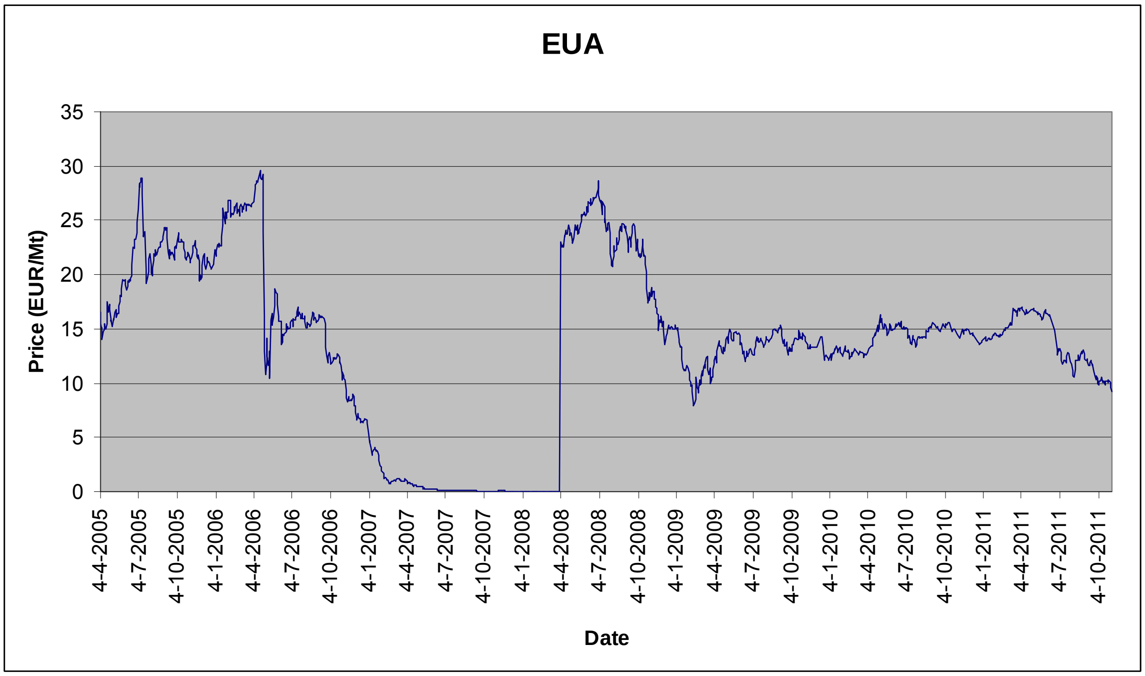
Comparing two country group cases will have different outcomes with respect to estimates of EUA prices and its effect on the electricity price. Analyzing these estimate differences enables to make statements on interaction.

Choosing the two separate groups for the analysis, is done on the basis of the height of the subsidy level and on effectiveness of the subsidy. Several papers on subsidy levels for wind generated electricity and on effectiveness are interpreted (BDEW, 2010; EWEA, 2009; Haas et al., 2006; Faber et al., 2007; Mulder, 2008) and used for the choice of the two country groups. Most efficient countries used are Denmark (DK), Germany (GE) & Spain (SP) and least efficient countries used are France (FR), Italy (IT) & Sweden (SW). As the model used, results in an overall estimate for all countries together, it is not necessary to take into account the country specific environments and situations to draw correct conclusions (as these are corrected for by country dummies). It is actually better the more differences exist, as in this way a more robust conclusion is to be made (Wooldridge, 2007). Therefore it is acceptable that the countries used have a totally different fuel mix or different wind conditions for electricity generators. The market must be the same though in having adopted the EU ETS and have some kind of subsidy for wind electricity generated, that stimulates the use of wind generated electricity.

Data: EUA

As the EUA market is important for the analysis, the price index of the European Energy Exchange (EEX, Germany)[2] is given in figure 4 to view structural breaks that are quite common in a young market. The other graphs of data used

Figure 4: EUA spot price 2005-2011



Source: EEX (from Bloomberg)

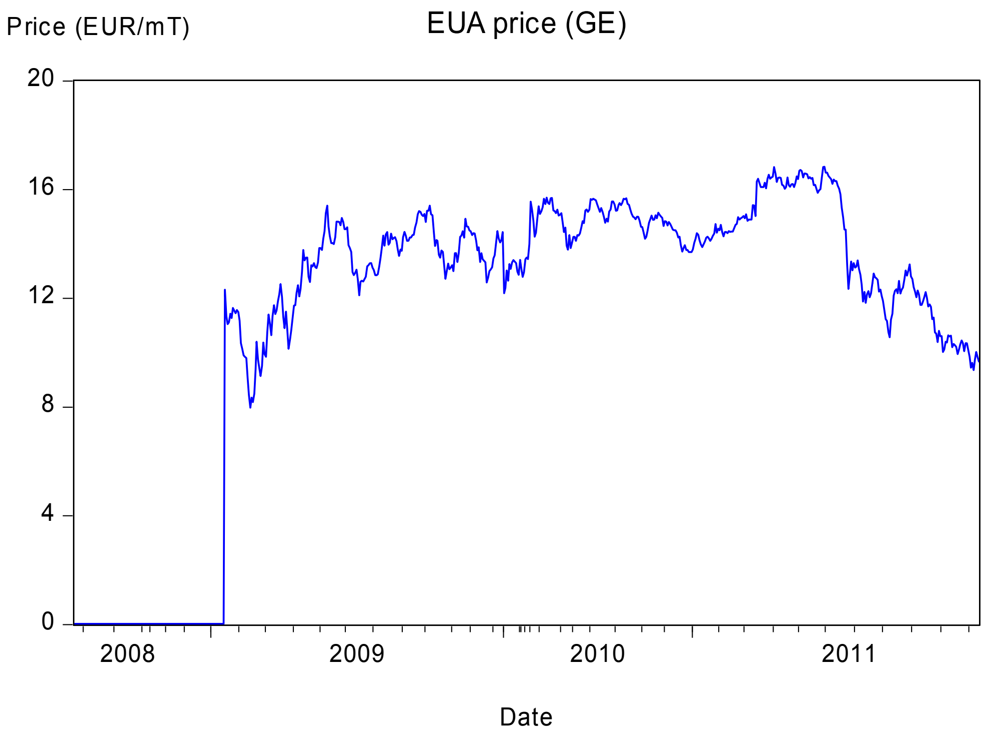
It is seen in figure 4 that the EUA price was volatile especially in its first trade period (2005-2007) and dropped to almost zero before the second trading period started in 2008. Main reason for this was the oversupply of allowances, the disability to bank (save) them into the next period and resulting large sale of EUAs before the new trading period started (Buchner & Ellerman, 2007; Convery & Redmond, 2007).

When assessing the results the model uses, it will be tried to analyze the whole period from 2005-2011, but the main focus should be on the second period from 2008-2011. Also because the country specific EUA prices show similar volatility at the end of 2007 and begin of 2008 (see figure 5). Figure 5 makes clear as well

[2] This market is chosen to get a general overview, as this market had most historical data from 2005 onwards.

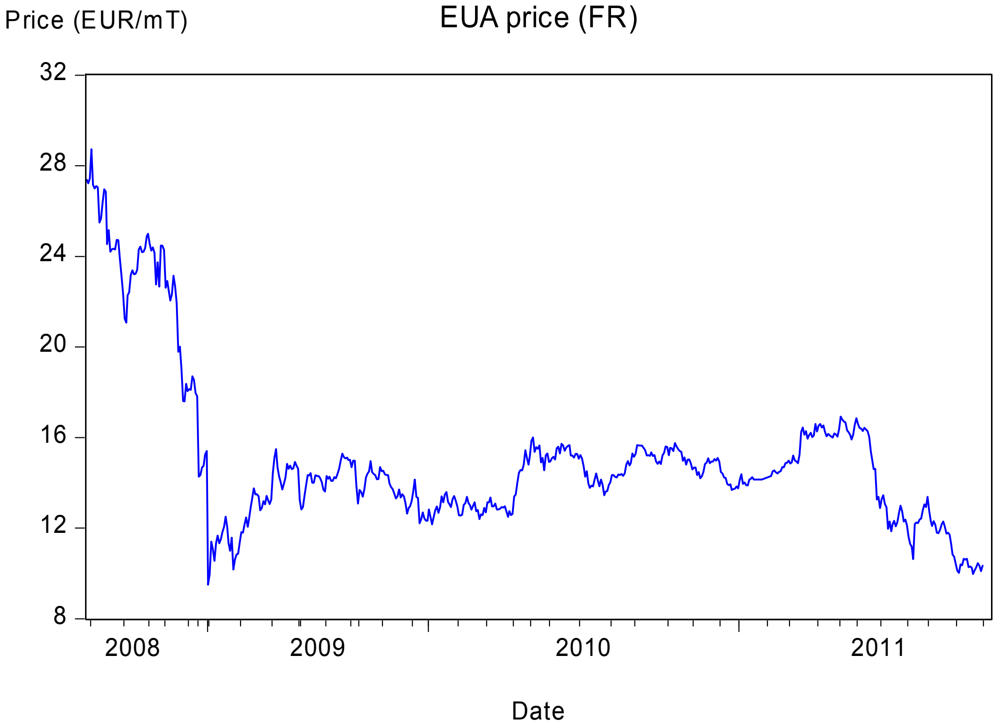
that from the second half of 2008 the EUA price shows more stability. This more stable period should provide more insight in the mechanisms at work (EUA prices of zero do not give much insight and will cause unwanted effects in the model proposed earlier).

