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What Moves the European Carbon Market? – Insights from Conditional Jump Models

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CESIFO WORKING PAPER NO. 3795
CATEGORY 10: ENERGY AND CLIMATE ECONOMICS
APRIL 2012

CESifo *Working Paper No. 3795*

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Abstract

This paper is concerned with carbon price volatility and the underlying causes of large price movements in the European emissions trading market. Based on the application of a combined jump-GARCH model the behavior of EUA prices is characterized. The jump-GARCH model explains the unsteady carbon price movement well and, moreover, shows that between 40 and 60 percent of the carbon price variance are triggered by jumps. Information regarding EUA supply and news from international carbon markets are identified as important drivers of these price spikes. These results can lead regulators the way if smoother carbon prices are desired.

JEL-Code: C220, Q500.

Keywords: emission allowance prices, GARCH, jumps, jump-induced variance.

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April 2012
Marc Gronwald is grateful for the hospitality of the University of California, Berkeley while working on the paper. Financial support by the Fritz Thyssen Foundation for this research visit is gratefully acknowledged.

"First, as I have long-argued, investment in green energy will never be certain unless we bring some stability to the price of carbon."

George Osborne, Chancellor of the Exchequer, 2011

1 Introduction

With the aim of reducing greenhouse gas emissions, different political steps are taken around the world. They range from command and control regulation to more market-based approaches. One renowned instrument is emissions trading which establishes a quantitative emissions target and requires offsetting climate-active gases with tradable certificates. The European Emissions Trading Scheme (EU ETS) is currently by far the largest existing scheme. Besides, the first compliance period of the Regional Greenhouse Gas Initiative - an initiative of ten North-eastern US states - started 2009. New Zealand has an emission trading scheme in place which is stepwise extended to more sectors and Australia will introduce carbon trading in 2015.[1] Moreover, China lately announced the implementation of six regional ETS by 2013.[2]

As more systems are in place and policy makers aim at linking them, it is necessary to gain confidence that these systems set the right incentives to market participants and spur emission abatement. These incentives to

[1] More information is available at: www.climatechange.gov.au/government/reduce/carbon-pricing.aspx

[2] Reuters, 11.4.2011. More information is available at: www.reuters.com

reduce emissions are given by the carbon price signal. However, there are several reasons for concern regarding the reliability of the price signal. First, Hintermann's (2010) paper finds that fundamentals provide an insufficient explanation of carbon prices in Phase I of the EU ETS. Second, Gronwald et al.'s (2011) finding of a stronger relationship between EUA prices and those of other financial commodities during the financial crisis suggests that undesired influences are present. Finally, concerns about price volatility in the newly established carbon market have been raised repeatedly, especially since the price for a European Allowance Unit (EUA) dropped by almost 50 % in April 2006 [Chevallier, 2011a]. Variation of the carbon price is the central feature of emissions trading, excessive volatility, however, reduces the efficiency of this policy instrument [Fankhauser et al., 2010]. A capricious price development increases abatement cost uncertainty in the short-run and is possibly detrimental to investments in the long-run. Therefore, policy makers and economists alike worry about the efficiency of the emission trading as a climate policy. With the aim of improving the European policy mechanism, policy makers as well as market participants should aspire to better comprehend the sources of carbon price fluctuations.

This paper aims at deepen the understanding of carbon price behavior in the EU ETS, whereby the focus lies on the identification as well as the explanation of sudden, extreme price jumps which disrupt the market most. Issues like volatility clustering and jumps have already been addressed in the carbon market literature. However, Chan and Maheu's (2002) combined jump-GARCH model applied in this paper improves the existing literature as it treats the main statistical features of the carbon price in an integrated approach. Moreover, the variance decomposition proposed by Nimalendram (1994) allows one to further assess the regression results and to determine which portion of the variance is attributable to jumps.

It is of the utmost importance to find an explanation for the high prevalence of jumps in the carbon market as emissions trading is mostly criticized for its uncertain and volatile price development. This paper investigates to what extent political events trigger the extreme price movements. Various studies show that markets that are subject to political influences are more likely to exhibit extreme price movements, see in particular Jorion (1988). In comparison to other commodity markets, the possibility to trade emission rights is a purely political decision. As the political framework is such an essential feature to the market, it is an obvious explanation for the dominance of jumps in the carbon price. This is further motivated by previous research on the EU ETS that finds a strong influence of the regulatory framework and related political decisions on the carbon market [Chevallier, 2011a; Mansanet-Bataller et al., 2011; Conrad et al., 2012]. Therefore, the present paper assesses systematically which jumps are related to decisions of the EU Commission or news from the international climate change arena.

The results can be summarized as follows: first, the jump-GARCH model provides a good fit to the data and, thus, explains the capricious carbon price movements very well. Second, no fewer than 40 % to 60 % of the carbon price variance are attributable to jumps. Third, a considerable number of the extreme price movements captured by the model's jump component can be related to information regarding EUA supply and changes in the administrative framework. This source of disturbance has not yet been researched widely enough, but it seems an important information channel in a strongly regulated market.

The remainder of this paper is organized as follows: Section 2 further explains this paper's contribution to the literature, Section 3 provides a description of the data and the empirical approach. Section 4 presents the estimation results and the variance decomposition. Section 5 discusses the occurrence and source of carbon price jumps. Finally, Section 6 finally offers some concluding remarks.

