CONCRETE EVIDENCE?

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PEP 06/10

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ABSTRACT

A number of previous studies have considered the effect of the EU Emissions Trading Scheme (EU ETS) on the competitiveness of energy-intensive industrial sectors. These studies typically make theoretical predictions about product pricing, and of the profitability of European firms whose CO\textsubscript{2} emissions are capped, or firms which are intensive electricity users. This paper adds to the literature by empirically testing specific predictions which have been made about one sector covered by EU ETS, namely the manufacture of Portland Cement.

The paper considers a variety of models that have been used to predict the economic effects of EU ETS. It then describes various oligopoly competition models in which firms are assumed to be short-term profit-maximisers, which can be used to make predictions about the expected impact of marginal costs on product prices. It examines in detail the specific predictions made one such model about the impact of EU ETS on UK product prices. It also reviews the methodology and results of a recent empirical study in the European electricity sector which appears to support these predictions. Finally, it analyses and interprets cement cost and price data, from a variety of sources, for seven European countries covering the period 1995–2005, and part of 2006. This includes the first year of operation of the Pilot EU Emissions Trading Scheme, when (for the first time) European cement producers faced a quantifiable opportunity cost for CO\textsubscript{2} emissions.

The results confirm that average cement prices (with the exception of one country for which there is evidence of a collapse in collusive behaviour) were stable and remained well above the marginal production cost. However, although the average price levels were broadly consistent with competition models based on Cournot theory, the observed pass-through of incremental CO\textsubscript{2} costs into cement prices during 2005 was substantially lower than predicted by such models. It was also lower than the rate of CO\textsubscript{2} cost pass-through empirically measured in the European electricity sector during the same period. The implication is that cement producers (in contrast to fossil fuel electricity generators in the power sector) did not earn significant windfall profits from EU ETS during 2005. Two possible interpretations of this observation are:

- that cement producers might be constrained from raising product prices by the threat of competition from outside the EU, and hence a longer term loss of market share and profits, with the possibility of a smaller free allocation of Allowances in any Trading Scheme operating after 2012; or

- that cement producers might be willing and able to pass through a significantly higher proportion of the marginal costs of CO\textsubscript{2}, but the price effects are not yet observable because of long contractual lags.
An attempt was made to test the validity of the second interpretation by modelling the dynamic effect of fuel costs on cement prices. However, the econometric results (obtained for individual country time series and also for cross-sectional panel data) proved to be inconclusive.

*Keywords:* EU Emissions Trading Scheme, competitiveness effects, spatial Cournot equilibrium, Portland cement, Eurostat trade database

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This research was funded by Sustainable Energy Ireland through an IRCSET Special Scholarship.
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1. INTRODUCTION.

1.1 Background to the EU Emissions Trading Scheme

This paper is intended to inform the ongoing debate about the impact of the EU Emissions Trading Scheme (EU ETS) on the pricing behaviour, and by implication the profitability and competitiveness, of Europe’s Portland cement producers.

The pilot EU ETS commenced in January 2005, and will be superseded by the full EU ETS which runs from January 2008 until December 2012. EU ETS is a market-based policy instrument intended to help reduce the European Union’s greenhouse gas emissions from commerce and industry\(^1\).

Under the terms of the Emissions Trading Directive\(^2\), installations operating in the so-called Traded Sector will be granted a free (‘grandfather’) allocation of EU Allowances for each Trading Period, typically related to their average level of historic emissions, or (for new plants) their expected emissions. These Allowances are tradable, so every Tonne of CO\(_2\) emitted by such installations represents an opportunity cost. The intended result is that all installations face the same marginal cost of emissions, represented by the prevailing market price of Allowances. It follows that the marginal cost of emissions abatement will be equalised across the entire Traded Sector, consistent with optimal economic efficiency.

The importance of the cement sector to achieving the EU’s emissions abatement targets, and the continuing controversy surrounding the impact of EU ETS on cement firms, are the primary reasons for undertaking this review. Apart from power generation, the cement sector probably represents the major opportunity (in Ireland at least) for future greenhouse gas abatement within the Traded Sector. (ICF/BOC, 2005) Moreover, although cement is traditionally regarded as a non-traded good due to the high ratio of transport costs to added-value, there has been a robust response from European cement industry representatives about the competitive threat from non-EU cement producers. For example, the industry association Cembureau\(^3\) has suggested that the availability of substantial export capacity in countries bordering the EU will severely limit the ability of emissions-capped firms to raise product prices sufficiently to cover the cost of permit shortfalls. This

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\(^1\) The underlying principle is that all combustion installations above 20MW thermal rating, or operating in specified industries, will need to surrender tradable permits (known as EU Allowances) equal to their annual Tonnage emissions of Carbon Dioxide (CO\(_2\)). The total number of EU Allowances to be issued by EU Member States in each Trading Period will be capped, thereby conferring a scarcity value which is reflected in the market price.


\(^3\) www.cembureau.be
assertion flatly contradicts the conclusions of a number of recent theoretical studies.

1.2 Background to the Competition Modelling Review

Depending on the context, the concept of competitiveness can have several different economic meanings. For example, the European Commission (2004) defines it at the highest level as ‘a sustained rise in the standards of living of a nation, and as low a level of involuntary unemployment as possible’. However, the same publication also defines another concept of competitiveness at the industry sector level as being ‘the ability of an industrial sector to defend and/or gain market share in open international markets by relying on price and/or the quality of goods’.

