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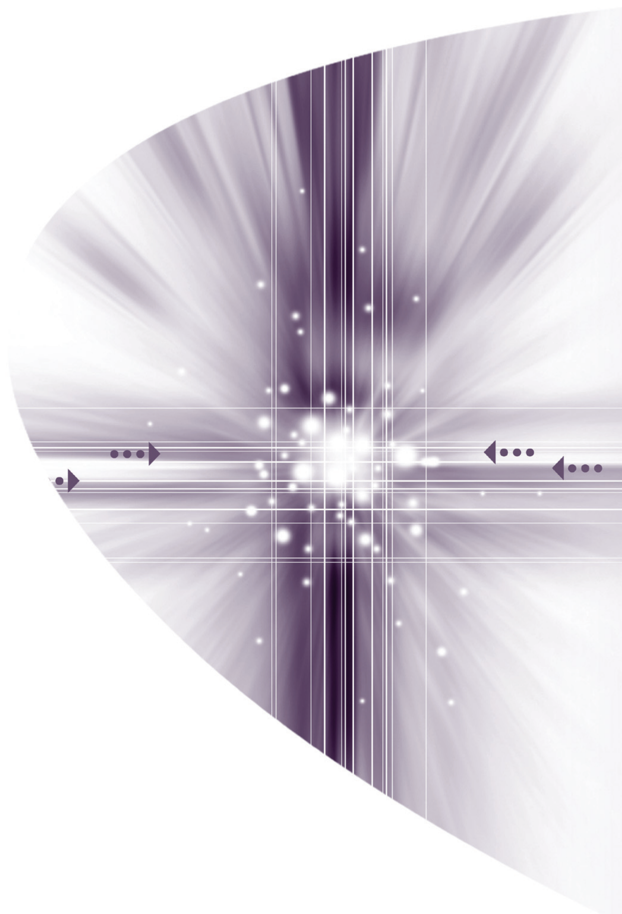

Impacts of emission trading on power industry and electricity markets

Guest Editors: Fushuan Wen and S.N. Singh

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Guest editorial

About the special issue

Climate change is deemed one of the most important issues in this millennium, and has become an emerging issue with extensive concern due to the ever-worsening global warming. Emissions trading, an efficient way to reduce the emissions of greenhouse gases in principle, has been implemented in the European Union, and proposed in a number of other countries including Australia and the USA. The electricity sector is one of the major contributors for the green house gases emission. Several energy and environmental policies have been adequately considered by governments in various countries for creation of certified emission reductions from clean development mechanism projects and emission reduction units. Policy makers and/or regulators suggest developing an emission trading system in which a market-based carbon dioxide emissions, and emission allowances can be traded. The potential impacts of emission trading on the power industry and electricity markets are believed to be significant, and much research work has been done around the globe in recent years.

The purpose of this special issue on impacts of emission trading on power industry and electricity markets is to investigate the impacts, or potential impacts, of various schemes of emissions trading on power industries and electricity markets, including key issues of emissions trading scheme design, the methods of allowance allocation and particularly their impacts on generation investments, enhancement of renewable energy sources and electricity prices. In this special issue, there are six papers covering many dimensions of the emission trading in the power industries. Emission trading considering the transmission capacity constraints, generation scheduling and block bidding strategy has been investigated in two papers. The impact of economic dispatch in emission trading utilizing benefit factor is analyzed. The issue of fairness and equity in apportionment of emission reduction is also discussed in one paper. Few papers addressed the issue of emission trading in the electricity markets considering different mechanism.

This special issue is very useful to researchers, academicians, practitioners, utility management team members, system operators and policy makers.

Fushuan Wen and S.N. Singh
Guest Editors

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Assessment of emission trading impacts on competitive electricity market price

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Abstract

Purpose – Besides organizational changes in the electricity supply industry there are growing concerns about environmental issues derived from the Kyoto Protocol for the reduction of greenhouse gas emissions as well as promoting renewable energies. The purpose of this paper is to address the source side emission trading impact on electricity prices in the competitive power market.

Design/methodology/approach – Various schemes are suggested and are being implemented to achieve this objective. It is expected that electricity price will increase due to imposition of emission taxes. This paper analyzes the impact of electricity prices in the competitive electricity markets having a uniform market clearing price mechanism.

Findings – It is found that the electricity prices depend on the system loading, generation mix, etc. at a particular hour. Various emission trading instruments are discussed with a special emphasis on the European market.

Research limitations/implications – Block bidding of the suppliers is considered whereas the demand is assumed to be inelastic.

Originality/value – The emission trading impacts are analyzed on a simple example.