2 Contribution to the Literature

This paper builds on two streams of empirical literature - studies assessing the carbon price determinants and studies analysing the carbon price behavior. Generally, the carbon price reflects supply as well as demand information of EUAs [Chevallier, 2011b]. While the supply is determined by the regulatory setting and, therefore, mainly by the European Commission who decides on the amount and the allocations of certificates, the demand for EUAs is determined by the amount of emissions that firms need to cover. This, in turn, is dependent on factors like weather conditions or the difference between the coal and gas price (Mansanet-Bataller et al., 2007]. If the use of less carbon-intensive gas becomes cheaper than the use of coal, power producers with switch-capacity can opt for gas and therefore reduce their need for carbon allowances [Chevallier, 2009; Christiansen, 2005]. The weather, on the one hand, affects the availability of renewable energy which can replace fossil energy sources [Hintermann 2010; Rickels et al. 2010]. On the other hand, particularly hot and cold temperatures increase the demand for air-conditioning or heating which thrives up the electricity demand. Besides these fundamentals, the literature is less clear about driving forces of carbon prices. The dependence with financial markets has been discussed controversially. Hintermann (2010) cannot find a relationship of carbon with the British FTSE equity index during the first trading phase. Chevallier (2009) shows that different variables from stock and bond markets have little influence on EUA futures. However, Daskalakis et al. (2009) identify negative correlations of EUA futures with equity market returns in Phase I. Notwithstanding this debate, the relationship between the EUA market and other financial markets grew stronger during the period of the financial crisis [Gronwald et al. 2011].

Many explanations for carbon price changes have been given, but still Hintermann (2010) shows that these demand-side fundamentals provide an insufficient explanation of the EUA development in Phase I. However, in order to better explain the carbon price, the regulatory framework and related decisions need to be included. In addition to the papers mentioned above, this issue is addressed by Alberola and Chevallier (2009) who emphasize the importance of the banking regulation which bans the transfer of allowances from Phase I to Phase II. Furthermore, Neuhoff et al. (2006) illustrate which distortions can arise depending on the allocation mechanism of EUAs. This paper will provide further insights on the importance of regulatory events.

Regarding the carbon price behavior, the most relevant results for this study arise from papers by Paolella and Taschini (2008), Benz and Trück (2009), Chevallier (2011a) as well as Daskalakis et al. (2009). As a common feature, these papers apply univariate time series approaches in order to investigate the empirical properties of EUA prices. While the former papers provide evidence of GARCH structure in the carbon price returns, Daskalakis et al. (2009) show that EUA future prices are characterized by jumps. Chevallier and Sevi (2010) include jumps when modelling the implied volatility of carbon price returns. This paper adds significantly to this literature as, in contrast to previous studies, jumps and conditional heteroscedasticity are treated in a single approach. Chan and Maheu's (2002) autoregressive jump-intensity (ARJI-)GARCH model is applied to European Union Allowance futures price returns covering both Phase I and II.

As the prevalence of jumps has been emphasized in the literature, the ARJI-GARCH lends itself well to capture the fluctuations present in the series. The model allows one to differentiate between the smooth and more disruptive price movements. The latter is captured by the model's jump component which identifies sudden, extreme market fluctuations exceeding the usually observed price movements. In the model, the intensity of jumps can vary over time which allows tracking when jumps happened. The derived jump series is purely data-driven as it does not require any pre-specification which sample period to study or which events cause jumps. By contrast, Sanin and Violante (2009) take ex-ante decisions regarding the events that potentially cause price jumps and then include these in their model. The ARJI-GARCH therefore provides an unbiased measure of jumps in Phase I and II of the EU ETS. Moreover, the contribution of jumps to the total volatility is assessed by employing Nimalendram's (1994) variance decomposition procedure.

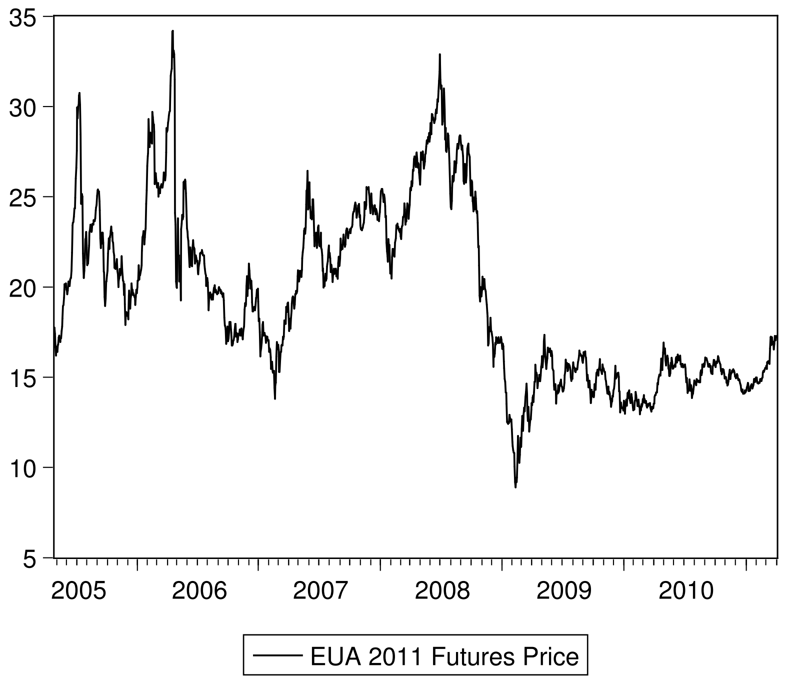
3 Data and Method

In order to grasp the carbon price behavior which is analyzed in the following, Figure 1 illustrates the development of the EUA futures price from May 2005 to April 2011. The EUA futures initially traded at levels between 20 to 30 €, but when the market learned about the oversupply with emission allowances in April 2006, the carbon price crashed. It did not recover and continued trading around 15 €. With the beginning of 2008 (Phase II), however, it rose back to about 30 €. Due to the economic crises, the market finally experienced a second large price decline. Together with the levels of production, demand for allowances fell and excess allocation were sold in order to generate funds [World Bank, 2009]. In autumn 2009 the price picked up again and traded between 10 € and 15 €, mainly driven by allowance demand for Phase III. The quantile-quantile plot displayed in Figure 2 vividly illustrates that extreme price movements are present and that an empirical model needs to be able to account for this behavior. Chan and Maheu's (2002) ARJI-GARCH method is useful in that regard. It extends traditional GARCH models, as introduced by Bollersev (1986), by a conditional-jump component.[3]

