The Role of CO2 in power markets – in line with Competition? [1]

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ABSTRACT

The economics that link markets for CO2 and power do not appear to be well understood by some regulators and policy makers. In Germany, for example, the competition authority originally alleged that the consumption of CO2 permits in electricity production did not imply an opportunity cost. The authority further claimed that electricity prices in Germany only rose in line with permit prices because market dominance allowed incumbents to pass on permit costs to consumers. In addition, the German government recently stated that it had intended to pass permits out for free as this would keep electricity producers from reflecting the market price of CO2 in their power offerings.

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[1] Note: This paper draws on previous work undertaken by Frontier on behalf of the Dutch energy regulator DTe and on work presented before the Bundeskartellamt during the public hearing in the current abuse investigation in the electricity sector.

These discussions reveal two fundamental misconceptions about the nature of opportunity cost and the pass through of cost in competitive industries which we address analytically and empirically in this paper.

We conclude that the reflection of CO2-prices in power prices is an indication of a working CO2 market and should be seen as a normal outcome within a competitive power market.

INTRODUCTION AND BACKGROUND

The beginning of 2005 saw the introduction of Phase I (2005-2007) of the European Union Emissions Trading Scheme (EU ETS). The scheme requires large emitting parties[2] to match any CO2 emissions with rights – so called CO2-permits – to those emissions. Firms that fall under this scheme were given a free initial allocation of permits. For each country, the initial allocation of the permits was specified through a national allocation plan (NAP). These permits are also tradeable Europe-wide, thus each participating party in the EU can decide whether to use the exact number of permits allocated to it, to reduce the level of emissions and sell permits or to increase the level of emissions and thus to purchase permits. Most importantly the overall allocation of permits was such that it implied a reduction in emissions compared to the expected level of emissions in the absence of the ETS. This created an overall scarcity of permits and conveyed a market value to these rights.

Electricity prices have since risen in line with the development of permit prices. This triggered the German Bundeskartellamt (BKartA hereafter) to open proceedings towards the end of 2005 against two large German electricity generators (RWE and E.ON) under provisions in German competition law similar to Article 82 of the EC Treaty. The BKartA asserted that these players had abused an alleged dominant position by reflecting the market price of the CO2-permits in electricity wholesale prices[3]. The BKartA considered this link between CO2-permit prices and electricity prices unwarranted, as these permits had been given out for free and as each player had received permits roughly to the extent "that he needed".

Underlying the BKartA reasoning were a number of economic misconceptions which this paper redresses. We do so by considering the following:

2 Such as most power generators albeit not the very small ones and industrial producers, like aluminium smelters.

3 See Bundeskartellamt, „Sachstandsbericht“, 20.März 2006, (www.bundeskartellamt.de).

- **Opportunity cost nature of CO2-permits** – it has been clear to economists since Coase's seminal paper[4] that the consumption of any good for which a property right could be defined – for example CO2-permits – and which has a positive value in the market implies an opportunity cost. This holds independent of whether the property right is originally allocated for free.

- **Logic of the pass through of the cost of CO2** – simple economic reasoning suggests that the degree to which a change in the production cost (e.g. through the introduction of the European CO2-regime) that affects all players in the relevant market is reflected in output prices depends on the competitiveness of an industry: the effective pass through will be highest for a competitive industry while it will be lowest for an uncompetitive industry. This implies that CO2-permit prices will more strongly be reflected in electricity prices if the electricity market is competitive. This finding appears to contradict the assertion by the BKartA that CO2-permit prices would only find their way into electricity prices in an uncompetitive industry.

- **Empirical evidence from Europe** – we look at experience from the UK, Scandinavia and the Netherlands to find that CO2-permit prices are indeed reflected in electricity wholesale prices in electricity industries that are generally considered to be competitive and that could serve as a benchmark for the level of pass through in Germany.

This paper therefore concludes that the reflection of CO2-permit prices in power prices is an indication of a working CO2-market and a normal feature of a competitive power market.

