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Impact of the carbon price on the integrating European electricity market

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HIGHLIGHTS

- We model the integrating European electricity market under emissions trading scheme.
- We examine the impact of carbon price on the electricity market prices.
- We test theoretical hypotheses with econometric models.
- Results show carbon price has a positive but uneven impact on electricity prices.
- Integration among electricity prices has increased during 2003–2011.

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ABSTRACT

We study the impact of the carbon price on the integrating electricity market in the EU. Our theoretical framework suggests that the price of carbon has a positive but uneven impact on electricity prices depending on the marginal production plant. The carbon price may increase price differences in the short run. We apply time series analysis on daily forward data from 2003 to 2011 and investigate whether we can find empirical evidence for our analytical findings. Our results support the hypotheses that integration in electricity prices has increased over time and that the carbon price has a positive but uneven impact on the integration of prices.

1. Introduction

The European Union is currently creating a single European electricity market. The EU Council has set the objective of a functioning internal electricity market by 2014 (EC 2009/72/EC). The integration of the EU electricity markets started already in the 1990s but the process has been slow. The key means to promote the creation of an internal electricity market has been market liberalization and increasing transmission capacity between regional electricity grids. All regional electricity markets are now physically connected to each other at least to some extent. This integration process is closely related to issues of competitiveness and energy self-sufficiency, which are also elements of general security policy. By the mid-2000s, climate change mitigation and adaptation policies at national and international level started to play an increasing role in the energy markets. In general, one can expect that while a harmonizing electricity market will lead to a convergence of electricity prices, climate policies, like the European Union emissions trading system, EU ETS, will increase electricity price levels in general.

In the electricity market, increasing transmission capacity and harmonization of trading rules in financial markets encourage marginal generation costs to equalize and the price of electricity to converge. In the electricity market, this progress has been strongest in the Nordic area. The EU ETS market, in turn, is a well established internal market of the EU which aims to reduce emissions in a cost-efficient way. It started in 2005 and its third phase is to start in 2013. The energy sector is the biggest sector in the EU ETS, and thus the interaction between these markets is of special interest. The way these markets interact is not, however, entirely evident. Both markets have their own institutional structure and the physical non-storability character of electricity creates an extra challenge. Therefore, it is interesting to investigate how the EU ETS impacts the price of electricity and the convergence of EU-wide electricity prices. This question constitutes the research problem of this paper. We answer the question by examining through what channels the price of the European Union emissions allowance (EUA) works in the electricity

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market to create harmonization. Clearly, the EU ETS has both short and long-term impacts.

We investigate the market integration in the EU electricity markets. We employ the definition of market integration by Engle and Rogers (2004): market integration shows up in price convergence that is in the reduction of internal price dispersion over time. Price converge provides efficiency gains, as marginal costs of production become equal between regions and countries. Drawing on this definition, we examine price convergence in four different regional electricity markets represented by six price areas in the EU: the Nordic, UK, Central Europe and Iberian electricity markets. The study period is from February 2003 to August 2011. We further divide this into three sub-periods in order to see how interdependences have evolved over time. Our specific research questions are the following: how has the EU ETS market affected the integration of the European electricity market and convergence of electricity prices? What is the impact of the carbon price on different regional prices? Do the prices of electricity and the EUA share a common trend?

To answer these questions, we first develop a theoretical framework for the electricity market under emissions trading. Comparative statics of market equilibrium shows that there are two mechanisms present at the same time. The EU ETS increases the costs of fossil fuel-based electricity production but may impact regional electricity prices differently thanks to differences in energy mixes. Electricity market integration in turn promotes the convergence of electricity prices. Based on this analysis our hypothesis for the empirical work is that while the integration of prices strengthens over time, emissions trading may originally even increase price differences.

Using econometric analysis of time series data for electricity and EUA prices we estimate the long-run price relationships between prices before the implementation of the EU ETS (2003–2004) and during the two phases of the EU ETS (2005–2007) and (2008–2011). We start with a simple correlation analysis and pairwise Granger causality analysis to elicit the relationships between the variables. We then run cointegrated VAR models with multivariate time series based on Johansen (1988) cointegration analysis. We study the common trends within these markets and study the variance decompositions to find the price relationships and driving forces within these markets.