Almost every financial market variable is characterized by periods of high volatility followed by more tranquil periods. This price behavior is referred to as conditional heteroscedasticity. A GARCH model is able to capture this behaviour by allowing the variance of the error term to change over time. The extended jump-GARCH model applied in this paper does to not only

[3]For a more thorough discussion of the method the reader is referred to Chan and Maheu's (2002) original paper.

Figure 1: Emission Allowance Prices

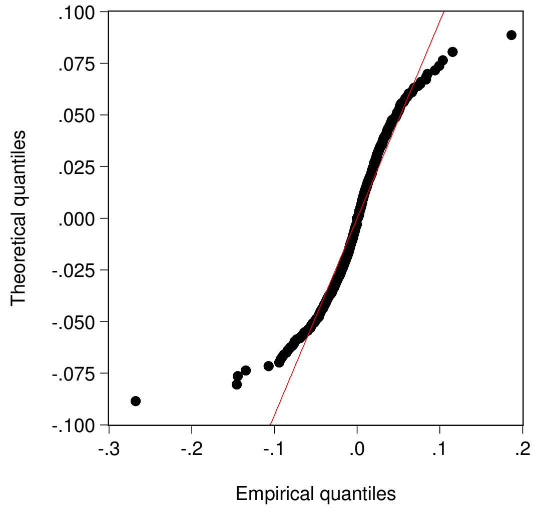


account for smooth volatility but also for the occurrence of extreme price jumps. The ARJI-GARCH has been successfully applied to stock market [Chan and Maheu, 2002], exchange rates [Chan, 2003; Chan, 2004] and the oil price [Lee et al., 2010; Gronwald, 2011)]. As asserted above, the carbon market is heavily influenced by political decisions which supply the market with new information in a discrete manner. Therefore, the application of a jump model seems to be a natural choice. The following model is considered:

$$y_t = \mu + \sum_{i=1}^{l} \phi_i y_{t-i} + \sqrt{h_t} z_t + \sum_{k=1}^{n_t} X_{t,k} \tag{1}$$

with $z_t \sim NID(0,1)$. $\sqrt{h_t} z_t$ contains the GARCH(p,q) term h$_t$ [Bollerslev,

Figure 2: Quantile quantile plot



1986] which follows an ARMA process:

$$h_t = \omega + \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} \tag{2}$$

The last expression in Equation 1 represents the so-called jump component. The conditional jump size $X_{t,k}$, given the history of observations $\Phi_{t-1} = \{y_{t-1}, \ldots, y_1\}$, is assumed to be normally distributed with mean θ_t and variance δ_t^2: $X_{t,k} \sim N(\theta_t, \delta_t^2)$. The number of jumps n_t that arrive between $t-1$ and t follows a Poisson distribution with $\lambda_t > 0$:

$$P(n_t = j | \Phi_{t-i}) = \frac{\lambda_t^j}{j!} e^{-\lambda_t}, \tag{3}$$

where λ_t measures the jump-intensity. Two variants of the model are considered here: a constant jump-intensity model with $\lambda_t = \lambda$, $\theta_t = \theta$, and $\delta_t^2 = \delta^2$; and a time-varying jump-intensity model. For the case of the latter, θ, and

δ^2 are still time-invariant, but λ_t is assumed to follow the auto-regressive process

$$\lambda_t = \lambda_0 + \sum_{i=1}^{r} \rho_i \lambda_{t-i} + \sum_{i=1}^{s} \gamma_i \xi_{t-i}. \tag{4}$$

Finally, let Σ^2 denote the total variance of y_t. According to Nimalendran (1994), Σ^2 can be decomposed in the diffusion-induced and the jump-induced variance and be written as follows:

$$\Sigma^2 = h_t + \lambda_t(\theta^2 + \delta^2). \tag{5}$$

This decomposition allows one to study the share of jumps in the total variance. As in the time-varying version of the jump-GARCH model, the decomposition analysis yields a flexible measure of jump development over time.

