The impact of CO_2 emissions trading on firm profits and market prices

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Abstract

The introduction of mandatory controls and a trading scheme covering approximately half of all carbon dioxide emissions across Europe has triggered a debate about the impact of emissions trading on the competitiveness of European industry. Economic theory suggests that, in many sectors, businesses will pass on costs to customers and make net profits due to the impact on product prices combined with the extensive free allocations of allowances. This study applies the Cournot representation of an oligopoly market to five energy-intensive sectors: cement, newsprint, steel, aluminium and petroleum. By populating the model with empirical data, the results are shown for three future emissions price scenarios. The results encompass the extent of cost pass-through to customers, changes in output, changes in UK market share, and changes in firm profits. The results suggest that most participating sectors would be expected to profit in general, although with a modest loss of market share in the case of steel and cement, and closure in the case of aluminium.

Keywords: Emissions trading; Firm behaviour; Market structure; Competitiveness; Grandfathering; Cournot

1. Introduction

The EU Emission Trading Scheme (EU ETS) has been hotly debated since the publication of the European Commission's Green Paper in 2000 (Commission of the European Communities, 2000). At the forefront of the debate are concerns that:

- by acting unilaterally, the EU's economy might be damaged and its firms might lose out to non-EU firms;
- by allowing Member States to determine allocations of allowances for their industrial sectors, with only broad guidance on harmonizing approaches across the EU, some Member States

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might use the allocation as a means of state aid, providing their firms with a reserve of cash with which to compete against firms in other EU Member States;
- emission reductions may be limited;
- prices, particularly those paid by household consumers of electricity, will rise.

A public debate has engaged both government and business. UK government ministers have said that the UK's draft National Allocation Plan 'recognises the need to preserve the competitive position of UK industry' (Defra, 2004a), while some industrialists were voicing concern about a threat to UK jobs. Strong differences in views were held at the time, in the first quarter of 2004. More than two years have passed since those early stages of debate, but the question of the impact of emissions trading on the competitiveness of UK firms has not diminished in importance.

In the academic literature, commentators have observed that there are likely to be increased profits from the introduction of emissions trading schemes. This conclusion, which may at first appear counterintuitive, is nevertheless founded upon conventional economic assumptions of profit maximization and the Cournot competition model, discussed below. The underlying reason is that although emission cap-and-trade schemes increase marginal costs, these costs are largely passed on to the consumer, and at the same time the free allocation of emissions allowances represents a large economic rent to firms. Based upon this logic, Vollebergh et al. (1997) recommended partial grandfathering of allowances (or taxes with partial credits) for carbon policy in the European Union. Bovenberg and Goulder (2000) came to similar conclusions in research on the coal, oil and gas industries in the USA. They proposed that no more than 15% of allowances needed to be grandfathered to preserve profits and equity values. Quirion (2003) similarly found that only 10–15% of allowances need to be grandfathered to achieve profit neutrality.

This article examines the impact of the EU ETS on UK competitiveness and addresses the potential changes in the prices, volume of sales and profits of UK firms and those of their rivals, as a result of the trading scheme. It encompasses research carried out by Oxera under contract to the Carbon Trust over the period 2004–2006, and a report published by Oxera (2004) containing an initial set of results. Later results are presented here.

2. Background

It is estimated that the industrial activities within the EU ETS were responsible for releasing 46% of all CO_2 emissions from the UK in 2002 (Defra, 2004b). However, the number of sectors involved, as classified by the Department of the Environment, Food and Rural Affairs (Defra), is small. In the UK, 12 sectors together represent 98.8% of all the emissions covered by the trading regime, but only approximately 11.1% of UK value-added in 2001 (National Statistics, 2002). Furthermore, these sectors tend to have several characteristics in common. They are all energy- and capital-intensive relative to the UK average. Energy is an important input into production, and the production plants tend to be large because of the associated economies of scale. Moreover, these firms are often vertically integrated into companies that produce the raw materials for their production process, or consume or retail their product. In combination, these factors result in sectors comprising relatively few firms, and entry by new firms into the sector is relatively uncommon.

This research was designed to show the consequences of the EU ETS on business. The sectors were selected expressly to make apparent the variation between:

- those in which exposure to international competition is a particular concern and those that are more insulated from overseas rivals;
- those for which energy expenditure constitutes a high proportion of their production costs and those for which it constitutes a relatively low proportion of production costs.

2.1. Defining the market

The economic model used to explore these questions delineates the behaviour of individual firms competing against each other in a market. Hence, it is necessary to define the relevant markets represented by the model.

Economists have devoted considerable attention to defining the relevant market, particularly in competition law investigations. Essentially, a market can be defined along two dimensions: the product market and the geographical market. For both dimensions, the issue concerns whether other products/regions provide an effective competitive constraint on the production of the particular product or on the region of production under examination. In short, a market may be defined as something worth monopolizing.

A number of tools have been developed to test the scope of the relevant market. However, it has not been necessary to use these tools in undertaking this study since, in all cases, an appropriate market had already been defined in competition law investigations at both the UK and the EU level. The products chosen within these sectors, and associated geographical markets as established in competition cases, are set out in Table 1. Since all these decisions were arrived at recently, there is little reason to believe that the nature of the markets will have changed substantially since then.

2.2. Choice of model

As mentioned earlier, many of the sectors in the EU ETS contain a relatively small number of large firms.[1] This suggests that it is appropriate to consider the markets as oligopolistic rather than perfectly competitive. There are important differences between oligopolistic and perfectly competitive markets in the way prices are determined. In a perfectly competitive market, prices are set by the marginal cost of production (the cost of producing an extra unit of output), and firms make profits equal to their cost of capital. In an oligopolistic market, the process is more complicated. Marginal cost still plays an important role, but the presence of fixed costs often means that prices are above marginal costs, allowing for the recovery of these costs and, potentially, if there are barriers to entry, significant economic profits to be made.

A number of theoretical models seek to explain the behaviour of firms in oligopolistic markets, including the classic Stackelberg, Bertrand and Cournot models.

In a Stackelberg equilibrium, the firms in the industry compete on quantity in a sequential fashion. One firm moves first, and then each moves in turn until the last. Working by backwards induction, the last firm seeks to maximize its profits, given the output decisions of all the other firms. The Stackelberg model was rejected because it is more complicated to implement and in most, if not all, of the markets being represented, there were no firms with a leading market share.