It is the latter definition which firms in the Traded sector would regard as most relevant to the debate on EU ETS. Prior to the start of the Pilot Scheme in January 2005 a variety of approaches were employed in an effort to predict different aspects of its likely economic impact on energy-intensive industries, particularly those in the Traded sector.

Walker (2005) presents an overview of relevant recent studies in each of the following four areas.

- Static Computable General Equilibrium (CGE) models such as GTAP\textsuperscript{4} and dynamic CGE models such as DART\textsuperscript{5} have been used to estimate the medium-term (5-8 year) and long term (10-100 year) impact on GDP growth, international trade or economic welfare;

- Partial Equilibrium frameworks such as the PRIMES Energy Systems Model and the POLES\textsuperscript{6} model) have been used to estimate the medium- and long-run marginal cost of CO\textsubscript{2} emission abatement for particular sectors;

- Power Market models (such as those offered by the UK energy consulting firms ICF and Ilex) have been used to estimate the short-run impact of EUETS on electricity prices and the dispatch of power stations; and

- Oligopoly models (typically assuming Cournot competition) have been used to estimate the short-run impact of Emissions Allowance costs on product prices and market demand, with implications for the profitability of individual firms.

Once the decision was made to provide free allowances to installations participating in the EUETS, a strong incentive was created on the part of the

\textsuperscript{4} Global Trade Analysis Project, Purdue University
\textsuperscript{5} Dynamic Applied Regional Trade Model, Kiel University
\textsuperscript{6} ‘Prospective Outlook for Long-term Energy Systems’, European Commission
firms affected to lobby for a generous allocation. Their industry associations at national and European level had a strong incentive to maximise the size of the envelope of total allowances allocated to the trading sectors.

A prominent feature of the case-making from all quarters has been a preoccupation with international competitiveness in all its forms. Various measures of competitiveness at the national, sectoral and firm level have previously been discussed in the context of climate policy by Jenkins (1998), Barker and Johnstone (1998), Haites (2003), Klepper & Peterson (2003, 2004), Peterson (2003) the OECD (2003), Convery at al (2004), Zhang and Baranzini (2004), Kuik and Gerlach (2005) and SRU (2006). These studies have generally concluded that any adverse impact on economic welfare, sectoral competitiveness, or the profitability of firms is likely to be minor. Indeed, Quirion and Hourcade (2004) estimate the competitive impact of EU ETS costs to be small even in comparison with effect of fluctuations in exchange rates. One dissenting opinion is COWI Consultants (2004) whose CGE modelling work purports to show that EU ETS could significantly reduce future economic growth. However, since the COWI study was commissioned by UNICE (an umbrella organisation for business employers) it might be interpreted as an indirect form of lobbying for more generous grandfathering of EU Allowances.

1.3 Research Objective

This study aims to extend the literature in one specific area, namely the impact of EU ETS on the long term profitability and competitiveness of European cement producers. It does so by assessing the ability of European cement-producing firms to pass variable cost increases through to customers without losing profits through reduced market share and/or reduced market demand. In particular, it considers whether a modelling framework based on the assumption of profit-maximising oligopoly competition takes adequate account of all the relevant factors.

1.4 Structure of the Paper

The remainder of this paper is organised as follows.

Section 2 reviews the literature on spatial and non-spatial oligopoly competition models, and their application in modelling product prices in unregulated industries. It then provides a more detailed review of an oligopoly competition model commissioned by the UK Carbon Trust which is specifically designed to predict the impact of EU ETS on the profitability of firms in the UK. Thirdly, it considers how such predictions could be empirically tested, and it reviews a recent econometric study of the European wholesale electricity market whose findings appear to support the predictions made by that model.
Section 3 provides an overview of the competitive structure of the European cement industry, and of the supply chain costs. A technical description of the manufacturing process is also appended for reference.

Section 4 sets out the methodology for estimating the rate of Emissions Allowance cost pass-through in the European cement sector during 2005, explains how the data was obtained, and discusses its limitations.

Section 5 presents and discusses the results for each of the seven country markets analysed.

Section 6 draws conclusions about the validity of the oligopoly model discussed in Section 2, and of the empirical assessment method described in Section 4. Finally, it offers some comments on the implications for policy, and proposes a number of areas for further research.
2. REVIEW OF MODELS USED IN COMPETITION ANALYSIS

2.1 Categories of Competition Model

There are numerous economic models which aim to characterise the competitive behaviour of firms. Examples include:

- Monopoly, where one firm supplies the entire market, setting its prices to maximise short term profitability, bearing in mind the price elasticity of demand.
- Perfect competition, where there are many firms, each taking the price as given, and each assuming that its actions will have no effect on other firms.
- Oligopoly competition, where there are a small number of firms, each seeking to maximise its short term profitability, bearing in mind that its actions may affect the strategic behaviour of other firms.
- Monopolistic competition, where each firm has a degree of ability to control prices locally, limited by the risk of losing market share to existing or potential competitors.

Competition in the European cement industry can reasonably be considered as oligopolistic. Section 3 will show that there are typically about four dominant producers in each country market, with the leading European firms having cement operations in more than one market.