THE OPPORTUNITY COST NATURE OF CO2-PERMITS

In this section, we discuss how the EU ETS works and how the use of CO2-permits constitutes an opportunity cost. In this context, it is first of all helpful to recall the aims of the EU ETS.

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[4] Coase, R., "The Problem of Social Cost", Journal of Law and Economics, 1960.

The aims and structure of the EU ETS

The EU ETS has been implemented in order to achieve a reduction of CO2-emissions to a politically pre-determined level in a (cost) efficient manner. The target – in line with the so called Kyoto Treaty – is that by 2008-2012 CO2-emissions in the EU are to be reduced by 8% compared to the 1990 level. Each country in the EU has been given an individual emission target under the so called burden sharing agreement, so that the EU overall achieves its target.

The targets will be achieved by allowing each country to hand out ("allocate") a number of permits for the time period 2008-2012 that corresponds to the country's target level of emissions. Industrial emitters such as power producers, cement companies, chemical firms etc. are required to hand in an emission certificate for each tonne of CO2 emitted. These certificates are tradable throughout the EU effectively creating a European permit market. Liquid trading in permits has developed at power exchanges such as EEX, EXAA and Euronext and in the over-the-counter (OTC) market.

In Phase I of the ETS (covering emissions in the period 2005-07) initial allocations are handed out for free to emitters by their respective national governments. National governments can decide what volumes of certificates they hand to companies in different sectors as long as the overall level of permits does not exceed a certain level (in line with the country's convergence to its individual emissions target for 2008-2012). National allocations are documented in National Allocation Plans (NAPs). In aggregate, these allocations imply a reduction in emissions relative to expected emissions in the absence of the ETS.

CO2-permits create an opportunity cost

CO2-permits are a scarce and therefore a valuable commodity. A producer such as a power generator will apply the following logic in his production decisions:

- should I continue production and "consume" permits; or
- should I reduce emissions and sell any overhang in permits.

This logic will lead producers to consider the opportunity cost of (the option to sell) permits in their production decisions and to factor the opportunity cost of permits into their price bids in the electricity wholesale market. Therefore, the introduction of the EU ETS has raised the variable costs of thermal power production.

That permits are indeed a valuable commodity and that therefore these costs are likely to be substantial is clearly evidenced by the fact that CO2-permits reached market values of 30€/t CO2 earlier in 2006, even if prices have somewhat fallen since then.

The (opportunity) costs of CO2-permits are independent of the initial allocation of the permits

An important point – initially not well understood by the BKartA – with respect to the opportunity costs that consumption of CO2-permits entails, is that these are independent of the initial allocation of the permits. In other words, the costs of consumption are incurred independent of whether additional permits have to be purchased by a party participating in the scheme or whether the decision is made not to sell a permit allocated for free and hence to burn it in the production process instead – so that an opportunity for realising the sales price of a permit is foregone and thus an opportunity cost is incurred.

An analogy which the European Commission uses in explaining the opportunity costs that are entailed by a free allocation of a valuable commodity is the situation in which someone inherits a house. Even if the house was received for free, the recipient will impute the market value in making the decision to use it or to sell it, i.e. independent of the free allocation. Of course, this is a well-known result from economic theory which was formulated by the economist Ronald Coase in 1960[5] and for he which received, amongst other contributions, the Nobel prize in 1991.

5 Coase (1960): "The Problem of Social Cost", Journal of Law and Economics.

THE TRANSMISSION OF CO2-COSTS IN THE ELECTRICITY SECTOR

In discussing how CO2-permit prices are passed through into electricity prices, we first turn to how the introduction of CO2-costs will change the cost structure and thus the incentives of electricity suppliers.