The Bertrand model of competition assumes simultaneous price setting between firms. This results in a zero economic profit equilibrium, where price equals marginal cost. The pure Bertrand competition model obviously cannot apply to an industry with fixed costs, as a price equals marginal cost rule would, in the long run, lead to closure of the entire industry. The pure Bertrand model would appear to be inapplicable to all the industries under examination here, as they all have significant fixed costs. A modified price-setting model, such as under monopolistic competition, however, could be employed.

The Cournot model is a standard oligopoly model, and it is often used in competition policy as a first approximation of how competition works (Martin, 1993). For our modelling purposes, the Cournot oligopoly model offered the best combination – faithful representation of market cost structure and behaviour, and flexibility to incorporate a mixture of profit-maximizing and sales-maximizing objectives – as well as tractable conversion into a spreadsheet modelling application.

The key assumptions of the Cournot model, as it is applied here, are as follows:

- firms are profit-maximizing
- firms compete on quantity rather than price
- the output that firms produce is homogeneous
- the cost structure consists of a fixed cost and a constant marginal cost, although the levels of these costs within this structure may, and in this model do, differ across companies
- the relationship between consumer demand and price is constant for all price/quantity combinations (i.e. there is a linear demand curve).

Using these assumptions, a model was constructed to predict market price, total sales, individual firm output, and individual firm profits. At first glance, the assumption over which there may be greatest concern is that firms compete on quantity. Experience suggests that, in many markets, firms compete on price. However, the economic literature has shown that the outcome predicted by the Cournot model may also be realized when firms first choose their capacity levels and then only later compete on price (Kreps and Sheinkman, 1983).

However, one important feature has been introduced in order to reflect a greater degree of compromise between profit maximization and long-term market share, specifically to ensure that price increases do not stimulate the entry of new firms to a degree that would reduce the incumbents' profits (see Ventosa et al., 2005).

This feature took the form of a parameter representing the degree of revenue-maximizing behaviour. The value of this parameter (between 0 and 1 within the mathematical framework of the model) was set so that, where there was a possibility of companies increasing their profits as a result of the policy levers, this would never be implemented in a manner such that it would attract new entry and therefore be self-defeating, i.e. that the firms exhibit limit pricing (see later discussion on profit maximization). As a result, new entry was only assumed to take place when companies did not have the opportunity of increasing their profits as a result of the policy levers introduced.

Having solved the Cournot equilibrium for a set of incumbent firms, any company that is no longer profitable is assumed to exit, and the Cournot equilibrium is re-calculated. Also, data from abatement curves is used to assess whether companies would profitably undertake any abatement, given the prevailing market conditions.

3. Operation of the model

Initially, the model assumes that the market is populated by a number of identical, 'typical' firms. All of the firms choose the same volume of output to maximize their individual profits. If, at this optimal level of output, the firms cannot pay their fixed and variable operating costs, including providing a 'reasonable' return to providers of finance, at least one firm would close. As a consequence of the closure (exit) of a firm, the individual outputs of the remaining firms would increase and their profitability would improve. The model automatically reduces the number of firms in the industry until the remaining firms cover their costs and achieve a reasonable profit.

The EU ETS affects costs (both fixed and variable), prices, and quantities in the market. It is helpful to divide these impacts into marginal and fixed effects: marginal effects determine the impact on the price or quantity sold; fixed effects do not alter these 'allocative' decisions, but have a direct impact on the profit made and hence on the number of surviving firms.

Under the EU ETS, CO_2 emissions become a factor of production that has to be paid for, in the same way as labour or raw materials. It is assumed in the modelling that marginal costs are constant across the range of output considered, i.e. that each additional unit of output has the same marginal impact on costs. The introduction of the EU ETS leads to two potential changes in the marginal cost of production:

- the direct CO_2 cost – the amount of CO_2 emissions from producing an additional unit of output multiplied by the market price of allowances. This affects EU ETS participants only;
- an increase in the price of electricity – the amount of electricity consumed in producing an additional unit of output multiplied by the change in wholesale market price of electricity caused by the EU ETS. This will affect all companies within the EU.

An increase in marginal cost has an impact on a firm's profits in three ways:

- the level of production is reduced – as the costs of production increase, quantity supplied is reduced, regardless of whether prices are changed;
- some costs are absorbed by the firm – this does not lead to an increase in price, but the margin achieved on each unit is eroded;
- some costs are passed on to customers – this does not erode margins, but the increase in price leads to a decrease in volumes and hence revenues.

The first of these impacts, which always takes place, reflects the fact that, as each unit of production is now more costly, the level of output at which marginal cost equals marginal revenue will also necessarily be lower. The extent to which this factor results in lower output depends critically on the number of other firms in the market that also face the marginal cost increase.

The second and third impacts depend on the extent to which the marginal cost increase is passed on to customers, and occur in inverse proportions. In the Cournot model, the extent of this pass-through is determined by each firm pursuing a profit-maximizing strategy (Varian, 1992, p. 290). Under certain assumptions, including the assumptions that demand is linearly related to price (each quantum of price rise reduces demand by a fixed amount), the extent to which a change in cost leads to an increase in price is given by the formula $X/(N + 1)$, where X is the number of companies affected by the cost change, and N is the total number of companies operating in the market.[2]

For example, for the extreme case of a monopolist, $N = 1$, and therefore X also $= 1$. As such, a monopolist facing linear demand passes through half of any increase in costs. However, as the sector becomes more competitive, and the number of firms increases, the amount of cost pass-through to customers rises until it is close to 100%. In other words, the more competitive the industry, the greater the cost pass-through. This is explained by the fact that, as an industry becomes more competitive, prices become more aligned with costs. This rule also shows that the smaller the proportion of firms in the market that are affected by the marginal cost increase, the lower the level of cost pass-through. Thus, a lower proportion of costs will be passed through if a larger proportion of demand is satisfied by small or overseas firms not affected by the EU ETS.

The same basic idea can be applied if demand is assumed to be isoelastic, i.e. demand is related to price with constant elasticity (ε) in which case the cost pass-through rule is:

$$dp/dc = N\varepsilon/(N\varepsilon + 1)$$

where N is the number of firms (Varian, 1992, p. 290).

For a monopolist ($N = 1$) facing a constant elasticity demand curve, the cost pass-through rule is thus $\varepsilon / (\varepsilon + 1)$, which corresponds to that found by Bulow and Pfleiderer (1983). Note that because $\varepsilon < -1$ for a monopolist, isoelastic demand therefore implies cost pass-through of more than 100% of any price change, and the pass-through would decline towards 100% for more competitive markets.