Ilex Energy Consultants (2004) have pointed out that in some oligopolistic industries such as power generation, prices may be regulated by an external authority. Ilex consider that in such circumstances, the rates of pass-through of the marginal costs of EU Emissions Allowances are likely to be determined more by regulatory policy than by the profit maximising behaviour of individual firms. Consequently, they predict that wide variations (5% - 95%) will be observed in the pass-through rate between Member States, despite similarities in their industry structures. However, this is not the case in cement production, where firms across Europe are free to negotiate prices with their customers without fear of regulatory intervention. It is therefore reasonable to expect that an oligopoly competition model, based on a branch of economics known as Game Theory, may provide useful insights into the pricing and production decisions made by European cement producing firms.

2.2 Simple Oligopoly Models for Cost/Price Analysis

Three of the better-known oligopoly models of industry competition are:

- the Bertrand Game, where players (firms) simultaneously set prices and the production of each firm follows customer demand;
• the Cournot Game, where firms simultaneously set their production quantities, after which a single market-clearing price is determined by the intersection of aggregate supply and demand; and

• Stackelberg Leadership, a two-stage Cournot game where the leader firm sets its production quantity on the understanding that the other firms will respond by setting quantities in a way that maximises their own profits.

In the Cournot Game, as the number of players increases, the equilibrium price falls. With a very large number of players, the outcome asymptotically approximates that of perfect competition. Paradoxically, though, a Bertrand game requires just two players (facing the same variable production cost) for equilibrium prices to be driven down to the marginal cost of production.

One criticism of the Cournot game model is that the competitive behaviour of firms in many industries is characterised as price-setting. Nevertheless, in many capital-intensive industries, outcomes associated with the Cournot model do appear to be more realistic than those of Bertrand model. In this regard, a widely-cited paper by Kreps and Scheinkman (1983) proposes a possible explanation. They consider a two-stage game in which capacity commitments are first made by each player, and Bertrand price-setting competition then follows. Under these conditions, the two-stage game results in the same equilibrium outcome as would be expected under Cournot competition.

This idea of equivalent outcomes was developed further by Boccard and Wauthy (1999) who showed that the same result can apply even in the case where firms can temporarily produce beyond installed capacity. The notion has also been tested experimentally. For example, Goodwin and Mestelman (2003) conducted laboratory-controlled duopoly game experiments in which players competed either under Cournot or Kreps-Scheinkman conditions. They found that the outcomes of each game typically converged as players became more experienced.

Ten Kate and Niels (2005) rely on Cournot game theory to predict what proportion of cost savings achieved by firms in an industry would be passed on to customers. Cost savings are equivalent to negative incremental costs, so the framework is directly applicable to the equilibrium pass-through of marginal costs from EU Emissions Trading. Ten Kate and Niels find that in Cournot equilibrium, the cost pass-through rate depends on the number of players but not on the price-elasticity of demand for the product. They also show that even under assumptions of Bertrand or Stackelberg equilibrium, or non-linear demand curves, the pass through rate should not depend on demand elasticity. It should be noted, though, that the elasticity of demand for

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7 The invariance of pass-through rate with respect to elasticity applies only to absolute changes (Euro/Euro). However, the relationship between percentage cost changes and price changes does depend on the value of the own-price elasticity of demand. See Stenneck & Verboven (2001).

8 This may be contingent on the first and second derivatives of the demand function satisfying certain mathematical conditions. Private communication, April 2006.
the product will affect the firm’s level of profit achieved at the new equilibrium, because of the market demand reduction resulting from any price increase.

2.3 Spatial Oligopoly Models

The models discussed above do not take into account the impact of factory location and transportation costs on competition. A number of published studies address this issue, and several of the findings would appear to be relevant to the cement sector.

Smale (2006) notes that a non-spatial model assuming price-setting competition for homogeneous products would predict prices close to marginal cost, implying the demise of an industry with high fixed costs. Smale suggests that a monopolistic pricing model, based on geographic differentiation, might be a tenable alternative framework. On balance, however, he considers the Cournot model to be more realistic.

Yang et al (2002) describe the Takayama-Judge framework for equilibrium modelling, where supply and demand is spatially dispersed, and the costs of transport must be considered. They consider conditions under which the outcome would be identical to that of the classical Cournot model. They also analyse shipments in the US coal industry, concluding that competition in this sector cannot be satisfactorily explained by the classical Cournot model. This suggests that caution may be needed in analysing the European cement sector without taking geographic factors into account.

La Regina (2003) provides a review of literature on spatial competition theory, and the application of spatial Cournot models in determining optimal plant locations. However, this finding may be of limited relevance to European cement sector, given that the logistics of production impose technical constraints on the choice of plant location9.

Lederer (2003) considers the characteristics of competition between spatially distributed profit maximising firms, noting that such firms are more likely to be setting ‘delivered’ rather than ‘mill’ (factory gate) prices. In the same vein, McChesney and Shughart (2005) discuss how, under the Bertrand framework profit maximising firms may be expected to exercise local market power by offering discriminatory delivered prices, whereby transport costs may be selectively absorbed. This has direct relevance to cement pricing regimes. Huveneers (1996), for example, discusses four types of spatial pricing systems, namely zonal prices, mill prices, basing-point prices, and competitive delivered prices with freight cost absorption. In the case of Belgium, Germany and the Netherlands, he finds that although there were ‘listed’ prices for cement at each centre of production, customers were prohibited from taking delivery at the producers’ factory gate. Huveneers also finds that the prices for

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9 As discussed in Section 3 below, the location of limestone and chalk quarries in the UK would appear to be a major factor both for the observed cluster pattern of cement plants, as well as for the plant design.
product delivered to the customer’s site included marginal freight cost only up to a distance of circa 100km, after which a uniform price was applied. By contrast, in the case of France, it appears that freight costs were passed on at cost without limit on distance, and that (in theory at least) customers could take delivery at the producer’s factory gate and organise their own transport.

D’Aspremont et al (2000) explain how either the Bertrand and Cournot models may be used in the analysis of competition policy within the cement sector, and why they lead to different predictions about the location of firms or their pricing decisions. They also draw attention to the different spatial pricing implications of ‘Land’ and ‘Marine’ models reflecting the economics of road or rail freight versus sea freight.

Syverson (2004) uses a two-stage simultaneous move game to test the notion that where spatial competition is important, the equilibrium price increases with the average spatial separation of production plants. He confirms the prediction in the case of the US ready-mixed concrete industry but also finds that heterogeneity in producer cost structures is also an important factor. This would have obvious implications for local rates of cost pass-through in the cement sector where individual kilns may be using different production technologies, different grades of raw material, and different types of fuel.

Martin (1999) reviews the pattern of cement company mergers and plant closures in France during the 1970’s, noting that access to cheap indigenous coal had been a source of advantage for some older plants which would otherwise be unviable. He concludes that inland plants are relatively sheltered from the emergent threat of seaborne imports from Mediterranean countries.

2.4 Modelling the Effects of EU ETS on Cement Trade

Reinaud (2004, 2005) asserts that producers operating in ‘highly competitive’ European industries may find it difficult to pass through the marginal costs of emissions allowances to their customers. In the Cournot competition framework, a high intensity of competition would normally be associated with a large number of competitors, in which case industry-wide marginal cost increases should be passed on at a high rate. However, if the domestic firms in a market faced actual or potential competition from outside the EU, they might not consider the incremental costs from Emissions Trading to be industry-wide, in which case the profit-maximising rate of cost pass-through would be reduced. Reinaud concludes that the high land-transport cost of cement protects the international competitiveness of EU cement producers, except those which face local competition from seaborne imports.

In this regard, there is a considerable body of relevant theoretical and empirical literature on the use of limit pricing by domestic firms to deter market entry. For example, Salvo (2004) suggests that a domestic oligopoly might

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10 The obvious corollary is that competing producers should have an incentive to create local geographic monopolies. The pattern of cement plant ownership in the UK, described in Section 3 below, would appear to be consistent with this.
maintain its prices artificially low in order to deter imports. Using the Brazilian cement industry as a case study, Salvo argues that the resulting cost-price margin is lower than would be expected from comparative static equilibrium analysis, giving the appearance of less market power, and hence a more competitive industry than is actually the case. This hypothesis would appear to be consistent with the views and comments of Irish cement sector representatives, as reported by Indecon Economic Consultants (2004). There is also anecdotal evidence\(^\text{11}\) that CRH plc previously engaged in limit pricing when its subsidiary Irish Cement was the sole producer based in the Republic.

Demailly and Quirion (2005a, 2005b) report the findings of a model-based study of the likely impact of emissions trading on international cement trade. Their study uses a spatial international trade model ('GEO') linked to a partial equilibrium model of the world cement industry ('CEMSIM') which itself is a module of the POLES model. Their model, which assumes Bertrand competition between countries and Cournot competition within countries, discusses the feasibility of using border taxes to preserve the competitiveness of European cement firms. The POLES model calculates prices by reference to a constant mark-up over marginal cost. For reasons of mathematical tractability, it invokes the somewhat arbitrary assumption of constant price-elasticity of demand\(^\text{12}\), under which the rate of cost pass-through into prices would be greater than 100%.

In a subsequent study, Demailly and Quirion (2006) use a modified\(^\text{13}\) version of the GEO/CEMSIM model to explore the implications of different possible allocation methods for EU Allowances. Specifically, they compare the outcomes expected under pure grandfathering (a lump sum allocation based solely on emissions prior to EU ETS) against those expected under Output-Based Allocation (OBA) based solely on current emissions. The latter arrangement represents a subsidy on production, by which the opportunity cost of emissions is reduced.

Demailly and Quirion note that if allocations to the cement sector depended on current cement production tonnage, this could encourage the reduction of clinker\(^\text{14}\) content in cement, but might also result in ‘carbon leakage’. Firms that started importing clinker from outside the EU for grinding into finished cement would continue to profit from free Allowances.

\(^{11}\) Private communication (April 2006) with representative of Ecocem, a firm which imports Blast Furnace Slag for supply to the ready-mixed concrete sector in Ireland.

\(^{12}\) A mathematical proof is given in Varian HR (2003) Microeconomic Analysis, Third Edition pp289-290. In the resulting Cournot equilibrium the ratio of Price to Marginal cost is equal to 
\[-0.2N/(1 - 0.2N)\] where N represents the total number of producers competing in a given market. The model described by Demailly and Quirion is empirically calibrated by selecting a value of N consistent with empirically observed gross profit margins, rather than the observed number of competitors in a given market.

\(^{13}\) Cournot competition is assumed to take place both within and between countries.

\(^{14}\) Clinker is an intermediate product in the manufacture of Portland cement. As described in the Technical Annex, its production is responsible for most of the industry’s CO\(_2\) emissions.
However, as Schleich (2005) has noted, an Output-Based Allocation method based on clinker tonnage instead of cement tonnage could dilute the incentives for cement producers that are considering abatement options involving reduction of the average clinker content in finished cement.