In the electricity sector this opportunity cost will change cost structures and incentives

Through the CO2-related increase in variable costs, three intended effects might result in the electricity sector:

- A "fuel-switch" from fuels with high CO2-emissions, in particular coal, to fuels with lower levels of emissions, such as gas, bio-fuels, nuclear power, wind etc. In the short run, with the existing generation park, this will – ceteris paribus – imply a higher utilisation of gas plants and a lower utilisation of coal plants. In the longer run, this will imply the construction of new plants with low emissions and the decommissioning of plants with high emissions. However, whether such a fuel switch actually occurs depends on the scarcity of certificates and their price, the process for allocating free certificates (if any) to new entrants as well as relative fuel prices, e.g. gas and coal prices because, while CO2-permits make coal burn *relatively* more expensive than gas burn, coal burn might still be cheaper in *absolute* terms. In conclusion therefore, permits result in a greater increase in the cost of electricity production, the more carbon intensive the generation technology per kWh.
- Investments that ensure a lower level of emissions with existing plants without a change in fuels, i.e. through so-called retro-fitting of plants.
- A reduction in demand for energy and CO2-intensive products through an increase in the prices of such products. For example, on the electricity wholesale market an increase in variable costs will increase prices at the margin. Given that demand is somewhat elastic, there will be a reduction in demand.

The EU ETS may also have some unintended consequences such as an increase in imports of electricity from (and/or a reduction in exports of electricity to) regions adjacent to the EU that are not within the EU ETS. However, the ability to import electricity from regions surrounding the EU is relatively limited – we therefore exclude this complication from our analytical discussion without this affecting the general conclusion.

In the electricity sector, CO2-permit prices will be reflected in competitive electricity wholesale prices

We now turn to the short run effects of emission trading which can have a bearing on electricity wholesale prices.

As in every market, the key determinants of prices in the electricity wholesale market is the supply and demand conditions. On the supply side, the variable cost of marginal electricity generation effectively represents short-term supply conditions and the marginal supplier will be key to price formation where the marginal supplier is the most expensive player that is needed to serve the last unit of (largely inelastic) demand. The so-called "merit order" is often considered together with the demand curve to illustrate the price formation process, where the merit-order shows the power plant portfolio of an area, in the order of increasing variable costs, thus showing the short term supply curve.

The resulting supply curve is shown in Figure 1, on the left-hand side (the chart on the right-hand side will be discussed further below).

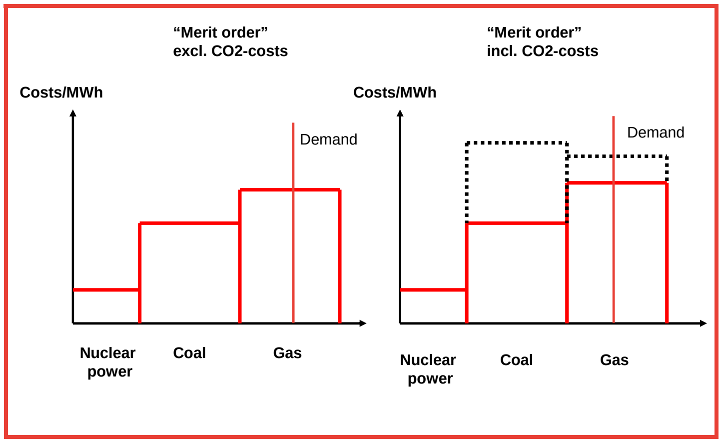

Figure 1: Possible change in the merit order as a consequence of the EU ETS

Source: Frontier

As demand varies substantially during the day, the marginal supplier and therefore the competitive market price will also differ over the course of the day.[6] When demand is very low, only nuclear power plants may run to serve demand in our stylized example, whereas in other hours during the day, more expensive coal plants may be called into the merit order until finally, gas and oil plants may become relevant as demand reaches its peak.

The right-hand side of Figure 1 shows that CO2-permit prices have resulted in an absolute increase in the variable costs of generation, and moreover also resulted in a relative change in the cost of producing energy with different fuel types. With relative prices as shown here, this will lead to a reversal of the merit order, i.e. the so-called fuel switch. A fuel switch will not necessarily happen as this depends on the relative prices of coal and gas and the price of CO2-permits – in fact, in European electricity markets a fuel switch has been hampered by the recent increase in gas prices relative to coal prices. Irrespective of whether a fuel switch occurs, the cost of electricity and – due to largely inelastic demand – electricity prices will rise under effective competition.