Figure 5: EUA spot prices, all countries



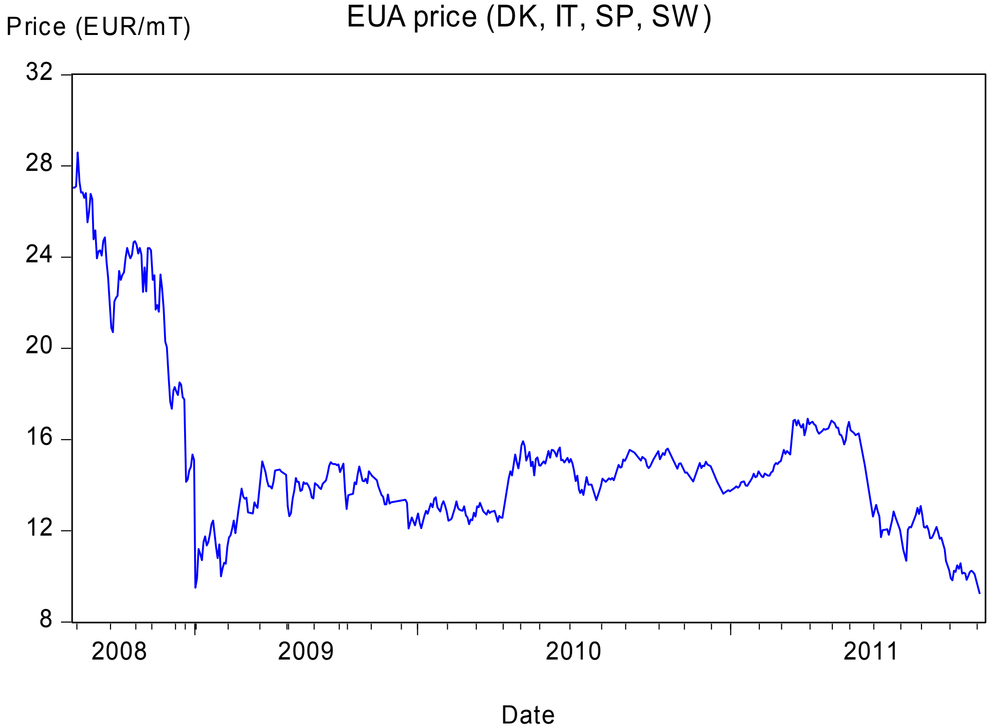
Source: EEX (from Bloomberg)

EUA price (FR)



Source: Bluenext (from Bloomberg)

EUA price (DK, IT, SP, SW)



Source: European Emissions Trading Spot Price (from Bloomberg)

Data used

The following data from Bloomberg database is used in the analysis[3]:

- all country specific day ahead base load electricity market prices are taken for each country:
  → Denmark: Nord Pool Power Exchange (NPX) Copenhagen
  → France: Paris Power Exchange (PPX)
  → Germany: European Energy Exchange (EEX)
  → Italy: Gestore Mercati Energetici (MGE)
  → Spain: Operador del Mercado Iberico de Energeia (OMIE)
  → Sweden: Nord Pool Power Exchange (NPX) Stockholm
- gas prices of Nord Pool Gas AS (Scandinavian market) are used for Denmark & Sweden
- gas price of Gaspool Balancing Services GmbH is used for Germany
- gas price of French Gas Exchange Point (PEG) Nord & Sud arithmetic average is used for France, for Spain PEG Sud (no own market) & for Italy PEG Sud (no own market)
- EUA prices of European Energy Exchange (EEX) is used for Germany
- EUA prices of Bluenext is used for France
- EUA price general index (European Emissions Trading Spot Price)is used for Spain, Denmark, Sweden & Italy (as no country specific marketplaces exist for these countries)
- Coal prices of Hamburg Institute of International Economics Coal Eurozone Europe are used for Germany
- Coal prices of the Intercontinental Exchange (ICE) are used for all remaining countries (these countries do not have an own local coal market). These are given in USD, therefore the European Central Bank (ECB) daily spot EUR/USD exchange rate is used to convert prices in EUR.

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[3] When one price index is used for multiple countries because no local market exists or is not found or available, justification for this is found because arbitration should take away differences between multiple local market prices.

Data properties

In table 1a, b, and c the descriptive statistics for the high subsidy countries are given (a graphical overview of all data used is given in appendix A). It is seen at first that there is a difference in the number of observations for the different data groups within and between countries, which is caused by different opening days of the markets and by overall unavailability of data. The problem when deleting all corresponding data points for each market, is that little data points will remain, also in light of the possible lag that needs to be used. That is why it is chosen to keep the “missing” data points in, and let the particular estimation correct for it if needed by using an unbalanced panel model.

Secondly it is seen that there is enough variation within the country group, caused by every countries’ own market prices, to make use of a panel model. As last, the same data is used for coal and EUA for Denmark and Spain, but the effect on its own electricity market should create variation in the given estimates to be used in the panel estimation.

Table 1a: descriptive statistics Denmark

Denmark	ELECTR	GAS	COAL	EUA
Mean	51.61976	19.73018	75.17475	14.97567
Maximum	298.16	34.80000	141.9900	28.59000
Minimum	19.59	7.200000	43.32000	7.900000
Standard Deviation	19.4369	5.842521	23.11332	3.940958
Skewness	5.610452	-0.362502	0.662373	1.470815
Kurtosis	61.51091	2.189404	3.156387	5.038921
Observations	616	680	680	547

Table 1b: descriptive statistics Germany

Germany	ELECTR	GAS	COAL	EUA
Mean	51.50164	19.06352	99.87279	11.42007
Maximum	116.0000	31.60000	163.9000	16.84000
Minimum	16.25000	7.000000	60.20000	0.020000
Standard Deviation	14.67438	5.852772	26.81534	5.364298
Skewness	1.208276	-0.433248	0.085464	-1.427900
Kurtosis	5.698707	1.967155	2.019180	3.525753
Observations	615	676	680	681

Table 1c: descriptive statistics Spain

Spain	ELECTR	GAS	COAL	EUA
Mean	47.04520	19.44491	75.17475	14.97567
Maximum	78.25000	32.00000	141.9900	28.59000
Minimum	16.75000	7.750000	43.32000	7.900000
Standard Deviation	11.36557	5.784075	23.11332	3.940958
Skewness	0.476658	-0.389410	0.662373	1.470815
Kurtosis	2.766997	2.082931	3.156387	5.038921
Observations	617	440	680	547

For the low subsidy countries the descriptive statistics are mentioned in table 2a, b and c (a graphical overview of all data used is given in appendix A). Where similar conclusions for volatility and data availability can be drawn. This is why the same reasoning as with the high subsidy countries shall be followed and an unbalanced panel model shall be used. The only difference is that for coal the same market is used for all countries, but as the main focus will not be on the effect of coal on the electricity price and as the other variables used are different, it will still be incorporated and will not hamper the use of a panel model.

Table 2a: descriptive statistics France

France	ELECTR	GAS	COAL	EUA
Mean	51.51518	19.33578	75.17475	15.07158
Maximum	115.7500	32.00000	141.9900	28.73000
Minimum	16.00000	7.575000	43.32000	9.500000
Standard Deviation	16.23359	5.786997	23.11332	3.547957
Skewness	1.244072	-0.418764	0.662373	1.807302
Kurtosis	4.872840	2.045361	3.156387	6.096973
Observations	573	440	680	562

Table 2b: descriptive statistics Italy

Italy	ELECTR	GAS	COAL	EUA
Mean	69.37601	19.44491	75.17475	14.97567
Maximum	120.0000	32.00000	141.9900	28.59000
Minimum	48.55000	7.750000	43.32000	7.900000
Standard Deviation	12.05172	5.784075	23.11332	3.940958
Skewness	1.370562	-0.389410	0.662373	1.470815
Kurtosis	5.408573	2.082931	3.156387	5.038921
Observations	574	440	680	547

Table 2c: descriptive statistics Sweden

Sweden	ELECTR	GAS	COAL	EUA
Mean	50.82224	19.73018	75.17475	14.97567
Maximum	298.1600	34.80000	141.9900	28.59000
Minimum	8.490000	7.200000	43.32000	7.900000
Standard Deviation	19.62884	5.842521	23.11332	3.940958
Skewness	4.480230	-0.362502	0.662373	1.470815
Kurtosis	49.43456	2.189404	3.156387	5.038921
Observations	563	680	680	547

For abovementioned reasons and because of limitations in observed data points for several countries an unbalanced panel model will be used and the periods chosen for the analysis are as follows (*date notation: DD-MM-YYYY*):

→ High subsidy countries (DK, GE, SP), from 24-06-2008 to 10-11-2011

→ Low subsidy countries (FR, IT, SW), from 24-06-2008 to 10-11-2011

4 Model estimation & results

Making use of two groups of countries, a pooling of data is performed and a unbalanced panel estimation will be performed. Panel estimation can be done by using a fixed effect model or by using a random effects model. Because most certainly the independent variables used in (1) are not covering all factors that could affect the electricity price, the model could suffer from omitted variable bias and thus from correlation between the error term & independent variables (Pindyck & Rubinfeld, 1998). For this reason a fixed effects model is probably the better choice, as this model controls for omitted variables & correlation, by fixing the country effects (country dummies) and using the differences of the particular data points to the "within" a country mean (Pindyck & Rubinfeld, 1998). The Hausman test will be performed to see if it is actually better to use this model. Next to that, the "normal" daily price indices of coal, gas & EUA and their effect on the day ahead electricity price, should be taken into account. It is done so by adding a lag of 1 day on the day ahead electricity price when estimating the models. So that then the price indices on day *t* affect the day ahead of the day before, thus aligning the point in time that the independent factors is influence the dependant factor.

As mentioned in the descriptive statistics, there are differences in data availability that results in gaps in the daily data frequency. This is accounted for by a separate OLS estimation per country and in the panel estimation the data set is used as if it is an unbalanced panel data set.

Ordinary Least Squares results

As the fixed and random effects models both have their limitations and assumptions, first a simple Ordinary Least Squares (OLS) estimation for the separate countries is performed. Use shall be made of the lag of electricity prices as explained above and the period from 24-06-2008 to 10-11-2011. The results of the country specific OLS estimates are given in table 3.

When examining the coefficients of the high subsidy efficient countries in the normal "lagged" model (upper row for each country), it is seen that the coefficient for coal is not significantly different from zero and has a minor impact on the electricity prices. The gas price does however have a significant and positive influence on electricity prices, as expected. EUA price coefficients in the high subsidy countries show in aggregate a high significance, but give different signs.

Table 3: OLS coefficient estimates (lagged model)

Country	c	Gas	Coal	EUA
Denmark (obs: 497)	10.75931 *** (3.116162)	1.188800 *** (0.209473)	-0.020102 (0.064567)	1.247606 *** (0.256348)
Germany (obs: 609)	35.28921 *** (1.987320)	1.289389 *** (0.127082)	0.033397 (0.026327)	-1.007928 *** (0.080610)
Spain (obs: 498)	10.55480 *** (1.354519)	1.254667 *** (0.083016)	0.042191 (0.026122)	0.626101*** (0.112522)
France (obs: 429)	-1.464058 (2.512721)	2.563572 *** (0.203469)	-0.444848 *** (0.060353)	2.506702 *** (0.214165)
Italy (obs: 346)	30.21603 *** (1.781016)	1.440004 *** (0.145536)	-0.029913 (0.042861)	0.907762 *** (0.152707)
Sweden (obs: 456)	15.81840 *** (3.923988)	1.460291 *** (0.322211)	-0.200013 ** (0.095730)	1.430693 *** (0.350436)

Dependant variable is the day ahead base load electricity price.
*Standard errors in parentheses. ***, **, * are given when the estimate is significant at the 1%, 5% and 10% level respectively.*

Denmark with a coefficient of 1.25 shows a positive relationship between EUA price and the electricity price, where Spain shows a less positive effect and Germany shows even a strong negative sign of -1 of EUA. The reason for the differences in EUA affecting electricity prices can exist in the different fuel/technology mix these countries have, but also in the fact that the model should be estimated using a logarithmic model, as is often done when estimating models which make use of only prices. This logarithmic model hopefully also gives more significant estimates of the coal coefficients, and is easier to be interpreted.

