

The impact of the European Union Emission Trading Scheme on electricity generation sectors

Djamel KIRAT & Ibrahim AHAMADA

Paris School of Economics, Université Paris 1 Panthéon-Sorbonne
IEW 2009

19 June 2009

- 1 Motivations of the paper
 - The global framework
 - Literature review
 - Research question
- 2 The econometric modelling
 - From stylized facts to the econometric model
 - Data
 - Estimation of the models
- 3 Results and interpretations
 - Equations of the mean
 - What's about temperature?
 - Impact of carbon spot price
 - The variance equations
- 4 Conclusion

The global framework

- The main objective of the EU ETS is to encourage the industry's most emitters to reduce their carbon emissions and invest in clean technologies
- The sector of electricity generation is the most CO₂ emitter
- Thus, **to know if the EU ETS gives appropriate economic incentives for an efficient and strong system in line with Kyoto commitments**, we study its impact on the sector of electricity generation
- If so, electricity producers should include the price of carbon in their costs functions

Literature review

- Sijm et al. (2005, 2006): An OLS estimate of a basic linear model (German and Dutch cases)
- Honkatukia et al. (2006): A VAR model (Finnish market case)
- Bunn et Fezzi (2007): A VAR model (English market case) with short run restrictions
- The coexistence of various electricity markets and the heterogeneity of energy mixes of the European Union countries leads to non unanimous response about the impact of the EU ETS on electricity producers
- These articles have covered, at most, the period from January 2005 to May 2006

Research question

- **The impact of the EU ETS during its pilot phase on electricity generation sectors taking into account the diversity of energy mixes of the European Union countries**
- We consider France and Germany since these countries participate to the EU ETS and have a very different energy mixes

From stylized facts to the econometric model

- The price of electricity depends on marginal cost. The marginal cost of electricity is equal to the cost of primary energy used to produce the last unit of electricity, operating cost thereon, plus any inclusion of carbon cost of production of that unit

From stylized facts to the econometric model

- The price of electricity depends on marginal cost. The marginal cost of electricity is equal to the cost of primary energy used to produce the last unit of electricity, operating cost thereon, plus any inclusion of carbon cost of production of that unit
- The level of electricity demand depends on climatic variables. The temperature exerts a dual effect on energy demand in general and that of electricity in particular

From stylized facts to the econometric model

- The price of electricity depends on marginal cost. The marginal cost of electricity is equal to the cost of primary energy used to produce the last unit of electricity, operating cost thereon, plus any inclusion of carbon cost of production of that unit
- The level of electricity demand depends on climatic variables. The temperature exerts a dual effect on energy demand in general and that of electricity in particular
- $P_t^{elect} = E_t [P_t^{elec*} | Z_t, P_{t-1}^{elec}, P_{t-2}^{elec}, \dots] = g(Z_t, P_{t-1}^{elec}, P_{t-2}^{elec}, \dots)$

From stylized facts to the econometric model

- The price of electricity depends on marginal cost. The marginal cost of electricity is equal to the cost of primary energy used to produce the last unit of electricity, operating cost thereon, plus any inclusion of carbon cost of production of that unit
- The level of electricity demand depends on climatic variables. The temperature exerts a dual effect on energy demand in general and that of electricity in particular
- $P_t^{elec} = E_t [P_t^{elec*} | Z_t, P_{t-1}^{elec}, P_{t-2}^{elec}, \dots] = g(Z_t, P_{t-1}^{elec}, P_{t-2}^{elec}, \dots)$