Keywords Emission trading, Market clearing price, Tradable green certificates, Emission credit, Electricity, Prices

Paper type Research paper

1. Introduction

The quantified emission targets for developed countries for the period from 2008 to 2012 has been set by the Kyoto Protocol which provided the creation of certified emission reductions from clean development mechanism projects and emission reduction units. Several energy and environmental policies has been adequately

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considered by electric utilities for their decision making, and regulators for their monitoring, since these have a significant impact on the profitability of investments and on the economic and environmental performance of the power sector.

The European Commission's directive 2003/87/EC of the European Parliament and of the council of the European Union (EU) established a scheme for green house gas emission allowance trading within community in order to promote reductions of greenhouse gas emissions in a cost effective and economically efficient manner (European Commission, 2009). The European council of March 2007 made a firm commitment to reduce the overall greenhouse gas emissions of Community by at least 20 per cent below 1990 levels by 2020 and by 30 per cent provided that other developed countries commit themselves to comparable emission reductions and economically more advanced developing countries contribute adequately according to their responsibilities and respective capabilities. By 2050, global greenhouse gas emissions should be reduced by at least 50 per cent below their 1990 levels. A review taken in 2007 has confirmed that a more harmonized emission trading system is imperative in order to better exploit the benefits of emission trading.

The emission trading system has been suggested by the European Commission where a market-based carbon dioxide emissions, and emission allowances can be sold and purchased within the EU area. The policy approach for regulating emission from the electric supply industry (ESI) in the European Union's emission trading scheme (EU-ETS) is to cap industry-wise emissions at the source and allow emission allowances to be traded between the regulated entities. This is termed as cap-and-trade source-based (SB) scheme. There are some criticisms that this scheme leads to the emission leakage. Several western states have utilized an alternative regulatory approach for the ESI, known as load based (LB) cap-and-trade scheme.

This paper addresses the source side emission trading impact on the electricity prices in the competitive power market. Various case studies are considered in a uniform market clearing price (MCP) mechanism. Block biding scheme of the suppliers has been taken in an inelastic demand response. It is found that the electricity prices depend on the system loading, generation mix, etc. at a particular hour. Various emission trading instruments are discussed with a special emphasis to the European market.

2. Tradable green certificates and tradable emission permits

The European Commission (2001), to promote the renewable energy sources, launched a directive on the share of the renewable energy sources in the member states based on the consumption of electric energy. Germany, France and Spain opted for their well-established feed-in tariff system to support the renewable energy sources whereas Sweden, Denmark, Italy, Belgium and the UK introduced tradable green certificates (TGCs), which differ in the way of implementation in each country. In Denmark, there were early discussions on replacing a support system based on fixed feed-in-tariffs, which has proved to be effective, with a TGC system (Danish Energy Authority, 2001). The main idea of TGC is to use market forces to determine necessary additional payment to investors in renewable electric plants. The green certificates, which are valid for both new and existing renewable capacities or only to new renewable capacities, depend on the country to country.

In Sweden, the TGC was initiated in 2003 and will continue until 2030. The main objective of TGC system is to promote electricity from renewable energy sources (RES-E). So far, RES-E production in Sweden has been increased but mostly from increased production in already existing biomass-combined heat and power plants. The renewable obligation (RO) scheme was initiated in UK in 2002. The current RO amounts to 15 per cent of electricity supply in 2020. So far, the RO system has under-achieved in relation to its quantitative target. Wind power is the dominant RES-E technology and the main investors/producers are the major utilities, the ex-monopoly companies (Stenzel and Frenzel, 2008). According to an analysis by the European Commission (CEC, 2008), the RO has been costly for the consumer similar to the Swedish TGC system. The Finland's TGC system was initiated in 2002 with a quota of 0.8 per cent of power sales and aiming at 6 per cent by 2010. An analysis of the period 2002-2007 shows that the RES-E production has increased to more than two TWh in 2007 (4.9 per cent of electricity sales). Most of the RES-E was delivered from bio-waste flows exploited by incumbent power companies or waste processing companies. The technologies ranged from co-incineration in inefficient old coal-fired plants to newly set-up biomass combustion using non-sustainable bio-fuels (e.g. palm oil).

The validity of the certificates also differs from country to country. In Italy, the validity of green certificate is for the reference year only whereas in Denmark and the Netherlands, it has no expiry date. The maximum and minimum prices are to be set to avoid the huge profitability for renewable or to avoid the penalty for not buying the certificates. To provide more certainty to the investments in new renewable energy, the minimum price will insure sellers of TGC to receive some minimum additional income from the green certificates. The price-cap on TGC had been introduced in several countries.