Emissions baseline updating arguably represents a diluted or delayed form of Output-Based Allocation, whereby producers ‘earn’ future grandfathered allowances by emitting CO\(_2\) in the current period. Although the baselines for allocations in the 2008-12 Trading Period were effectively settled by each Member State during 2006, cement producers may still behave as if they expect the grandfather allocation for any ‘post-Kyoto’ Trading Period (starting after 2012) to reflect average emissions during the 2005-07 period. The outcome is likely to lie somewhere between pure grandfathering and OBA.

Ahman (2005) has suggested that if a free allocation of permits is unavoidable, the level of production subsidy associated with baseline updating could be made acceptably small by requiring that any new reference period is at least 10 years in the past.

Regardless of whether allocations are partly output-based, there may be other reasons to challenge the assumption that firms will pursue short term profit maximisation. Smale (2006) for example suggests that European managerial salaries tend to incentivise the maximisation of sales and market share, rather than profits. Smale concludes that factors such as entry deterrence might induce incumbent firms to limit their price response to CO\(_2\) emissions cost increases, and suggests that the Cournot result should be subject to an adjustment factor reflecting the expected degree of limit pricing\(^{15}\).

Caution is therefore required in applying a simple non-spatial Cournot model to assess the trade impact of EU ETS, or in assuming firms’ pricing responses to be independent of whether EU Allowances are auctioned or grandfathered. Nevertheless, one such model, described below, provides valuable insights into the likely impact of EU ETS on the competitiveness of firms in the Traded sector.

2.5 EU ETS and Sectoral Competitiveness – the Oxera Model

During 2004, Oxera Consulting was commissioned by the UK’s Carbon Trust to develop an analytical framework which would allow an assessment of the likely impact of EU ETS on the profitability of UK firms.

The resulting report, Oxera Consulting (2004), considers all of the industry sectors covered by EU ETS, as well as one sector (aluminium smelting) which falls outside Traded Sector. It explicitly assumes non-spatial simultaneous Cournot (quantity-setting) competition in each of the industry sectors considered. It does acknowledge that competition in some of these sectors

\(^{15}\) This approach was previously proposed by Ventosa et al (2005) for modelling electricity markets.
may be characterised by price-setting rather than quantity-setting behaviour, but it relies on the finding by Kreps & Scheinkman (1983) that Cournot outcomes can nevertheless be expected given short-term constraints on available capacity.

For reasons discussed in Section 2.2 above, the elasticity of demand is assumed to have no direct bearing on the pass-through rate of costs in Oxera’s framework. However, it does have an impact on the change in a firm’s EBITDA\textsuperscript{16} because of the consequent effect on market demand and hence on sales revenue per firm. The model specifies an own-price elasticity of -0.27 for the EBITA calculation.\textsuperscript{17}

Chart 2.1 graphically illustrates the following simple relationship (which is formally derived in Appendix 1) between the pass-through rate of a marginal cost increase, the total number of Cournot players in the market (N), and the number of these players which are actually subject to the marginal cost increase (X).

\[ \text{Cost pass-through rate} = \frac{X}{N+1} \]

Chart 2.1. Oxera’s assumption about cost pass-through rate.

\textsuperscript{16} Acronym for a company’s ‘Earnings Before Interest, Tax, Depreciation and Amortization’.

\textsuperscript{17} Equal to the value of own-price elasticity of demand which was econometrically estimated for the Danish cement industry by La Cour and Molloegaard (2003).
In the case of the UK cement sector, Oxera assumes there are five firms, all of which are equally affected by EU Allowance costs, leading to an expected 83% pass-through rate\(^\text{18}\).

The Oxera framework treats the grandfathering of EU Allowances as equivalent to a cash endowment. Baseline updating is therefore not taken into account, implying that the marginal cost of each Tonne of CO2 emitted is equal to the market price of EU Allowances.

The model operates iteratively to calculate the profit impact of a marginal cost increase. It initially assumes a specified number of profitable competing firms, and it calculates the reduction of market demand resulting from the cost pass-through into prices. It then calculates whether the economic profit of each firm is reduced to the point where one of them would decide to exit the market. It then recalculates the market price, and firm profitability. The cycle repeats until profitability is restored to a level at which no firm would wish to exit. This represents a new Cournot price equilibrium being established, possibly following an industry shake-out.

Oxera examines three combinations of permit price and allocation shortfall. These notionally correspond to the pilot phase 2005-07, the first full trading period 2008-12, and a relatively tough post-Kyoto regime. Figure 2.1 graphically summarises Oxera’s findings, namely that none of the EU ETS sectors is seriously at risk of economic damage, and that no firms are expected to close. Indeed, several sectors could actually be more profitable as a result of emissions trading, reflecting the economic value of grandfathered Allowances. Phase 1 refers to the pilot trading period 2005-07, Phase 2 refers to the period 2008-12 and Phase 3 refers to post-Kyoto.

**Figure 2.1 EU ETS impact on Sectoral EBITDA impact.**

Reproduced from Oxera (2004)

\(^{18}\) The assumption that CO\(_2\) emissions per Tonne of cement are the same for all firms ignores the effect of differences in fuel efficiency due to process design.
Oxera (2004) concludes that the cement sector should be no worse off as a result of Emissions Trading up to 2012, noting that the risk of imports into the UK is limited by relatively high road freight cost. However, it acknowledges that in a ‘downside’ case, UK market prices may be capped by the threat of seaborne imports. Extracts from Oxera’s work have been published by The Carbon Trust (2004) and by Grubb (2004). These support Oxera’s conclusions, in each case acknowledging concerns expressed by industry representatives that some firms could be highly exposed to the costs of EU ETS with limited ability to raise prices in response. As shown in Figure 2.2, Grubb is ambivalent about the ability of firms in the cement sector to raise prices in response to increased costs. It appears that the jury is still out on the controversial question of whether the UK cement sector will be a net winner or loser from EU ETS.