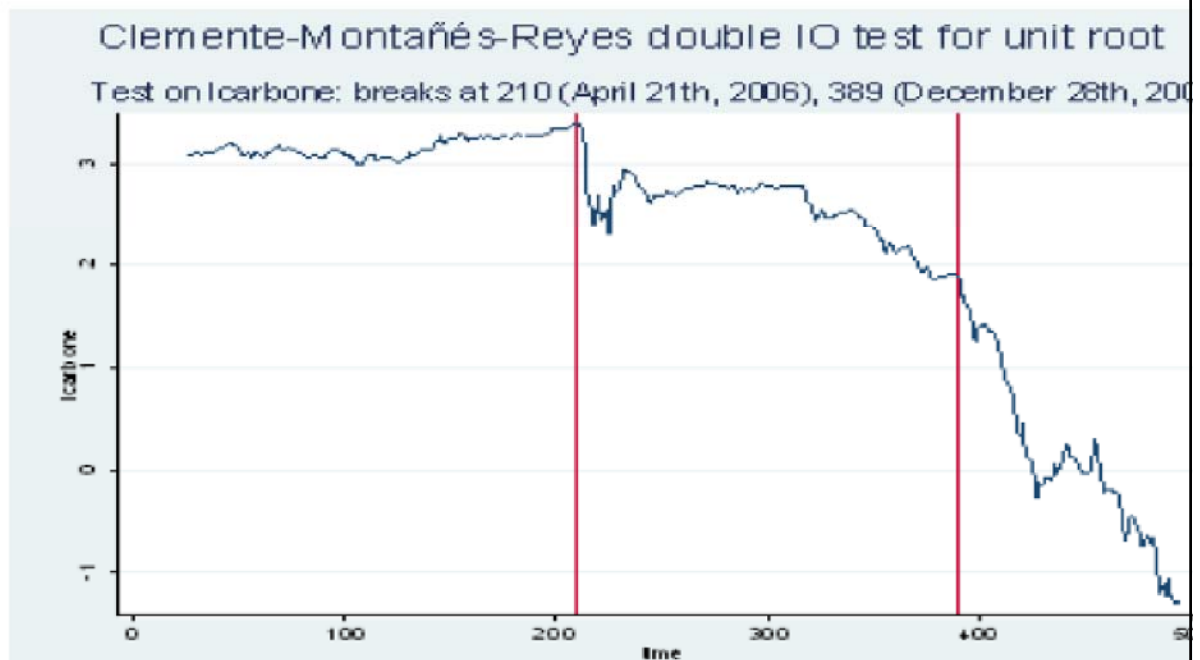
$$P_t^{elec} = \alpha_0 + \sum_{i=1}^p \alpha_i P_{t-i}^{elec} + \beta P_t^{gas} + \delta P_t^{coal} + \gamma P_t^{carbon} + \lambda_1 T_t^{cod} + \lambda_2 T_t^{hot} + \varepsilon_t$$

DATA

The data used in this study are weekdays frequency and run from July 4th, 2005 to June 29th, 2007

- Day-ahead and month-ahead base load electricity prices of the French and German electricity stock exchanges
- The carbon spot price of the Powernext stock exchange
- The gas price of the month-ahead future contract traded on the Zeebrugge hub
- The coal price of the month-ahead future contract Coal CIF ARA.
- The temperature variables T^{hot} and T^{cod} were built from the Powernext daily index of temperature (expressed in degrees Celsius) for both countries

The carbon spot price



Estimation of models representing Month-ahead electricity contracts

- The French case:

$$P_t^{elec} = \alpha_0 + \alpha_1 P_{t-1}^{elec} + \beta P_t^{gas} + \delta P_t^{coal} + \gamma P_t^{carbon} + \lambda_1 T_t^{cod} + \lambda_2 T_t^{hot} + \varepsilon_t$$

Estimation of models representing Month-ahead electricity contracts

- The French case:

$$P_t^{elec} = \alpha_0 + \alpha_1 P_{t-1}^{elec} + \beta P_t^{gas} + \delta P_t^{coal} + \gamma P_t^{carbon} + \lambda_1 T_t^{cod} + \lambda_2 T_t^{hot} + \varepsilon_t$$

- The German case:

$$P_t^{elec/ger} = \alpha_0 + \sum_{i=1}^2 \alpha_i P_{t-i}^{elec/ger} + \beta P_t^{gas} + \delta P_t^{coal} + \gamma P_t^{carbon} + \lambda_1 T_t^{cod/ger} + \lambda_2 T_t^{hot/ger} + \sum_{j=2}^5 \psi_j season_j + \varepsilon_t^{ger}$$