To promote the renewable energy use and to reduce the greenhouse gas emission at lowest possible cost, a market-based scheme with tradable CO_2-emission permit (TEP) was proposed to come in force in 2005. With this there is two market-based systems in parallel and there is a string relation between these two markets. However, it is not clear how these schemes will impact on the energy prices.

3. Impact on Nordic countries

It has been reported that EU emissions trading increases the electricity generation costs of all production modes with CO_2 emissions. The average annual electricity price increase depends on the periods that each generation mode is setting the marginal price. The average cost increase with coal condensing power in the Nordic market is about 0.9 €/MWh for every 1.0 €/tone CO_2, which results from the average efficiency of coal condensing plants in operation and the CO_2 emission factor. In the first phase of the EU emission trading, the majority of emission allowances have been allocated to the operators as free allocation. A part of the emission allowances needed for CO_2 emitting producers can be bought from the market, and it is likely that the marginal costs of emission allowances is fully passed to the electricity price. Carbon tax is to be charge on the net energy production rather than the install capacity to avoid the leakage.

The average impact of emission trading on electricity prices in the Nordic market has been studied in Unger and Ahlgren (2005) up to the year 2010. A basic assumption for generation capacity was that there will be a slight increase in renewable production like wind and biomass, and some natural decommissioning within fossil fuel plants like coal. The amount of nuclear power will grow due to the 1,600 MW Finnish unit presently under construction. As a result of CO_2 emissions trading, the annual average electricity price was found to rise 0.74 €/MWh for every 1 €/tonne CO_2 in the Nordic area (Koljonen *et al.*, 2004). This is a result of the periods that each generation mode is setting the marginal price in an average year.

The EU-ETS allocates a limited amount of rights to emit CO_2 (EU-Allowances) to electricity producers using fossil fuels in their power generation (Rathmann, 2007). Member States administered the allocation for the 2005-2007 trading period. Most Member States allocated the EU Allowances for free to the participants, based on their historic emissions (Grandfathering). Owing to the fact that EU-Allowances can be traded a price for CO_2-emissions can now be established as market forces come into play. Thus, electricity producers have to face costs for emitting CO_2 as they have to buy EU-Allowances if they exceed CO_2-emissions allocation. One of main criticism made that EU-ETS discourages rather than encourages investment in new and low-carbon technologies in the long-term.

In the liberalized wholesale electricity market, electricity prices are set by the marginal generator including the value of emissions in the allowance market. If the marginal producer is a (high-carbon) coal power generator, the power price can increase significantly as a result of the EU-ETS. Low-carbon electricity generators such as hydro, nuclear or renewables will have substantial rents from generally higher power prices without incurring extra costs. Power generators in an essentially domestic EU market find it easy to pass on additional carbon costs. As a result, power generators are paid twice: once by the power prices, including the full cost of carbon and once in the form of free allowances, in fact receiving windfall profits. It is difficult to assess the exact level of economic rents or windfall profits gained by power companies as the impact of CO_2 allowance prices on power prices is hard to establish. Power prices are determined by a large variety of factors, including fuel prices, available generation capacity, euro/dollar exchange rates, investment costs, power imports, weather conditions, heat demand ("must runs"), the flexibility of gas contracts as well as market expectations and more.

4. Market clearing price

The market-clearing price is the lowest price that would provide enough electricity from accepted sales bids to satisfy all the accepted purchase bids. Each generator bids to sell its available supplies at some offer price and each utility (or other load serving entity) bids to purchase electricity at some offer price. The price formation is an internal decision of sellers and buyers. Generators having several types of plants (thermal, hydro, combine cycle, etc.) price their commodities so as to be commercially successful in the supply-demand competitive electricity market. A supplier may have the dispatch strategies that will reflect numerous technical and commercial particularities.

To obtain the market-clearing price, the sales bids are ranked from the lowest offer price to the highest offer price, i.e. in their merit order. Similarly, the purchase bids are ranked from their highest offer price to the lowest offer price. Equivalently, for purchasers that simply offered to buy a fixed quantity, the quantities would just be added up. At some price, the total of sales bids up to that point in their merit order would be equal to the total of purchase bids down to that point in their merit order. That price is the market-clearing price. Once the market-clearing price is determined, all bids to sell with offer prices lower than or equal to the MCP and all bids to purchase with offer prices greater than or equal to the market-clearing price is accepted. All sales bids with higher offer prices or purchase bids with lower offer prices would be rejected.

