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The determinants of allowance prices in the European Emissions Trading Scheme - Can we expect an efficient allowance market 2008?

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Abstract:

The European emissions trading scheme (EU-ETS) for CO_2 is the largest existing emissions trading scheme in the world. The main reason for the implementation of this scheme is to reach the European Kyoto targets at minimal cost and to establish a price for emissions. The right to emit CO_2 therefore becomes a scarce production input. In this paper we want to analyze the determinants of the price for allowances in the EU-ETS and study whether it reacts to fundamental influence factors such as energy prices. The results show, that as long as the market viewed the allowances as a scarce input factor, the price reacts to changes in energy prices and weather variations.

Keywords: European Emissions Trading Scheme, allowance prices, energy prices, weather variation

JEL classification: C22, Q56, Q58, Q54

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1 Introduction

The European emissions trading scheme (EU-ETS) is the largest existing emissions trading scheme in the world. It was implemented to reach the European Kyoto targets efficiently at minimal cost and to establish a price for emissions. It covers the CO_2 emissions of around 12.000 installations in energy activities, the production and processing of ferrous and non-ferrous metals, the mineral industry and the pulp, paper and board production. The EU-ETS officially started 1st January 2005. For the first trading period from 2005 to 2007 about 2.2 Gt CO_2 have been allocated annually to the installations covered by the EU-ETS. The period is seen as a test period for the second trading period from 2008 - 2012 that coincides with the first Kyoto commitment period. This raises the question, whether the EU-ETS passed the test and showed evidence for an efficient market. In other words, the question is: What determined the price for allowances in the EU-ETS? Besides shedding some light on the question whether the price reflects market fundamentals or whether it is seriously distorted, this question is also important for the companies that have to manage their emissions.

So far only few studies have tried to analyze EU-ETS prices and market efficiency. There are some price estimates from numerical simulations models, that try to simulate the allowance price before the start of the trading scheme (Klepper and Peterson 2004; Capros and Mantzos 2000; Criqui and Kitous 2003) and when first information on the allocation was already known (Klepper and Peterson 2006). The resulting allowance prices in these studies vary between 6 Euro and 35 Euro per ton of CO_2 depending on the model and the scenario. This is about the range of the actual prices as well, but these models only simulate equilibrium prices and neither want nor can explain price fluctuations over time.

Two other studies (Borak, Härdle, Trück, and Weron 2006; Paolella and Taschini 2006) investigate the pattern of the EU-ETS market focussing on the term structure between future and spot prices of allowances and their stochastic properties. Borak et al. (2006) use the concept of convenience yields for commodities and claim CO_2 emissions as a scarce input factor. They find though that the emission allowance price behavior differs from those of other commodities, changing in the first period from backwardation to-

wards contango[1]. The study of Paolella and Taschini (2006) covers the EU-ETS market and the U.S. Clean Air Act Amendments and focusses mainly on the tail behavior and the heteroscedastic dynamics in the returns of the emissions allowances in order to investigate hedging and purchasing strategies. In their introduction the authors argue that movements in the market price for oil or gas are not sufficiently reflected in the price movements for allowances. "It turns out that any price scenario delineation based on the trend analysis of a few variables considered as proxies for the fundamentals that affect the supply-side cannot suffice. One might consider implementing the fundamental analysis into the mean equation of the return process and use GARCH-type structures,..., for the variance equation, though we leave such ideas for future possible research,"(Paolella and Taschini 2006, pp. 12-13). Both studies build to some extend on the studies of Bailey (1998) and Montero and Ellerman (1998). The former study explains the concept of convenience yields and looks for the implication for the U.S. SO_2 allowance market. The study of Montero and Ellerman (1998) explains the low sulfur dioxide price with an unanticipated decline of emissions due to the cost-based market penetration of low sulfur western coal. All studies provide evidence that via the introduction of an emissions trading scheme emissions become a scarce production input so that price determination mechanisms of other commodities can be used to explain the price behavior of allowances. Yet, the study of Borak et al. (2006) shows that the allowance market differs from existing commodity markets with respect to its term structure. For the early period of the EU-ETS the liquidity and efficiency of the future and forward market may therefore be doubted. Nevertheless, Manasanet-Bataller, Pardo, and Valor (2007) tried econometrically estimate the effects of some determinants of ETS daily forward prices for the year 2005. The explaining variables are oil, natural gas and coal prices. The study also includes weather variables, which are generally seen as an important determinant of allowance prices. The relation between weather variations and emission was also proved by Considine (2000), who shows that higher heating degree days and greater cooling requirements have a significant impact on energy consumption and therefore on

[1]When the future price at point t with delivery in T, is less or equal the spot price at point t, this situation is described as backwardation. On the other hand the market is said to exhibit contango, when the future price for delivery in T exceeds the spot price in t.

emissions. Therefore these temperature deviations should have an effect on allowance prices. In summary their results are, that the most important variables that determine the EU-ETS allowance price are the prices of oil and gas that both have a positive effect on allowance prices. The weather variables that are included in the study (hot and cold days) are significant and have a positive influence on the allowance price.

Our study is very much in the spirit of Manasanet-Bataller et al. (2007), even though there are significant differences. First, we extend the period under investigation from Jan 2005 until December 2006, which leads to some new insights. Second, our study uses spot prices that explain daily developments best and therefore, the explanatory energy prices are spot prices as well. Third, we use a different and as we believe better coal price data series which may be one reason, why the coal price is significant in our estimations while it is not in Manasanet-Bataller et al. (2007). Fourth, Manasanet-Bataller et al. (2007) use a mixture of very detailed German Weather data and European data from seven countries, whereas we apply European weather data which cover the complete ETS member countries. Fifth, we follow the suggestion of Paolella and Taschini (2006) and spend careful attention to the variance process of the price series by including appropriate GARCH-type models. Finally, we also checked for a long-term relationship in the data and completed our empirical investigation by a cointegration analysis.