$\varepsilon_t^{ger} \rightsquigarrow GARCH(1, 1)$

Estimation of models representing day-ahead electricity contracts

Concerning the price series of day-ahead contracts, the concern to take into account any interdependence of the French and German electricity markets leads us to retain the following model with Dynamic Conditional Correlation (Engle, 2002; Engle and Sheppard, 2001) $DCC_E(1,1)$ errors:

$$\left\{ \begin{array}{l} P_t^{elec/fra} = \alpha_0 + \sum_{i=1}^2 \alpha_i P_{t-i}^{elec/fra} + \beta P_t^{gas} + \delta P_t^{coal} + \gamma P_t^{carbon} \\ \quad + \lambda_1 T_t^{cod/fra} + \lambda_2 T_t^{hot/fra} + \varepsilon_t^{fra} \\ \\ P_t^{elec/ger} = \alpha_0 + \sum_{i=1}^2 \alpha_i P_{t-i}^{elec/ger} + \beta P_t^{gas} + \delta P_t^{coal} + \gamma P_t^{carbon} \\ \quad + \lambda_1 T_t^{cod/ger} + \lambda_2 T_t^{hot/ger} + \sum_{j=2}^5 \psi_j season_j + \varepsilon_t^{ger} \\ \\ (\varepsilon_t^{fra}, \varepsilon_t^{ger}) \rightsquigarrow N(0, H_t) \end{array} \right.$$

The DCC(1,1) model

The model $DCC_E(1, 1)$ is defined as:

$$\begin{cases} H_t = D_t R_t D_t \\ D_t = \text{diag}(\sqrt{h_{11t}}, \sqrt{h_{22t}}) \\ R_t = (\text{diag } Q_t)^{1/2} Q_t (\text{diag } Q_t)^{-1/2} \end{cases}$$

Where the 2×2 symmetric positive definite matrix Q_t is given by:

$$Q_t = (1 - \theta_1 - \theta_2) \bar{Q} + \theta_1 u_{t-1} u_{t-1}^T + \theta_2 Q_{t-1}$$

Table 1. Estimation results of the selected models

Country Contract	France Month ahead	France Day Ahead			Germany Day Ahead			Germany Month Ahead		
		full	before	after	full	before	after	full	before	after
	period	period	break	break	period	break	break	period	break	break
Mean equation										
P_{t-1}^{elec}	0.927*** (0.018)	0.610*** (0.052)	0.329*** (0.064)	0.363*** (0.098)	0.471*** (0.038)	0.442*** (0.038)	0.237*** (0.129)	0.636*** (0.12)	0.779*** (0.086)	0.422*** (0.121)
P_{t-2}^{elec}		0.214*** (0.051)	0.215*** (0.065)	0.159 (0.097)	0.251*** (0.056)	0.246*** (0.071)	0.212** (0.106)	0.293 (0.129)	0.123 (0.050)	0.078 (0.152)
P_t^{gas}	0.042*** (0.010)	0.094*** (0.030)	0.125*** (0.036)	0.040 (0.097)	0.128*** (0.043)	0.170*** (0.042)	0.070 (0.115)	0.090*** (0.026)	0.062*** (0.023)	-0.030 (0.132)
P_t^{coal}	0.007 (0.026)	-0.181* (0.104)	-0.017 (0.145)	0.638 (0.612)	0.037 (0.145)	0.140 (0.146)	1.49* (0.904)	0.068 (0.076)	0.056 (0.073)	0.541 (0.267)
P_t^{carbon}	-0.001 (0.002)	0.004 (0.007)	0.067*** (0.023)	0.019 (0.022)	0.019** (0.009)	0.002*** (0.021)	0.016 (0.027)	0.002 (0.004)	0.022** (0.011)	-0.019 (0.019)
T^{hot}	-0.006 (0.001)	0.012*** (0.004)	0.006 (0.005)	0.028*** (0.009)	0.011*** (0.004)	0.007 (0.005)	0.031*** (0.008)	0.004* (0.002)	0.005* (0.003)	0.001 (0.004)
T^{cool}	0.001 (0.001)	-0.001*** (0.004)	-0.000*** (0.006)	-0.007*** (0.007)	-0.014*** (0.004)	-0.012*** (0.005)	-0.025*** (0.012)	-0.012 (0.009)	-0.009*** (0.004)	0.006 (0.055)
$cons$	0.103* (0.037)	0.732*** (0.222)	0.181 (0.244)	-0.431 (1.230)	0.695** (0.229)	0.313 (0.230)	-1.52 (1.02)	0.084 (0.131)	-0.027 (0.164)	0.582 (0.092)
$season_{12}$					-0.075*** (0.029)	-0.078*** (0.029)	-0.067 (0.067)	0.052*** (0.022)	0.076*** (0.022)	0.026 (0.026)

