Energy Economics 33 (2011) 995–1003

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

The impact of the European Union emission trading scheme on the electricity-generation sector ☆

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ARTICLE INFO

Article history:
Received 15 September 2009
Received in revised form 22 January 2011
Accepted 23 January 2011
Available online 4 February 2011

JEL classification:
C14
C32
C51
Q49
Q58

Keywords:
Carbon emission trading
Multivariate GARCH models
Structural breaks
Non-parametric approach
Energy prices

ABSTRACT

In order to comply with their commitments under the Kyoto Protocol, France and Germany participate in the European Union Emission Trading Scheme (EU ETS) which predominantly concerns the electricity-generation sectors. In this paper we ask whether the EU ETS provides the appropriate economic incentives to produce an efficient system in line with the Kyoto commitments. If so, electricity producers in the countries concerned should include the price of carbon in their cost functions. After identifying different sub-periods of the EU ETS during its pilot phase (2005–2007), we model the prices of various electricity contracts in France and Germany and look at the volatility of electricity prices around their fundamentals while evaluating the correlation between electricity prices in the two countries. We find that electricity producers in both countries were constrained to include the carbon price in their cost functions during the first two years of the EU ETS. Over this period, German electricity producers were more constrained than their French counterparts, and the inclusion of the carbon price in the electricity-generation cost function was much more stable in Germany than in France. We also find evidence of fuel switching in electricity generation in Germany after the collapse of the carbon market. Furthermore, the European market for emission allowances has greatly contributed to the partial alignment of the wholesale price of electricity in France to that in Germany.

1. Introduction

To implement the Kyoto Protocol, the European authorities established the European Union Emissions Trading Scheme (EU ETS). This is mainly concerned with energy[2] and the major emitters of the industrial sector. The market is based on a "*cap and trade*" mechanism. Market players receive free annual carbon-emission permits at the beginning of the year. They then fulfil their commitment by providing permits corresponding to the tons of CO2 they have emitted by the end of the year. Those that have emitted more CO2 than their allocation comply by buying more permits on the market. The energy sector, and particularly the electricity-generation sector, is by far the biggest CO2 emitter. It hence received the largest share of the Community allocation of permits over the 2005–2007 period. This allows us to trace out more clearly the close relationship between the electricity market, the market for fossil fuels used in electricity generation and the European market for CO2 permits.

The main objective of the EU ETS is to encourage the industry's biggest emitters to reduce their carbon emissions and invest in clean technologies. Achieving this objective relies on a real carbon price signal inducing electricity producers to make long-run choices to produce electricity with fewer emissions. In this context, the ex-post empirical analysis of the impact of the European market for CO2 permits on energy markets is essential for the assessment of the efficiency and consequences of the EU ETS.

The price of electricity is determined by the cost of fossil fuels, the impact of environmental policies, and climatic factors such as temperature and rainfall. Economic theory suggests that the carbon price is a marginal cost and that the opportunity cost of the carbon permit equals its market price. As such, the carbon price should be reflected in the price of electricity. Empirically, the sharp fall in the price of CO2 of about 10 €/t in April 2006 which was immediately followed by a fall of 5 to 10 €/MWh on the electricity market (Reinaud, 2007), and the English company British Energy losing 5% of its market capitalization over three days in the same period (Bunn and Fezzi, 2007) suggest a link between the carbon and electricity markets.

There has been considerable work on the effect of carbon prices on electricity prices in various European markets over the past five years. Sijm et al. (2005, 2006) use OLS to determine the fraction of the

☆ We would like to thank Katheline Schubert, Andrew Clark and the anonymous referees of this paper for their helpful discussions and comments. We also thank discussants and participants in the "Environmental Economics" seminar held in Lille on February 10th, 2009 and the 2009 International Energy Workshop conference (Venice).

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0140-9883/$ – see front matter
doi:10.1016/j.eneco.2011.01.012

carbon price reflected in electricity prices in Holland and Germany. Honkatukia et al. (2007, 2008) consider the long- and short-run dynamics of electricity, gas and coal prices and the price of carbon permits in the Finnish market via a VAR analysis. Bunn and Fezzi (2007) adopt a similar approach to analyze the English electricity market, without taking into account the price of coal but including temperature and seasonal dummies as exogenous variables. They carried out a structural analysis of the relationship between energy and carbon prices through short-run restrictions.

The results are mixed regarding the effect of the EU ETS on electricity prices (Reinaud, 2007). This is mainly due to the coexistence of different electricity markets in Europe and the heterogeneity of National energy mixes. In addition, existing analysis has been restricted to the January 2005 to December 2006 period and has neglected any structural breaks in the carbon spot price.