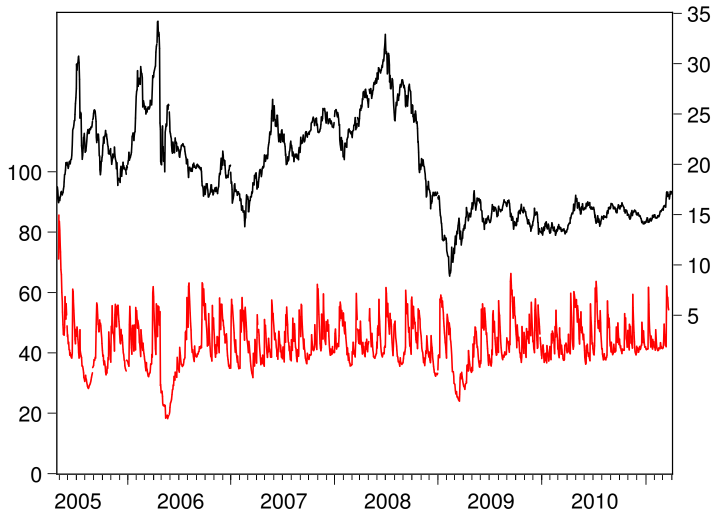
4 Results

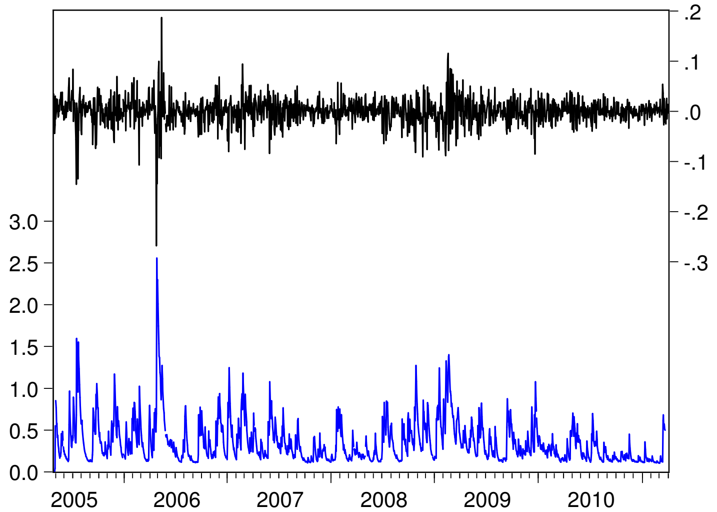
The estimation is based on the EUA 2011 futures series from 2005 to 2011.[4] The model is estimated in first log-differences and a constant is included. Table 1 provides the estimation results for the constant and the time-varying jump intensity models.

It is evident that all jump parameters are highly significant. This already demonstrates that the jump-augmented GARCH model used here is appropriate for modeling carbon price returns. In addition to that, the model selection criteria for a simple GARCH model (estimated as benchmark) and the augmented models shows that the latter should be preferred (Table 2).

[4]The data is obtained from the ICE London.

Figure 3: EUA Prices, Jump Intensity and Variance decomposition





Note: The upper panel shows the EUA price (black) together with the share of the variance that is triggered by jumps (red). The lower panel shows the growth rate of the EUA price (black) and the time-varying jump intensity (blue).

Table 1: Constant and Time-Varying Jump-Intensity Models

Parameter	Constant	ARJI
μ	1.4E-03 (0.0086)	1.7E-03 (0.0010)
ω	1.1E-05 (0.0241)	1.3E-05 (0.0034)
α	0.1039 (0.0001)	0.0571 (0.0013)
β	0.8227 (0.0001)	0.8602 (0.0001)
δ	0.0297 (0.0001)	0.0268 (0.0001)
θ	-7.0E-03 (0.0438)	-5.6E-03 (0.0349)
λ	0.2003 (0.0180)	0.0427 (0.0431)
ρ	-	0.8806 (0.0001)
γ	-	0.4819 (0.0035)

Note: p-values in parentheses. μ is the constant, ω, α and β are the usual GARCH parameters. The jump parameters are displayed in the bottom part of the table. The jump mean and variance are denoted by δ and θ. λ denotes the jump intensity, which follows an ARMA process with parameters ρ and γ in the time-varying model.

All three criteria, the AIC, BIC and HQ, indicate a better performance of jump-augmented GARCH models.[5] The likelihood-ratio tests confirm these results.

The importance of jumps becomes even more apparent in Figure 3. Displayed are the EUA price as well as its growth rate. The jump behavior is depicted by the time-varying jump intensity from the GARCH model as well as the share of the EUA variance that is triggered by jumps, based on Nimalendran's (1994) variance decomposition procedure. A careful analysis of the decomposed variance yields interesting insights regarding the function-

[5] AIC is short for Akaike's Information Criterion, BIC for Bayesian Information Criterion and HQ for Hannan-Quinn Information Criterion.

Table 2: Model selection criteria

Information Criteria			
Criterion	GARCH	Constant	ARJI
LogL	3,588.263	3,639.028	3,648.04
AIC	-4.716	-4.779	-4.788
BIC	-4.702	-4.754	-4.757
HQ	-4.711	-4.770	-4.776
Likelihood Ratio Test			
Compared models	Test statistic		
Constant vs. GARCH		101.53	
ARJI vs. GARCH			119.55
ARJI vs. Constant			18.02

ing of this market. After the first turbulent month, the portion of variance triggered by jumps is generally found to fluctuate around 50%. Only in two cases this portion drops below 40%: in the aftermath of the 2006 price drop and during the price recovery that followed the financial crisis price collapse.[6] In these periods, the variance generally increased, but a larger portion of this increased variance is captured by the GARCH component of the model. This is plausible as the respective movements do not reflect reactions to single events but rather price movements in a "nervous" carbon market. Comparing these figures to those obtained in other applications of Chan and Maheu's (2002) method clearly indicates that price jumps play an important role in the EU ETS. Gronwald's (2011) study of the oil market shows that in periods after 1998 the portion of variance triggered by jumps is about 30 % while this portion during the 1980s is found to be about 50%. At first, the oil market was characterized by a generally tranquil price movement with only few extreme movements while later periods were generally

[6]The drop in that measure that occurred 2005 took place in extremely early stages of the EU ETS. Price movements of that time cannot be deemed very meaningful, see e.g. Hintermann (2010).

more volatile with less influence of single events. Thus, carbon price behavior seems to be similar to the behavior of oil prices during the 1980s. What is more, Huang et al. (2007) find that less than 30% of the variance in the Taiwanese stock index are triggered by jumps. During the election period in which the political uncertainty is particularly high and, therefore, jumps are more likely to occur, this share increases to around 40%.