As a theoretical basis we also consider emissions as a scarce input factor. The demand for allowances in the short run is therefore driven by demand shocks, represented by weather variations and changes in fuel switching costs, which are determined by the relative prices of fossil fuels for the variable part of energy provision. This variable part is described by the medium and peak load and provided by a composite of gas, hard-coal and oil powerplants. Our results show that as long as the fundamental market assumption of a short position of allowances holds, the prices of these fossil fuels determined to some extend the variations in the allowance price. Demand shocks due to weather variation are also significant, but have a rather low impact. The remaining variation in the allowance prices is expected to be explained by market uncertainties especially about policy decisions, which determine the supply side of the market.

This paper proceeds as follows. In section 2 we give some background on the EU-ETS and outline in more detail the variables that academic and market agents consider as the major determinants of EU allowance prices. In section 3 we give a qualitative overview over the price movements in the EU-ETS that could be observed and corresponding policy decisions, energy prices developments and weather variations. Sections 4 then describes the observable variables and the selected empirical data and provides the econometrical analysis. Section 5 concludes.

2 Determinants of EU allowance prices

The factors influencing EU-ETS allowance prices can be divided into supply factors, demand factors and factors related to market structure, regulation and intervention (Sijm, Bakker, Chen, Harmesen, and Lise 2005). Another possibility is a distinction between factors that are relevant in the short term compared to those relevant in the long-term (KfW 2005).

Supply Factors

The main supply factor is the total allocation of EU emission allowances (EUAs) to the EU-ETS participants which are specified in the so called National Allocation Plans (NAPs) that each EU member state has to prepare for each EU-ETS trading period and which have to be approved by the European Commission. Since NAPs are only set every few years, the allocation is in principle influencing allowance prices in the long run. In the process of defining and approving the NAPs for the first trading period though, daily prices reacted visibly to news concerning the final NAP versions. The supply of EUAs can also be extended converting carbon credits from "Clean Development Mechanism" (CDM) and "Joint Implementation" (JI) projects under the Kyoto Protocol into EUAs. Due to institutional constraints and a slow international certification process though, the CDM and JI market is still very thin and its future size as well as future carbon prices are highly uncertain so that currently its influence on EUA prices is likely to be low. The possibility to bank or borrow EUAs also influences their supply. While the possibility of banking limits the supply of allowances in one period and thus puts an upward pressure

on allowance prices, the possibility of borrowing has the opposite effect. So far banking and borrowing is allowed between different years of one trading period but not across trading periods[2]. Banking of CDM credits though is allowed.

Summarized, the supply of EU allowances is mainly affected by coverage of the EU-ETS, rules regarding banking and borrowing and allocation methodology within the NAPs. Especially the limited ability to bank permits restricts the duration of the production input factor carbon emission, as allowances of different trading periods can be viewed as different commodities.

Demand Factors

The demand for EUAs is mainly determined by expected emissions. The limitation of carbon emissions via EUAs makes them a scarce input factor for production. Therefore, the demand of allowances in the long run can be described by economic growth and marginal abatement costs. The upper cap for the allowance price is in theory, the penalty for non-compliance. In the EU-ETS the penalty amounts to 40 Euro per tCO_2 produced without allowances in the first trading period and to 100 Euro per tCO_2 in the second trading period while firms still have to surrender an amount of allowances equal to their emissions.

Since - abstracting from very long term investments like carbon capture and storage - CO_2 emissions cannot be reduced by end-of-the-pipe technologies, the long-term marginal abatement cost are determined by investment decisions in low-carbon energy utilities and energy efficiency. Regarding the high investment costs and the uncertainties about the future of the ETS in 2005, firms are faced mainly with short term abatement costs in the first trading period when deciding on their allowance demand. The short term abatement decisions and thus the demand for allowances are mainly driven by unexpected fluctuations in energy demand and energy prices. CO_2 emissions in the EU-ETS are one to one linked to the use of fossil fuels and the demand for fossil fuels in turn depends on their absolute and relative prices. The marginal fuel switching costs from high-carbon sources of energy to low-carbon sources for power and heat generation are the single most

[2]The only exception is France, where a small portion of allowances can be transferred from the first to the second trading period.

important measures for carbon abatement in the short run since public power and heat represented about 57% of verified emissions covered by the EU-ETS in 2005 (Kettner, Köppel, Schleicher, and Thenius 2007). In particular, a price increase of one fossil fuel is expected to increase the price for EUA allowances in the short run, if it is substituted by another fossil fuel with a higher carbon content. In the long run the substitution effect may be dominated by the price effect and therefore the price increase leads to lower demand for energy at all. In the short run the demand for power is presumingly rather inelastic, so that only the switching effect is existent. Since it is not possible to switch a brown coal power plant to use oil, there are in the short run no substitutions possibilities in the base. In Germany, for example, the base load consisted in 2004 of 46.5 % nuclear power, 46.5 % brown coal and 7.0 % hydropower (Schiffer 2005). Prices for all three inputs are rather constant, which is one more reason why short term adjustment in the base load cannot be expected. The case is different for the medium and peak load. In Germany, this was for example provided in 2004 to 43.9 % by hard coal, 28.1 % by gas, 10.5 % by oil and the remaining 17.5 % by pump-storage power plants and others (Schiffer 2005). Here, it is more easy to substitute between different fossil fuels since it is possible to adjust the usage rate of different power plants to meet medium and peak load demand. Looking at the power generation for Germany for the years 1991 until 2004 for different energy carriers we saw that the variance coefficient of annual power provided by nuclear power is 0.0484, that for brown coal 0.0524, that for hard coal 0.0374, but that for gas 0.2125 and that for oil 0.3 (own calculations based on Schiffer (2005)). There is thus for Germany some evidence that the possibility of substitution exists at least for the medium and peak load. We therefore want to consider the price levels of oil, gas and hard coal and as well their price ratios. As the carbon content of coal is compared to oil around 25% higher and compared to gas around 70% higher (DEHST 2006), we expect that especially the gas-to-coal and the oil-to-coal price ratios are important determinants of EUA prices. The other factor influencing the demand for allowances are unexpected fluctuations of demand for energy in the short run. As outlined by the other studies (Considine 2000) they are mainly driven by unexpected weather variations like temperature, rainfall and wind. Cold winter weather e.g. increases the need for heating by electricity or fuels,

whereas a warm summer leads to higher electricity demand for cooling and also to a lower rate of utilization of nuclear power plants due to reduced cooling by rivers. Rainfall, wind speeds and sun shine hours will affect the share of power generated by carbon free power and heat generation from hydropower, wind energy resp. solar energy. Weather is widely acknowledged to have played an important role for past CO_2 prices.

Market stucture, regulation and intervention

One of the vaguest factors influencing EUA demand are market sentiments, which are often quoted as being important. This refers to factors such as uncertainty about future prices and policy decisions. Such factors are especially important in an immature market such as the present EU-ETS market.

Uncertainty about future prices and policy decision is rather important for the explanation of the term structure between allowance spot and future markets. The studies presuming the existence of a convenience yield argue, that the benefits of holding reserves on hand due to stochastic future CO_2 emissions and uncertain abatement costs, explain the lower present value of the future allowance price in comparison to the spot market. As the CO_2 allowance market shows a different pattern (see Borak et al. 2006) and as we are solely interested in spot price behavior, we refer for this concept to the study of Bailey (1998). Market structure in terms of the number of parties active in the market and the ability of parties to exert market power is also important for the market price. Although there are in theory 12.000 EU-ETS installations, many countries have been very slow in setting up the necessary infrastructure for trading and especially small firms are only slowly building up the necessary human capital to handle trading. As a result, the market was at least in the beginning very thin and a small group of large sellers and buyers could exert market power. Whether these affect prices is difficult to assess. In the long term, when the market becomes more liquid and mature, the problem of market power is likely to vanish. Finally, market regulation and intervention can affect CO_2 prices. Examples include decisions on penalties, coverage of the EU-ETS, rules regarding banking and borrowing, allocation methodology. Table 1 summarizes the different factors, their direction and likely strength.

Table 1: Summary of CO_2 price determinants

Factor	Time[a]	expected impact onCO_2[b]
Supply Factors:		
Overall allocation	long-term	-
CDM and JI supply	medium-term	-
Banking of permits	long-term	+
Borrowing of permits	long-term	-
Demand Factors:		
Economic growth	medium-term	+
Extreme temperatures	short-term	+
Rainfall and wind	short-term	-
Oil,coal and gas prices	short- & long-term	-
Relative prices oil/coal, gas/coal	short- & long-term	+
Abatement costs	long-term	+
Info on abatement	long-term	-
Market power	medium-term	+/-
Fundamentally shortage	long-term	+
Fundamentally surplus	long-term	-

[a] Short-term was defined as being effective within a few days, medium-term as being effective within a few months, long-term as being effective within several years
[b] Impact when factor increases

Source: Adaptation from Sijm et al. (2005) and KfW (2005).

The short term impacts will be the elements of the empirically investigation in fourth section. In the next section we want to describe in detail the influence of news about policy announcement of the allowance prices.

3 Description of the development of the allowance price

While there are few sound studies on the determinants of the EUA prices there is quite a lot annecdotical evidence. Different newsletters on the EU-ETS provide a daily or weekly overview of EUA prices and the factors that are believed to have caused recent price movements[3].

Figure 1 shows the price development of phase I EU emission allowances between the official start of the scheme on the first of January 2005 and the end of 2006. As one can

[3]Such information is e.g provided by Point Carbon (www.pointcarbon.com), Climate Corporation(http://climatecorp.com) or www.co2-handel.de

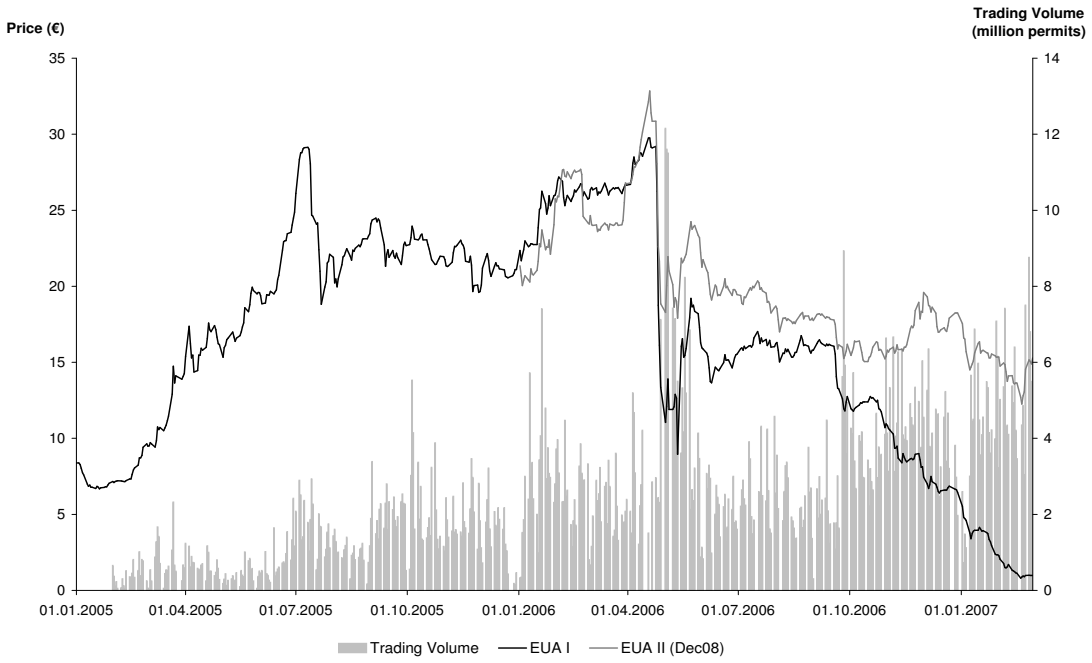

Figure 1: Price Development of EUA I
Source: the author; the shown prices are the OTC prices reported by PointCarbon.

see it is possible to partition the two years into five periods with varying developments:

1. The first half of the year 2005, seeing strong price hikes from around 7 Euro per EUA close to 30 Euro.

2. The second half of the year 2005, starting with a sudden decline in prices followed by sideway movements and a slight downward trend.

3. January to April 2006 , where prices increased from 22 Euro to 28 Euro.

4. May to September 2006 with the dramatic drop in prices due to the publication of the countries' CO_2 emissions for 2005, followed by a volatile period and then a sideways movement at around 16 Euro.

5. October to December 2006 with declining prices, approaching 6 Euro per EUA at the end of 2006.

In the following, we describe these periods in more detail and present possible explanations for the price movements taken from the Newsletters by Point Carbon and Climate

Corporation. These explanations are not derived from econometric estimates or thorough analysis but are the factors that market participants and analysts claimed to be important.

January - July 2005

At the official start of the EU-ETS in January 2005, one EUA was traded at around 8 Euro. After a decrease to 6.50 Euro in the beginning of January, prices rose steadily and reached almost 30 Euro in July. This first period of the EU-ETS was still strongly influenced by political decisions on outstanding NAPs. Between February and May, the European Commission announced decisions regarding Italy, Poland and the Czech Republic to further cut their NAPs, and denied the United Kingdom to extend the amount of certificates. An increased volatility could be observed after each decision. As an example, two days before the announcement regarding the Italian NAP on May 23, the price climbed in the morning on a new all time high of 19 Euro. When rumors told that the Italian NAP would be cut less than expected, the price dropped below 18 Euro and bounced back in the afternoon when the rumors turned out to be wrong. When the EC-decision of the expected cut was finally announced on May 25, the price increased close to 20 Euro and jumped over this mark one day later. Market participants also attributed the rising prices in the first half of the year 2005 to weather conditions and energy prices. After a mild January throughout Europe, a cold February and March led to higher emissions. Crude oil prices, which can also be regarded as an early indicator for the development of gas prices rose from 30 Euro per barrel at the beginning of the year to almost 50 Euro in July, which may help to explain the strong increase in CO_2 prices up to 30 Euro.

July - December 2005

The second half of 2005 started with a sudden drop in prices. From July 13, when prices were at 29 Euro, they declined to 19 Euro within only 10 days and afterwards stabilized at around 23 Euro in August and September. During the rest of the year 2005, prices slightly decreased to around 20 Euro. While the first half of 2005 was influenced by political decisions on the outstanding NAPs, this was not the case for the second half, when all decisions for the first trading period had been announced. Though oil prices

decreased from close to 50 Euro to 46 Euro this is not a sufficient argument for the sharp fall of prices in July, especially since oil prices in the aftermath rose even beyond 50 Euro. However, market observers mentioned psychological reasons: falling oil prices made clear that prices can drop as quickly as they rise. Furthermore, the price of 30 Euro was regarded as a level where fuel switching from coal to gas gained attractiveness. On the market side, there appeared to be additional sellers on the market. Firms might have decided to sell oversupplied certificates as long as prices were still high and before new sellers from Eastern Europe entered the market. The small price fluctuations after July and the slight decline from September to December was explained by market participants with similar fluctuations in oil prices. However, prices for natural gas climbed while coal prices decreased, which should lead to rising CO_2 prices due to the more expensive fuel switching between coal and gas.

January - April 2006

In the beginning of 2006, one EUA was traded at 22 Euro. During January, the price rose to 26 Euro and during April, it climbed further up to 29 Euro. In January and February, market participants often cited the cold weather in Europe as a reason for the rising prices. Furthermore, prices of crude oil increased from 50 Euro per barrel to 54 Euro at the end of January and once again from 50 Euro per barrel in the beginning of March up to almost 60 Euro per barrel at the end of the period due to the unresolved Iran crisis. However, though rising oil prices seem to have influenced prices for CO_2 emissions, the declining oil price in February, when it fell back from 54 Euro to 50 Euro, caused no similar reaction in the prices of the EUAs. Another issue that may have caused higher prices during this period was that most reports on the EU-ETS forecasted that Europe would fundamentally be short of allowances. A critical forthcoming date was May 15, when the Commission published the verified emissions reports of the companies under the EU-ETS. The market became increasingly nervous and was aware that differences from the expectations to one or the other side could lead to drastic adjustments of prices.