Before going into the logarithmic model (using natural logarithms of all variables), first the low subsidy efficient countries will be looked at and compared with the other group, which could give a first glance already of the interaction effect mentioned in the theory part of this paper.

The coefficients of gas show similar signs compared to the high subsidy countries, as expected. For coal there are differences, being the significance of the coal estimates in France and Sweden which show a negative sign. Multiple reasons could exist, which shall not be elaborated on now, as our main focus is on the EUA effect. This EUA effect is in general more positive when comparing with the high subsidy countries, as is expected according to theory and which is an encouraging first result showing the interaction between subsidy and EUA could be in place. Creating a less positive (or even negative in the case of Germany) effect of the CO2 allowance price on electricity prices in the high subsidy efficient countries compared to the lower group.

Table 4: OLS coefficient estimates (lagged logarithmic model)

Country	c	LOG(Gas)	LOG(Coal)	LOG(EUA)	R^2
Denmark (log) (obs: 497)	1.518696 *** (0.134462)	0.337876 *** (0.050629)	0.103626 (0.063773)	0.353959 *** (0.048663)	0.491845
Germany (log) (obs: 609)	2.307499 *** (0.144280)	0.344398 *** (0.042288)	0.145359 *** (0.051268)	-0.038510*** (0.003329)	0.587856
Spain (log) (obs: 498)	1.740810 *** (0.108408)	0.435332 *** (0.036026)	0.075959 (0.047156)	0.186095 *** (0.038711)	0.606490
France (log) (obs: 429)	1.885693 *** (0.177891)	0.582595 *** (0.073937)	-0.248038 *** (0.093062)	0.514628 *** (0.064756)	0.443620
Italy (log) (obs: 346)	2.673751 *** (0.083030)	0.255285 *** (0.035886)	0.103013 ** (0.044573)	0.137047 *** (0.030753)	0.660519
Sweden (log) (obs: 456)	2.093478 *** (0.205912)	0.605812 *** (0.093741)	-0.434759 *** (0.112498)	0.694368 *** (0.080415)	0.311356

*Dependant variable is the natural logarithm of the day ahead base load electricity price. Standard errors in parentheses. ***, **, * are given when the estimate is significant at the 1%, 5% and 10% level respectively.*

The logarithmic model of the aforementioned lagged model (table 4) shows quite similar results for both country groups, and creates better significance for coal estimates, which is now significant in Germany and in Italy. It also decreases the differences between the EUA coefficients in both the high as the low subsidy groups. For the high subsidy countries the EUA coefficients show a slight positive influence on the electricity price, from 0.35 in Denmark to -0.038 in Germany. This is compared to the low country coefficient on EUA with a stronger positive relationship (0.69 for Sweden, 0.51 for France and 0.14 for Italy), indeed less positive and in line with the theoretical expectations. The negative sign of Germany hints, that there is indeed an interaction effect that creates an unexpected outcome when implementing this policy instrument. As policy makers probably expect a (strong) positive relationship between the allowance price and the electricity price, creating an incentive to generate less CO2 emitting power and incentivize renewable energy.

Panel estimation results (lagged model)

A general panel estimation was run (Panel Least Squares (PLS)), where no period or country is fixed, nor a random model is used. Afterwards other models shall be estimated and tested.

Resulting coefficients are found in table 5, in the first 2 rows. This general estimation already shows, compared to the separate country OLS and OLS with logarithms, that the coefficients on coal in both the high and low subsidy group have become significantly different from zero. Also the other coefficients remained their high significance as well and show almost the same coefficients compared to the OLS without logarithms.

Here also the comparison of the EUA coefficients between the high and low subsidy countries, clearly give estimates as was expected: a more positive sign of the low subsidy group (1.465680) relative to the high subsidy group (-0.251427). The latter group estimate is even depicting a negative sign, which is a stronger result as was expected by theory. What is unfolding is thus the different effect (or even opposite effect) that EUA prices and thus EU ETS may have on electricity prices, dependant on their subsidy effectiveness and implementation.

In trying to shed more light on this interaction effect and to check earlier found results, now also a fixed effect (holding countries fixed, by using dummies) and a random effects model shall be tested for. The results are given in row 3 & 4 of table 5 for the fixed effects estimation and row 5 & 6 of table 5 for the random effect estimation. Both the fixed effect, as well as the random effect estimates, give comparable significant results as the general estimates, and also result for the EUA in a negative sign for the high country group and a positive sign for the low country group.

It thus seems that indeed earlier found opposite relation for the high versus the low country group, between EUA prices and the electricity price is valid. Although both the fixed and random effect model give highly significant estimates, the random effect model results in lower R^2 values, which could indicate that this model is not the most optimal to use.

Table 5: PLS coefficient estimates, general, fixed and random effects model (lagged model)

Country	c	Gas	Coal	EUA	R^2
High (obs: 1604)	20.25235 *** (1.279274)	1.285450 *** (0.068338)	0.099494 *** (0.014827)	-0.251427 *** (0.061669)	0.421397
Low (obs: 1231)	14.72458 *** (2.115851)	1.674210 *** (0.171979)	-0.17039 *** (0.050895)	1.465680 *** (0.183244)	0.276165
High F.E. countries (obs: 1604)	20.39433 *** (1.281919)	1.244209 *** (0.085037)	0.111234 *** (0.020987)	-0.275613 *** (0.068997)	0.429704
Low F.E. countries (obs: 1231)	14.42047 *** (1.791599)	1.801284 *** (0.146228)	-0.224422 *** (0.043330)	1.598289 *** (0.155413)	0.483371
High Random effects	20.84487 *** (1.397051)	1.301983 *** (0.073709)	0.094541*** (0.015073)	-0.292726*** (0.057882)	0.354225

(obs: 1604)					
Low Random effects (obs: 1231)	15.37041*** (2.300722)	1.649862*** (0.185489)	-0.163890 *** (0.055103)	1.417309 *** (0.199815)	0.230539

Dependant variable is the day ahead base load electricity price.
*Standard errors in parentheses. ***, **, * are given when the estimate is significant at the 1%, 5% and 10% level respectively.*

Hausman test

In order to be sure to use the correct panel model estimation and as the random effects model results in quite low R^2 values, a Hausman test is performed on the above random and fixed effect coefficient estimates. Because the random effects model, quite strictly, assumes there is no correlation between independent variables and the error term and also assumes that all variables explaining the change in electricity price are included in the model, the Hausman test shall guide us into the random or fixed model direction. It does so by comparing the fixed and random effect estimates and tests whether the errors are correlated with the independent variables (Wooldridge, 2007).
The null hypothesis is that they are NOT correlated and thus if H0 is not rejected, a random effects model should be used (Wooldridge, 2007). Use is made of the Chi-square probability given by the test, which should be $p < 0.05$ to reject Ho, and to use a fixed effect model.

Chi-square probabilities of the Hausman test for the "fixed and random effects model" above in table 5 are:

- High group: $p = 0.0007$
- Low group: $p = 0.0659$

For the high country group a fixed effect model should be used, while for the low country group a random model may be used (probability only slightly higher than $p= 0.05$). So because of this and for comparison, both models shall be used for both groups and as this paper is comparing differences in estimates and not concluding on an exact estimate, this will also be done for the remainder of the tests (of course giving the Hausman probabilities, to see if given statement is still valid).

Panel estimation results (lagged logarithmic model)

Applying the same rational for testing with natural logarithms of the dependant and independent variables as above with the separate country OLS, now the logarithmic fixed effects and random effects model shall be tested, resulting in estimates given in table 6.

At first glance, it can directly be seen that R^2 values for both models and both groups have increased.

Table 6: PLS coefficient estimates, fixed & random effects model (lagged logarithmic model)

Country	c	LOG(Gas)	LOG(Coal)	LOG(EUA)	R^2
High F.E. countries (obs: 1604)	1.942878 *** (0.076010)	0.318534 *** (0.024929)	0.247685 *** (0.028912)	-0.033573 *** (0.003251)	0.533559
Low F.E. countries (obs: 1231)	2.203188 *** (0.102208)	0.501345 *** (0.044385)	-0.214716 *** (0.054774)	0.460303 *** (0.038354)	0.522514
High Random effects (obs: 1604)	2.082121 *** (0.068586)	0.399097 *** (0.019987)	0.155898 *** (0.020395)	-0.021597 *** (0.002716)	0.442517
Low Random effects (obs: 1231)	2.094713 *** (0.132732)	0.445275 *** (0.057352)	-0.128656 * (0.070715)	0.423886 *** (0.049801)	0.285149

*Dependant variable is the natural logarithm of the day ahead base load electricity price. Standard errors in parentheses. ***, **, * are given when the estimate is significant at the 1%, 5% and 10% level respectively.*

The fixed effect estimates (row 1 & 2) show a significant positive relationship of gas prices for both groups of countries and both have a positive intercept. When gas prices go up with 1%, then electricity prices will go up by 0.32 % and by 0.5% in the high and low country group respectively. The coal prices show a mixed result for the two groups, which could mean that the low group countries use less coal intensive technologies and maybe more gas (as there the coefficient is higher for the low group). This will not be elaborated on, as the coefficient of main interest, is the EUA estimate.

EUA estimates make clear that earlier found opposite signs for the two country groups, still hold. And although the absolute difference between the two estimates is smaller, it still gives opposite significant signs and a stronger effect of EUA prices on electricity prices for the low group. The estimate for the high subsidy group concludes that a 1% change in CO_2 allowances creates a 0.034% decrease of the electricity price, and for the low subsidy group a 1% change creates a 0.46% increase in the electricity price.

Random effect estimates from table 6 (row 3 & 4) have similar results, and also result in opposite signs of the EUA coefficient for the two groups. The choice of model, in this case thus makes no difference in the comparison and correctness of the earlier found results. Hausman tests conclude that in this lagged logarithmic model it is better to use the fixed effect model for both groups (Chi square probabilities < 0.05, that is $p = 0$ and $p = 0.0463$ for the high group and low group respectively), so also therefore no further interpretation of the random model is performed.

Further testing: peak load day ahead prices

Until now the base load day ahead electricity price was used and tested for, but now the peak load day ahead electricity prices will be viewed and checked for results (using the same period). This is done to further strengthen the correctness of earlier found results.

A problem though with this data is that only Germany (EEX) and France (PPX) give peak load prices (both retrieved from Bloomberg database; graphical overview given in appendix B). That is why only an OLS is performed, and results of it will be compared between these two countries. The results of the lagged and the lagged logarithmic estimates are given in table 7 and 8. In table 7 it can be viewed that in peak load prices, similar results are shown as earlier EUA estimates, albeit higher in absolute value. France gives a significantly high positive effect of EUA prices (3.856617) on the electricity price, where subsidy efficient Germany gives a significant negative effect (-1.827603).