The role of competition within EU or in world markets

While it is clear therefore that the variable costs of parties participating in the scheme – electricity and non-electricity alike – could be expected to increase, the BKartA argued that under working competition, this cost increase would not find its way into prices. This reasoning was based on the (purported) observation by the BKartA that in competitive non-electricity sectors that are subject to competition from outside the EU, these cost increases could not be passed through into prices. However, in this assessment the BKartA did not acknowledge the distinction between:

- Markets in which only EU players compete, e.g. electricity – in such markets all players in the industry are subjected to the rules of the EU ETS and incur the opportunity cost of

6 The demand curve has been added by Frontier.

CO2-permits. As all players will reflect these opportunity costs in their bids or the production plans, the opportunity cost will inevitably feed through into prices.

- Markets in which EU players compete with players from outside the EU (e.g. in the steel industry) which are not subjected to the EU ETS. In this instance price setters could be players that do not face the opportunity cost of CO2-permits and thus CO2-permit prices are not reflected in (world) market prices.

Therefore, the relevant benchmark would have been other industries in which all players are subjected to the EU ETS and not those where players compete with companies from outside the EU.

As we discuss next, the degree of competition in the electricity wholesale market may however effect the extent to which CO2-permit prices are reflected in electricity prices.

Intensity of competition affects the degree of pass through – a standard result

In fact, it is a standard result of micro-economic theory that, where all players are affected by an increase in variable costs, the more intense the competition, the stronger the relationship between cost – and changes to cost – and prices. This logic is in contrast to the assertions by the BKartA which alleged that the link between CO2-permit and electricity prices would only arise in an uncompetitive industry. To demonstrate this, we consider the general result for an elastic demand curve which is a basic tenet of economic theory.

Consider the two extreme cases that a firm could face in selling its products, i.e. monopoly and perfect competition. Figure 2 shows the response of a monopolist to an increase in marginal costs (from MC1 to MC2) which could be brought about, for example, by the opportunity cost of consuming permits following the introduction of the EU ETS. In this case the monopolist sets the profit maximising price at a level of output where marginal revenue equals marginal cost.[7] The firm raises prices from P1 to P2. In the case of a linear demand

7 The corresponding profit maximising price is found by plotting a horizontal line onto the average revenue (= demand) curve.

curve, theory tells us that the profit maximising monopolist will pass on 50% of the cost rise to its prices[8].

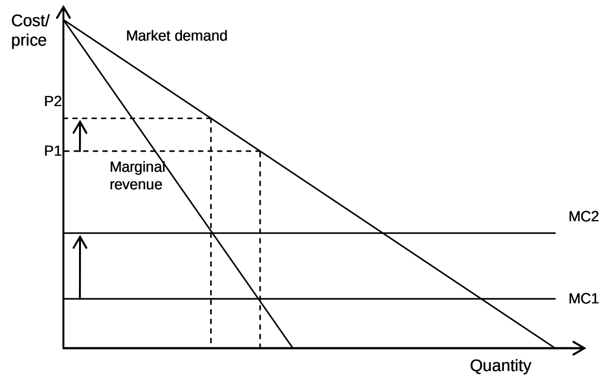

Figure 2: Cost pass through in the case of a monopolist

Source: Frontier

We now turn to the case of perfect competition, at the opposite end of the spectrum. Figure 3 shows the impact upon market price should all firms face the same increase in marginal cost (from MC1 to MC2).