We here aim to provide a sound assessment of the impact of the EU ETS on the electricity-generation sector, taking the heterogeneity of National energy mixes into account. We deal with the volatility of the electricity price around its fundamentals and compare two European countries with very different energy mixes, France and Germany. The estimated models are based on electricity-generation cost functions including the cost of carbon. The estimation methodology allows us to measure the instantaneous correlation between the wholesale electricity prices across the two countries. We cover the whole pilot phase of the EU ETS (2005–2007) and take into account different sub-periods. The paper is organized as follows. Section 2 presents the functioning of the electricity sector and the EU ETS, and the price-formation mechanism for emission permits and their impact on the electricity sector. Section 3 presents a descriptive analysis of the relationship between electricity markets on the one hand and primary energy and carbon markets on the other; this section also describes the econometric modelling. Section 4 presents the results and their interpretation, and Section 5 concludes.

2. The electricity-generation sector and the EU ETS

The electricity sector received nearly 55% of the Community CO2 permit allocation in the pilot phase of the European market. Before analyzing the impact of the introduction of carbon constraints, it is probably useful to describe how the sector is organized. There are four main areas: production, transportation, distribution and marketing. There are also purely financial activities such as brokerage and trading (over the counter or on power exchanges). Electricity generation is the main polluting activity and since 1998 has been opened up to competition in the process of liberalizing the European electricity market. Electricity is produced from various primary energy sources: nuclear, coal, oil, gas, hydropower, biomass, wind, solar and geothermal power. The share of each of these describes the energy-source mix in electricity generation. This mix differs sharply from one European country to another due to differences in energy policies and the particular geographical and geological features of each country. In addition, electricity differs from other goods as it is not storable, which explains some of the particular characteristics of the generation sector described below.

2.1. The profitability of power plants and the merit order between power generation technologies

There are considerable fluctuations in electricity demand from one hour, day and season to another. Continuous adaptation of electricity supply is thus required to meet demand. The cost of electricity production differs according to the primary energy source used, and therefore so does profitability. Electricity production is characterized by the sequential use of production technologies depending on production costs. Producers start up power plants to meet demand, in increasing order of their variable marginal costs of production. This is the concept of "*merit order*" between different technologies which is determined by the variable marginal cost of production (where variable costs refer to fuel and operational costs).

This *merit order* between technologies is not fixed. In particular, the inclusion of the price of carbon allowances in the cost functions of polluting technologies can affect the order of profitability. The switching price was thus defined by Sijm et al. (2005) as the price of carbon at which it becomes more profitable for a producer to use a gas power plant rather than a coal plant.

The choice of power production plans does not depend only on the *merit order*, but also on technical parameters such as the number of functioning hours necessary for the profitability of a given type of plant, the depreciation of fixed capital invested in different plants, and the availability of the KWh produced. Electricity producers make complex calculations of production costs of different technologies while ensuring that production follows real-time demand. In peak periods, a number of production units are used, and as demand falls so does the number of production units. This implies stopping and restarting units depending on demand. The operational features of the production units (including start-up time, the levels of maximum and minimum production, and energy efficiency) imply that power plants may be used continuously or discontinuously.

2.2. The emissions-trading scheme and its impact on electricity producers

The CO2-emission permit is freely-traded, and its price is determined on the market. We should here distinguish between the short-run daily market and the long-run annual compliance to which market participants commit themselves. This distinction suggests that persistent shocks may occur when agents react to a greater extent downstream to the information from the carbon market, by incorporating the price of emission allowances into their long-run strategies.

The permit market was initially scheduled to run in two phases (Phase 1 in 2005–2007; and Phase 2 in 2008–2012). In each phase, each European Union member had to accept a national allocation plan for an annual reduction of CO2 emissions while retaining the prerogative over major variables, such as the emissions ceiling, the list of plants concerned and the rules for allocating quotas to existing and new facilities. The plan stipulates that the percentage of emission reductions for each installation in a country is "*grandfathered*". There is therefore an obligation to reduce annual CO2 emissions and thus, throughout the European Union, a supply function of CO2-emission reduction (Bunn and Fezzi, 2007) reflecting the increasing marginal costs of reducing emissions over a year. In the electricity-generation sector, this supply function reflects changes in the *merit order* curve between the primary energies. As these changes depend on the energy mixes and existing installations in each country, the emissions supply function includes the lower costs of substituting lignite for coal in Germany, and the higher abatement costs of substituting gas for coal. The response of the electricity sector to reducing annual CO2 emissions differs from one EU country to another, depending on the country's energy mix, the prices of primary energies and the price of the carbon quota.

Agents buy and sell permits for CO2 emissions in the daily allowance market. They make their decisions based on their forecasts $E_t[f(D_j)]$, where f is the emission reduction supply function and D_j the required emission reduction during phase j. These forecasts, which focus on the annual equilibrium price of CO2, will evolve continuously over the year (Bunn and Fezzi, 2007). As electricity producers who emit more CO2 than their allowances will buy allowances on the market to be in compliance, the carbon price should be added to the fuel and operational costs of electricity generation. On the other hand, due to the free allocation of CO2-emission allowances to participants at the beginning of the period and the emergence of a carbon price from the daily market, these permits are a new liquid asset available to participants, creating an opportunity cost for emission permits which equals their market price (Sijm et al., 2006).