Table 7: OLS coefficient estimates (lagged model)

Country	c	Gas	Coal	EUA
Germany (obs: 583)	53.87584 *** (2.576798)	1.342081 *** (0.164342)	0.030120 (0.034080)	-1.827603*** (0.105311)
France (obs: 323)	-7.030372 * (3.738941)	2.995484 *** (0.297754)	-0.584433 *** (0.090203)	3.856617 *** (0.317489)

Dependant variable is the day ahead peak load electricity price.
*Standard errors in parentheses. ***, **, * are given when the estimate is significant at the 1%, 5% and 10% level respectively.*

Table 8: OLS coefficient estimates (lagged logarithmic model)

Country	c	LOG(Gas)	LOG(Coal)	LOG(EUA)	R^2
Germany (log) (obs: 583)	2.796552 *** (0.146097)	0.280140 *** (0.041951)	0.121780 ** (0.051365)	-0.057281 *** (0.003387)	0.625562
France (log) (obs: 323)	1.878378 *** (0.204176)	0.462015 *** (0.080775)	-0.179734 * (0.104196)	0.619370 *** (0.072278)	0.457819

Dependant variable is the natural logarithm of the day ahead peak load electricity price.
*Standard errors in parentheses. ***, **, * are given when the estimate is significant at the 1%, 5% and 10% level respectively.*

In table 8 this is seen as well, with high positive influence of the EUA price on electricity prices in France compared to zero or negative effect of the EUA price in Germany. All thus confirming the signs found in the base load day ahead price model estimations.

Further testing: different period, base load day ahead prices

Now further PLS estimation is performed on a different period, to be sure that the relationship found earlier is not period dependant. The period chosen for this is 25-02-2009 to 10-11-2011, as this period shows more stable EUA prices (see figure 4 and 5).

The results of performing the exact same PLS estimation as in table 5, are given in table 9. The panel estimation is without using a Hausman test, as the results are only used for comparison with earlier estimates. It becomes immediately clear that the high subsidy country group estimate for EUA is not significantly different from zero. What could mean that the found negative relationship between EUA prices and electricity prices, could also be more or less zero in other periods. More sophisticated econometric models could give more insight in this and a longer test period could also help to check the results. But for the comparison used here with the low subsidy country group, it does have no implications. The main conclusion remains also in table 9: the low subsidy group shows a more positive influence of EUA prices on electricity prices, than the high country group. This is true for all PLS estimations given, where the fixed effect model has the highest R^2 (0.318626 and 0.355361 for the high and low subsidy group respectively) and also the biggest difference in coefficient estimate, that is 0.043169 for the high group and 0.766100 for the low group.

Earlier made comparison conclusions on the EUA coefficient estimate are thus valid, albeit that given negative sign for high countries could be closer to zero than actually being negative. This last is also more intuitive, as a negative sign means a decrease in electricity prices when EUA prices rise. But as also stated earlier, it is not the goal of this paper to make conclusions on the sign.

Table 9: PLS coefficient estimates, general, fixed and random effects model (lagged model)

Country	c	Gas	Coal	EUA	R^2
High (obs: 1243)	23.21062 *** (2.490474)	1.028367*** (0.085824)	0.052337 *** (0.019602)	0.039962 (0.172570)	0.296774
Low (obs: 1038)	26.44217*** (4.212467)	1.300616 *** (0.266224)	-0.078528 (0.081167)	0.603272 ** (0.293624)	0.121629
High F.E. countries (obs: 1243)	23.43643 *** (2.492947)	1.037370 *** (0.147636)	0.046986 (0.039648)	0.043169 (0.170524)	0.318626
Low F.E. countries (obs: 1038)	25.66425 *** (3.618143)	1.495099 *** (0.231060)	-0.149321 ** (0.070596)	0.766100 *** (0.251936)	0.355361
High Random effects (obs: 1243)	23.18398 *** (2.524441)	1.032422*** (0.085470)	0.051747 *** (0.019337)	0.040097 (0.174885)	0.288944
Low Random effects (obs: 1038)	29.39299 *** (4.779043)	1.374929 *** (0.291516)	-0.106011 (0.089087)	0.432742 (0.333293)	0.088799

Dependant variable is the day ahead base load electricity price.
*Standard errors in parentheses. ***, **, * are given when the estimate is significant at the 1%, 5% and 10% level respectively.*

Estimation is now done for the same logarithmic lagged model as given in table 6, by using the period from 25-02-2009 to 10-11-2011. These results are seen in table 10 and point out in an exact same way that EUA coefficients of the high country group is not significantly different from zero. But they also show that here the same relation holds as was seen earlier: high subsidy countries' electricity prices are less affected by EUA prices than low subsidy countries.

Table 10: PLS coefficient estimates, fixed & random effects model (lagged logarithmic model)

Country	c	LOG(Gas)	LOG(Coal)	LOG(EUA)	R^2
High F.E. countries (obs: 1243)	2.032587 *** (0.139207)	0.236249 *** (0.039378)	0.248970 *** (0.050429)	0.010794 (0.037050)	0.455389
Low F.E. countries (obs: 1038)	2.220120 *** (0.195639)	0.390734 *** (0.057198)	-0.089269 (0.072014)	0.368947 *** (0.058260)	0.425761
High Random effects (obs: 1243)	2.222893 *** (0.124397)	0.322554 *** (0.023679)	0.141780 *** (0.024905)	0.022542 (0.042084)	0.373079
Low Random effects (obs: 1038)	2.127674 *** (0.252107)	0.319471 *** (0.073393)	0.012490 (0.092244)	0.317618*** (0.075539)	0.149713

*Dependant variable is the natural logarithm of the day ahead base load electricity price. Standard errors in parentheses. ***, **, * are given when the estimate is significant at the 1%, 5% and 10% level respectively.*

The further testing and estimating confirm the estimated relationship found in table 5 & 6 and validates the conclusion made there. But more advanced econometric techniques are necessary to be able to state anything on the correctness of the EUA coefficient estimate sign.

5 Concluding remarks

In assessing the interaction of two different policy instruments, by using the electricity market as main stage, it can be concluded after OLS and panel estimation that the interaction between subsidies and EUA prices is mixed and probably dependant on the subsidy scheme in a country and the effective implementation of it.

One the one hand it can be seen that in a country with large subsidy efficiency the EUA has a less positive impact (or even negative impact) on the electricity price than in a less subsidy efficient country. This is created through the "over performance" of the subsidy, that created strong growth in wind energy, but that thus also caused a decrease of efficiency of the other policy instrument, that is the EU ETS.

On the other hand it can be seen that in a country where the subsidy was less efficient, the EUA price did have a strong positive influence on the electricity price. Leading to the following line of argumentation: In a country where little wind generation exists and little subsidy is used to incentivize firms to generate wind electricity, EU ETS creates an incentive that does affect these firms and can create cleaner investment decisions for future generation capacity. The problem with this argumentation is however, that the investment costs of installing new wind capacity is higher than investing in carbon emitting efficiency technologies, and will thus not happen soon.

In that way the wind energy subsidy does seem a good instrument, as it targets directly those firms and technologies (instead of indirect effect of EUAs), creating a direct benefit of investing in wind energy and not in carbon efficiency.

But with this last it is seen in the analysis and in empirics, that the one policy instrument weakens the other or can create different unexpected outcomes. Which in the end can lead to low EUA prices and creates skewed outcomes towards using EUAs only for the most polluting generation technologies. Whether this extreme case of using EUAs only for the most CO2 intensive technologies, is actually taking place cannot be said here. Mainly as then the generation mix of a country should be analyzed and a different model should be used. But it **is** seen that there is a weakened effect of EU ETS (via EUAs) on electricity prices in the high subsidy countries. Which may be a first sign that indeed CO2 prices are less demanded in this group and only used for a few most CO2 intensive generators.

This paper has shown that there is interaction between wind subsidy and EUAs, which can cause unwanted policy outcomes, where in subsidy efficient countries the EU ETS effect on electricity prices is decreased by an effective wind energy subsidy. How much this interaction actually distorts the wanted outcomes of reducing CO2 emissions and how large the interaction is, cannot be concluded here and needs further empirical research. What becomes clear is that for wind energy policy and EU ETS to be effective next to each other, the aforementioned effect and mechanism on the electricity market of both instruments should be analyzed and taken into account, to prevent overlapping policies OR even counteracting policies.

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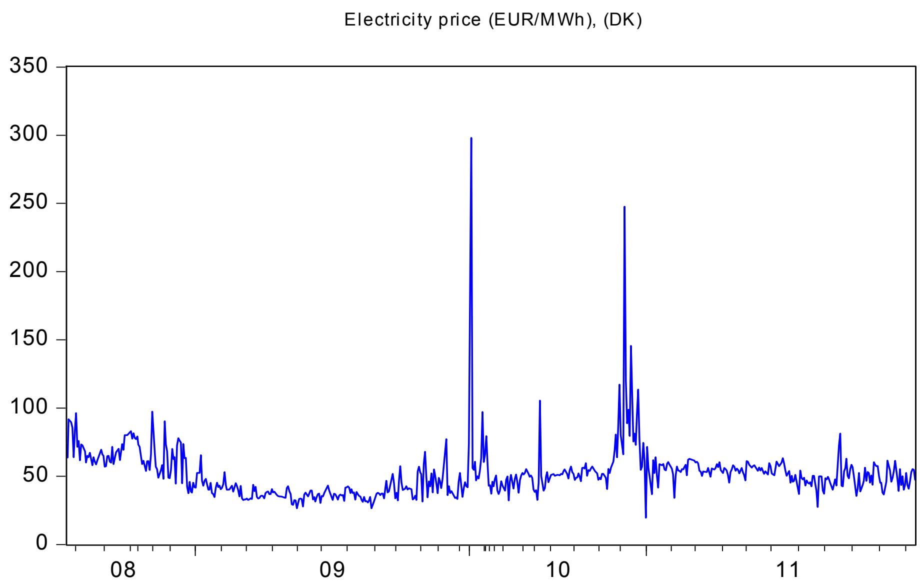
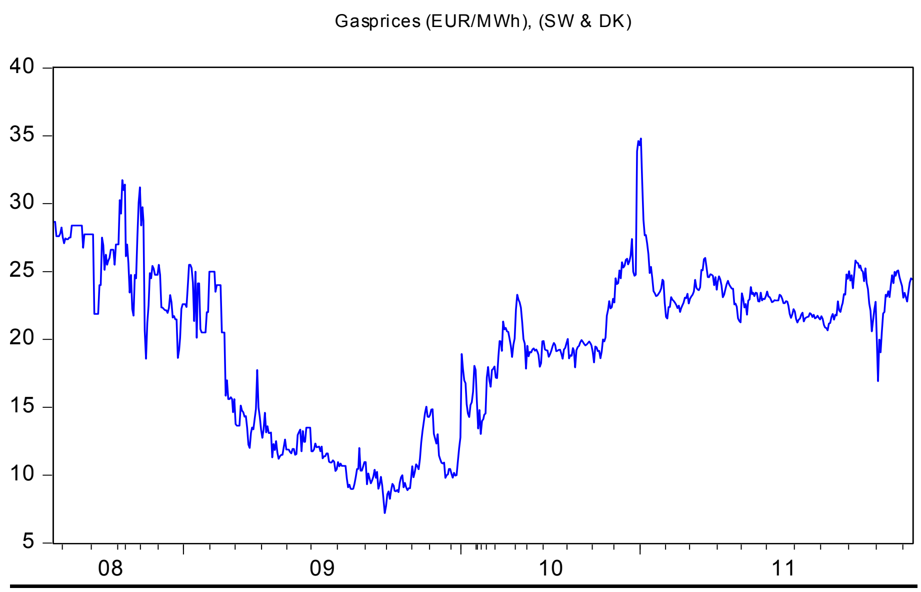
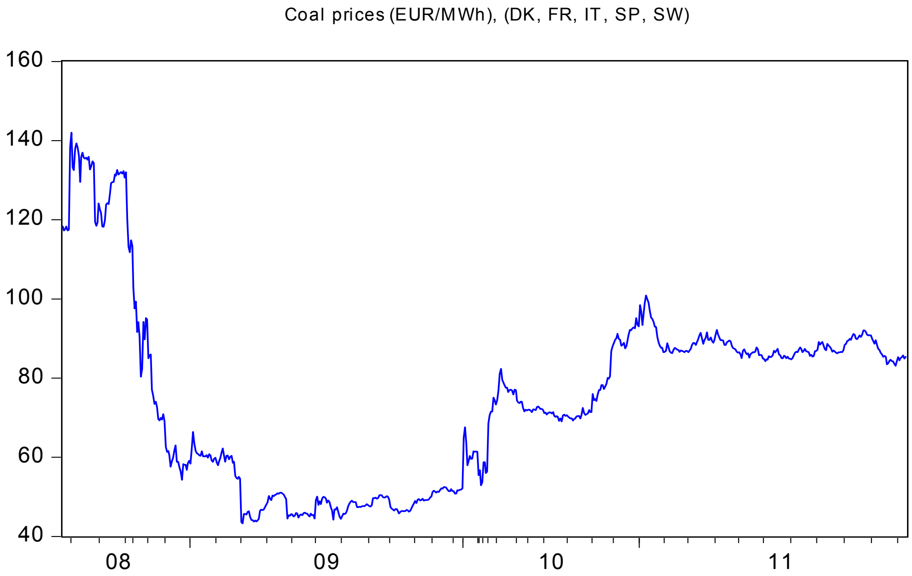
Appendix A