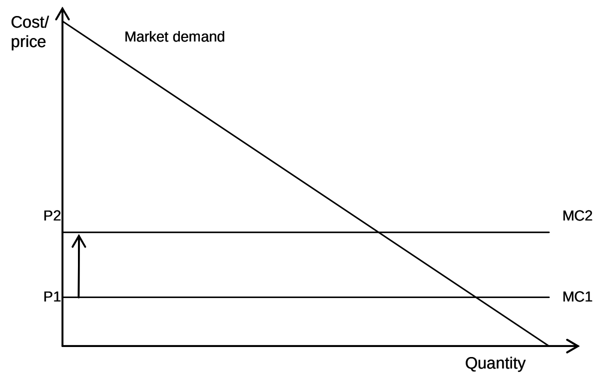

Figure 3: Industry-wide cost pass through in perfectly competitive markets

Source: Frontier

As can be seen from the curve which now reflects aggregate market demand, the firms effectively act as one when the marginal cost rises. This is because residual demand for individual players is perfectly elastic – if one player priced higher, he would lose his entire market share. Pricing above competitors is therefore irrational. Pricing below the full

8 Ashenfelter, Ashmore, Baker and McKernan, "Identifying the firm specific cost pass through rate", prepared for the FTC, January 1998.

opportunity cost (e.g. by not factoring CO2-permit prices into cost would be similarly irrational as we discussed earlier). Assuming that relative market shares remain constant, all firms reflect the cost of CO2 in their price bids to the market with the effect that the opportunity cost resulting from CO2 will be fully (100%) reflected in electricity prices. The fall in the quantity demanded by the industry as a result of rising prices is determined by the sector level price elasticity of demand but this has no influence on the degree of cost pass through that each firm undertakes.

The theoretical outcome relies on all (price setting) firms facing exactly the same increase in costs. However, this framework also allows an insight into a situation where not all firms face the cost increase in question.

Therefore, consider by contrast a situation where few firms experience a rise in their marginal costs independently of other firms (that, for example, reside outside the EU, as is the case for example in the steel industry). Under conditions of perfect competition, each firm faces a very high firm specific elasticity of demand. Any increase in the firm specific bid price over the market price will lead customers to switch to alternative suppliers. In this case, producers in the EU could not expect that the price of CO2 is reflected in the product price and a rational response would be to stop production in the EU and to sell the permits (and possibly relocate to a site that is not subject to the EU ETS).

How the workings of the EU ETS in the electricity sector were perceived by policy makers internationally

That electricity prices would increase in line with CO2-permit costs can also be gauged from statements made by policy markers outside Germany in relation to the expected workings of the EU ETS and to how this has shaped their decisions to allocate the permits to the different sectors involved.

In considering the effect of the EU ETS on the electricity sector, international policy makers, e.g. the European Commission and the British and Swedish governments anticipated that the ETS would have the effect of raising cost and prices in the electricity sector:

- The **EU Commission** in designing the EU ETS stated that[9]
  - *"The Kyoto Protocol sets a cap on allowable greenhouse gas emissions, which means that the EU economy is becoming a carbon-constrained economy."*; and
  - *"This carbon constraint gives value to the allowances and leads to changes in relative prices in the EU economy. Goods that contain more carbon will be relatively more expensive than goods that contain less carbon."*
- The **UK Government** department responsible for designing the NAP, DEFRA, recognized that the demand for electricity is highly inelastic and that therefore a reduction in the demand for electricity would not be the mechanism through which CO2-reductions would take place. It was therefore expected that supply side substitution in the electricity wholesale market would bring about the necessary reduction in CO2-emissions. DEFRA stated[10]:
  - *"The potential of different sectors to achieve emissions reductions by using technologies which are cost-effective has been taken into account in setting the sector totals."* (page 21, Paragraph 2.10).
  - DEFRA goes on that *"Power stations are being required to deliver the additional emissions trading savings because this sector faces limited international competition and is thought to have a relatively large scope for low cost abatement opportunities. […] This trade is also concentrated in the EU market, all of which is affected by the*

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9 The EU Commission's Website on the EU ETS has a " Questions & Answers on Emissions Trading and National Allocation Plans". Our quotes refer to question14) "Will emissions trading lead to higher electricity prices?", 8.March 2005. See http://europa.eu.int/rapid/pressReleasesAction.do?reference=MEMO/05/84&format=HTML&aged=1&language=DE&guiLanguage=en

10 „EU Emission Trading Scheme – Approved National Allocation Plan", May 2005.