For the purposes of the analysis in this article, we assume a linear demand, partly because the higher rates of pass-through under isoelastic demand are inconsistent with the claims and concerns of many industries regarding the difficulty of passing through cost changes.[3] As shown below, even assuming linear demand, it can be shown that significant pass-through occurs along with resulting profit-making from the EU ETS; adopting the isoelastic assumption would simply tend to make these effects even greater.

Once the proportion of cost increase that is passed on to customers is known, the impact on profits from a decrease in margins can be established relatively easily. The magnitude of this effect is given by the sensitivity of demand to price, the ‘own-price elasticity of demand’. Estimates of this elasticity are available in the economic literature.

The final impact is on the fixed costs of firms. A firm’s fixed costs may rise as a result of abatement investment undertaken to reduce exposure to the marginal cost impact of the EU ETS. Knowing the cost of CO_2 emissions, a company can decide whether to invest in abatement technology to reduce emissions. Using published abatement cost curves, the model estimates the level of abatement investment for both CO_2 emissions and electricity consumption. For simplicity’s sake, it is assumed that the cost associated with the introduction of new technology is entirely a capital cost, and that the new technology does not change the fixed or variable operating costs of production, except to the extent that marginal costs are reduced due to the lower intensity of electricity or CO_2 consumption.

More important than abatement investment (in financial terms) is the free allocation of allowances to firms. This is equivalent to a fixed, lump-sum revenue transfer to the firm, because the revenue that the company could generate from selling these allowances is independent of its own production volumes.

While, in the short run, the number of companies in the sector is fixed, in the long run firms can enter or exit. The model shows the financial impact of the EU ETS as though it were distributed equally across all the firms in the market. If the reduction (increase) in profitability is sufficiently great, it is expected to cause firms to exit (enter) the market. This alters the degree of cost pass-through (through the $x/(n+1)$ rule), and requires further iterations of the model, giving a new financial impact estimate. The iterations continue until a long-run equilibrium number of firms in the industry is established. The treatment of firm entry and exit is discussed further below.

4. The assumption that firms pursue profit-maximization

The assertion that firms maximize profits is so common in economic analysis that it might seem surprising to question it. Yet it is widely discussed, and its importance in the context of modelling the EU ETS is that it determines the fundamental trade-off that firms face between maximizing profits in the short term, and maximizing market share (and hence gross revenues) and thus potentially maximizing profits in the longer term. Raising product prices increases profits but leads over time to loss of market share.

Generally, shareholders have a shorter time horizon than the investment cycle of firms, and thus the assertion that firms maximize profits (in a given period of analysis, such as 5 or 10 years) is based upon the implicit set of assumptions that (1) shareholders seek profit maximization; (2) management aims to best achieve shareholder objectives; and (3) management is able to achieve its aims. All three assumptions have been questioned, as discussed below.

4.1. Do shareholders desire profits?

It can hardly be denied that shareholders seek profits. It is an open question as to whether they have motivations other than profits. In recent times, there has been an emergence of an ethical investment sector, where managed funds pursue profits in conjunction with additional ethical objectives, such as environmental protection. These additional objectives are often satisfied simply by placing constraints on the types of firms these funds will invest in. On other occasions, the fund is a more active participant in guiding firm policies. Even so, however, the question of most interest in the popular press is whether the ethical sector is more or less profitable than other sectors. In short, the focus is still squarely on profits, and it is safe to proceed on the assumption that shareholders seek profit maximization (see Baumol, 1958; Jensen and Murphy, 1988; Murphy, 1985).

4.2. Do managers seek to achieve shareholder objectives?

The crux of the debate concerns the divergence between the incentives of shareholders and managers. This debate is not new. Over 40 years ago, Koplin (1963) stated that the 'profit maximization assumption has long been under attack, chiefly on the grounds that it lacks realism'. The attack was largely begun by Baumol (1958, 1959), who conjectured that managers' salaries appeared to be more closely correlated with total sales revenue rather than bottom-line profits. As such, he asserted that managers induce over-expansion of firms, not for reasons of profitability, but because managers see expansion as a means to obtaining higher salaries.

All firms consist of several distinct groups of stakeholders (employees, managers, shareholders and customers) and each group has different objectives. The dominant groups are generally the owners and the managers. As Stiglitz (1991) encapsulates it: the fundamental problem of owners of firms is how to motivate their managers to act in the interest of the owners. This, of course, is just an example of the classic principal–agent problem.

Baker et al. (1988) noted the relatively stable empirical finding that managers' salaries increase by 3% for every 10% increase in sales and, perhaps more importantly, Murphy (1985) showed that this relationship is causal, and not merely a matching of more productive workers to larger firms, implying that pay can increase with firm size even if this reduces firm value. Stiglitz (1991) agrees that managers often behave to the detriment of shareholders, pointing out that managers sometimes prevent takeovers that would be in the best interests of their shareholders by taking 'poisoned pills' (entering the firm into contracts costs that would impose costs on the new owners) and 'golden parachutes' (entering the firm into commitments to pay high levels of financial compensation to managers who are ousted during a takeover). Given that managers have an incentive to increase sales as well as (or even instead of) profits, sales maximization appears to be empirically plausible.

The implications from this are that firms should be expected to maximize the dual objectives of profits and sales if (1) managers are powerful relative to shareholders, or (2) the market structure is oligopolistic and quantity leadership provides a profit advantage. It follows that managers might find it optimal to use the lump sum represented by their grandfathered allowances as a 'war chest' with which to reduce prices and increase sales in the output market, in an attempt to take Stackelberg leadership, as outlined earlier.

4.3. Can management achieve its aims?

The final argument used to question models based on profit maximization centres on the claim that managers are incapable of determining the profit-maximizing strategy. Instead, managers operate by rules of thumb. The intellectual background for this view is to be found in the concepts of satisficing and bounded rationality, and this is increasingly being expounded in the economic literature concerned with behaviour. Several rules of thumb are now considered.

Average-cost pricing, also known as markup pricing or cost-plus pricing, is where a markup is added to the average unit cost of production. This appears to be particularly common in the retail sector, where the proliferation of products implies that a careful study of demand for each product is uneconomic.

Survey evidence suggests that this practice is particularly widespread. Govindarajan and Anthony (1983) concluded that most firms in the Fortune 500 price their products based on average cost, and Shim and Sudit (1995) found that 69.5% of the 600 US manufacturing companies surveyed claimed to base their pricing decisions on full costs, with only 12.1% using a variable cost method. Lucas (2003) presents a useful survey of the various econometric and case study evidence for and against average cost pricing, and suggests that both average cost and marginal cost pricing are plausible, and that further empirical research is required before any conclusions can be drawn.