Graphs, all data; price on vertical axis and year on horizontal axis

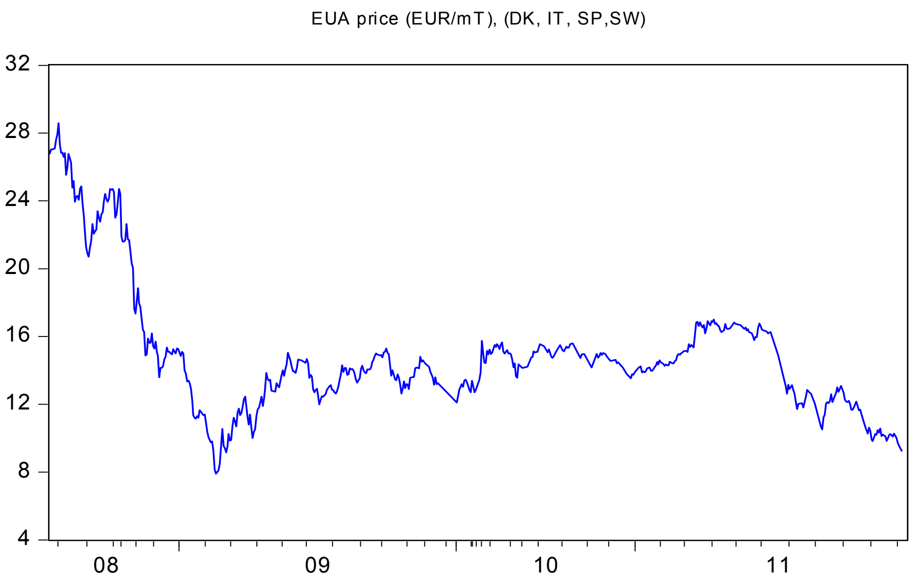
Denmark (DK)





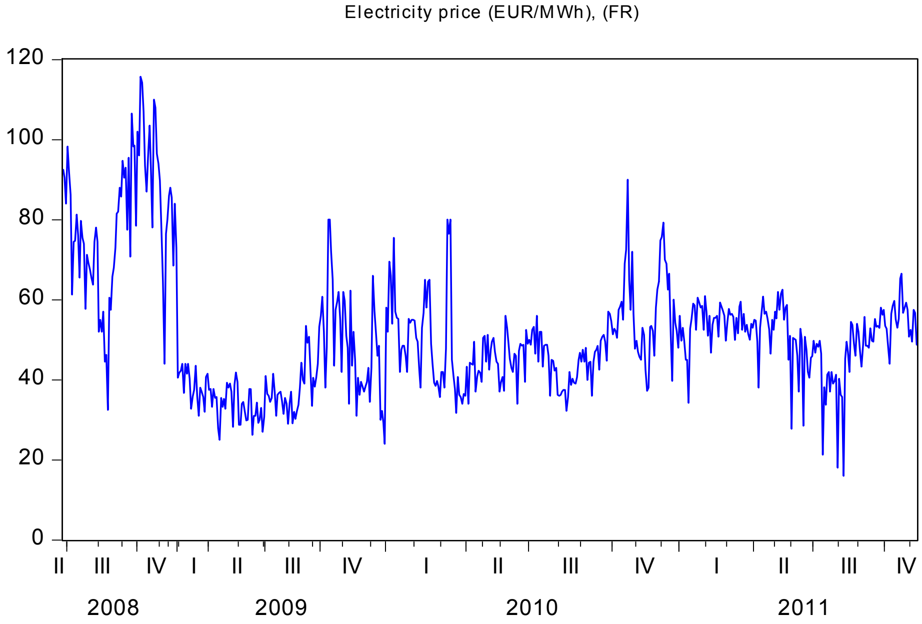


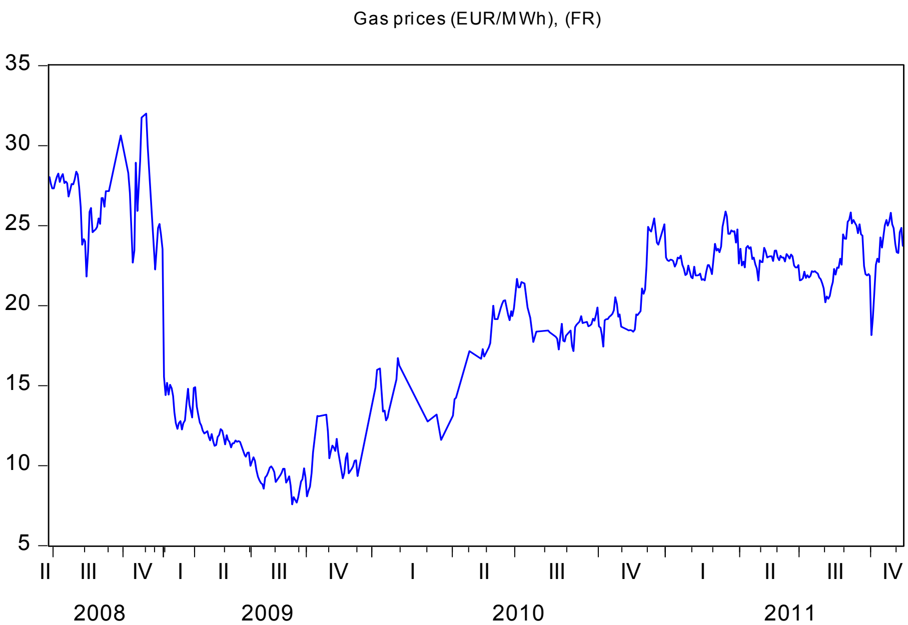
Coal prices (EUR/MWh), (DK, FR, IT, SP, SW)
160
140
120
100
80
60
40
08
09
10
11



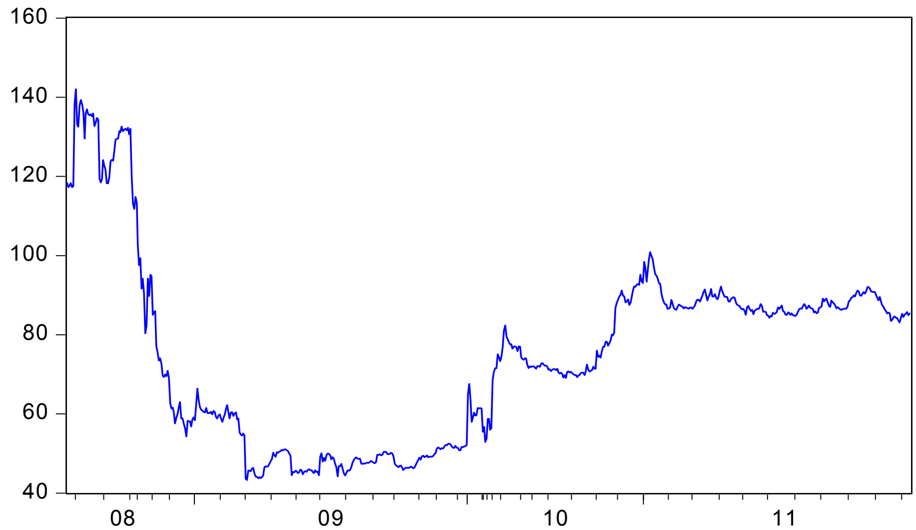
EUA price (EUR/mT), (DK, IT, SP,SW)
32
28
24
20
16
12
8
4
08
09
10
11

France (FR)

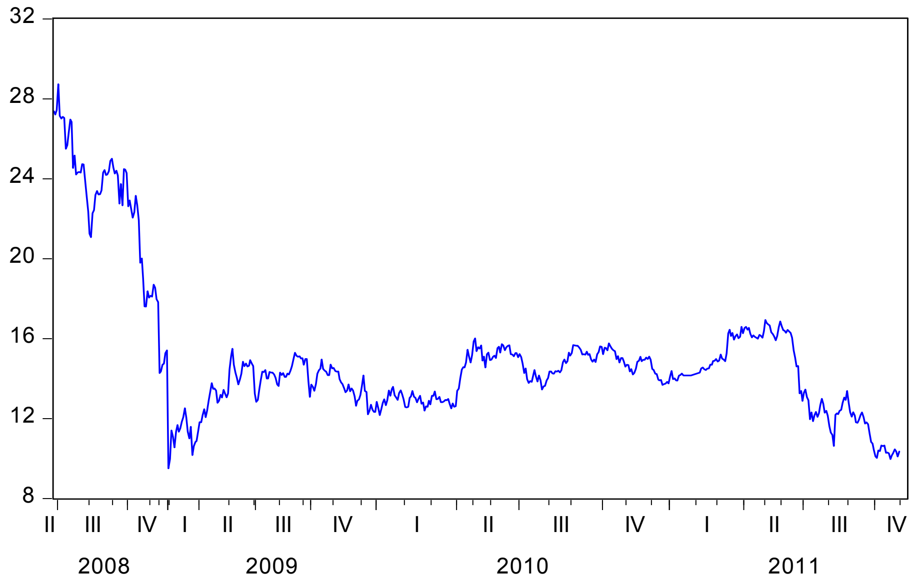

Electricity price (EUR/MWh), (FR)
120
100
80
60
40
20
0
II III IV I II III IV I II III IV I II III IV
2008 2009 2010 2011