EU Scheme. […] Over time, the continued introduction of new gas-fired plant and retirement of older coal fired plant will help to reduce emissions. Generators are not subject to competition from firms outside the EU ETS. Thus, this sector may be better placed to incorporate the marginal cost of carbon to reflect the higher marginal costs of generation from fossil fuels resulting from the Scheme. Once the EU ETS comes into force, we expect the value of carbon to be reflected in electricity prices across Europe." (Page 21, Paragraph 2.12).

- The **Swedish Energy Agency** had developed a similar view[11]:
  - *"The price of electricity is determined by the cost of generating electricity at the margin in the energy system. In the Nordic electricity market, this cost normally consists of the prices of coal and the emission rights required to generate the last unit of electricity."* (Page 3, Section 1.1.2).
  - They continue that *"The phenomenon that electricity prices rise by the same amount for everyone, so that producers of carbon dioxide-free electricity are overcompensated, is in itself not a sign of lack of competition. It is a consequence of applying the principle of marginal cost pricing."* (Page 7, Section 1.1.5).

In conclusion, therefore, it is clear that CO2-permits create a (opportunity) cost which in particular changes the level of short run production costs in electricity generation and possibly also the structure of the supply curve, making less carbon intensive fuels more economic. Secondly, due to the nature of competition in electricity markets and because virtually all generators relevant to price setting are affected by the rise in costs due to the EU ETS, a rise in electricity prices in line with CO2-permit opportunity costs is entirely consistent with competitive electricity wholesale markets. As shown in the next section, this conclusion is supported by empirical evidence.

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11 Swedish Energy Agency, „Price Trends for electricity and emission rights, as well as for international fuel markets", 2005.

THE EMPIRICAL EXPERIENCE FROM EUROPE

To demonstrate an influence of CO2-permit prices on power prices is a phenomenon of competitive electricity wholesale markets, we examined the empirical relationship between electricity and CO2-permit prices in several electricity markets which are generally deemed competitive. The key electricity wholesale market chosen as a comparator was the UK. In addition – being considered as broadly competitive electricity markets – the Netherlands and Scandinavia were analysed.

Apart from generally being perceived as a more or less isolated[12] – and thus free from foreign, possibly uncompetitive influences – electricity market, the UK market was qualified as a comparatively competitive market by the European Commission in 2004 and 2005. This was further confirmed by the recent Sector Enquiry into the competitiveness of the European energy markets[13]. As can be seen in Table 1, for example in 2005, the European Commission considered that the level of concentration in generation capacity was "moderate" in the UK, the best rating the Commission has assigned so far and better than the rating for Germany.

	concen-tration at generation level (on HHI basis)	**Capacity share of the 3 largest generator**	**Production share of the 3 largest generators**
UK	Moderate	40%	39%
NL	Moderate	80%	69%
Scandinavia	Moderate	40%	40%
Germany	High	70%	72%

Table 1: Comparison of competitiveness of electricity wholesale markets

Source: EU Commission[14]

12 There is an interconnector between Great Britain and France with a capacity of about 2000MW and an interconnector between Great Britain and Northern Ireland with a capacity of about 500MW. This compares to a peak demand in Great Britain of about 63,000MW.

13 European Commission, „Preliminary Report" (of the Sector Inquiry), 2006.

14 European Commission, „Technical Appendix of the 4th EU Benchmarking Report " (January 2005) as well as „Technical Appendix of the Draft of the 5th EU Benchmarking Report" (November 2005).

Similarly, the Netherlands and Scandinavia are generally considered to be electricity wholesale markets which are broadly competitive and therefore suitable for addressing the question as to whether a relationship between electricity wholesale and CO2-permit prices is observed as a feature of competitive electricity markets. For both the Netherlands and Scandinavia, the Commission found in its 4th and 5th Benchmarking report[15] that the level of concentration in electricity generation was "moderate".