Limit pricing consists of pricing to ensure that no additional firms will find it profitable to enter the industry. It is a long-run profit maximization strategy for monopolistic or oligopolistic firms. In a survey of 54 industries in the USA, Koutsoyiannis (1984) found evidence against short-run profit maximization (and sales maximization) and evidence for limit pricing. He substantiated this view by citing 37 industries where the evidence is consistent with limit pricing, while in the remaining 17 industries the evidence is inconsistent. The model parameters were set to achieve limit pricing in those circumstances where limit pricing was a profitable strategy.

Profit maximization and other assumptions: lessons for modelling

As discussed in the text, although it is clear that shareholders desire profits, it is unclear whether managers seek to maximize profits. In particular, there is good evidence to show that they seek to maximize sales instead, although sales maximization is actually a profit-maximizing strategy in some oligopolistic industries. Sales maximization results in the conclusion that managers would not keep all the rents from grandfathered allowances, and would instead use them to reduce prices and increase output.

This has implications for model design. A model in which firms maximize a weighted average of profits and sales may provide a more realistic representation of markets than one which purely maximizes profits. The weights on sales and profits would determine how much of the economic surplus is spent on increasing revenues, and how much is retained as profit.

There is a final popular argument which should also be taken into account. Irrespective of whether the three assumptions are fulfilled, Friedman (1953) has argued that in a competitive environment, firms must maximize profits or they will eventually be driven out of the market. Thus, he states that 'under a wide range of circumstances individual firms behave *as* if they were seeking rationally to maximize their expected returns'.

However, Dutta and Radner (1999) have rigorously examined a model similar to that which Friedman puts forward and have arrived at the opposite conclusion. They say that if innovating firms in a stochastic environment are subject to competitive pressure, the result will be that the profit-maximizing firms will eventually go bankrupt and, after a period of time, practically all the surviving firms will not be maximizing profits. The Dutta and Radner (1999) setting does not apply here, but it does question the legitimacy of the 'as-if profit-maximization' of Friedman (1953), which is commonly encountered in the literature.

Furthermore, Nabil et al. (2004) consider an oligopolistic market with product differentiation where firms adopt real-world accounting practices, including practices where fixed (and sunk) costs are bundled in together with variable costs. With the assumption that firms follow adaptive learning in adjusting prices, they find that pricing above marginal cost predominates, and all firms end up showing a sunk cost bias. This provides further evidence against the Friedman (1953) hypothesis.

5. Initial market conditions

With the number of companies in the market established, the actual profits made by each company can be calculated. A check is performed to ensure that all companies that enter remain profitable. Therefore, a company that enters the market 'first' and makes high profits could end up making losses due to the subsequent entry of other companies. Thus, the model finds an equilibrium where all the companies in the market are profitable and any company that is not in the market would not make profits by entering. Note that the geographical scope of the market is either the UK, Europe or global, as set out in Table 1. Since the EU ETS changes the production costs of EU firms relative to global firms, where it has an effect on the market share of UK or EU firms the effect is that market share is gained by non-EU firms.

Table 1. Sectors, products and geographical markets

Sector	Product market	Relevant market	Selection of European Commission Cases
Cement	Grey cement	UK	Lafarge/Blue Circle (Comp/M.1874, 07.04.2000)
Newsprint	Newsprint	Europe	
Petroleum	Refined products	Europe	
Steel	Cold-rolled carbon steel flat products	European	Usinor/Arbed/Aceralia (Comp/ECSC.1351 21.11.2001)
Aluminium		Global	Alcan/Alusuisse (Comp/M.1663, 14.03.2000) Norsk Hydro/VAW (Comp/M. 2702, 04.03.2002) Elkem/Sapa (Comp/M.2404, 26.06.2001)

With the number of companies in the market established, these companies are then labelled as being either UK, (other) EU or global companies. This is decided on the basis of the share of supply that was gathered from published research.

The cost shocks of environmental policy are then introduced. Depending on the scenario being modelled, either fixed or marginal costs can change. UK companies are assumed to be affected by both UK and EU policies, while other EU companies are assumed to be affected only by the EU ETS. There is no attempt to address the financial impact of national environmental policies other than those introduced by the UK government. There is assumed to be no change in the costs of global companies, operating outside the EU.

With these amended costs, the revised prices, quantities and profits of the companies in the market can be calculated. In examining these short-term effects, it is assumed that there are no changes in the number of companies in the market and that companies cannot respond to the policy shocks by changing their costs, i.e. that no abatement takes place.

6. Data

The data required to run the model were substantial. They included financial data of individual companies, fuel use and CO_2 emissions per product, in addition to the price of an average product. Other data inputs included the own-price elasticity of demand, the total volume of product consumed, the number of firms manufacturing the product, and the proportion of total consumption supplied by imports.

These data were gathered for each of the following sectors: cement, newsprint, steel and petroleum. Numerous sources were used, including academic articles, competition inquiries, company accounts, company environmental reports and material gathered from trade associations, the UK Department of Trade and Industry, the UK Office of National Statistics, and The Carbon Trust. The market data is sourced from sector market reports; while the elasticity estimates are taken from the economic literature, although, in the case of aluminium smelting, no elasticity estimates could be found. The production cost data are concerned with the marginal cost of production (although the average variable cost of production is often used as a proxy); the fixed cost of production (including fixed operating costs, depreciation of capital assets and financing costs); and an abatement curve of the unit cost and potential for reducing electricity use and abating CO_2 emissions. The production cost data are taken from published sector studies and

Table 2. Data sources

Variable	Data sources
Industry elasticity	Academic articles and competition inquiries
Import penetration	Competition inquiries, analyst reports and national trade statistics
Energy intensity	The Carbon Trust and company environmental reports
Fixed and marginal costs	FAME database and competition inquiries
Price	Companies and competition inquiries
Quantity	Trade associations and competition inquiries

Table 3. Assumptions

Variable	Cement	Newsprint	Petroleum	Steel	Aluminium
Price elasticity of demand	–0.27	–0.5	–0.8	–0.62	–1.1
Marginal/average variable cost of production	£14/t	£195/t	£0.08/litre	£190/t	£786/t
Tonnes CO_2 emitted/marginal unit of output	1.09/t	0.63/t	0.0002/t	1.75/t	2.2/t
Electricity consumer/marginal unit of output (kWh/t)	136	648	0.1	330	15,351
Market share of non-EU suppliers (%)	5	15	11	20	70

were corroborated with company accounts from a sample of firms. Abatement cost data are taken from a database developed for the UK Department of the Environment, Food and Rural Affairs supplemented with material derived from industry discussions. Tables 2 and 3 detail some of the sources and assumptions.