Gas prices (EUR/MWh), (FR)
35
30
25
20
15
10
5
II III IV I II III IV I II III IV I II III IV
2008 2009 2010 2011

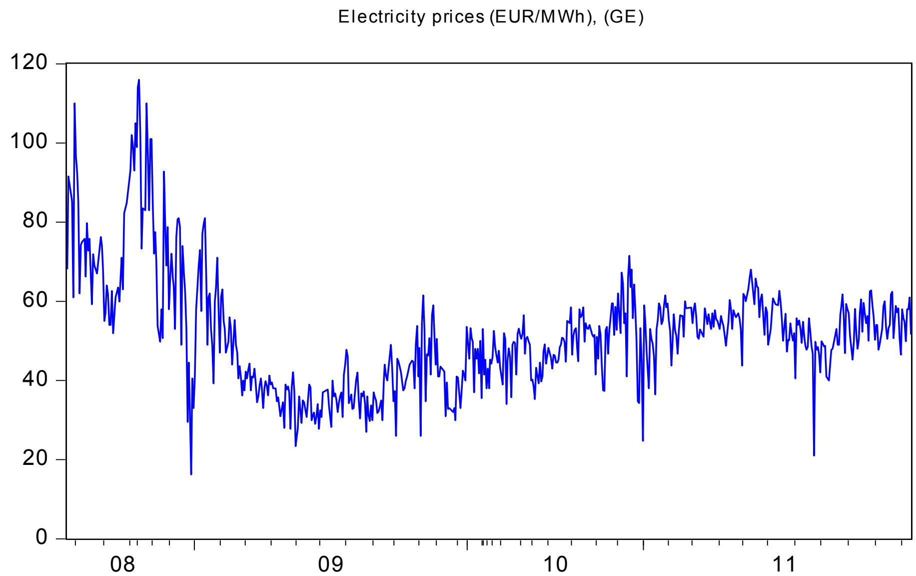
Coal prices (EUR/MWh), (DK, FR, IT, SP, SW)



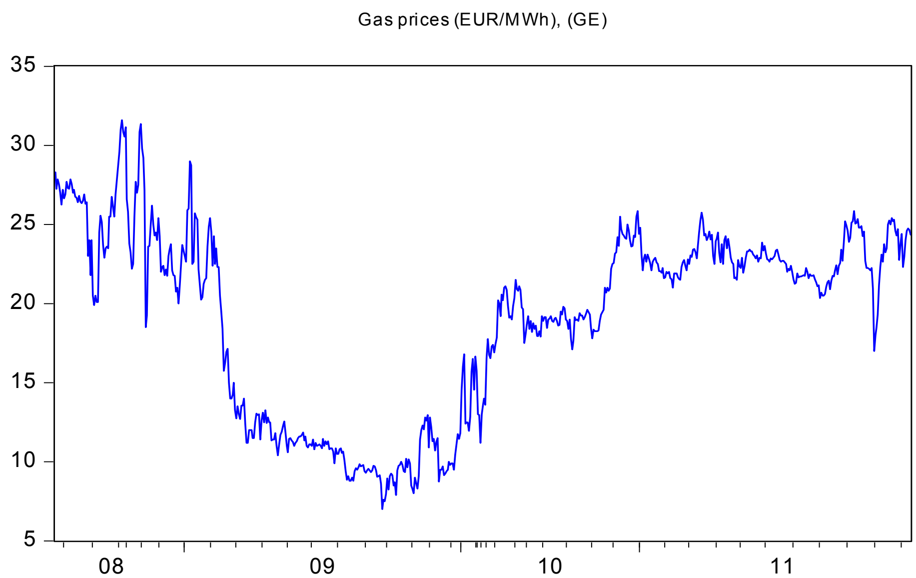
EUA prices (EUR/mT), (FR)



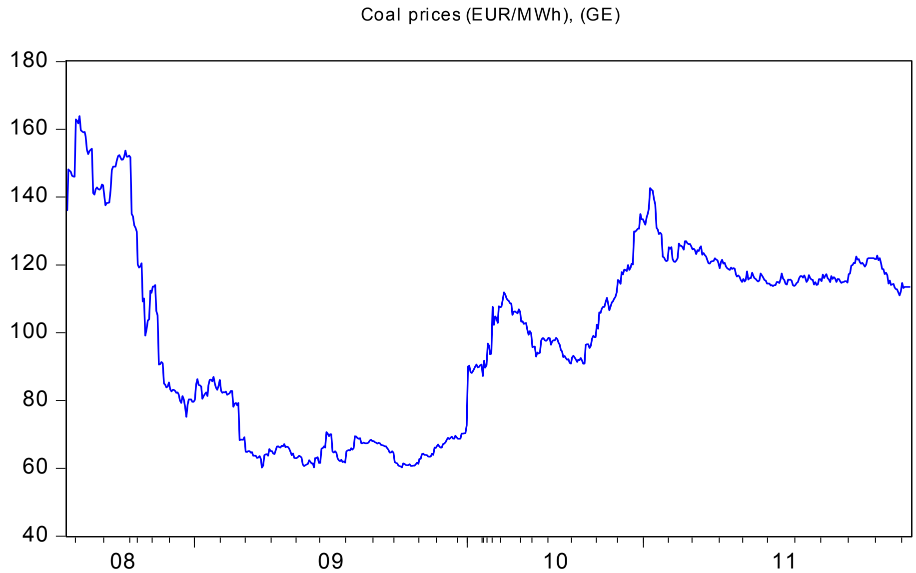
Germany (GE)

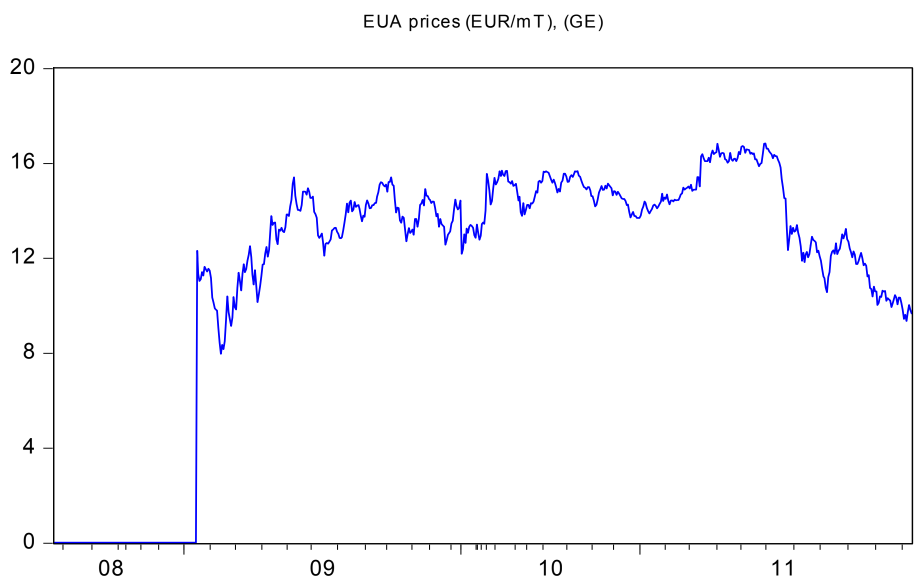


Electricity prices (EUR/MWh), (GE)
120
100
80
60
40
20
0
08
09
10
11

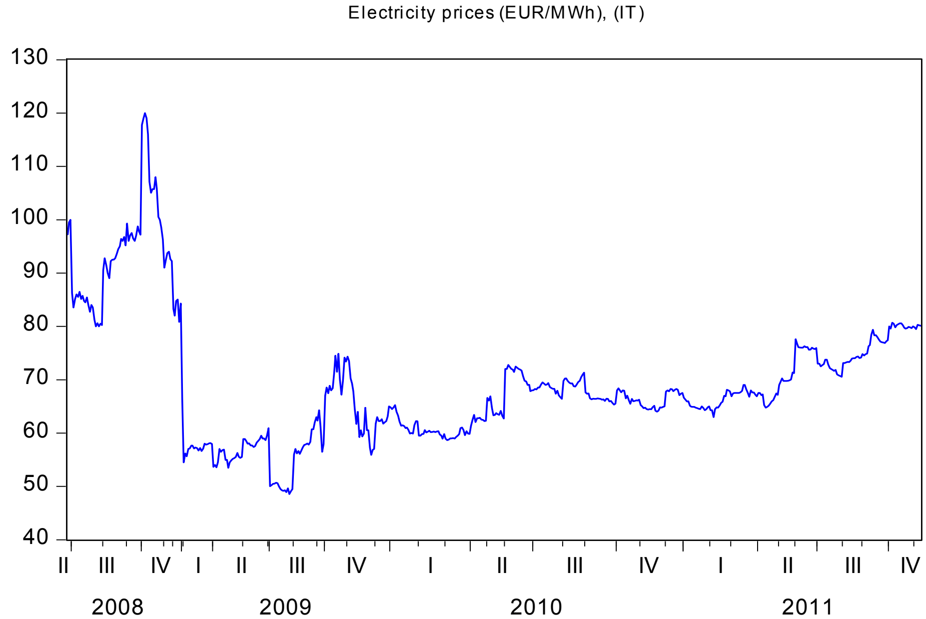


Gas prices (EUR/MWh), (GE)
35
30
25
20
15
10
5
08
09
10
11

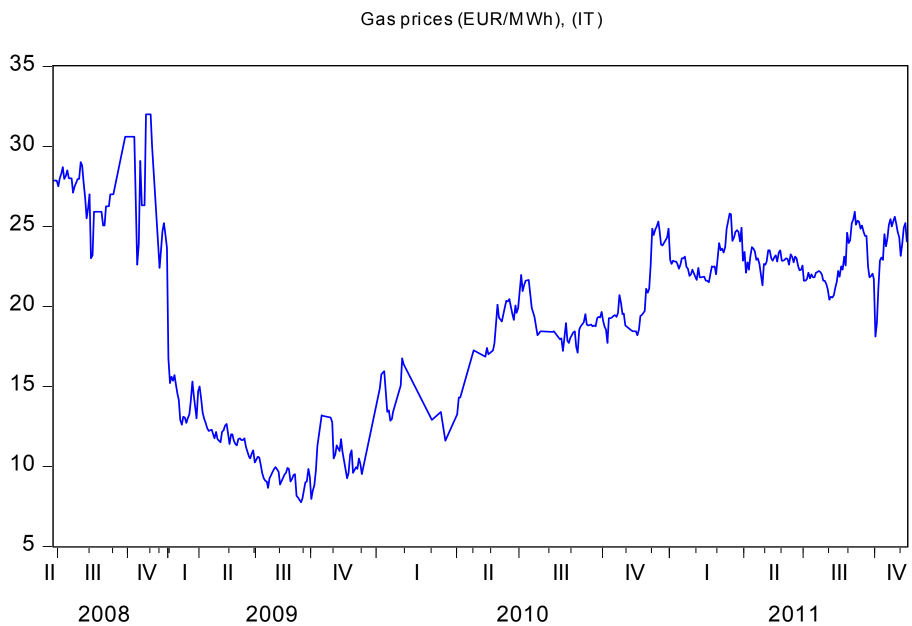

Coal prices (EUR/MWh), (GE)
180
160
140
120
100
80
60
40
08
09
10
11


EUA prices (EUR/mT), (GE)
20
16
12
8
4
0
08
09
10
11

Italy (IT)