Further, all of these markets can be seen as suitable for a comparison as, in each case, the variable costs of thermal plants are relevant for price setting. In the UK, as in Germany, the typical marginal plant would be a gas or coal plant, accounting for 72% of all electricity produced in the UK. Other plant types, i.e. nuclear or wind power, do not tend to be price setting in the UK. Both types of price setting plant thus need CO2-permits to produce electricity and therefore (opportunity) costs are incurred in the production of electricity in the UK. Equally, in both the Netherlands and Scandinavia price setting plants will generally be those that cause CO2-emissions, so that the CO2-permit price will be a component of cost at the margin – in the Netherlands, only 10% of electricity is produced by power plants that do not burn fossil fuels[16] and in Scandinavia coal-fired power plants will set prices in the majority of hours[17].

The core of the empirical analysis was to establish whether there was a strong relationship between electricity wholesale prices on the one hand, and CO2-permit prices on the other, suggesting a causal link. In doing this, the following methodological considerations were applied:

- **Forward prices** – year-ahead forward prices were used for measuring the statistical relationship between electricity wholesale prices and CO2-permit prices. Put simply,

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15 European Commission, „Technical Appendix of the 4th EU Benchmarking Report " (January 2005) as well as „Technical Appendix of the Draft of the 5th EU Benchmarking Report" (November 2005).

16 See International Energy Agency (IEA), (2002), www.iea.org.

17 Swedish Energy Agency, „Price Trends for electricity and emission rights, as well as for international fuel markets", 2005.

year-ahead forward prices represent the price of electricity for a contract agreed in previous calendar years for electricity delivered in a specific calendar year (in our case the calendar year for delivery of interest was 2006 (Cal06), as traded 2005). The use of forward rather than spot prices has the advantage that short term changes in the market (demand, wind availability etc.) are typically not reflected in prices.

- **Peak and off-peak hours** – to distinguish between electricity prices for periods of low demand and for periods of high demand, both prices for peak contracts (e.g. in the UK, electricity forward contracts that cover the delivery period 8:00 to 20:00 on weekdays) and prices for off-peak contracts (covering delivery in all other hours[18]) were used. The distinction of peak and off-peak prices is useful as different types of plant which operate with different CO2-intensity tend to set prices in peak and off-peak periods. Therefore, the effect of CO2-prices on electricity prices may be different for peak and off-peak periods. For data reasons, it was however not possible to draw this distinction for Scandinavia as only baseload price data exists.

- **Prices and spreads** – for the UK, in addition it is possible to assess whether there was a notable relationship between so-called spreads and CO2-permit prices. Spark-spreads measure the difference between the market price of electricity and gas costs for generation and dark-spreads measure the difference between the market price of electricity and the cost of coal needed for generation. The spreads can therefore be interpreted as a raw margin of production. In this way, price movements caused by movements in gas or coal prices are controlled for in assessing the relationship between electricity prices and CO2-permit prices. To control for the possible impact of different types of generators being price setting during different time periods, we related spark spreads to CO2 permit prices during peak periods and dark spreads to CO2 permit prices during off-peak periods.

18 Dutch peak hours are conventionally defined (e.g. in contracts) to be between 7:00 and 23:00 hrs during weekdays.

The following figure illustrates, as an example, the strong correlation between electricity prices and CO2-permit prices in the UK. With all other data, similarly strong relationships between electricity forward prices or spreads and permit prices could be observed.