May - September 2006

The price crashed from almost 30 Euro to 15 Euro and below within a few days. On April 25, the Netherlands and Czech Republic were the first to report on the 2005 CO_2

emissions of their installations, followed by Belgium, France and Spain on the next day. In contrast to many reports that forecasted an undersupply of emission allowances, the figures coming out indicated in fact an oversupply of EUAs. This led to the price crash. After these announcements, the price stayed very volatile for the next weeks and trading volumes were high. Although the EC asked member states not to publish any information regarding the 2005 emissions before the official release date, Lithuania and Sweden presented their figures, indicating an oversupply of allowances as well. On May 12, one trading day before the release of the official figures by the European Commission, the price plummeted to around 9 Euro, following rumors on a very large oversupply of the EU-ETS. When the official figures were out on May 15, the price bounced back to 16 Euro as the oversupply was not as strong as expected at that time. The leakage of information before the official date on 15th May was very unpleasant for the European Commission and the EU-ETS as a whole. It discredited the market and severely questioned its maturity. During this time, fundamentals like energy prices or weather had no significant influence on prices. After the huge volatility following the release of the 2005 emissions data, the market stabilized in June to 16 Euro per EUA. For the rest of the period until mid of September 2006, the price remained relatively stable at this level. Influences from the prices of energy like oil, gas and coal prices were hardly mentioned by market participants. News on the NAPs for second phase of the ETS in 2008-2012 should not influence the prices of the phase I EUAs. Although some countries considered to allow banking of allowances from the first phase of the scheme to the second phase, a decision by the European Commission on this issue was still outstanding and expected to be negative.

October - December 2006

On September 19, prices started to fall for the rest of the year. This decline occurred in several stages, but each time when a ground was thought to be found, prices dropped even further. Finding explanations for the price movements in this period is very difficult. Although oil prices decreased slightly in September, the same occurred already some weeks in advance and it cannot explain the strong declines in EUA prices. The mild start of the winter in December may have negatively influenced prices, but the major

reasons have to be found elsewhere. Often mentioned by market participants was the over-allocation of EUAs in the first trading phase, which was revealed with the release of the emission data in May. Since the over-allocation was now obvious, prices had to fall. Furthermore, through auctions of remaining EUAs by national states towards the end of the year, more and more allowances were dumped on the market. With the EC decision on several NAPs for phase II on November 27, the European Commission made clear that banking of phase I EUAs to the phase II EUAs would not be possible without reducing the amount of phase II EUAs by the same magnitude. This was a major reason that the spread between the prices of EUA I and EUA II became larger and price developments drifted apart.

Summarizing this annecdotical evidence about the determinants of the EUA prices, it seems that news on NAPs and emissions might have been important determinants in many cases and dominated any other variables, especially at the beginning of the EU-ETS. Nevertheless until the price crash in April 2006, it seems that the market reacted as expected in section 3 to variations in weather and even more energy prices. Still this development indicates that there are other forces determining the EUA prices, especially the uncertainty about the shortage of allowances. This may to some extent describe the high prices of almost 30 Euro in July 2005. These prices were approaching the upper limit of 40 Euro set by the penalty. The uncertainty about the magnitude of actual emissions vanished in the moment when the verified data for 2005 were published on 15 May 2006. As it became clear that the market was rather long, prices crashed and after a short period of stabilization at around 16 Euro between June and September, continued to fall since. Due to over-allocation of allowances the input factor carbon emission became less scarce and therefore firms moved on their marginal abatement cost curve close to the business as usual level. Energy prices or weather data seemed not to have any longer a significant influence on permit prices since the publication of the emission data. In the next section we will test whether the data contain significant influence of demand side factors as energy prices and weather data on the EUA price. The most important observation is that the publication of the first verified emission data seems to have spilt the two-year period in two parts. Before the publication, CO_2 prices could have been

influenced by energy prices and weather data, after the publication this is very unlikely.

4 Empirical analysis

Our analysis focusses on the first two trading years of the ETS, i.e. the years 2005 and 2006 for which we include oil, gas and coal prices, as well as relation of the gas to coal and oil to coal price to capture the effect of fuel switching in the electricity sector.

Daily allowance prices are taken from *PointCarbon*. Prices prior to April 19 2005 are calculated as a volume-weighted price index.[4] From April 19 2005 onwards, prices at *PointCarbon* are calculated as bid-offer close to over-the-counter prices, i.e. prices are calculated from information supplied by active OTC brokers and traders at close of the market. Compared to contracts delivered on December 1st of each year, that are also available at PointCarbon, these spot prices reflect daily developments best.

Daily oil prices for the crude oil Brent - the benchmark price for oil production from Europe, Africa and the Middle East are taken from the German "Sachverständigenrat zur Begutachtung der Gesamtwirtschaftlichen Lage".[5] For coal and gas which are for the most part traded on long-time contracts with fixed prices allowing only for occasional, small adaptations, daily prices are more difficult to obtain. However, there is still some amount of gas and coal traded at exchanges. We use daily prices as listed in the Financial Times London for this analysis. The price for coal is the price for the global Coal RB Index, the price for gas is the price for Euro Gas traded in Zeebrugge. All energy prices are converted in Euro per ton of CO_2[6].

Weather variations are represented by three indices. The first measures comparatively cold days, the second measures comparatively warm days in Europe and the last measures the actual wind speed at that day. All indices describe weather data for European countries within the ETS. The temperature deviation is calculated relatively towards its 20-years mean, averaged for each country and are aggregated in a weighted average for

[4] For detailed information see www.pointcarbon.com
[5] See www.sachverstendigenrat-wirtschaft.de.
[6] The conversion factors are taken from (DEHST 2006)

Europe, where the weights are BIP for the year 2005 and 2006. A positive value within the Warm-Deviation time series measures a hot day, where the realized temperature was higher then the expected temperature. A negative value within the Cold-Deviation time-series describes a cold day, where the realized temperature was lower then the expected temperature and vice versa. The wind data is solely the realized wind speed at that day and the weights for the index was installed wind capacity in Europe for 2006[7]. We did not include rain in our analysis, as we could not get reliable rain data for Europe for the period under investigation.