Figure 2.2. EU ETS Sectoral Impact Matrix:

Reproduced from Grubb (2004).

In view of the particular uncertainty relating to economic impact of EU ETS on the cement sector, Walker (2005) has suggested that an empirical analysis of trade data might shed light on the issue. The data collection approach and analytical methodology which described in Section 4 below are a direct consequence of that proposal.
2.6 Empirical tests of the Oxera framework

There does not appear to have been any previously-published empirical study of variable cost pass-through into UK or European cement prices. However, a study published by Sijm et al (2005) presents results of an econometric analysis by ECN\textsuperscript{19}, assessing the pass-through of EU Allowance costs into European wholesale electricity prices during the first seven months of emissions trading.

The cost pass-through rate of EU Allowance into power prices is estimated by assuming that 100% of the fuel costs are reflected in the wholesale price, and then calculating what additional CO\textsubscript{2} cost would make the graphical trend line for carbon-adjusted ‘dark-spread’ (for coal) or ‘spark-spread’ (for gas) appear horizontal over the seven months. This is complemented by a more rigorous analysis involving linear regression modelling, although again there is an explicit assumption of 100% work-on of fuel costs\textsuperscript{20}. These different analyses result in a range of estimated CO\textsubscript{2} cost pass-through rates, as summarised in Table 2.1.

<table>
<thead>
<tr>
<th>EU ETS cost pass through</th>
<th>Wholesale power prices In Germany</th>
<th>Wholesale power prices In the Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak demand hours</td>
<td>69% - 73%</td>
<td>39% - 44%</td>
</tr>
<tr>
<td>Off-peak demand hours</td>
<td>42% - 46%</td>
<td>47% - 55%</td>
</tr>
</tbody>
</table>

These empirically estimated pass-through rates are somewhat lower than predicted by the Oxera framework\textsuperscript{21}. Sijm et al suggest a number of factors which might account for the apparent discrepancy, such as:

- whether the opportunity cost of emitting one metric Tonne of CO\textsubscript{2} would always be equal to the market price of EU Allowances
- whether the grandfathering of allocations to new entrants would encourage investment in new capacity thereby reducing the capacity margin (relevant if generation capacity is scarce to begin with)
- the fact that may not be a one-to-one correspondence between the ‘add on’ of EU Allowance costs in a generator’s bid price, and the resulting ‘work on’ of costs as manifested in the resulting wholesale pool price
- exposure to import competition from generators not capped by EU ETS
- the conjectured behaviour of renewable or nuclear generators (at times when such firms are the marginal generator, they may or may not seek to capture economic rent by raising bid prices in line with CO\textsubscript{2} prices)

\textsuperscript{19} The Dutch Energy Research Agency
\textsuperscript{20} If this assumption were incorrect, and the actual work-on of fuel costs was actually less than 100%, then the estimated rate of CO\textsubscript{2} work-on might be biased downwards.
\textsuperscript{21} Given that there are 3-4 firms competing in each wholesale market, Chart 2.1 would predict a pass-through rate of 75%-80% assuming all firms were equally affected. (This ignores the impact of non-fossil generators such as nuclear power stations.)
• the possibility of regulatory intervention to limit price increases
• possible time lags in adjusting prices to reflect CO$_2$ cost changes

Sijm et al use the empirically-estimated cost pass-through rates as inputs to COMPETES, a proprietary power network model developed jointly by ECN and the School of Engineering at The John Hopkins University, Baltimore. This model simulates behaviour among the larger European generators, allowing parametric adjustment of Conjectured Supply Functions for each generator, such that the nature of competition can range anywhere between pure Cournot and pure Bertrand.

In a follow up paper, Sijm et al (2006) present regression results for German and Dutch power prices covering the period January – December 2005, the first full year of emissions trading. The relationship between CO$_2$ costs and power prices observed during the final five months of this period appears to be different from that observed in the first seven months. Accordingly, the estimated range of pass-through rates (40% – 100%) is different from that previously reported.

Both these papers acknowledge problems in correcting for autocorrelation, noting that the use of first-differenced variables could give biased results due to the manner in which daily data are collected. Nevertheless, by applying the results as inputs to the COMPETES model, both papers conclude that the incremental revenue to generators is substantially more than the cash cost of making up the shortfall between the required number of EU Allowances and the number which were freely allocated. The stated inference in each case is that the electricity generators are significant net beneficiaries$^{22}$ from EU ETS.

The applicability of this type of analytical approach to measure the impact of EU ETS in the cement sector is discussed in Section 4.

$^{22}$ The finding about increased EBITDA in the power sector apparently confirms predictions by Neuhoff and Martinez (2004).
3. DESCRIPTION OF THE EU CEMENT SECTOR.

This Section presents an overview of the European cement market, including the drivers of demand. It also makes an estimate of the number of cement producing firms effectively competing in each national market prior to the start of Emissions Trading, in order to calibrate the Oxera modelling framework described in Section 2.5.