UK costs were used for companies in the UK, Europe and the rest of the world, and no account was taken of existing differences in the terms of trade. Market shares for each location of company were achieved by attributing an appropriate number of companies to that location. Thus, for example, in a sector where the model was predicted to have 10 companies, if the UK market share was 40%, European 30% and rest of the world 30%, then four companies were labelled as UK, three European and three rest of the world.

7. Scenarios

The scenarios involved combinations of allowance prices of €7.5/tCO_2, €15/tCO_2 and €30/tCO_2, all with allowances fully grandfathered. Shortly before the EU ETS was introduced in 2005, allowance prices had been around €7/tCO_2. The scenario with a price of €7/tCO_2 reflects this initial situation. However, once participating countries had fixed their allocations and as gas prices rose, increasing demand for coal and increasing the demand for allowances, the price rose to around €25/tCO_2. The two higher-price scenarios are intended to reflect the recent range of actual allowance prices and to encompass some departure from this range to either higher or lower prices in the future while acknowledging that future prices could lie outside the range of these scenarios.

Table 4. Effect on marginal costs

Sector	Impact of carbon price on short-run marginal production cost (% increase)	
Allowance price	€15/tCO_2	€30/tCO_2
Cement	70	144
Newsprint	2.6	6.0
Petroleum	0.3	0.6
Steel	8.0	17
Aluminium	4.0	13

The scenarios also incorporate the UK's Climate Change Levy (a tax on the business use of energy) and Climate Change Agreements. The Agreements are sectoral targets for energy use or energy intensity which, if achieved, entitle the holder to an 80% reduction in the tax rate applicable under the Climate Change Levy. Within the model, their only effects are to modify the cost of electricity and to cause a minimum level of energy efficiency improvement to take place.

The impact of the opportunity cost of carbon allowances on the marginal cost of production has been estimated and is shown in Table 4. It ranges from 0.3% for petroleum refining with an allowance price of €15/tCO_2, to 17% for steel with an allowance price of €30/tCO_2. The cement sector is an exception, with the impact on its marginal production costs lying well outside this range, at up to 140%.

8. Results

The results, shown in Table 5, exhibit the following features.

The EU ETS delivers emissions reductions and has a positive (or at least non-negative) impact on earnings before interest, tax, depreciation and amortization (EBITDA). This is because companies respond to the increase in marginal cost brought about by the EU ETS by cutting back output and so increasing prices to cover the additional costs, and simultaneously benefiting from the free allocation of grandfathered allowances. The petroleum refining sector shows little reduction in

Table 5. Results, Effect of EU ETS and UK policy measures, percentage change

Sector	Emissions		Physical production output		EBITDA	
Allowance price scenario	Euro 15/tCO_2	Euro 30/tCO_2	Euro 15/tCO_2	Euro 30/tCO_2	Euro 15/tCO_2	Euro 30/tCO_2
Cement	–12	–14	–1.2	–4.4	13	25
Newsprint	–4	–4	–0.2	+0.68	9	15
Petroleum	–0.4	–0.7	–0.2	–0.7	0.4	0.6
Steel	–14	–21	–2.1	–10.6	12	18
Aluminium	–100	–100	–100	–100	–100	–100

Source: Oxera.

emissions because it has a low intensity of emissions and has relatively little opportunity for abatement.

UK aluminium smelters are assumed to be outside of the trading part of the scheme, but still exposed to the UK-specific electricity price increase that this would engender. In practice, some aluminium smelters may own and some may have contractual arrangements with fossil-fuel power stations, meaning that they do participate in the EU ETS, and the results described below will not apply to them.

There is a stark contrast between the results for the aluminium smelting sector and those for the other sectors. In short, because aluminium smelting is assumed to be a global market, even relatively small changes in cost are predicted to have significant impacts on the competitiveness of UK/EU companies relative to global companies (which are assumed not to have environmental policies applied to them).

Prior to the introduction of the policies, there is one representative UK aluminium smelting company, one representative EU company and four representative global companies in the model equilibrium. From this starting position, the model simulation produces an outcome that in any of the scenarios tested the UK (and EU) aluminium smelters exit the market and their place is taken by companies operating exclusively outside the UK or EU. There is a subtle difference between the scenarios concerning how this position is reached. On some occasions, the initial impact of the policy is sufficiently severe to cause both the UK and EU companies to exit the market immediately. In other situations, one of the two companies remains in the market initially (with the other one closing), but the impact of a new global company entering in order to take the place of the first closure is, in turn, sufficient to precipitate the exit of the second non-global company. While this discussion has been framed in terms of global companies entering the market and non-global companies leaving the market, it can also equally well be thought of as existing companies located in the UK/EU relocating to outside of these areas.

UK and EU aluminium smelters are much more exposed to adverse competitiveness implications from the introduction of environmental policies, due to the global nature of competition in this market, than participants in any of the other markets analysed. However, as previously noted, some aluminium smelters are protected via contracts or association with electricity generators who either participate in the EU ETS or generate power from renewable sources. Hence the impact of the trading scheme may be that instead of the aluminium smelting activity ceasing, the profitability of the power generation activity is made lower than that of comparable power generators, where power prices are under the contracts or between associated companies are not raised to the new levels in the electricity market at large.

For other sectors, the ostensibly toughest policy scenario, where the CO_2 price is €30/t, leads to the largest increase in profits. This is because, although the CO_2 price, and hence marginal cost rise, is significant, the grandfathered allowances are more valuable. As the proportion of allowances to be grandfathered remains high in these scenarios, the effect of receiving such a valuable allocation dominates the higher marginal costs. If the high CO_2 price were associated with a much lower proportion of allowances being grandfathered, the profit impact would be expected to be markedly different.

The pattern of impact between the sectors is that the steel and cement sectors are notably more affected, in terms of both profit and predicted emissions savings, than the newsprint sector. In contrast, the petroleum sector is only very marginally affected, due to its relatively low energy, and hence carbon, intensity.

Although emissions are cut while profits are boosted, the increase in costs, and in prices, invariably has a negative impact on output produced and sold, and prices to consumers rise. The impacts on output across the different sectors are reported in Table 5. The output changes drive a large proportion of the total UK emissions reduction in each sector, also reported in Table 5.