To summarize, this application of Chan and Maheu's (2002) method yields strong evidence of conditional jumps in emission allowance prices. This implies that these prices are not only characterized by conditional heteroscedasticity and are but are also subject to large unexpected price movements which, furthermore, occur with time-varying intensity. A considerable portion of the total variance is triggered by jumps. It is therefore worthwhile to study the underlying causes of these price jumps.

5 The Role of Events

It is a purely political decision that CO_2 is a tradable asset. In comparison to other commodity markets, the carbon market thus exhibits much stronger ties with its political and regulatory framework. A number of studies show that the EC decisions on National Allocation Plans (NAPs) influence EUA prices [Mansanet-Bataller et al., 2011; Conrad et al., 2012)]. Furthermore, the importance of the banking and the allocation mechanism has been emphasized [Alberola and Chevallier, 2009; Neuhoff et al., 2006; Chevallier, 2012]. This research is extended in the present paper by assessing to which extent these type of regulatory decisions lead to extreme price jumps.

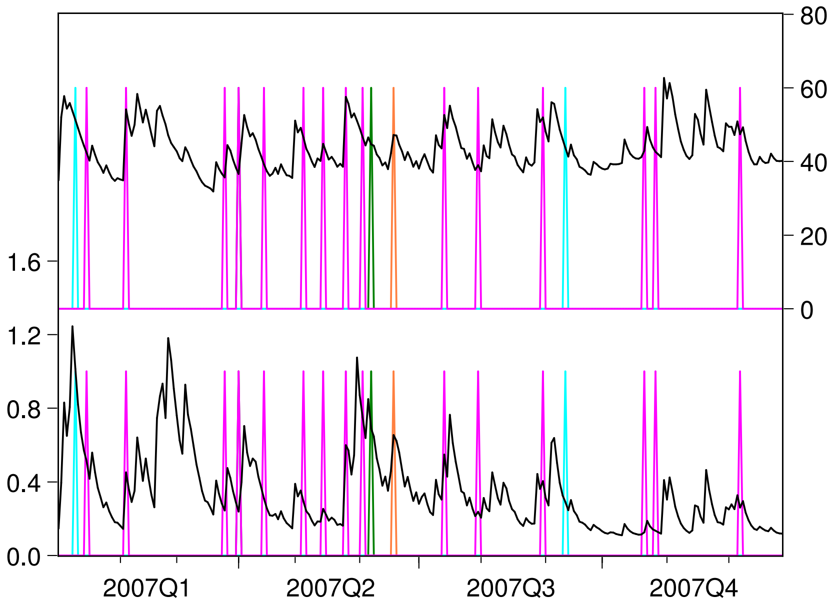
For that purpose, a data base is developed that captures the important decisions of the European Commission as well as changes in the global carbon market framework. These events are classified into different categories. The group *EU ETS NAPs* summarizes decisions by the European Commission on the supply with EUAs in Phase II through so-called National Allocation Plans. *EU ETS Compliance* lists the publication dates of compliance and emissions data which regularly inform the market about EU ETS demand. The category *EU ETS III* consists of the main decisions on the EU ETS framework and supply with EUAs in Phase III. Similarly, the category *Global Carbon Market* covers influential events in the international carbon market. Some categories are easier to complete than others. NAP decisions, compliance data publication are well known and have a regular pattern. By contrast, the categories *EU ETS III* and *Global Carbon Market* are harder to encircle as these events are more divers and not pre-scheduled. In order to obtain a coherent list, regular carbon market publications by CDC Climat Research, Euractiv and Unicredit as well as the European Commission's communication have been considered.[7] Tables of the selected events can be found in the Appendix.

In order to study the temporal connection between regulatory events and the depicted jumps, Figures 4 to 7 presents year-to-year plots of the respective time series. Each upper panel presents the jump-related variance share derived in the decomposition analysis and the lower panel shows the time-varying jump intensity from the GARCH model. The first observation from

[7] Available at www.bluenext.eu/publications/tendances.html; www.euractiv.de; www.ec.europa.eu/clima/policies/ets.

these graphs is that the jump-intensity as well as the jump-induced variance exhibit different phases over time. The years 2007 and 2010 were more unsteady as there are considerably more sharp spikes in the jump-measures. However, in 2008 and 2009, in the beginning of Phase II and the financial crisis, the movements of the jump intensity measures are more sedate.

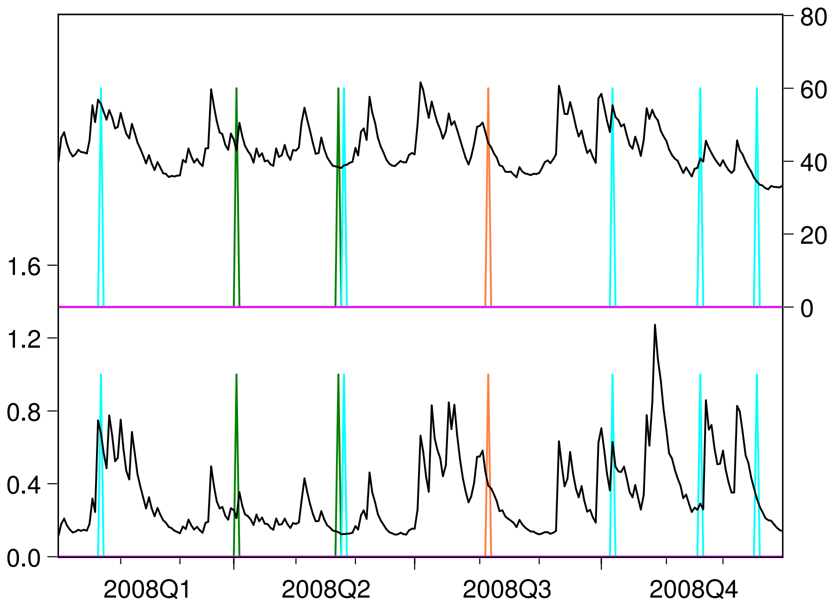
Figure 4: 2007



Note: The upper panel shows the jump-related variance, the lower panel the GARCH jump intensity measure. Both measures are combined with the same event variables: *EU ETS III* (light blue), *EU ETS NAPs* (pink), *EU ETS compliance* (green) and *Global Carbon Market* (orange).