3.1 Size and Structure of the European Market.

According to Cembureau (2004) the estimated worldwide production of cement in 2004 was 2.1 Billion Tonnes, of which producers in the EU15 Member States accounted for about 200 Million Tonnes.

Cembureau identifies up to 27 common grades of cement, tailored to have different setting curing rates, chemical resistance and strength. However, about 85% of total Tonnage consists either of grey Portland Cement or Portland composites, with the remainder being speciality materials such as granulated Blast Furnace Slag (a by-product of steelmaking).

Exports and imports each represented about 10% of European cement production, so total consumption in 2004 was also 200 Million Tonnes, or just over 0.5 Tonnes per head of population. However, there were significant per capita variations across Europe, with certain countries (Italy, Spain, Greece and Ireland) consuming twice the European per capita average, and other countries (France Germany and the UK) consuming about half the average.

This reflects the fact that the demand cement is derived from construction and maintenance of industrial and residential infrastructure. Table 3.1 shows the Cembureau estimate of construction spending across the EU in 2004:

Table 3.1. European construction expenditure – 2004 Activity Report

<table>
<thead>
<tr>
<th>Category</th>
<th>Value € Billion</th>
<th>Percentage of total construction spend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential – new build</td>
<td>271</td>
<td>23.5%</td>
</tr>
<tr>
<td>Residential – maintenance</td>
<td>270</td>
<td>23.3%</td>
</tr>
<tr>
<td>Non-residential – new build</td>
<td>204</td>
<td>17.6%</td>
</tr>
<tr>
<td>Non-residential – maintenance</td>
<td>155</td>
<td>13.4%</td>
</tr>
<tr>
<td>Civil engineering – new build</td>
<td>169</td>
<td>14.6%</td>
</tr>
<tr>
<td>Civil engineering – maintenance</td>
<td>88</td>
<td>7.6%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1157</td>
<td>100%</td>
</tr>
</tbody>
</table>
The aggregate 2004 expenditure on cement (circa 200 Million Tonnes at an average retail price of say, €80 per Tonne) represents about 1.4% of total construction spending. Even in relatively concrete-intensive civil engineering projects, the cost of cement probably accounts for only a few percent of the total budget.23

Table 3.2 below compares the Cembureau estimate of total cement consumption for selected countries against the Eurostat production statistics for Portland cement. These seven countries collectively account for nearly 90% of EU15 consumption. The Eurostat figures refer only to Portland cement and its composites, whereas the Cembureau figure includes other speciality materials.

Table 3.2 – Consumption and Production in 2004

<table>
<thead>
<tr>
<th>National Cement Market</th>
<th>Cembureau Consumption Estimate Million Tonnes</th>
<th>Eurostat Production Database Million Tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>48.0</td>
<td>42.3</td>
</tr>
<tr>
<td>Italy</td>
<td>45.8</td>
<td>35.4</td>
</tr>
<tr>
<td>Germany</td>
<td>28.8</td>
<td>21.8</td>
</tr>
<tr>
<td>France</td>
<td>21.9</td>
<td>17.0</td>
</tr>
<tr>
<td>UK</td>
<td>13.1</td>
<td>12.2</td>
</tr>
<tr>
<td>Greece</td>
<td>10.6</td>
<td>14.8</td>
</tr>
<tr>
<td>Portugal</td>
<td>9.1</td>
<td>8.8</td>
</tr>
<tr>
<td>Sub-total</td>
<td>177.3</td>
<td>152.3</td>
</tr>
</tbody>
</table>

Charts 3.1, 3.2 and 3.3 respectively show the trends in annual Portland cement production, imports and net exports as reported by Eurostat for these seven countries during the period 1995-2004. Points to note are that:

- production tonnage has grown in Spain and Italy, has declined in Germany, and has remained stable in the other four countries; the overall increase between 1995 and 2004 was 22%
- imported tonnage has grown in France, Italy, UK and Portugal, has declined sharply in Germany, and has remained stable in the other two countries
- the ratio of gross imports to domestic production across these seven countries has declined from 9% in 1995 to just 7% in 2004, although most of this is due to the German market
- Germany ceased being a net importer and became a net exporter during the period; meanwhile Greece, Spain and the UK all experienced a drop in net exports. Most EU cement trade appears to be intra-Community.

23 This would be consistent with a low value of price elasticity of demand.
Chart 3.1 – Cement Production 1995-2004 (Eurostat Production Database)

Annual Production Volumes - Grey Portland Cement

Chart 3.2 – Cement Imports 1995-2004 (Eurostat Production Database)

Annual Import Volumes - Grey Portland Cement
3.2 Competitive Structure of the Cement Industry in Europe

The production of cement within Europe is dominated by a group of eight multinational firms, of which seven\(^{24}\) are listed in Table 3.3. Typically, about four of these firms can be found operating one or more factories in the major country markets.

<table>
<thead>
<tr>
<th></th>
<th>France</th>
<th>Germany</th>
<th>Italy</th>
<th>UK</th>
<th>Spain</th>
<th>Greece</th>
<th>Portugal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lafarge</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holcim</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cemex</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heidelberg</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italcementi</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buzzi</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cimpor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

\(^{24}\) The Irish firm CRH is considered to be a major player in European cement production, although it does not operate factories in any of the seven countries considered here.
There is anecdotal evidence that some of the consolidation in European cement over the past 20 years has been due to defensive acquisitions, the objective of which were to reduce the intensity of local competition, either by removing independent players from a market or by forestalling import competition. For example, the opening of Eastern Europe posed a significant threat to Western European producers due to its surplus capacity and depressed prices. The risk was largely neutralised by the major firms buying out and subsequently rationalising that capacity.

