Option market and volatility in the EU ETS

Julien CHEVALLIER

Imperial College London (Grantham Institute for Climate Change) and University of Paris 10 (EconomiX-CNRS)

Yannick LE PEN

Université de Nantes (LEMNA)

Benoit SEVI

Université d’Angers (GRANEM) and (LEMNA)

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Introduction

- Two possible consequences on the tradable permits markets:
  1. Options do not increase volatility, but rather increase the liquidity and the informational efficiency of the underlying market (Mayhew (2000))
  2. Options may affect the volatility of the underlying market, since they affect producers’ decisions through intertemporal arbitrage (Weaver et al. (1990))
- Aims of this paper:
  - Empirical investigation on the effect of the introduction of options on the volatility of the carbon market.
Outline of the presentation

Introduction

Data

Empirical analysis
Introduction: the EU ETS: a *compliance* market

- Approximately 10,600 installations covered
- Each installation needs to surrender each year a number of allowances
- Allowances are fixed by each Member State in its National Allocation Plan (NAP), equal to its verified emissions (Ellerman and Buchner (2008), Alberola et al. (2009))
- To comply with their emissions target, installations exchange quotas:
  - over-the-counter
  - through brokers and market places.
Introduction: main European markets

1. **Bluenext** (formerly called *Powernext Carbon*) - Paris
   - dedicated to CO₂ allowances
   - created on June 24, 2005
   - the most liquid platform for spot trading: 72% of the volume of spot contracts are traded on Bluenext.

2. The **European Climate Exchange** (ECX) - London
   - created on April 22, 2005
   - October 13, 2006: options introduced by ECX
   - the most liquid platform for futures and options trading: 96% of the volume of futures contracts are traded on ECX.
Introduction: previous works

• Studies on the EU ETS option market remain very scarce.
    • describe extensively derivative instruments on the EU carbon market based on qualitative surveys.
  2. Chesney and Taschini (2008)
    • application of CO₂ price dynamics modelling to option pricing.
  3. Chevallier et al. (2009)
    • a case-study of investors' changes in risk aversion around the 2006 compliance event using both futures and option prices.

• no prior study has investigated the effects of the introduction of the option market in the EU ETS (to the best of our best knowledge)
Introduction: aims and methodology of our paper

- We examine the following central questions:
  1. What has been the impact of the option market on the carbon price in terms of volatility, efficiency, and autocorrelation?
  2. Do other factors such as institutional decisions, energy and global commodity markets contribute to changes in volatility?

- Our methodology:
  - A GARCH (1,1) model with a dummy variable for modelling the opening of the option market.
  - Introduction of exogenous variables in the modelling of conditional volatilities
  - Rolling estimation and endogenous structural break test detection.
Data

- Daily futures and option prices for the December 2008 and 2009 contracts traded in euro/ton of CO₂ on ECX.
- 756 daily observations from April 22, 2005 to April 04, 2008
  - 378 daily observations before and after the introduction of option prices on October 13, 2006
- source: ECX, Bloomberg and Reuters.
Descriptive statistics

Table: Descriptive Statistics of ECX EUA Futures Returns

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<td>Carbon Futures Returns</td>
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<td>29.1426</td>
</tr>
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</table>

- Comments:
  - negative skewness
  - excess kurtosis
  - a non gaussian distribution
Impact of the option market in the EU ETS

- Our aim: to compare the level of volatility of the underlying allowance market \textit{before} and \textit{after} the opening of the option market;
- A GARCH(1,1) model with a dummy variable
- $DF_t = 0$ for the pre-option period, and 1 for the post-option period.

\begin{equation}
R_t = \beta_0 + \beta_1 R_{t-1} + \epsilon_t
\end{equation}

\begin{equation}
\epsilon_t \sim \sqrt{h_t} e_t \quad \text{with} \quad e_t \sim iid(0, 1)
\end{equation}

\begin{equation}
h_t = E(\epsilon_t^2 | \phi_{t-1}) = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma DF_t
\end{equation}
Impact of the option market in the EU ETS: results

**GARCH(1,1) estimates with and without dummy variable**

*Carbon futures returns of maturity December 2008 and December 2009*

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<th>EUA\textsubscript{DEC08}</th>
<th>EUA\textsubscript{DEC09}</th>
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<tbody>
<tr>
<td>Mean equation</td>
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<tr>
<td>$\beta_0$</td>
<td>0.0023** (0.001)</td>
<td>0.0021** (0.001)</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.1398*** (0.048)</td>
<td>0.1413*** (0.047)</td>
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<td>Variance equation</td>
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</tr>
<tr>
<td>$\alpha_0$</td>
<td>7.74e-05*** (1.45e-05)</td>
<td>8.33e-05*** (1.61e-05)</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>0.3039*** (0.027)</td>
<td>0.2858*** (0.029)</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>0.6544*** (0.037)</td>
<td>0.6710*** (0.039)</td>
</tr>
<tr>
<td>$DF_t$</td>
<td>-1.85E-05 (1.26E-05)</td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>1680.86</td>
<td>1681.38</td>
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</table>

Notes: The dependent variables are the EUA carbon futures return for the contract of maturity December 2008 and December 2009, depending on the column under consideration. Other variables are explained in eq(4) and (5). Standard errors in parenthesis. *** indicates significance at 1%, ** at 5% and * at 10%. LL refers to the log-likelihood.
Impact of the option market in the EU ETS: conclusions

1. $DF_t$ not significant $\Rightarrow$ no impact of the official opening of the option market on volatility.

2. Another explanation: the level of the volatility may be affected by other risky factors.
Exogenous variables in the variance equation

- The main risk-driving factors on the carbon market linked to:
  - energy prices
  - institutional decisions (compliance event)
  - see (Christiansen et al. (2005), Mansanet-Bataller et al. (2007),
    Alberola et al. (2008), Chevallier (2009)).
- Another source of risk:
  - the variation of global commodity markets
- we consider estimated standard deviations for several energy-related
  factors.
- standard deviations computed by a moving window of 25 days
  (about one trading month)
Exogenous variables in the variance equation

1. Energy variables: the volatility of
   - returns on brent, coal and natural gas prices, (proxy for the influence of power producers)
   - clean dark and clean spark spreads and the switch price (fuel-switching behavior on carbon price changes)


3. A dummy variable $D_{APR06} = 1$ from April 25 to June 23, 2006, and 0 otherwise
   - sharp price break in carbon prices of all maturities in April 2006 (Alberola et al. (2008)).
   - consequence of institutional development of the EU ETS during phase I: verification of 2005 emissions in April 2006
Exogenous variables in the variance equation

- we modified the GARCH model as follows:

\[ h_t = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma DF_t + \varphi X_t \]  \hspace{1cm} (4)

- \( X_t \) a vector of exogenous variables
  - the dummy variable \( D_{APR06} \)
  - estimated standard deviations for energy variables,
  - the \( CRB \) variable.
Exogenous variables in the variance equation: results

**GARCH(1,1) estimates with (significant) exogenous factors**

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<th>(EUA_{DEC09})</th>
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<td>(2)</td>
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<tr>
<td>Mean equation</td>
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</tr>
<tr>
<td>(\beta_0)</td>
<td>0.0020** (0.0009)</td>
<td>0.0012 (0.001)</td>
</tr>
<tr>
<td>(\beta_1)</td>
<td>0.1292*** (0.048)</td>
<td>0.1986*** (0.052)</td>
</tr>
<tr>
<td>Variance equation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\alpha_0)</td>
<td>9.26e-05*** (4.86e-05)</td>
<td>0.0002*** (1.68e-05)</td>
</tr>
<tr>
<td>(\alpha_1)</td>
<td>0.2130*** (0.032)</td>
<td>0.3615*** (0.057)</td>
</tr>
<tr>
<td>(\alpha_2)</td>
<td>0.7136*** (0.043)</td>
<td>0.6584*** (0.042)</td>
</tr>
<tr>
<td>(DF_t)</td>
<td>-3.21e-05** (1.30e-05)</td>
<td>-7.55e-05*** (1.72e-05)</td>
</tr>
<tr>
<td>(vol\ oil)</td>
<td>0.0105* (0.005)</td>
<td>-0.0003*** (2.69e-06)</td>
</tr>
<tr>
<td>(vol\ clean\ spark)</td>
<td>-8.89e-06*** (1.65e-06)</td>
<td>-1.27e-05*** (1.43e-06)</td>
</tr>
<tr>
<td>(vol\ clean\ dark)</td>
<td>7.01e-06*** (2.08e-06)</td>
<td>1.96e-05*** (4.15e-06)</td>
</tr>
<tr>
<td>(vol\ coal)</td>
<td>-0.009*** (0.003)</td>
<td>-0.0112*** (0.0008)</td>
</tr>
<tr>
<td>(vol\ power)</td>
<td>0.0003** (0.0001)</td>
<td>8.45e-05 (0.0001)</td>
</tr>
<tr>
<td>LL</td>
<td>1638.798</td>
<td>1626.26</td>
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</table>

Notes: The dependent variables are the EUA carbon futures return for the contract of maturity December 2008 and December 2009, depending on the column under consideration. Other variables are explained in eq. (4) and (6). Standard errors in parenthesis. ** indicates significance at 1%, *** at 5% and * at 10%. LL refers to the log-likelihood.
Exogenous variables in the variance equation: comments

- $DF_t$ becomes statistically significant at the 5% and 1% levels for, respectively, the December 2008 and December 2009 contracts.
- The sign of $DF_t$ is negative,
- the introduction of the option market has decreased volatility in the EU ETS.
- Dapril06, $CRB$: insignificant variables
Endogenous search for structural break

• One problem of the previous methodology: the date of the structural break is chosen \textit{a priori}.

• the impact of the introduction of the option market may have appeared at a date different from its official opening.

• the dynamics of conditional volatility may have been affected by other structural breaks not yet taken into account in our empirical analysis

• two methods in order to detect possible structural breaks
  1. rolling estimation
  2. test for a structural break in unconditional volatility
Rolling estimation

- Estimation of a GARCH (1,1) model:

\[
R_t = \beta_0 + \beta_1 R_{t-1} + \epsilon_t
\]

(5)

\[
\epsilon_t \sim \sqrt{h_t} e_t \quad \text{with} \quad e_t \sim iid(0, 1)
\]

\[
h_t = E(\epsilon_t^2 | \phi_{t-1}) = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 h_{t-1}
\]

(6)

for a rolling window of \(L=200\) observations.

- a sequence of time indexed estimates of the autoregressive coefficient \(\{\beta_1|t-L, t\}\) and the coefficients of the GARCH model:

\(\{\alpha_0|t-L, t\}, \{\alpha_1|t-L, t\} \) and \(\{\alpha_2|t-L, t\} \)
Rolling estimation: results

From left to right:

autoregressive $\{\beta_1|_{t-L}, t\}$, arch $\{\alpha_1|_{t-L}, t\}$, garch $\{\alpha_2|_{t-L}, t\}$ coefficients
Rolling estimation: comments

- Changes in the GARCH coefficients ⇒ changes in the dynamics of conditional volatility.
- first change :date $t = 05/05/2006$:
  - increase in the ARCH coefficient from 0.4 to 1
  - decrease in the GARCH coefficient from 0.6 to 0.4.
  - ⇒ increased impacts of shocks on conditional volatility
- coincides with the strong adjustment of market operators’ anticipations following the publication of the first report of verified emissions by the European Commission (Alberola et al. (2008))
Rolling estimation: comments

- second change: date $t=05/02/2007$
  - decline in the ARCH coefficient
  - increase in the GARCH coefficient
  - lower impact of shocks on volatility
- can be interpreted in light of the 2007 compliance event (verification of 2006 emissions)
- The operators may have anticipated the release of the European Commission report
- The adjustment of the anticipations may have occurred early than in 2006
Tests for structural breaks

- Iterated Cumulative Sum of Squares (ICSS) to detect multiple breaks in variance.
- Evidence of five possible breaks in unconditional variance.
- Highest level of variance for the period: 24/04/06 to 15/05/06.
- Decline of unconditional volatility after...
Breaks in the time profile of unconditional variance
Conclusion

1. The ECX option market seem to have reduce the volatility of the carbon market.

2. “youth” of the carbon market and rules in the making concerning the second trading period (2008-2012)
   - high volatility around yearly compliance events during the first years of the EU ETS
   - strong reversals in anticipations of market participant
   - no noticeable change in volatility dynamics, once agents have a better knowledge of the market