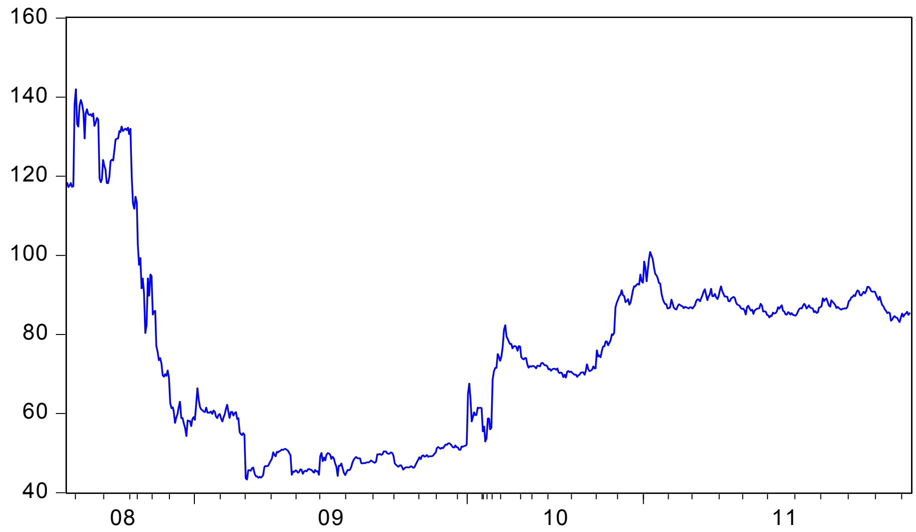


Electricity prices (EUR/MWh), (IT)
130
120
110
100
90
80
70
60
50
40
II III IV I II III IV I II III IV I II III IV
2008 2009 2010 2011

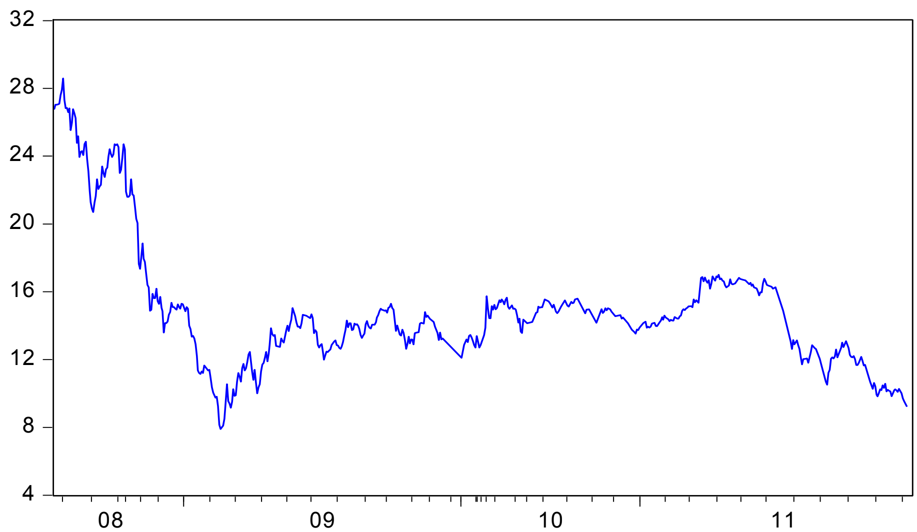


Gas prices (EUR/MWh), (IT)
35
30
25
20
15
10
5
II III IV I II III IV I II III IV I II III IV
2008 2009 2010 2011

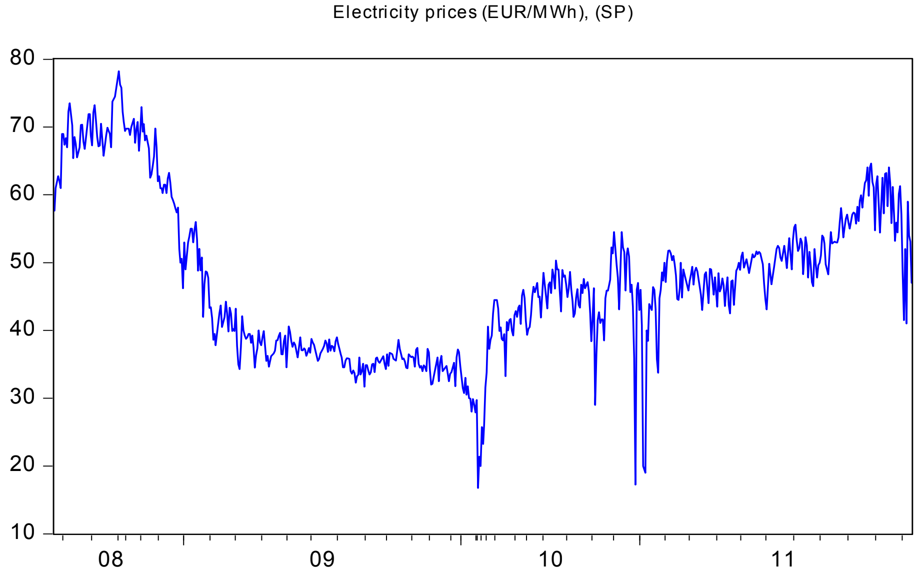
Coal prices (EUR/MWh), (DK, FR, IT, SP, SW)

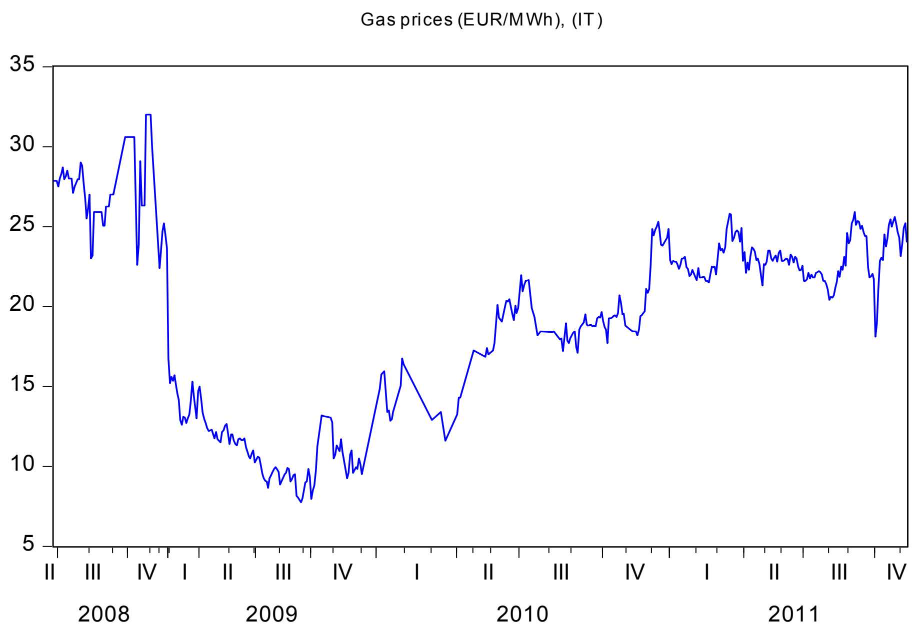


EUA price (EUR/mT), (DK, IT, SP,SW)

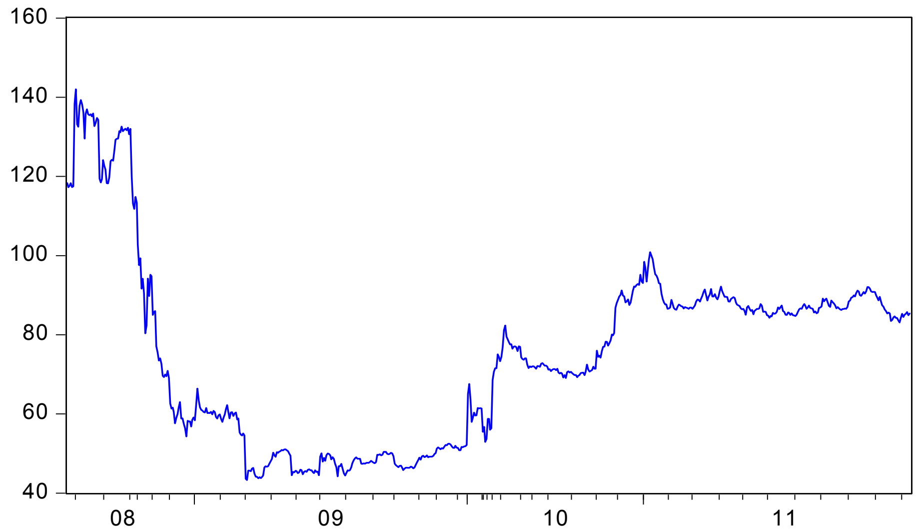


Spain (SP)