Our work relates to previous literature as follows. Integration of the electricity market has been studied a lot since the first drafts of market decoupling. Bower (2002), Armstrong and Galli (2005) and Turvey (2006) study regional prices empirically and evaluate the success of EU policy on electricity market integration. Recently, Huisman and Kiliç (2013), Zachmann (2008) and Bunn and Gianfreda (2010) conclude that the European electricity market is not yet strongly integrated. Bosco et al. (2010) examine and find long-run price relationships between European electricity prices and gas prices. The long-run relationship between carbon prices, electricity prices and fuel prices has been examined using similar methods to ours in Fezzi and Bunn (2009) and Creti et al. (2012). Sijm et al. (2006) have a wide analysis on the pass-through of carbon costs to electricity prices. To our knowledge, previous literature has not, however, examined the joint integration of these two markets. We include the impact of the EUA price on integrating electricity markets. Our results suggest that the emissions trading market has a positive but diverse impact on converging electricity prices. In addition, the impact of the EUA on electricity market integration varies in the short and long run. The overall integration of electricity markets has increased over the study period and after the launch of the EU ETS has become even stronger.[1]

The rest of the paper is organized as follows. Section 2 sets out the theoretical framework and hypotheses for the empirical part. Section 3 describes the two European internal markets, the electricity market and the EU ETS market and the data used in the analysis. Section 4 presents the econometric models and the results and finally Section 5 concludes the principal findings of the theoretical and empirical analysis.

2. Theoretical framework: Impact of permit price on electricity markets

Consider an electricity sector comprising multiple firms using different energy sources to produce electricity. The grid must at all times meet the demand for electricity. Hydro and nuclear power plants generate the base load and are always connected to the grid, which may be domestic or function jointly between many countries. Therefore, changes in demand are met using more expensive but adjustable fossil and renewable energy sources. Provided transmission cables to nearby grids exist, electricity can be exported or imported to smooth required changes in electricity supply in both grids.

We denote by $D(p)$ the residual demand for adjustable electricity generation. We consider power plants based on combustion; they can generate electricity from gas or coal or by co-firing fossil and renewable energy sources. Furthermore, we allow some plants to generate electricity based on non-combustion technologies, such as wind or solar energy. We start describing how emissions trading impacts the behavior of each plant and then determine the electricity market impacts.

Starting with single-fuel plants (coal or gas), we follow Lintunen and Kangas (2010) and describe the choice of single-fuel plant using a cost function that imposes a penalty cost once generation approaches maximum capacity. Let one unit of fossil energy source, x, produce emissions of an amount εx. Furthermore, let η describe generation efficiency, which is a linear function of the energy source used. We denote the penalty function by $\phi(x)$, with positive first and second derivatives. The profit-maximization problem of the fossil fuel plant under emissions trading can then be expressed as follows,

$$\pi = p\eta(x) - wx - q\varepsilon x - \phi(x). \tag{1}$$

The first-order conditions are

$$p\eta - w - q\varepsilon - \phi'(x) = 0. \tag{2}$$

Interpretation is conventional. The second-order conditions hold, and warrant comparative statics which showing that $x = x(p_+, q_-, w_-, \varepsilon_-)$. The result is as expected. A higher price of electricity, p, increases the use of fossil fuel to expand generation, whereas a higher permit price, q, input cost, w, and unit emission, ε, decrease it.

Consider next a plant co-firing both fossil and renewable energy sources. The cost of using fossil fuel is as before and we assume that the use of a renewable resource, r, in generation entails increasing costs (e.g. due to increased transport costs). We denote these costs by $\xi c(r)$, where ξ is a shift parameter of the cost

[1] The single European electricity market has been studied a lot both analytically and empirically since the first drafts of legislation in the early 1990s (Helm, 2004; Sioshansi, 2006). The European electricity market reform is driven by two directives in 1996 and 2003 (96/92/EC, 2003/54/EC). Jamasb and PollittPollit (2005) discuss these in detail. Newbery (1999), Joskow (2006) and Littlechild (2000) are among the scholars who discuss analytically the unbundling of electricity generation and transmission and privatization of electricity markets. Bower (2002), Armstrong and Galli (2005) and Turvey (2006) have all studied market integration in European day-ahead market prices. Bower (2002) analyzes the same countries as we do and finds already in 2001 a degree of market integration. Turvey (2006) focuses on the impact of interconnectors in the integration process and finds insufficient correlations between the price differentials and physical transfer.