Figure 4, for the year 2007, is dominated by the decisions regarding so-called National Allocation Plans (NAPs) which are taken by the EC. The NAPs determined the final supply with allowances in Phase II and therefore convey fundamental information. Figure 4 shows that *EU ETS NAPs* events coincide with sudden carbon price changes in 2007. This result is generally

Figure 5: 2008

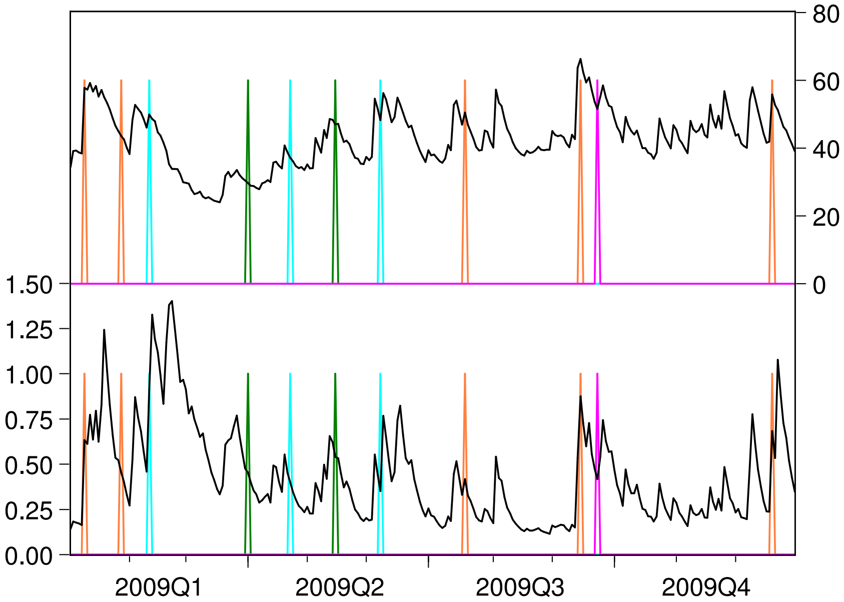


Note: The upper panel shows the jump-related variance, the lower panel the GARCH jump intensity measure. Both measures are combined with the same event variables: *EU ETS III* (light blue), *EU ETS NAPs* (pink), *EU ETS compliance* (green) and *Global Carbon Market* (orange).

in line with the existing literature [Mansanet-Bataller et al., 2011; Sanin and Violante, 2009]. Information regarding NAPs, however, is not only influential in the year 2007. The decision on 23. September 2009 by the European Court that Estonia and Poland obtained to few EUAs in their original allocation, lead to an EUA price drop.

The importance of the NAP events shows that information about EU ETS supply is crucial for market participants. The influence of the demand side can also be evaluated when concentrating on the EU ETS compliance events. Every spring, the European Commission publishes two pieces of information: first, the emissions data during the first days in April through the CITL

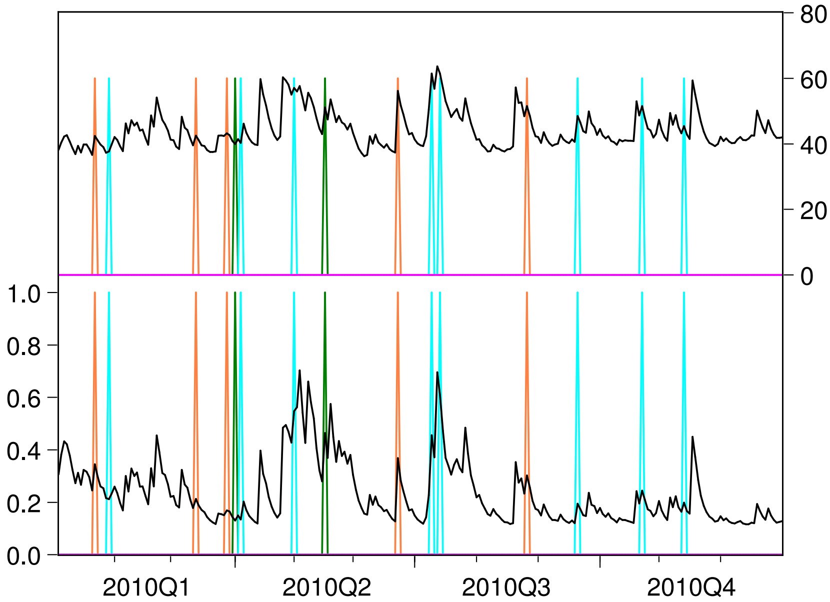
Figure 6: 2009



Note: The upper panel shows the jump-related variance, the lower panel the GARCH jump intensity measure. Both measures are combined with the same event variables: *EU ETS III* (light blue), *EU ETS NAPs* (pink), *EU ETS compliance* (green) and *Global Carbon Market* (orange).

and, second, the surrendered EUAs in a press release mid of May. These publications clarify whether installations are over- or undersupplied with allowances. In 2006 this information led to the distinct price crash shown in Figure 1. From 2007 onwards the publication of emissions seems not to surprise the market. This can be depicted when concentrating on the green lines in each graph which does not overlap with the jumps. Accordingly, the demand side seems more predictable after the market adjusted in 2006. This confirms the expectation of Seifert et al. (2008) who conclude that market participants have a better estimate of EUA demand after the first EU ETS emissions report in 2006.