4.1 Single price market clearing process

Single price market clearing process is also known as uniform MCP mechanism, in which all the sellers would receive the market-clearing price for their electricity, even if they bid less than that price and all buyers will pay the market-clearing price, even if they bid more than that price. The theory behind such a bidding system is that all bids to sell electricity would be priced at the marginal cost of that electricity. Bidding at a lower price than marginal cost would also not change the revenues if the bid were lower than the market-clearing price. However, such a bid could result in the firm selling electricity at a price lower than its marginal cost and thus losing money. Therefore, for a firm operating competitively, bidding a price equal to its marginal cost would lead to the greatest profit. In theory, such a competitive market would be desirable, suggested by economist, for the wholesale electricity markets and would result in the lowest total cost to generate a given amount of electricity.

4.2 Pay-as-bid market clearing process

In this mechanism, the bidders just paid as what they bid, rather than to pay them the market-clearing price. The total cost of all purchases would be averaged, and each buyer would pay the average bid price. Many have argued that a system of paying on pay-as-bid basis, rather than on a market-clearing basis, would result in smaller total payments by the buyers of electricity. Under pay-as-bid system, each firm makes the most profit by guessing the cut-off price and bidding at or just below that price, as long as the cut-off price is at least as high as its marginal cost. Thus, even in a competitive market, suppliers would not bid at their marginal costs. If all firms could guess the cut-off price perfectly, each firm whose marginal cost was no larger than the cut-off would bid the cut-off price and each would be paid the cut-off price. The cut-off price would be the same as the market-clearing price.

The advantage often postulated for such a system would disappear under the perfect guessing. Although each firm would learn much from observing the results of the hourly bids, 24 a day, there would undoubtedly be mistakes, and to compensate, firms would bid somewhat below their estimate of the cut-off price. Some lower-cost firms would guess incorrectly and bid above the cut-off price, thereby leading to increases in the cut-off price. Thus, some higher-cost firms would generate electricity and some lower-cost firms would remain idle. The total cost of generating the given quantity of electricity would, therefore, be increased above the cost in a market-clearing system. The net result would be some variability in the prices paid for electricity at any hour, with some prices higher than what would have been the market-clearing price and some possibly lower.

Whether such a system would increase or decrease the total payments for obtaining a given quantity of electricity would depend on the precise bidding strategies of the various market participants. However, pay-as-bid system could be expected to increase the total cost of generating electricity and would, therefore, be less efficient than a one-price market-clearing system. There is another difficulty with the auction system, arising because the system is based on hourly or half-hourly bidding and market clearing. Some generating plants, typically operating as base-load plants, have very long and very costly periods for ramping up from no production to full capacity. These plants might be profitable to operate if they received at least a particular price for a large fraction of the day or for all of the peak period of a day. However, if they were operating only a few hours, even at a higher price, they might not be profitable to operate, since the fixed costs of ramping up could be greater than the profit earned during those more limited hours. For such plants, their offer price at any hour must depend on whether they would be generating electricity at the other hours of the day.

5. Determination of electricity pricing

Two types of bid models are suggested: linear bid and block bid. Block bid model seems to be very promising and practiced in several electricity markets, moreover the linear bid model are being user in the analysis purposes. In this paper, block bid model had been used to frame the supply function of any individual generator-*i* as (Singh and Erlich, 2008):

$$q_i(p) = \sum_{j=0}^{NB} q_{ij}(u(p, p_{i,j}) - u(p, p_{i,j+1})) \quad \forall p_{i,j} \in P_i \tag{1}$$

where q_{ij} is the power output of ith generator during jth block. $p_{i,j}$ ($p_{i,j} < p_{i,j+1}$) is the price of jth block of ith generator. NB is the number of bid blocks. $u(p, p_{i,j})$ is the unit function defined as:

$$u(p, p_{i,j}) = \begin{cases} 1 & if \quad p \geq p_{i,j} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

The cumulative supply curve of all the generators having Ng in numbers can be written as:

$$q(p) = \sum_{i=1}^{Ng} \sum_{j=0}^{NB} q_{ij}(u(p, p_{i,j}) - u(p, p_{i,j+1})) \tag{3}$$

For a given demand fixed demand D, the MCP p^* can be obtained by solving following equation:

$$\sum_{i=1}^{Ng} \sum_{j=0}^{NB} q_{ij}^* \left(u(p^*, p_{i,j}) - u(p^*, p_{i,j+1}) \right) = D \tag{4}$$

The payment given to supplier-i will be $p^* q_i^*$, where q_i^* is the total output power of supplier-i to be dispatched.

If the customers are also allowed to bid in the blocks, the demand curve of any rational customer can be expressed as: