Postprint: Impact of Major Announcement Events on Carbon Prices in the EU Carbon Emission Rights Market

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Date: 2018-01-09T00:00:00+00:00

Abstract

As global climate change issues become increasingly prominent, the establishment of carbon emissions trading markets has become a crucial measure for governments worldwide to combat climate change and control greenhouse gas emissions. As a nascent market, carbon market prices are vulnerable to substantial shocks from major institutional announcement events. This article proposes an event study methodology employing bilateral correction dummy variables by incorporating such variables into both the mean and volatility equations of the traditional AR-GARCH model. Using the EU carbon market' s National Allocation Plan (NAP) announcements and Verified Emissions Announcement (VEA) events as case studies, we analyze the potential impacts of important announcements on carbon prices. Empirical results indicate that the bilateral correction dummy variable approach can effectively capture the pre-event and post-event impact processes of announcement events on carbon price returns and volatility. National Allocation Plan announcements generate a significant positive impact on carbon price returns and demonstrate a relatively extended pre-event effect. Verified Emissions Announcements produce a significant post-event negative impact on carbon price returns during Phase I of the carbon market, while yielding significant pre-event and post-event positive impacts on carbon price returns in Phases II and III, with no significant effects on carbon price volatility in either phase. The verified emissions information from Phase I provides an accurate reference for market expectations, thereby attenuating the impact of verified emissions announcements on the carbon market in Phases II and III.

Full Text

Introduction

To control and reduce greenhouse gas emissions, the international community has successively reached the Kyoto Protocol and the Paris Agreement, which specify emission reduction targets for member states from 2008-2020 and establish arrangements for global climate change action beyond 2020. As a cost-effective emission reduction policy instrument, carbon emission trading mechanisms have been adopted by an increasing number of countries and regions. The European Union Emission Trading Scheme (EU ETS) represents the world' s largest carbon market to date. As a newly established market, various institutional announcements may generate significant shocks to carbon prices. For instance, in April 2006, the release of verified emissions announcements (VEA) for countries including the Czech Republic and the Netherlands caused structural breaks in carbon prices. Therefore, analyzing the impact of pivotal announcement events on carbon prices can enhance understanding of carbon price formation mechanisms and deepen comprehension of carbon market operations.

In the EU ETS, National Allocation Plan (NAP) announcements and the VEA system are particularly crucial. NAPs determine the total quantity and allocation method of allowances for each phase, and the sum of allowances in national NAPs defines the total supply for Phase I (2005-2007) and Phase II (2008-2012). VEA annually reports the previous year' s carbon dioxide emissions, thereby crystallizing the randomly varying CO_2 emissions that fluctuate with energy prices and weather conditions into definite figures that reflect compliance entities'demand for allowances. These two types of announcements directly influence market expectations regarding allowance supply and demand, potentially generating significant shocks to carbon prices.

Although the United States announced its withdrawal from the Paris Agreement in June 2017, China remains committed to advancing the agreement' s implementation and achieving its 2030 carbon reduction targets. China is currently actively preparing to establish a unified national carbon market, aiming to achieve emission reduction goals at lower cost through carbon trading mechanisms. However, drastic carbon price fluctuations can severely impact the stable operation of carbon markets. By analyzing the impact processes of NAP and VEA—two major institutional mechanisms—this study clarifies how announcement events affect carbon markets, providing ex-ante and ex-post impact assessments for market regulators and offering references for traders to develop reasonable trading strategies.

Literature Review

Common methods for studying event impacts include event study methodology and dummy variable approaches. Event study methodology captures the impact process by calculating abnormal returns during event windows. The dummy variable approach incorporates variables representing event occurrence into regression equations, quantitatively examining event impacts through the coefficients of these dummy variables. Existing literature has employed both methods to analyze carbon market events. Miclaus et al. used an AR(1)-GARCH(1,1) model to estimate normal carbon price returns and found, through analysis of abnormal returns before and after events, that VEA and NAP announcements in 2005 had more pronounced effects than those in 2006. Hitzemann et al. employed standard event study methodology to analyze VEA impacts from 2005–2009, finding that announcement effects weakened annually with no evidence of information leakage. Mansanet-Bataller and Pardo, as well as Lepone et al., combined event study methodology with truncated normal return outliers and dummy variable approaches to study NAP and VEA announcements, concluding that both significantly affected carbon price returns but had weaker effects on volatility. Deeney et al. found that when the European Parliament released non-partisan political decisions during periods of low market sentiment or sensitivity, carbon prices declined and return volatility increased. Koch et al. examined the impact of EU ETS cap adjustments on carbon prices, showing that decisions to postpone auctions caused price declines, while announcements of EU climate policies for 2020 and 2030 led to price increases.

In research on carbon price drivers, studies introducing dummy variables representing climate factors have found that carbon prices are affected not only by energy prices but also by weather conditions. Specifically, Mansanet-Bataller et al. found that extreme temperatures in Germany had significant positive effects on carbon price returns. Rickels et al. discovered that extremely hot weather in Europe significantly negatively impacted carbon price returns. Wilfried et al. demonstrated that wind speed did not significantly affect carbon price returns during 2005–2006, whereas Chen and Wang found that wind speed had significant negative effects from May 2006 to the end of 2007. Creti et al. showed that other climatological factors such as rainfall did not significantly influence carbon price returns. Alberola and Chevallier found, using dummy variables, that France’ s announcement prohibiting the banking of surplus allowances from Phase I to Phase II suppressed carbon prices. Conrad et al. introduced dummy variables into a fractionally integrated asymmetric power GARCH model for high-frequency carbon price analysis, finding that Phase II NAP-related announcements had stronger and more persistent effects than announcements of economic performance indices for the US and Germany. Liu and Su found that the European debt crisis beginning in 2009 significantly impacted carbon prices.

By improving dummy variable modeling methods, persistent event impacts can be characterized. Schmidbauer and Rosch added dummy variables on one side of events to capture the impact of OPEC announcements on oil prices. Jia et al. modified dummy variables on both sides of events to capture impact processes. This study employs bilaterally modified dummy variable modeling to overcome the limitation of traditional dummy variables that can only capture single-direction effects, thereby completely characterizing the impact processes of NAP and VEA announcements on carbon prices (the process of impact generation → persistence → dissipation) and analyzing the effects of these two announcement types on carbon price returns and volatility during Phases I and II of the EU ETS.

Methodology

Bilateral Modification of Dummy Variables for Impact Process Modeling

Traditional dummy variable modeling can only characterize event impacts through 0-1 variables (Figure 1 [Figure 1: see original paper]). This study uses bilaterally modified dummy variables to capture the impact process of announcements: when the impact begins, how long it persists, and how it dissipates.

This study employs an AR-GARCH model to model carbon prices, incorporating bilaterally modified dummy variables into both the mean and variance equations to characterize the impact processes of NAP and VEA announcements on expected carbon price returns and volatility. The Akaike Information Criterion (AIC) is minimized to select optimal parameters for the modified dummy variables and the optimal model for modeling expected carbon price returns and volatility.

The AR-GARCH model is specified as follows:

$$r_t = c + \sum a_s r_{t-s} + b d_t + \varepsilon_t, \tag{1}$$

$$\varepsilon_t = v_t \sqrt{h_t}, \tag{2}$$

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} + \gamma d_t, \tag{3}$$

$$d_t = \begin{cases} 1, & \text{if announcement occurs on day } t, \\ 0, & \text{if no announcement on day } t. \end{cases} \tag{4}$$

Equation (1) models carbon price returns, where c is the constant term; r_t is the daily log-differenced carbon price series on day t, representing the log return of carbon price on day t; r_{t-s} is the lagged s-period carbon price log return series; and a_s are the coefficients corresponding to r_{t-s}. The variable d_t is the traditional dummy variable, defined in equation (4), used in equation (1) to capture the impact of announcements on expected carbon price returns, with b as its corresponding coefficient. ε_t is the residual on day t. Equations (2) and (3) constitute the GARCH(1,1) model for the conditional variance of carbon price returns, where h_t is the conditional variance of ε_t on day t, and v_t is Gaussian white noise with $\mathrm{Var}(v_t) = 1$. In equation (3), ω is the constant term in the variance equation; ε_{t-1} is the lagged residual series; α is the coefficient for ε_{t-1}; h_{t-1} is the lagged conditional variance series; β is the coefficient for h_{t-1}; d_t is the traditional dummy variable capturing the impact of announcements on carbon price return volatility; and γ is its corresponding coefficient.

Event Duration Impact Model

Based on modeling carbon price returns and volatility, this study incorporates modified dummy variables into both the mean and variance equations to characterize the impact processes of announcement events. The optimal parameters for the modified dummy variables and the optimal model are selected by minimizing AIC.

Given a dummy variable sequence $d^{(0)} = (d_t) = (0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0)$, where t is the announcement date, the modification process involves four steps:

1. Set s_1 ones after the position of the 1 in $d^{(0)}$ to obtain $d^{(1)}$.
2. After the last 1 in $d^{(1)}$, replace the subsequent zeros with a geometric sequence starting with s_2 and having common ratio s_2, where $s_2 \in [0, 1)$. When the terminal term of the geometric sequence falls below 0.1, set that position and all subsequent positions to 0, yielding $d^{(2)}$.
3. Set s_3 ones before the first 1 in $d^{(2)}$ to obtain $d^{(3)}$.
4. Before the first 1 in $d^{(3)}$, in reverse order, replace zeros with a geometric sequence starting with s_4 and having common ratio s_4, where $s_4 \in [0, 1)$. When the terminal term falls below 0.1, set that position and all preceding positions to 0, yielding $d^{(4)}$.

The modified dummy variable $d^{(4)}$ is determined by four parameters $s_i (i = 1, 2, 3, 4)$, with the tuple (s_1, s_2, s_3, s_4) representing a scheme. Here, s_1 depicts the number of days the constant impact persists after the announcement; s_2 depicts the speed of impact dissipation; s_3 depicts the number of days the constant impact persists before the announcement; and s_4 depicts the speed of impact establishment. The resulting modified dummy variable $d^{(4)}$ is illustrated in Figure 2 [Figure 2: see original paper]. When $s_i = 0 (i = 1, 2, 3, 4)$, the modified dummy variable equals the traditional dummy variable definition, i.e., $d^{(4)} = d^{(0)}$.

Optimal Model Selection

When selecting the optimal scheme for modified dummy variables, we first fit equation (1) with dummy variables modified by each scheme (s_1, s_2, s_3, s_4) sequentially, choosing the scheme with the minimum AIC value as optimal. After identifying the optimal scheme for equation (1) and confirming that its residuals ε_t pass serial correlation and heteroskedasticity tests, we fit equations (2) and (3), repeating the selection process to obtain the optimal modified dummy variable scheme for equation (3). By screening for optimal dummy variable modification schemes, we derive the optimal models characterizing expected carbon price returns and volatility. The algorithm is implemented through R programming.

Data

This study uses daily price data for carbon allowance futures contracts expiring in December each year, sourced from the European Environment Agency and the Intercontinental Exchange, covering 2005–2013. Since surplus allowances from Phase I could not be used in Phase II, while allowances from Phases II and III are interchangeable, the impact of Phase I announcement events is examined separately, while Phases II and III are combined for analysis.

Table 1 presents the dates of NAP announcements for Phases I and II with brief descriptions of their content. Table 2 provides the release dates and data descriptions for VEA announcements in both phases. Table 3 shows the annual allocated allowance quantities and verified emissions from 2005–2012, along with their annual and cumulative differences.

Based on Augmented Dickey-Fuller (ADF) unit root tests, all price series are integrated of order one, I(1). Therefore, all price series are transformed into first-order log differences to suit the models used in this study.

Empirical Results and Discussion

4.1 Impact of NAP Announcements

Table 4 and Figure 3 [Figure 3: see original paper] demonstrate that NAP I announcements significantly positively impacted Phase I carbon price expected returns but did not significantly affect carbon price volatility. NAP II announcements significantly positively affected expected returns and significantly increased carbon price volatility. Specifically, the impact of NAP I announcements on expected returns began forming 33 days before the announcement, establishing a constant effect 11 days prior to the announcement (Table 4) that persisted until 6 days after the announcement. However, NAP I announcements did not significantly impact carbon price volatility. The impact of NAP II announcements on expected returns began 7 days before the announcement and lasted until 3 days after. Additionally, NAP II announcements significantly increased carbon price volatility, with the effect beginning to form 31 days before the announcement and establishing a constant impact 10 days prior that persisted until 6 days after the announcement.

In terms of impact direction, both NAP I and NAP II announcements significantly positively affected expected returns, indicating that when NAP information was disclosed, the market perceived allowance supply as relatively tight and did not anticipate the subsequent oversupply.

Regarding impact magnitude, the effect of NAP II announcements (0.011) was substantially weaker than that of NAP I announcements (0.035). This may be attributed to two factors: first, NAP I provided valuable lessons for NAP II formulation, enabling the market to form relatively accurate expectations about NAP II provisions; second, the emission caps and national reduction targets for Phase II (2008–2012) had already been determined before NAP II formulation, allowing the market to anticipate allowance allocations in national NAP IIs with reasonable accuracy.

Figure 3 reveals that the ex-ante impact duration of NAP announcements is noticeably longer than the ex-post impact, likely due to the characteristics of the NAP system. The preparation, submission, review, revision, and approval of NAPs constitute a lengthy and iterative process. Before formal approval, the market may have already formed expectations based on prior information, generating a prolonged ex-ante impact. After announcement release, the market requires relatively little time to absorb the information, resulting in a shorter ex-post impact.

4.2 Impact of VEA Announcements

Table 5 presents empirical results for the impacts of VEA I and VEA II on expected carbon price returns and volatility, corresponding to parameters in equations (1)-(3). Figure 4 [Figure 4: see original paper] illustrates the effects of VEA I and VEA II across different phases.

Table 5 and Figure 4 show that VEA I significantly negatively affected expected returns, while VEA II significantly positively affected expected returns. Neither phase' s VEA significantly impacted carbon price volatility. Specifically, VEA I' s impact on returns began on the announcement day and persisted until 3 days after, after which it dissipated rapidly. VEA II' s impact on expected returns began 4 days before the announcement and lasted until 3 days after, completing the full impact process.

Regarding impact direction, VEA I significantly negatively affected expected returns, while VEA II significantly positively affected them. The annual oversupply of allowances in Phase I caused VEA releases to generate negative shocks to expected returns. In Phase II, early-stage allowance supply fell short of demand, while later-stage supply began to exceed demand (Table 3). This shift in supply-demand dynamics ultimately caused VEA II to generate significant positive impacts on expected returns on average.

In terms of impact magnitude, VEA II' s effect (0.012) was substantially weaker than VEA I' s (0.146). Verified emissions data from Phase I provided a reliable reference for market expectations in Phase II, thereby weakening VEA' s impact.

Examining the impact patterns, VEA I exhibited only ex-post effects, indicating that announcement information was gradually absorbed by carbon prices after release, with no evidence of information leakage. VEA II demonstrated symmetric ex-ante and ex-post impacts, likely resulting from information leakage. The ex-ante impact duration of NAP announcements may stem from the protracted and iterative NAP formulation process. VEA I only generated significant ex-post negative impacts on expected returns, while VEA II produced significant ex-ante and ex-post positive impacts. Compared with VEA I, VEA II' s impact magnitude decreased significantly, possibly because Phase I emissions data provided reliable references for Phase II market expectations.

4.3 Robustness

In addition to using carbon futures price data, this study also employs spot price data from the European Energy Exchange and the Bluenext exchange to analyze the impact of NAP or VEA announcements on carbon prices. Furthermore, by appropriately shortening or lengthening the carbon price time series, we analyze the robustness of announcement event impacts. The empirical results show high consistency, confirming the robustness of our findings.

Conclusion

This study employs an event study methodology using bilaterally modified dummy variables to analyze the impacts of NAP and VEA announcements on expected carbon price returns and volatility in the EU ETS, thereby completely characterizing the impact processes. The results indicate that both NAP and VEA announcements significantly affected carbon prices, demonstrating that information on allowance supply revealed by NAP announcements and information on allowance demand revealed by VEA announcements prompted market participants to adjust their carbon price expectations, thereby facilitating price discovery.

NAP I announcements only significantly positively affected expected returns. NAP II announcements significantly positively affected expected returns and significantly increased carbon price volatility. Compared with NAP I, NAP II’ s impact on expected returns weakened considerably, likely reflecting the market’ s gradual absorption of information from national allocation announcements. NAP announcements exhibited prolonged ex-ante impacts, possibly due to the iterative and lengthy NAP formulation process. VEA I only generated significant ex-post negative impacts on expected returns, while VEA II produced significant ex-ante and ex-post positive impacts; compared with VEA I, VEA II’ s impact magnitude decreased significantly, as Phase I emissions data provided reliable references for market expectations in Phase II.

In carbon markets, NAP and VEA mechanisms directly determine allowance supply and demand. Designing appropriate allowance supply levels represents both a challenge and a key consideration in carbon market design. While excessively tight allowance supply would increase compliance costs for enterprises and negatively impact economic development, overly loose supply can lead to persistently low carbon prices, dampening market participants’ enthusiasm for investing in low-carbon technologies. Market designers should consider establishing flexible allowance supply mechanisms to maintain carbon prices within reasonable ranges. Additionally, EU ETS experience shows that NAP and VEA announcements can sometimes increase carbon price volatility, raising carbon asset risks. Market designers should explore effective mechanisms to reduce market shocks from announcements to maintain stable market operation.

To promote energy conservation, emission reduction, and climate change mitigation, China is actively planning a unified national carbon market. As a model for carbon markets, the EU ETS’ s mechanism design and empirical experience offer valuable lessons for China. First, emission cap design represents a key challenge in carbon trading mechanism design. Phase I experience from the EU ETS shows that if the emission cap (NAP I) is set too loosely, the release of emissions information (VEA I) can generate negative market shocks, undermining enterprises’ incentives to invest in low-carbon technologies. Establishing flexible emission cap mechanisms to stabilize carbon prices represents one solution. Currently, the EU ETS has implemented short-term measures to postpone auctioning some allowances since 2014 and plans to establish a Market Stability Reserve as a long-term mechanism starting in 2019. These approaches offer insights for China’ s carbon market design. Second, major announcement events may increase carbon price volatility, and market designers should explore effective mechanisms to reduce announcement impacts and safeguard stable market operation.

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