Figure 7: 2010



Note: The upper panel shows the jump-related variance, the lower panel the GARCH jump intensity measure. Both measures are combined with the same event variables: *EU ETS III* (light blue), *EU ETS NAPs* (pink), *EU ETS compliance* (green) and *Global Carbon Market* (orange).

In 2008 only some decisive events change the price pattern. The adoption of the EU Climate Package on 23. January 2008 and the supportive vote of the EU Parliament's environment committee on the EU's climate policy in early October seem to move the market. When the link between the registries ITL und CITL is announced on 16. October 2008 another small jump can be observed. The events in 2008 seem to be important landmarks for the future of the carbon market and attracted the traders attention in an otherwise rather silent phase.

In 2009 the market seems very interested in the decisions regarding aviation. Several steps need to be taken before the flight sector can be included in 2012. Hence, the market receives many new signals related to this extension of the scope. Moreover, surprising news come from the international area: Russia is expelled from the international carbon trade and the COP15 climate conference in Copenhagen cannot live up to the global expectations.

The year 2010 has been exceptionally eventful. In the beginning, a number of unusual news are accompanied by carbon price spikes. The debate about the mistakes in IPCC reporting and the phlishing of European registries agitate the public. Another concern is the so-called CER recycling in March, when it became obvious that governments sold CERs that already had been submitted for compliance beforehand.[8] From mid-year onwards, the market reacts sensitive to news on the cap in Phase III and auctioning decisions. Moreover, a spurt of the carbon price can be observed when HFC projects are banned from the international and the European carbon market in summer 2010.

The results of this event study show that decisions regarding the availability and the restrictions of EUAs are important information for the carbon market. So far, the literature only focused on the NAP decisions in Phase II. These decisions are important regulatory events, but by far not the only source of turbulence. The EUA allocation decisions for Phase III also induced new information. The news regarding the global carbon market design have an astonishingly strong feed-back to the EUA price. Having said this, news about EUA and CER supply changes the price fundamentals and should actually have an influence on the carbon market. However, most information

[8]For more information please check: CMIA, CER recycling will damage credibility of EU member states and depress CER and EUA prices, 12. March 2010, www.cmia.net.

disclosure surprises market participants and leads to abrupt price changes. Moreover, a number of events do not change the fundamentals but can still be related to the administration of the EU ETS, as for example the phlishing attack on the registries or the recycled CERs. Surely, such incidents are bound to happen in a newly established scheme and can be prevented if the regulator learns from the past events and their impact.

6 Conclusions

Emission trading schemes seem the preferred policy to reduce carbon emissions. Theoretical arguments that are usually put in the balance include that emission trading belongs to the cost-efficient instruments to reduce carbon emissions and, moreover, it provides dynamic incentives to adapt existing and to develop new abatement technologies, respectively. Even more important, establishing a market for emission rights is politically easier to enforce than the introduction of carbon taxes. In order to validate these statements, it is of particular importance to analyze the performance of existing systems and to have a sufficient understanding of emission allowances prices and their determinants. As the largest system, the EU-ETS, is in operation for 7 years now, a steadily increasing number of studies uses data from that market in order to investigate this issue.

This paper sheds light on the behavior of the carbon price by applying Chan and Maheu's (2002) jump-augmented GARCH model to the EU ETS. The empirical results clearly indicate that EUA prices are characterized by both GARCH and strong conditional jump behavior - in both Phase I and

Phase II. Based on the estimation results it is shown that a considerable portion of the variance - between 40 and 60 % - are triggered by jumps. Thus, studying the underlying reasons of these price jumps yields valuable insights in the functioning of this market. It is shown that a considerable amount of extreme EUA price movements is related to new information regarding EUA supply. This is epitomized by the price reactions in response to the announcements of the EU ETS NAPs and equally the EU ETS cap for Phase III. However, the EUA demand seems less influential. Moreover, the carbon price peaks when relevant news from the global carbon market is released, as international carbon credits can be used for compliance in the EU ETS. Thus, the political framework is an essential driver of carbon price developments.

A market that is also under strong influence of regulatory authorities, is the money market. There, the central bank controls the base rate with the aim of achieving low inflation (European Central Bank) and possibly additional goals such as the general economic performance (Federal Reserve Bank in the US). The vast literature on monetary policy discusses the optimal central bank behavior. It is often argued that, in addition to controlling the level of inflation, a central bank should also ensure that inflation volatility is not overly large as this would have negative consequences for economic growth.[9]

The same can be said for the carbon market. Here, the level and the volatility of the carbon price are a result of the market design. At the same time, they are important determinants of investments in abatement technol-

[9] Papers that provide discussions of these issues include Friedman (1977), Sack and Wieland (2000) and Rudebusch (2002).

ogy. The price level is a crucial parameter for the profitability of abatement techniques. In addition, unduly volatile carbon prices make the investment decision more complex. Obviously, the emission cap is the main determinant of the price level. But controlling price volatility does not seem out of reach. Similar to a central bank, the European Commission should monitor the carbon price level and its fluctuations - in a for the market credible manner. This paper's results show that the regulator has some scope in this regard. Going forward, the authorities should keep in mind that the EUA price is easily disrupted by their decisions. The transition in Phase III from 29 single NAP to a single cap decision is therefore a welcome move. The same information is conveyed, but in a less interfering manner. However, the extremely low price currently induces speculation regarding a set-aside of allowances or a 30% reduction target. This is precisely the sort of debate which is undesired. A more clear and calculable communication could stabilize the carbon price signal.