For our analysis we used natural logarithms first differences of the price data.[8] Then we set up two test equations, one including the prices and the other including the price ratios of gas and oil with coal in order to obviate multicollinearity. The simple OLS representations of this equations look therefore like this:

$$\begin{aligned} EUA_t &= \beta_1 OIL_t + \beta_2 GAS_t + \beta_3 COAL_t + \beta_4 ColdDev + \beta_5 WarmDev + \beta_6 Wind + u_t \\ EUA_t &= \beta_1 (\frac{OIL}{COAL})_t + \beta_2 (\frac{GAS}{COAL})_t + \beta_4 ColdDev + \beta_5 WarmDev + \beta_6 Wind + u_t. \end{aligned}$$

As outlined in the section 3 the data for the allowance prices obtain a structural break at that point in time, where the disclosure of national registers revealed that the market is rather long in allowances. A Chow Breakpoint test confirms this evidence, indicating a structural break between April, 24 2006 and May, 15 2006[9]. We therefore split our data-set, testing for the first period from January, 1 2005 until April, 23 2006 where the market perceive CO_2 emissions as a scarce commodity and for the second period from May 15, 2006 until December, 31 2006, where the market lost this characteristic. Checking the residuals of the first OLS estimation, we discover serial correlation, which is confirmed by the Breusch-Godfrey-Langrange-Multiplier test at the 1% level and we included therefore a first order autoregressive variable AR(1). With this specification the serial correlation in the residual series vanishes, but a look at the residual series indicates a heteroskedastic

[7] These indices were calculated and provided by the HSH N Financial Markets Advisory AG, www.fma-ag.de, contact Robert Poczety, robert.poczety@fma-ag.de

[8] The price series were checked by an ADF test. They have a unit-root in levels, but are stationary at the 1% level in first differences.

[9] The F-statistic is 8.7783, rejecting the null-hypothesis for F(12,497) at the 1% level.

pattern. We ran an ARCH-LM test, which reveals the existence of autoregressive conditional heteroskedasticity. Therefore we specified the variance equation as GARCH(1,1). Without any knowledge about the distribution of the first difference allowance prices, we kept the assumption of a Gaussian Error distribution, but adjusted the covariance with the BHHH algorithm to obtain heteroskedasticity consistent covariance.[10]

With these modifications we present the estimation output for the prices and the price ratios in table 2. The explanatory variable wind is missing in both estimations, since different runs with lagged, counted or dummy representations of wind did not show any significance. The signs of the coefficients confirm the theoretical considerations. The coefficients for the oil and gas price are both positive and significant at the 1% level, indicating that a price increase leads to switching effect towards coal, which increases emissions and therefore the demand for CO_2 allowances. An increase in the price of coal leads to a switching effect in the opposite direction, lowering therefore the demand of allowances and the sign of the coefficient is as expected negative and as well significant at the 1% level. The absolute influence of the weather variables is rather low, but both are significant at the 5% level and the signs are in line with theory. Remember that COLD_Dev measures the deviation of temperature at cold days. So, when it is colder than expected, the variable is negative and therefore leads to an increase in allowance prices due to higher demand.

The estimation of the second time span from May 15, 2006 until December 29, 2006 confirms our qualitative results that fundamental market mechanism broke down when the market participants no longer viewed carbon emissions as a scarce input factor. The results can be found as well in Table 2. The coefficients for coal, gas and deviation of temperature at hot days now become insignificant. Only the variable oil price in the first equation, the ratio of oil and coal prices in the second equation and the deviation of temperature at cold days remain significant. A very small and negative R-squared though indicates that the goodness of fit is very low and that the relation may be rather weak.

[10] By quasi maximum likelihood theory the maximization of a misspecified Gauss log-likelihood function due to nonnormal innovations is justified.

Table 2: OLS Estimations

Variables	Jan, 03 2005 - April, 23 2006 Estimation 1	Jan, 03 2005 - April, 23 2006 Estimation 2	May, 15 2006 - Dec, 29 2006 Estimation 3	May, 15 2006 - Dec, 29 2006 Estimation 4
OIL	0.1889** [0.00]	—	0.3629* [0.01]	—
GAS	0.062** [0.00]	—	0.0024 [0.97]	—
COAL	-0.2216** [0.01]	—	-0.144 [0.35]	—
OIL_COAL	—	0.18** [0.00]	—	0.2984* [0.02]
GAS_COAL	—	0.0614** [0.00]	—	-0.0031 [0.96]
WARM_DEV	0.0029* [0.02]	0.0029* [0.03]	0.0007 [0.45]	0.0006 [0.51]
COLD_DEV	-0.0023** [0.01]	-0.0023** [0.01]	0.0134* [0.03]	0.0156* [0.04]
AR1	0.226** [0.00]	0.227** [0.00]	0.162 [0.13]	0.18 [0.11]
R^2	0.0966	0.0944	-0.1499	-0.1727
adjusted R^2	0.0746	0.0752	-0.2099	-0.226
Variance Equations				
CONST	0.0000** [0.00]	0.0000** [0.00]	0.0002** [0.00]	0.0002** [0.00]
RESID(-1)^2	0.3788** [0.00]	0.3813** [0.00]	0.3132** [0.01]	0.3287** [0.01]
GARCH(-1)	0.6029** [0.00]	0.625** [0.00]	0.4497** [0.00]	0.449** [0.00]

**/* Significance at the 1%/5% level
p-value in parenthesis

As we obtained a low R-squared for the first period as well, we estimated purely autoregressive equations as a benchmark for both periods. Whereas we could not get any better results for the first period than our presented results in Table 2, the estimation for the second period is clearly outperfomed by an ARMA(1,1) model resp. an ARIMA(1,1,1) model [11].

The comparison of our results with the results of Manasanet-Bataller et al. (2007) shows, that there are only some common findings. Both analysis detect a positive effect of oil prices on allowance prices as well as a positive effect of the price of gas. While this analysis finds negative effects for coal, in line with theory, Manasanet-Bataller et al. did not find significant influence of the price of coal which is contradicting theory. Regarding weather data, this study confirms the Bataller results by finding significant coefficients for cold and hot days. Differences within the two studies can be explained by different data and variables and a different estimation period. Though our study has some shortcomings as well, we believe the results to be more reliable than those of Manasanet-Bataller et al. - they also match better the theoretical predictions.