What's about temperature?

- Temperature do not affect the prices of month-ahead electricity contracts in both countries
- Softening temperature influence the price of day-ahead electricity contracts to decline and variations in temperature towards extreme values influence these prices in increase
- Temperature influences only the prices of day-ahead electricity contracts. The short term of day-ahead contracts and the difficulty to predict with accuracy the level of temperature beyond a few days explain that electricity supply intended to meet the changes in electricity demand due to temperature variations is provided through day-ahead contracts

...and carbon spot price?

- On average and over the whole period the carbon spot price was not a determinant of the prices of French electricity contracts. In Germany, carbon spot price had an impact only on the price of day-ahead contract

...and carbon spot price?

- On average and over the whole period the carbon spot price was not a determinant of the prices of French electricity contracts. In Germany, carbon spot price had an impact only on the price of day-ahead contract
- However, the carbon spot price has been a determinant of the price of electricity during the first two years of the EU ETS operation. Then, the price of electricity was completely disconnected from the carbon spot price in the last year of the pilot phase of EU ETS

The variance equations (1)

- A greater stability of the price of German day-ahead electricity contract around its long run equilibrium path compared to the price of French day-ahead one

The variance equations (1)

- A greater stability of the price of German day-ahead electricity contract around its long run equilibrium path compared to the price of French day-ahead one
- Day-ahead electricity prices in Germany and France were much more correlated during the first two years of operation of the EU ETS than over the period that followed

The variance equations (1)

- A greater stability of the price of German day-ahead electricity contract around its long run equilibrium path compared to the price of French day-ahead one
- Day-ahead electricity prices in Germany and France were much more correlated during the first two years of operation of the EU ETS than over the period that followed
- The highest correlation has coincided with the period during which the electricity producers had been most constrained by the EU ETS

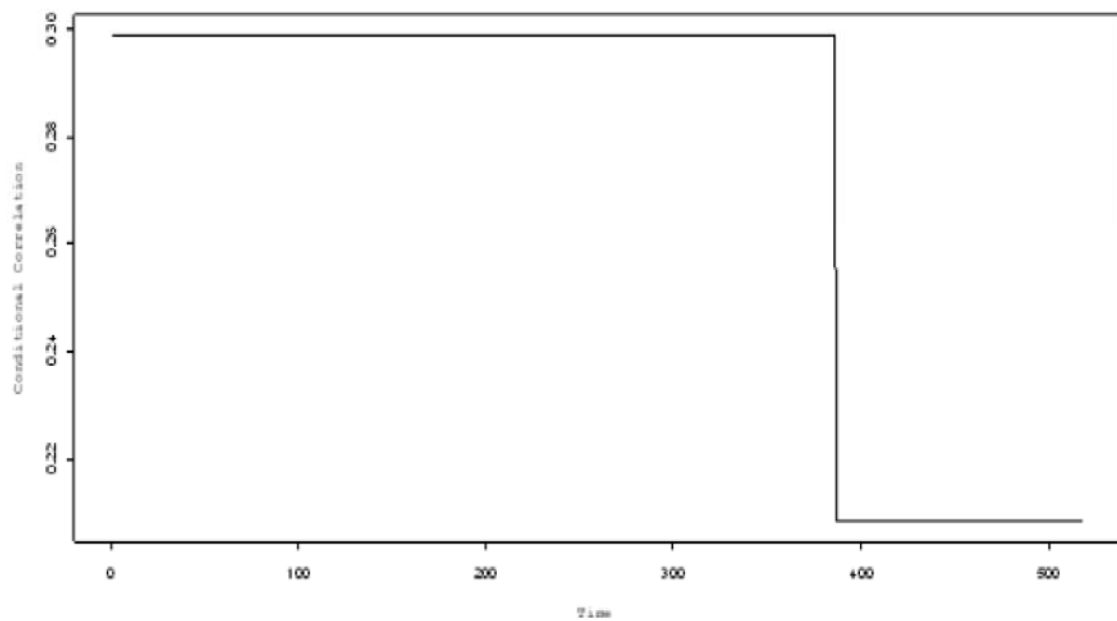
The variance equations (2)