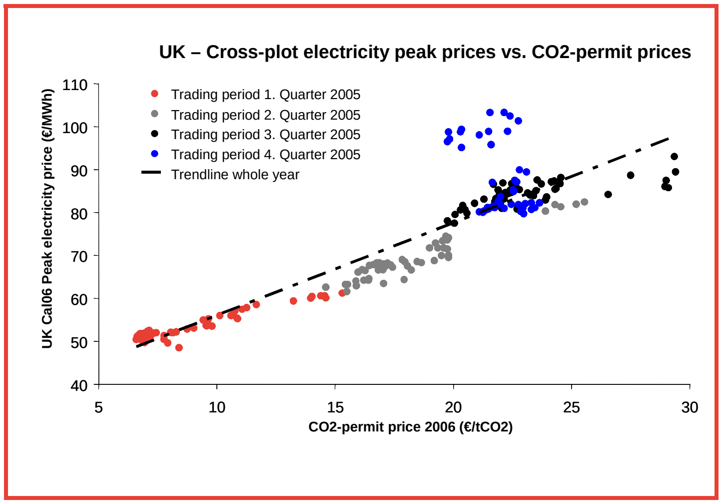

Figure 4: Cross-plot UK electricity peak prices (Cal06) vs. CO2- permit prices for 2006

Source: Frontier calculations on the basis of Spectron, Point Carbon, TFS, European Central Bank data

This type of co-movement is also captured in the relevant correlation coefficients[19] shown in Table 2 below.

We note that in Q4 2005, prices during some days are less well explained by CO2-permit prices. The reason is that in Q4 2005 we are nearing the delivery period of the electricity forward contract. In this case, short term market developments start to have an impact on the forward price. For example, in Q4 international meteorological offices started developing forecasts of a cold winter. The market inferred high electricity demand and consequently higher electricity prices. This could also have affected the forward price for Cal06.

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19 Formally, a correlation of a data series X with a data series Y (with a number of i =1…n observations) is given by:

$$\mathrm{Kor}_e(X,Y) := \varrho_e(X,Y) := \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\cdot\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}}$$

Each observation X_i and Y_i are measured as deviations from the averages of X and Y (the expressions in brackets). If the deviations from the averages for X and Y are identical, then we get Kor=1 and the correlation is said to be "perfect", as each movement of X – relative to its average – is mirrored by the corresponding deviation by Y.

Korrelationen Cal06	**Whole year**	**W/o 4th quarter**
UK: Peak prices vs. permit prices	91%	97%
UK: Off-peak prices vs. permit prices	97%	98%
UK: Spark spreads vs. permit prices (for peak hours)	89%	95%
UK: Dark spreads vs. permit prices (for off-peak hours)	93%	95%
NL: Peak prices vs. permit prices	91%	92%
NL: Off-peak prices vs. permit prices	95%	96%
Scandinavia: Baseload prices vs. permit prices	97%	98%

Table 2: Correlations between electricity forwards and spreads Cal06 and CO_2 – permit prices 2006 (2005)

Source: Frontier Calculations

Note: The following data sources have been used. For UK: Spectron, Point Carbon, TFS, European Central Bank, for NL: Platts, Spectron, Point Carbon. For Scandinavia: Nordpool, Spectron, Point Carbon.

As can be seen, the correlation between electricity prices or spreads and permit prices is in all cases but one higher than 90%. In conclusion, therefore, we see that there is a strong empirical link between CO2-permit prices and electricity prices in European electricity wholesale markets which are generally known to be competitive.

It would not be possible from our analysis to infer that an electricity market that does not show such a high correlation is not competitive. Factors unrelated to the level of competition could reduce the strength of the relationship between permit prices and electricity prices, including:

- mechanisms that affect the relative costs of the price setting generator that are unrelated to the spark and dark spreads and the price of CO2-permits such as temperature effects, the prices of other fuels etc., especially when different types of plant can be price setting at the margin; and

- a spread between the opportunity cost of consuming a CO2-permit and the market price for CO2 permits (for example if the future allocation of permits to a new "replacement" plant was related to the current consumption of permits in the old (to be decommissioned) station.

CONCLUSION

In conclusion, therefore, the empirical analysis demonstrates that in electricity wholesale markets that are deemed to be broadly competitive, we see a strong statistical relationship between electricity prices and permit prices. This suggests that there is an element of pricing in permit costs at the margin, although we did not measure the extent that permit prices determine or explain, statistically speaking, electricity prices. This confirms our fundamental considerations grounded in economic theory that suggest that CO2-permit prices create an opportunity cost which in electricity markets will be reflected in prices.

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