To complete our analysis we also checked our data for a cointegration relation. Since all our price variables are non-stationary, theoretically a stationary linear combination of them could exist which would indicate a long-term relationship between the variables. Because the time period under investigation is rather short and describes the launching of a new market, such a long term relationship is rather unlikely. But when we checked for the whole period by including appropriate dummies for the structural breaks, the Johansen Trace test indicates cointegration relations. Since a VECM model confirmed that the variables oil, coal and gas are weakly exogenous for the error correction term, we moved our analysis to a single equation error correction model. The resulting ECM test then strongly rejects the assumption of a cointegration relation. The indicated cointegration within the Johansen test failed for the single equation as we included a GARCH representation for the description of the variance. We therefore conclude, that there is no economic relevant cointegration relation in the data, which is also confirmed

[11] Second period ARMA regression results: -0.3148 AR(1) p-value[0.026], 0.5428 MA(1) p-value[0.000] with an adjusted R-squared of 0.3724. To correct for the heteroskedasticity in the data we chose an GARCH(0,1) variance equation and again adjusted the covariance with the BHHH algorithm.

by the Johansen Cointegration test, when it is performed solely for the single periods. The results of this complete analysis can be found in the appendix.

5 Summary and conclusions

In this paper we review the first two years of the EU Emission Trading Market and obtain some qualitative and quantitative results. During the period 2005-2006 we observed different price developments. Until mid 2005 prices, rose from around 7 Euro per EUA close to 30 Euro. The second half of the year 2005 started with a sudden decline in prices followed by sideway movements and a slight downward trend. From the beginning of 2006 until April prices increased again from 22 Euro to 28 Euro. After the countries' CO_2 emissions for 2005 became public in April 2006, prices dropped dramatically and after a short, very volatile period, stabilized at around 16 Euro until September 2006. The rest of the year saw declining prices, approaching 6 Euro per EUA at the end of 2006.

The price development seems to be influenced by numerous factors. Especially at the beginning it seems that news on NAPs and emissions have had a dominant influence on prices. Nevertheless we observe that a market for scarce input commodity established which reacts to fundamental price determinants like fossil fuel prices and weather variations. This relation broke down when it became clear in April 2006 that the market was rather long and prices crashed. Although prizes stabilized at around 16 Euro during June and September, they have been falling since. The over-allocation of allowances became the main determinant of CO_2 prices. These conclusions are confirmed by our econometric analysis. The regression models indicate that before April 2006 the allowance price reacts to price variations of fossil fuels which are used to satisfy medium and peak load energy demand. As expected, the switching effect is present in the data, indicating that the switching between different fossil fuels with different carbon content are mirrored on the allowance market. Demand shocks induced by weather variations also turn out to be significant determinants of the allowance price. This relations breaks down to a large extend for the second period.

Both results together confirm that our explanation of the price determination based on CO_2 as a scarce input factor has some justification. Still, the allowance market is rather immature. As expected, we are not able to identify any long-term equilibrium relation, which was confirmed by a cointegration analysis. But we also have to state that a lot of the variation in the prices is not explained by the fundamentals, but rather by news on the allocation of allowances. The magnitude of these effect is difficult to assess. Even when we observe a more liquid and mature market in the long term, political decisions influencing the supply side will remain important determinants of allowance prices. These factors are decisions on penalties, coverage of the EU-ETS, rules regarding banking and borrowing and allocation methodology.

Finally, the question remains if our choice of the fossil fuel price data reflect the decision parameters of participants of the EU-ETS in an appropriate way. It is well possible that decisions are rather influenced by monthly forward prices than by daily spot prices. Nevertheless, we think that our price data of hard coal and gas capture some of the fundamental inputs for cost factors for energy suppliers. We also would have liked to include proxies for the water level and temperature of rivers, which determine the utilization of nuclear power plants, but unfortunately we could not get reliable data for European precipitation or data for the main rivers. A follow-up analysis may overcome these drawbacks and may reveal new insights, especially since the market becomes more mature over time.

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A Appendix

In this appendix we describe the cointegration analysis that was done to test for a long-term relationship between the variables.

In a first step, we run a Johansen Trace Test for the allowance, oil, coal and gas price series. The included lags for the levels were determined by the Akaike Info Criterion. We tested for the period Jan, 03, 2005 until April, 23, 2006, the second period from May 15, 2006 until Dec 27, 2006 and for the whole period, including two dummy variables for the structural breaks. For the single periods we assumed a constant in the deterministic equation, since that makes it more likely that the null hypothesis of no cointegration is rejected. For the whole period assumed we tested for a constant but also for a constant plus a linear trend in the deterministic equation. The Johansen Trace Test accepts the null hypothesis of no cointegration at the 5% significance level for the two single periods, but it rejects this hypothesis for the whole period at the 1% significance level.

Table 3: Johansen Trace Test for CO_2, coal, oil and gas

period 01/03/2005 - 12/26/2006							
Deterministic Part: Intercept				Deterministic Part: Intercept+ Trend			
Dummy for 04/23/2006 - 05/15/2006				Dummy for 04/23/2006 - 05/15/2006			
Dummy for 05/16/2006 - 12/27/2006				Dummy for 04/23/2006 - 05/15/2006			
r	LR	95 % critical value	p-value	r	LR	95 % critical value	p-value
0	105.91	67.88	0.0000	0	108.99	77.56	0.0000
1	47.84	46.17	0.032	1	50.91	53.57	0.0859
2	21.77	28.36	0.2836	2	22.35	33.40	0.4743
3	7.78	14.56	0.4167	3	8.69	16.83	0.5065
Akaike Info Criterion: 2				Akaike Info Criterion 2			

Due to the results we estimated in the next step two VECM models, one with two cointegration relations and one with one cointegration relation, since we are solely interested whether there is a long-term relationship explaining the price behavior of the allowance prices.