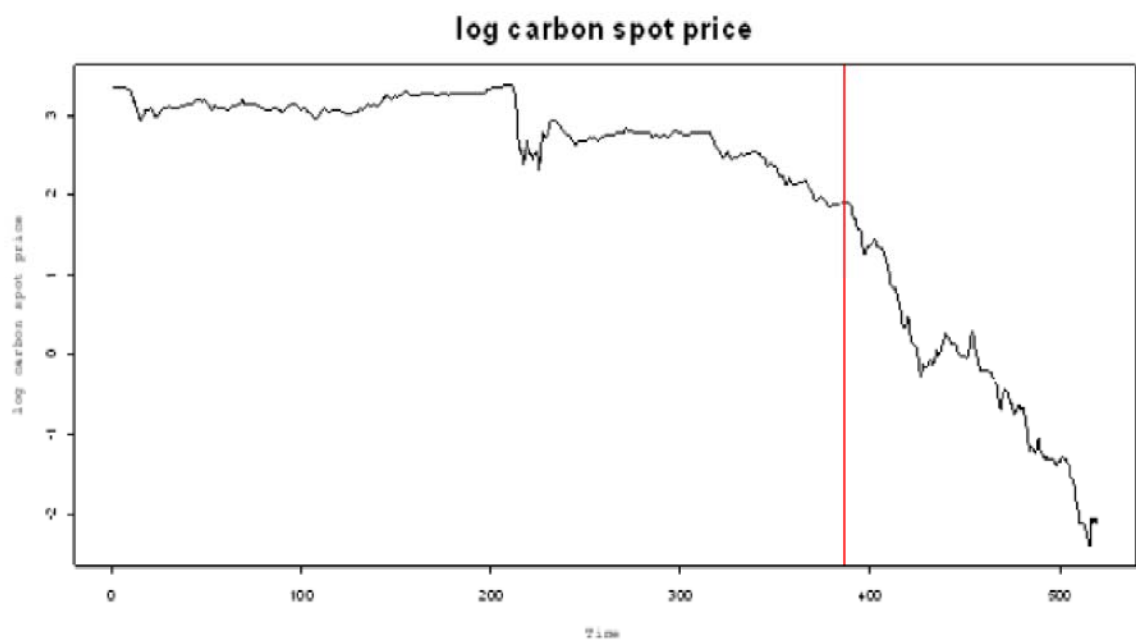
- So, in a context where the debate on the possible manipulation of the electricity wholesale prices in France by the historical producer is still relevant today, it seems reasonable to expect that the wholesale prices of electricity in France are partially aligned with those of Germany

The variance equations (2)

- So, in a context where the debate on the possible manipulation of the electricity wholesale prices in France by the historical producer is still relevant today, it seems reasonable to expect that the wholesale prices of electricity in France are partially aligned with those of Germany
- During the first two years of EU ETS operation, the carbon market has allowed French electricity producers to pull more profits from the composition of their productive parks

Time varying conditional correlation





Conclusion

- The EU ETS had an impact on the sector of power generation in both countries even if it was not of the same magnitude
- German electricity producers have more undergone the carbon constraint than their French counterparts
- During its pilot phase, the impact of the EU ETS on electricity generation sectors has experienced two phases
- The EU ETS increased the market power of the historical French electricity producer and greatly contributed to the partial alignment of the wholesale price of electricity in France with those in Germany

Thank you

djamel.kirat@univ-paris1.fr
ibrahim.ahamada@univ-paris1.fr