One of the main criticism regarding existing carbon markets is the price uncertainty. Emission trading schemes are established in many parts of the world and are probably the most realistic policy option to combat climate change. Therefore, it would be imprudent not to counteract this criticism.

Acknowledgements

The authors gratefully acknowledge valuable comments by Klaus Wohlrabe, Michael Kleemann, Markus Zimmer, Luca Taschini, Beat Hintermann, Aviel Verbruggen as well as Maximilian Auffhammer.

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APPENDIX

Table 3: EU ETS III

Date	Event	Source
10.01.2007	EC invites members to 'unilaterally' reduce GHG by 20% in 2020	Unicredit
12.09.2007	Strong divergences regarding the plan to cap GHG from aviation	Euractiv[1]
23.01.2008	European Climate Package	EC[2]
27.05.2008	Scope of aviation legislation unclear	Unicredit
07.10.2008	Reports on emissions trading, GHG reduction 'effort' sharing and CCS	Euractiv[3]
19.11.2008	Amending of the EU ETS Directive in order to include aviation	EC[4]
17.12.2008	Revision of the Emission Trading Directive	Euractiv[5]
11.02.2009	EC publishes preliminary list of aviation operators included in the EU ETS	EA[6]
23.04.2009	Revised EU ETS Directive 2009/29/EC	EC[7]
08.06.2009	Detailed interpretation of the aviation activities	EC[8]
28.01.2010	Phlishing - registries closed	Unicredit
06.04.2010	Auctioning proposal by the Commission	Euractiv[9]
03.05.2010	Brussels discusses a 30% CO_2 reduction target	Euractiv[10]
09.07.2010	Cap first step: number of EUAs to be issued for 2013	EC[11]
14.07.2010	CC Committee agrees on auctioning	Unicredit
21.09.2010	Debate on aviation activities in the EU ETS	EC[12]
22.10.2010	Cap second step and publication of benchmark study	EC[13]
12.11.2010	The EC formally adopts the auctioning regulation on 12 November 2010	EC[14]

[1] www.euractiv.com (Article 166690)
[2] www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uriC̄OM:2008:0016:FIN:en:PDF
[3] www.euractiv.com (Article 176099)
[4] www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uriC̄ELEX:32008L0101:EN:NOT
[5] www.euractiv.com (Article 133629)
[6] www.environment-agency.gov.uk/business/topics/pollution/112384.aspx
[7] www.ec.europa.eu/clima/policies/ets/documentation_en.htm
[8] www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uriŌJ:L:2009:149:0069:01:EN:HTML
[9] www.euractiv.com (Article 493948)
[10] www.euractiv.com (Article 493637)
[11] www.europa.eu/rapid/pressReleasesAction.do?referenceM̄EMO/10/314
[12] www.ec.europa.eu/clima/news/articles/news_2010092101_en.htm
[13] www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uriŌJ:L:2010:279:0034:0035:En:PDF
[14] www.ec.europa.eu/clima/news/articles/news_201011180_en.htm

Table 4: Global Carbon Market

Date	Event	Source
19.06.2007	German *Bundestag* decides on 22% CER use in EU ETS	Unicredit
06.08.2008	Link ITL und CITL announced	Unicredit
09.01.2009	Russia is expelled from international trade	Unicredit
28/01/2009	Commission's proposal for a global pact in Copenhagen	EC[1]
20.07.2009	Czech, Poland, Romania and Ukraine sell AAUs	Unicredit
15.09.2009	CDM validator SGS is suspended	Unicredit
18.12.2009	COP Copenhagen 07.12.09 - 18-12.09	Unicredit
21.01.2010	IPCC mistakes	Unicredit
29.03.2010	Validator TÜV and Cemco suspended	Unicredit
12.03.2010	Recycled CERs	Unicredit
23.06.2010	Discussion on HFC projects in the CDM EB	Unicredit
26.08.2010	Discussion on HFC projects reaches EU ETS	Unicredit

[1]EC, Climate change: Commission sets out proposals for global pact on climate change at Copenhagen, Press Release IP/09/141, 28/01/2009.

Table 5: EU ETS NAPs

Date	Event
16.01.2007	NAP Belgium, Netherlands
05.02.2007	NAP Slovenia
26.03.2007	NAP Czech Republic, France, Poland
02.04.2007	NAP Austria
16.04.2007	NAP Hungary
04.05.2007	NAP Estonia
15.05.2007	NAP Italy
25.05.2007	Poland and Czech Republic plan to sue EU over NAPs[1]
04.06.2007	NAP Finland
13.07.2007	NAP Ireland, Latvia, Lithuania, Sweden
31.07.2007	Latvia does not accept EU cap[2]
31.08.2007	NAP Danmark
22.10.2007	NAP Portugal
26.10.2007	NAP Bulgaria, Romania
07.12.2007	NAP Slovakia
23.09.2009	Court decision on Polish NAP[3]

Source: www.ec.europa.eu/clima/policies/ets/allocation/2008
[1]www.euractiv.com (Article 164066)
[2]www.euractiv.com (Article165990)
[3]www.euractiv.com (Article 185715)

Table 6: EU ETS Compliance

Date	Event
02.04.2007	Verified emissions
07.06.2007	Compliance data publication
02.04.2007	Verified emissions
23.05.2008	Compliance data publication
01.04.2007	Verified emissions
15.05.2009	Compliance data publication
01.04.2007	Verified emissions
18.05.2010	Compliance data publication

Source:www.ec.europa.eu/clima/policies/ets/monitoring