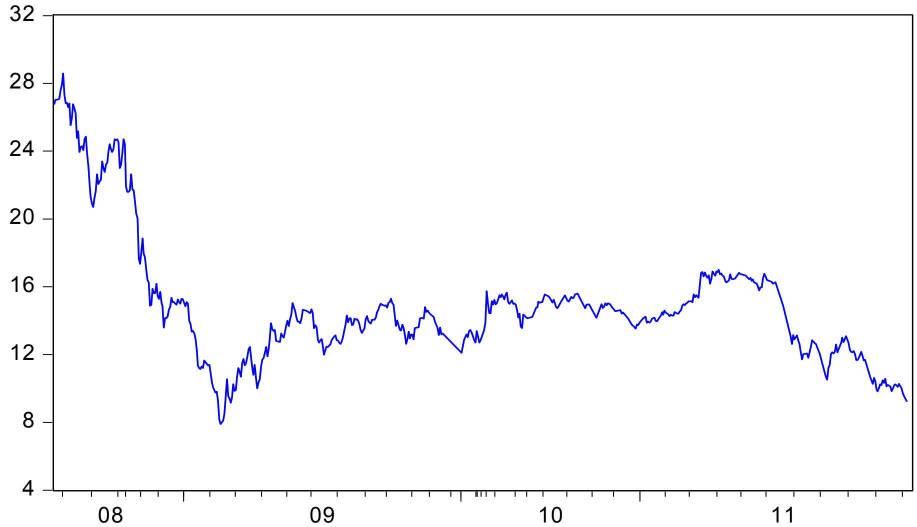

Electricity prices (EUR/MWh), (SP)
80
70
60
50
40
30
20
10
08
09
10
11


Gas prices (EUR/MWh), (IT)
35
30
25
20
15
10
5
II
III
IV
I
II
III
IV
I
II
III
IV
I
II
III
IV
2008
2009
2010
2011

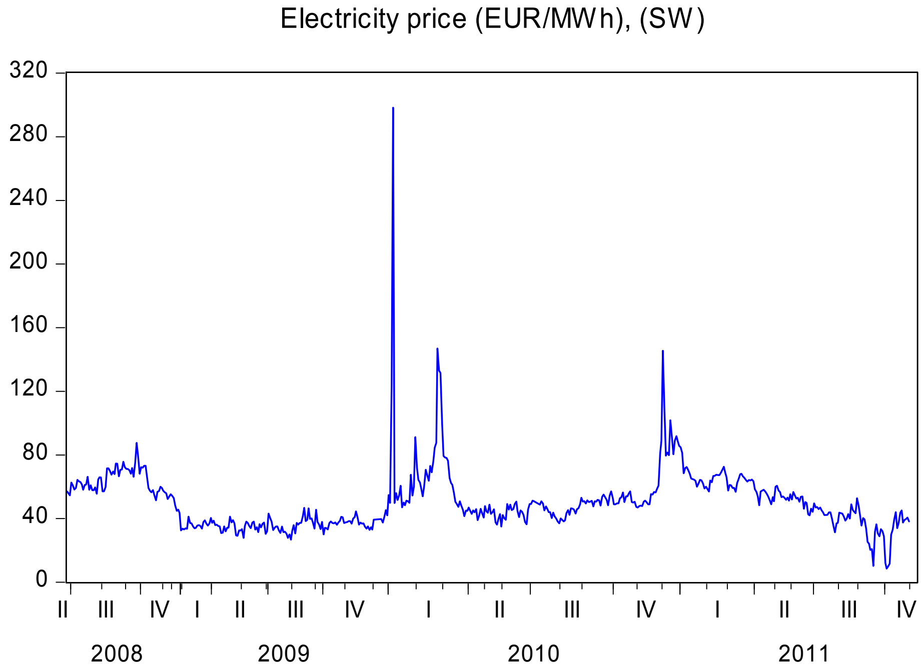
Coal prices (EUR/MWh), (DK, FR, IT, SP, SW)



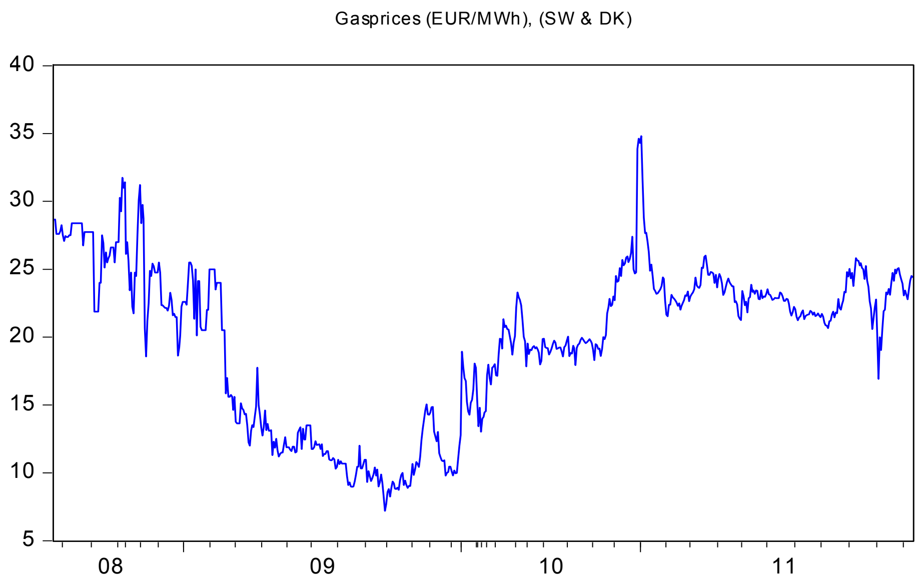
EUA price (EUR/mT), (DK, IT, SP,SW)



Sweden (SW)

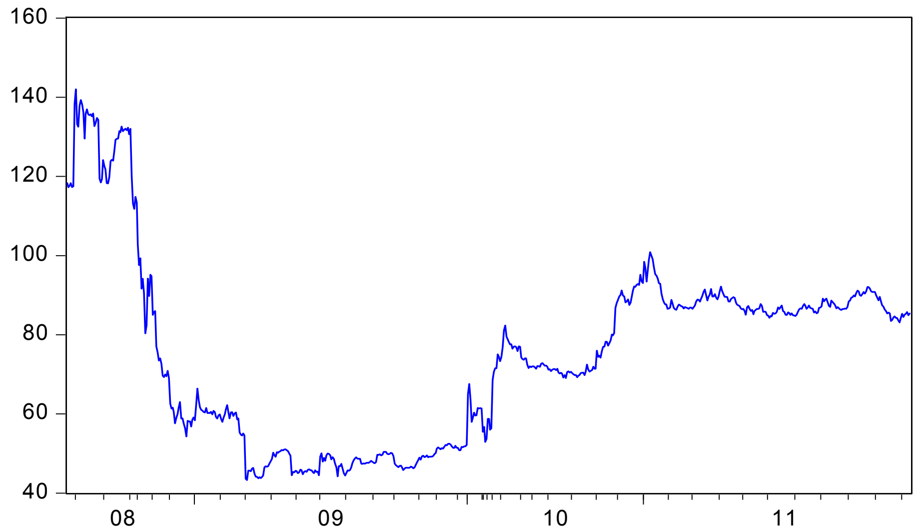


Electricity price (EUR/MWh), (SW)
320
280
240
200
160
120
80
40
0
II III IV I II III IV I II III IV I II III IV
2008 2009 2010 2011

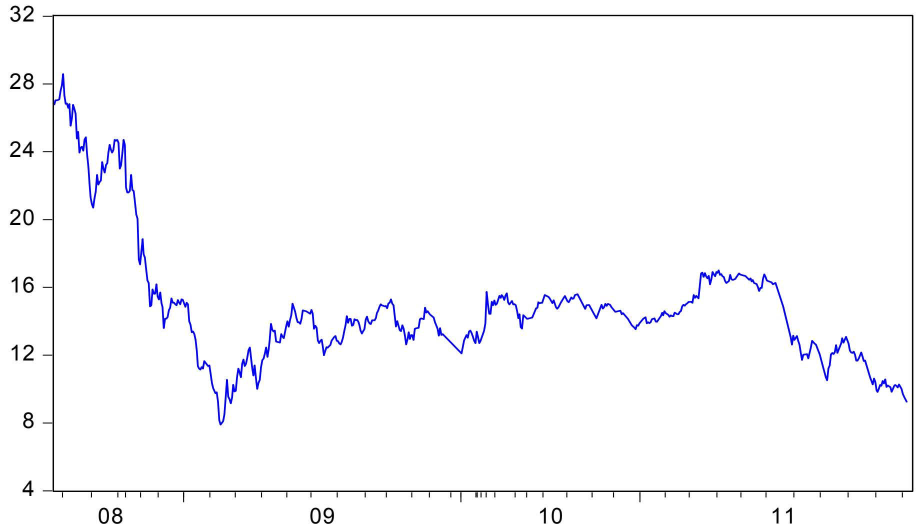


Gasprices (EUR/MWh), (SW & DK)
40
35
30
25
20
15
10
5
08 09 10 11

Coal prices (EUR/MWh), (DK, FR, IT, SP, SW)

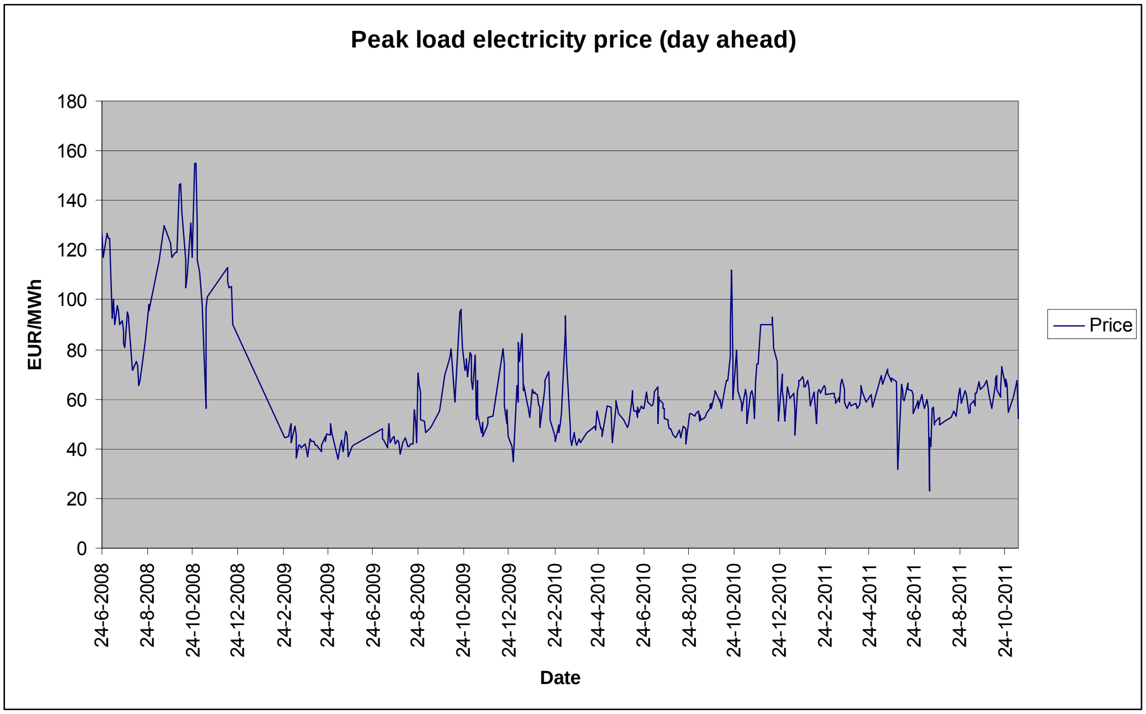


EUA price (EUR/mT), (DK, IT, SP,SW)



Appendix B

France: peak load electricity price



Germany: peak load electricity price