Again, a number of observations can be drawn.

In all the markets modelled other than aluminium, the impact of the introduction of the policies is to reduce the total amount of output produced and sold within the UK.

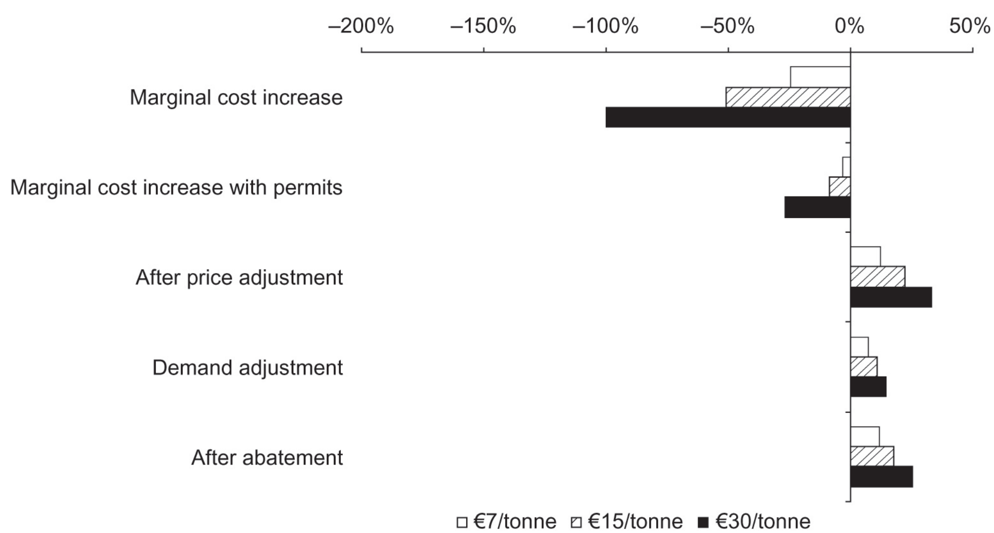
When the geographic market is wider than the UK, the impact of the output reduction within the market can be asymmetric across locations of companies. Most clearly, for the market in which there is non-EU production (steel), despite the overall fall in market output, the non-EU companies are predicted to see their output increase. In the case of newsprint in one scenario, the change in output is actually predicted to be positive, because there is an implied reduction in the marginal cost of production as a result of improved energy efficiency.

The composition of these effects on prices, output and profits is shown in Figures 1–5.

The figures show the cumulative change in EBITDA:

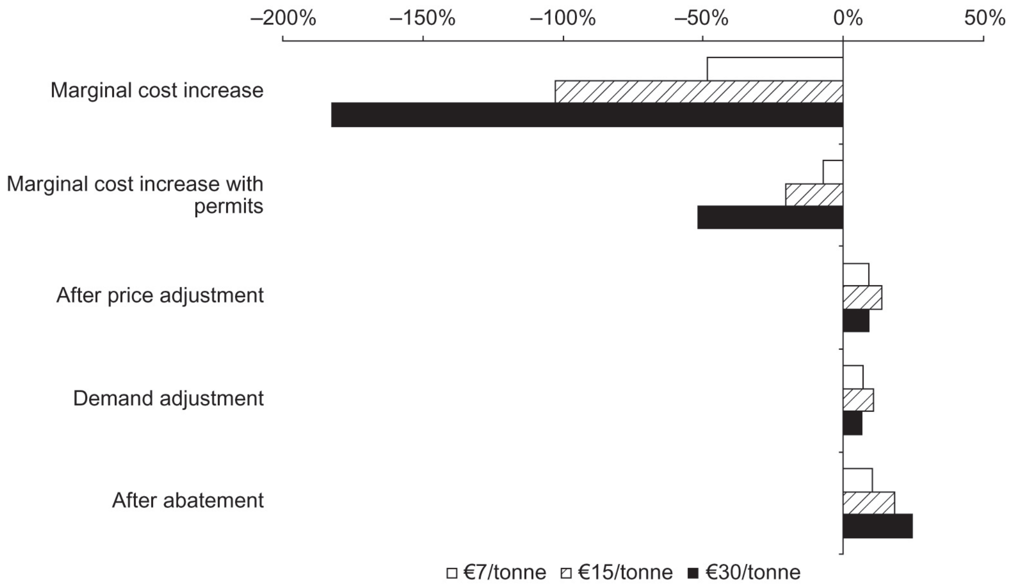
- from the increase in the marginal cost of production
- compensated by the allocation of allowances
- after adjusting for changed product prices
- accounting for change in demand
- noting the effect of abatement action.

This presentation shows the extent to which the impact of profit is a consequence of marginal cost increases, the extent to which this is compensated for by additional income from grandfathered



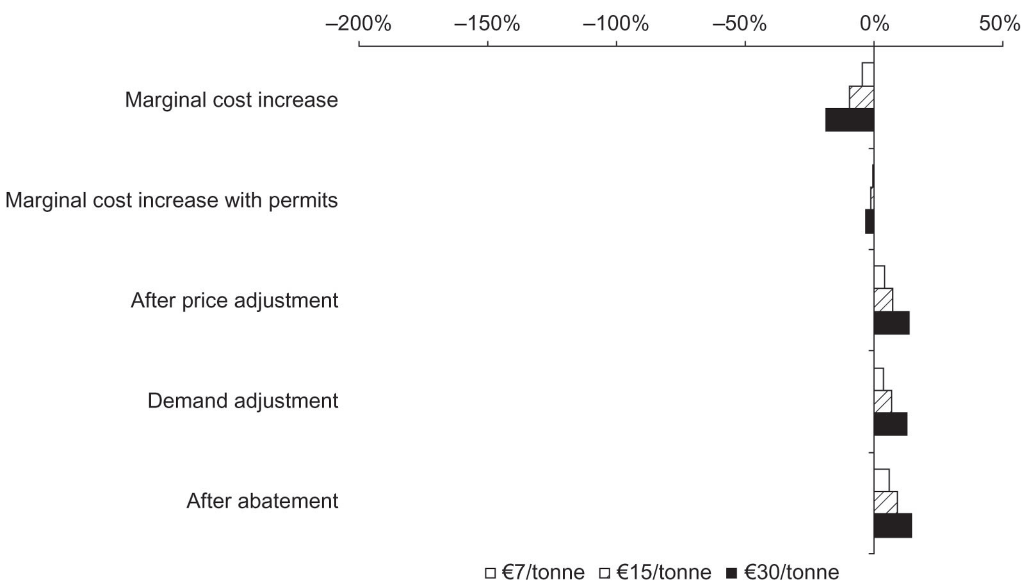
Source: Oxera.