Table 4: Johansen Trace Test for CO_2, coal, oil and gas

period 01/03/2005 - 04/24/2006 Deterministic Part: Intercept				period 05/17/2006 - 12/27/2006 Deterministic Part: Intercept			
r	LR	95 % critical value	p-value	r	LR	95 % critical value	p-value
0	50.99	53.94	0.0911	0	38.46	53.94	0.5535
1	25.90	35.07	0.3522	1	20.54	32.25	0.6933
2	8.81	20.16	0.7544	2	22.35	6.4	0.9244
3	2.61	9.14	0.6615	3	1.01	7.6	0.9355
Akaike Info Criterion: 2				Akaike Info Criterion 3			

Table 5: Johansen Trace Test for CO_2, gas_coal, oil_coal

period 01/03/2005 - 12/26/2006 Deterministic Part: Intercept Dummy for 04/23/2006 - 05/15/2006 Dummy for 05/16/2006 - 12/27/2006			
r	LR	95 % critical value	p-value
0	40.58	46.17	0.1808
1	17.08	28.36	0.6299
2	6.63	14.56	0.543
Akaike Info Criterion: 3			

Table 6: Johansen Trace Test for CO_2, gas_coal, oil_coal

period 01/03/2005 - 04/24/2006 Deterministic Part: Intercept				period 05/17/2006 - 12/27/2006 Deterministic Part: Intercept			
r	LR	95 % critical value	p-value	r	LR	95 % critical value	p-value
0	20.70	35.07	0.6833	0	24.57	35.07	0.4313
1	9.61	20.16	0.6818	1	9.3	20.16	0.7109
2	2.13	9.14	0.7496	2	2.6	9.14	0.6627
Akaike Info Criterion: 3				Akaike Info Criterion 1			

The Akaike Info Criterion indicates that it is optimal to include endogenous lags of order one, whereas the Hannan-Quinn Criterion and the Schwarz Criterion indicates to include no endogenous lags. In the first run, we tested the two VECMs with one endogenous lag. In the second run, we specified subset restrictions and used the search strategy SER provided by Jmulti for which we chose to follow the Hannan-Quinn Info Criterion. In both VECMs, the this restriction suggests that the error term resp. the first error term has only a significant influence on the first difference of the allowance prices. Here we present the VECM for the case of no endogenous lags without any subset restrictions (note t-values in parenthesis):

$$
\begin{pmatrix} d(CO_2)_t \\ d(Gas)_t \\ d(Coal)_t \\ d(Oil)_t \end{pmatrix} = \begin{pmatrix} -0.074 \\ (-7.477) \\ -0.031 \\ (0.313) \\ 0.002 \\ (0.788) \\ -0.010 \\ (-0.356) \end{pmatrix} \left[\begin{pmatrix} 1.0 & -0.010 & -0.501 & -0.32 \\ (-) & (-0.862) & (-1.285) & (-7.504) \end{pmatrix} \right.
$$

$$
\left. + \begin{pmatrix} 12.364 & 24.406 & 21.042 \\ (11.737) & (8.963) & (4.024) \end{pmatrix} \begin{pmatrix} Dummy1_{t-1} \\ Dummy2_{t-1} \\ CONST \end{pmatrix} \right]
$$

$$
\begin{pmatrix} 0.033 & 0.023 \\ (1.377) & (0.969) \\ 0.127 & 0.284 \\ (0.521) & (1.196) \\ -0.007 & -0.026 \\ (-0.923) & (3.698) \\ -0.044 & -0.026 \\ (-0.658) & -0.722 \end{pmatrix} \begin{pmatrix} WarmDev_t \\ ColdDev_t \end{pmatrix} + \begin{pmatrix} u1_t \\ u2_t \\ u3_t \\ u4_t \end{pmatrix}
$$

Looking at this VECM, we see that the t-values of the loading coefficients of the error correction are rather low for the other variables beside the allowance price. The search strategy SER suggested that within the subset restriction the influence of the error term on the first differences of the other variables can be set equal to zero. We therefore test whether these are weakly exogenous. Testing the reduced model with a single influence of the error correction term on the allowance price, the likelihood ratio test of the restricted model does not reject the null hypothesis of a misspecified restriction(Value: 7.8889, p-value 0.6397). Thus, a single equation model approach is justified. Still, these results have to be handled with care, because the LM-statistic for autocorrelation up to order 5 is 12.2086 and rejects the null-hypothesis of no autocorrelation at the 1 % significance level. Also an ARCH-LM test rejects the null hypothesis of no heteroscedesticity at the 1% level (test statistic 746.8721). We thus turned to the single equation approach and specified a ECM model of the form:

$$\begin{aligned} d(CO_2)_t = &-(1-b_0)(CO_2)_{t-1} + (a_0+a_1)OIL + (a_0+a_2)COAL + (a_0+a_3)GAS \\ &+ \beta_1 WARMDEV + \beta_2 KALTDEV + \rho_1 DUMMY1 + \rho_2 DUMMY2 + u_t. \end{aligned}$$

We tested then if the loading coefficient $-(1-b_0)$ is negative. Within the regression we corrected for heteroskedesticity with an GARCH(1,1) specification. Again we assumed normally distributed errors terms, while applying heteroskedasticity consistent covariances. The corresponding t-value respective the z-statistic (normality holds only asymptotically) is only -0.847, which is within the bounds of the the 5 % critical values for the Banerjee test of -3.74 (if we presume just a constant in the series, with a constant and trend, the critical value is even -4.12). At this stage there is therefore no economic relevant cointegration relation in the data, which is also confirmed by the Johansen Cointegration test, when it is performed solely for the single periods.