Figure 1. Decomposition of effect on EBITDA for steel.



Source: Oxera.

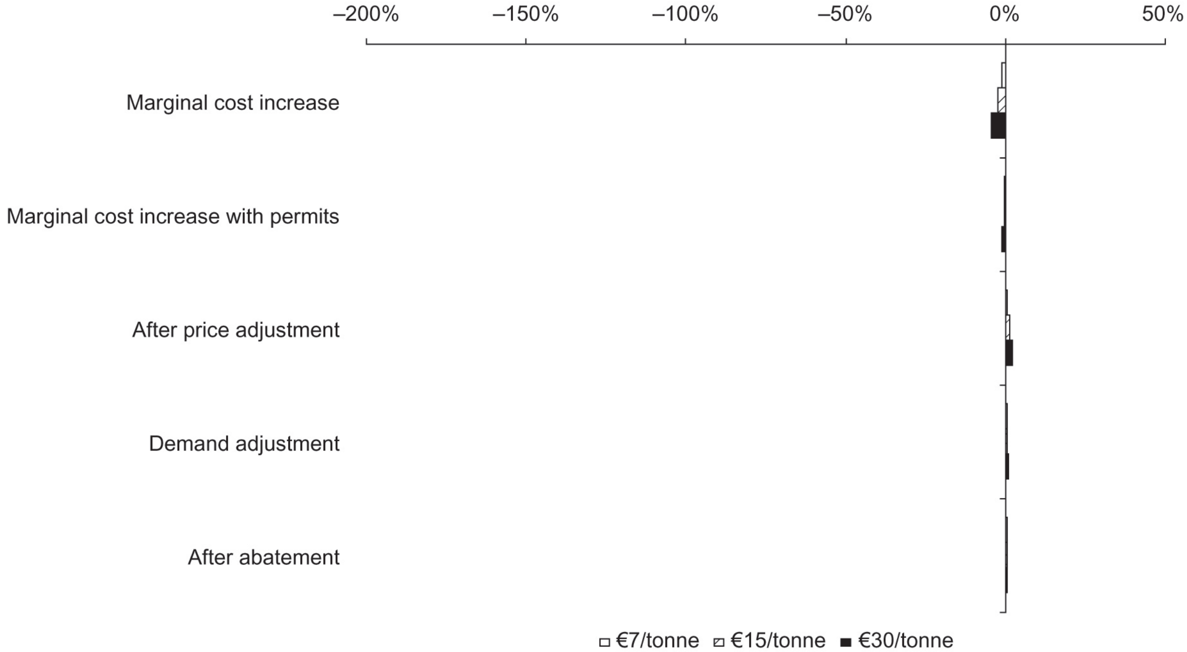
Figure 2. Decomposition of effect on EBITDA for cement.



Source: Oxera.

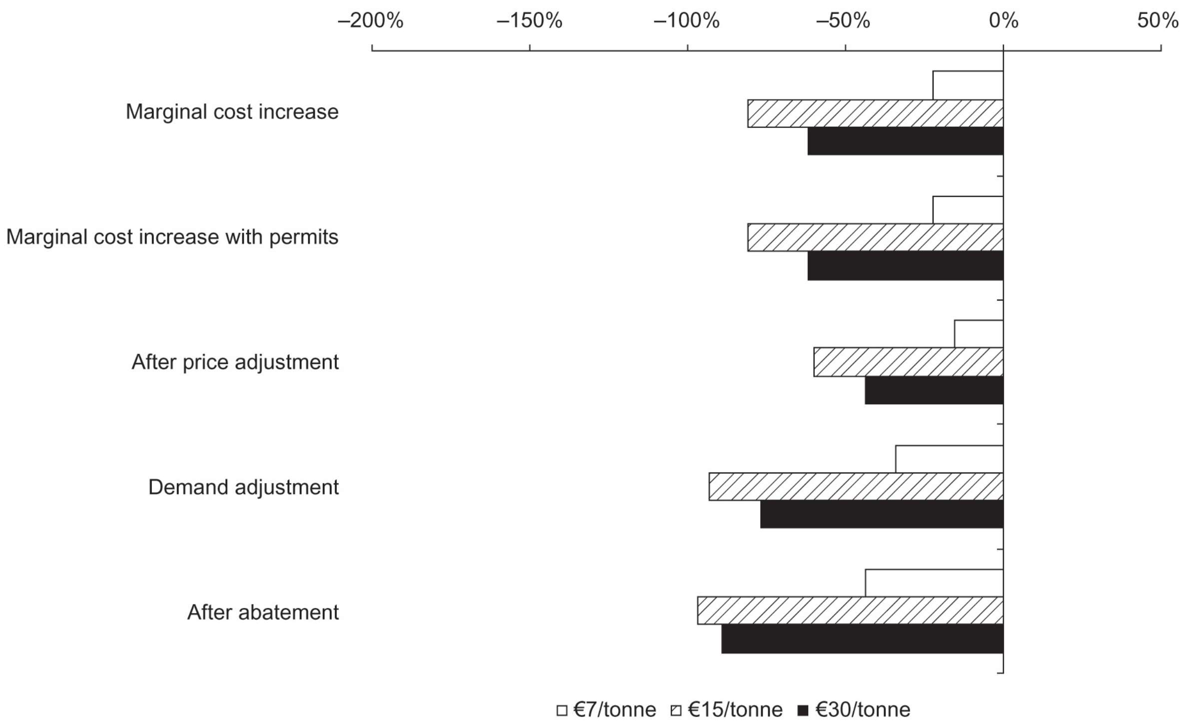
Figure 3. Decomposition of effect on EBITDA for newsprint.

allowances or higher prices, and the relative offsetting of this position by demand changes and abatement cost savings.



Source: Oxera.

Figure 4. Decomposition of effect on EBITDA for petroleum.



Source: Oxera

Figure 5. Decomposition of effect on EBITDA for aluminium.

9. Conclusions

9.1. The impacts on profits

The impacts of policies were most significant in the most energy-intensive sectors and those facing the greatest international competition. Even here, changes in EBITDA were commonly positive and large, being greater than 10%, and reaching as high as 25%. Prices rise in the cement sector, which is a UK market, because the EU ETS applies to 90–95% of the product supplied in the UK; and thus cement manufacturers are able to pass costs on to consumers. Prices rise in the steel sector, which is an EU market, because the EU ETS applies to 80% of the product supplied in Europe; as such, steel manufacturers are able to pass on a proportion, 65%, of their marginal cost increases to consumers.

At the same time, across all the sectors and policies, there was a reduction in volume of production, in most cases by much less than 1%. In two extreme cases – steel and cement – under the 'toughest' policy scenario, the output reductions were of 10% and 5%. This supports the suggestion, made for example by the CBI, that the EU ETS might cause a reduction in employment in some sectors.

The one exception to this picture is aluminium smelting, which, if not tied to electricity production, is exposed to large increases in marginal cost, with consequential migration of production outside the EU trading area. In all the scenarios, EU production of aluminium ceases.

9.2. The impact on emissions

The emissions reduction effects are caused in part by a reduction in UK output – a combination of a change in the share of the UK market held by UK producers and of weaker demand from consumers as a consequence of higher prices. They are also caused by investment in carbon-efficient technologies. Most of the emissions reduction is attributable to greater carbon efficiency, driven by the carbon abatement curves prepared for The Carbon Trust by Ecofys. Only in the steel and cement sectors does output reduction contribute to a significant carbon reduction.

It is notable that the abatement curves predict similar levels of emissions reduction across all policy scenarios. There is an initial level of abatement that is achieved under low allowance prices, according to the abatement curve method. This is presumably because the curve contains a volume of abatement that has been deemed beneficial or costless to the company. Thereafter, little additional abatement is stimulated by increasing incentives from tougher policies, which indicates that the abatement curve is quite steep, i.e. abatement costs rise steeply after the initial, virtually costless, actions are exhausted.

9.3. The impact on output

In the steel and cement sectors, there were reductions in output of 10% and 5% in the scenarios involving the highest penalties on carbon emissions, although, in both cases, these reductions were accompanied by greater increases in profits as prices rose. The increased profits combined with slightly reduced output result in a stronger financial position for the companies. In reaching the new equilibrium level of output, in none of the scenarios is capacity hit so hard that profits fall and companies exit the market, although there might be some shedding of labour and manufacturing capacity within companies.

In newsprint, a sector with medium energy intensity, impacts on output were small, at around 1% or less, but the effects on profits were still significant in some cases, being as large as +15%. These levels of output and profit change are unlikely to have a material effect on labour or investment.

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We thank, at Oxera, Gareth Davies, and at The Carbon Trust, James Wilde, for comments on this article, and Amra Topcagic for her contribution to the Oxera research. We also thank the referees for their insightful questions and helpful suggestions.

Notes

1 The significance of this market structure is that firms pass less of a marginal cost increase through to their customers than firms in a perfectly competitive market would do.
2 See, for example, Ten Kate and Niels (2005).
3 Incomplete cost pass-through can be consistent with isoelastic demand if the cost increase is not industry-wide, which is relevant to industries subject to intense international competition.

References

Baker, G.P., Jensen, M.C., Murphy, K.J., 1988. Compensation and incentives: practice vs. theory. Journal of Finance 43, 593–616.
Baumol, W.J., 1958. On the theory of oligopoly. Economica 25(99), 187–198.
Baumol, W.J., 1959. Business Behavior, Value and Growth. Macmillan, New York.
Bovenberg, A.L., Goulder, L.H., 2000. Neutralising the Adverse Industry Impacts of CO_2 Abatement Policies: What Does it Cost? Resources for the Future Discussion Paper 00–27.
Bulow, J.I., Pfleiderer, P., 1983. A note on the effect of cost changes on prices. Journal of Political Economy 91, 182–185.
Commission of the European Communities, 2000. Green Paper on Greenhouse Gas Emissions Trading within the European Union.
Defra, 2004a. UK Announces Consultation on Draft National Allocation Plan for the EU Emissions Trading Scheme [available at www.defra.gov.uk].
Defra, 2004b. UK Draft National Allocation Plan for 2005–07 [available at www.defra.gov.uk].
Dutta, P.K., Radner, R., 1999. Profit maximization and the market selection hypothesis. Review of Economic Studies 66(4), 769–798.
Friedman, M., 1953. Essays in Positive Economics. University of Chicago Press, Chicago, USA.
Govindarajan, V., Anthony, R., 1983. How firms use cost data in pricing decisions. Management Accounting, July, 30–37.
Jensen, M.C., Murphy, K.J., 1988. Compensation and incentives: practice vs theory. Journal of Finance 43, 593–616.
Kreps, D., Sheinkman, J., 1983. Quantity precommitment and Bertrand competition yield Cournot outcomes. Bell Journal of Economics 14, 326–337.
Koplin, H.T., 1963. The profit maximisation assumption. Oxford Economic Papers 15(2), 130–139.
Koutsoyiannis, A., 1984. Goals of oligopolistic firms: an empirical test of competing hypotheses. Southern Economic Journal 51(2), 540–567.
Lucas, M.R., 2003. Pricing decisions and the neoclassical theory of the firm. Management Accounting Research 14, 201–217.
Martin, S., 1993. Advanced Industrial Economics. Blackwell.
Murphy, K.M., 1985. Corporate performance and managerial remuneration: an empirical analysis. Journal of Accounting and Economics 7, 11–42.
Nabil, A-N., Baliga, S., Besanko, D., 2004. The Sunk Cost Bias in Managerial Pricing decisions. Mimeo.
National Statistics, 2002. United Kingdom National Accounts Blue Book, and further information provided by National Statistics.
Oxera, 2004. CO_2 Emissions Trading: How Will it Affect UK Industry? Report prepared for The Carbon Trust [available at www.oxera.com].
Quirion, P., 2003. Allocation of CO_2 Allowances and Competitiveness: A Case Study on the European Iron and Steel Industry. Mimeo.
Shim, E., Sudit, E., 1995. How manufacturers price products. Management Accounting 76, 37–39.
Stiglitz, J.E., 1991. Symposium on Organizations and Economics. Journal of Economic Perspectives 5(2).
Ten Kate, A., Niels, G., 2005. To what extent are cost savings passed on to consumers? An oligopoly approach. European Journal of Law and Economics 20, 323–337.
Varian, H.R., 1992. Microeconomic Analysis. W.W. Norton, London.
Ventosa, M., Baillo, A., Ramos, A., River, M., 2005. Electricity market modelling trends. Energy Policy 33, 897–913.
Vollebergh, H.R.J., de Vries, J.L., Koutstaal, P.R., 1997. Hybrid carbon incentive mechanisms and political acceptability. Environmental and Resource Economics 9, 43–63.