The same imperative may account for the recent pattern of investments by the major cement firms in new or existing production capacity located in North Africa. The Italian-controlled Italcementi Group has been particularly active in this respect. An embryonic import market for the granular intermediate product (clinker) may now be developing\textsuperscript{25} in southern Europe.

Appendix 2 graphically presents data on individual plants as published by the British Cement Association (BCA)\textsuperscript{26} to illustrate the pattern of geographic consolidation in the UK. Fourteen of the UK’s fifteen factories are subsidiaries of the leading multinationals listed in Table 3.3. The clustering by plant ownership arguably carves the geographic market into regional monopolies. Oxera (2004) recognised this effect, but nevertheless decided to treat the UK cement sector as a single market in Cournot equilibrium, with five players, and hence a predicted cost pass-through rate of 83%. The BCA data would, however, be more consistent with three or four players, and therefore a pass-through rate of 75% - 80%.

The degree of industry concentration in four of the other six countries listed in Table 3.2 appears to be similar to that of the UK, so it might be expected that similar rates of emissions trading cost pass-through (75%-80%) could be expected, assuming that all firms are equally affected by emissions trading. In the case of Greece and Portugal, further research would be necessary to establish the number of local competitors in the market before drawing inferences about the expected pass-through rate. However, the expected rate of cost pass-through would not be less than 50%, corresponding to monopoly.

It is worth noting that although the market concentrations are similar across five of these seven Member States, their average cement market prices do vary considerably, suggesting that they are not determined solely by the number of competitors. Other variables, such as the level of plant capacity utilisation, may be of comparable importance.

In this regard, Chart 3.4, extracted from Pinatel and Godet (2006) estimates the current level of UK cement plant capacity utilisation to be in the range 80% - 90%. This is somewhat lower than the estimate for France and Spain but higher than in Portugal, Greece and Spain, and considerably higher than Germany.

\textsuperscript{25} This suggests a parallel with the European fertiliser industry, where many firms have withdrawn from ammonia manufacturing due to uncompetitive gas costs, but have retained a profitable market share by importing generic product for blending into specific formulations.

\textsuperscript{26} URL http://www.cementindustry.co.uk/main.asp?page=120

Table 3.4  UK Plant Capacity and Allocations Under EU ETS NAP1.

<table>
<thead>
<tr>
<th>Company</th>
<th>Plant</th>
<th>Capacity 000 Te/year</th>
<th>Process Type</th>
<th>NAP allocation Te CO2</th>
<th>Production Implied 000 Te</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lafarge</td>
<td>Aberthaw</td>
<td>550</td>
<td>Dry</td>
<td>373,382</td>
<td>512</td>
</tr>
<tr>
<td>Lafarge</td>
<td>Barnstone</td>
<td>100</td>
<td>Dry</td>
<td>17,139</td>
<td>23</td>
</tr>
<tr>
<td>Lafarge</td>
<td>Cauldron</td>
<td>930</td>
<td>Dry</td>
<td>700,038</td>
<td>959</td>
</tr>
<tr>
<td>Lafarge</td>
<td>Dunbar</td>
<td>850</td>
<td>Dry</td>
<td>686,521</td>
<td>940</td>
</tr>
<tr>
<td>Lafarge</td>
<td>Hope</td>
<td>1400</td>
<td>Dry</td>
<td>975,438</td>
<td>1,336</td>
</tr>
<tr>
<td>Lafarge</td>
<td>Medway (planned)</td>
<td>1200</td>
<td>Dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lafarge</td>
<td>Northfleet</td>
<td>1200</td>
<td>Semi-wet</td>
<td>1,198,637</td>
<td>1,642</td>
</tr>
<tr>
<td>Lafarge</td>
<td>Westbury</td>
<td>765</td>
<td>Wet</td>
<td>664,981</td>
<td>911</td>
</tr>
<tr>
<td>Castle</td>
<td>Ketton</td>
<td>1300</td>
<td>Dry</td>
<td>976,165</td>
<td>1,337</td>
</tr>
<tr>
<td>Castle</td>
<td>Ribblesdale</td>
<td>1300</td>
<td>Wet/Dry</td>
<td>1,077,309</td>
<td>1,476</td>
</tr>
<tr>
<td>Castle</td>
<td>Padeswood (new)</td>
<td>500</td>
<td>Wet/Dry</td>
<td>422,136</td>
<td>578</td>
</tr>
<tr>
<td>Rugby</td>
<td>Barrington</td>
<td>250</td>
<td>Wet</td>
<td>266,343</td>
<td>365</td>
</tr>
<tr>
<td>Rugby</td>
<td>Rugby</td>
<td>1250</td>
<td>Wet</td>
<td>801,526</td>
<td>1,098</td>
</tr>
<tr>
<td>Rugby</td>
<td>South Ferriby</td>
<td>750</td>
<td>Semi-Dry</td>
<td>592,826</td>
<td>812</td>
</tr>
<tr>
<td>Buxton</td>
<td>Tunstead (new)</td>
<td>750</td>
<td>Dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lafarge</td>
<td>Cookstown</td>
<td>500</td>
<td>Semi-dry</td>
<td>349,344</td>
<td>479</td>
</tr>
<tr>
<td>Others</td>
<td>Various</td>
<td>60</td>
<td>Dry</td>
<td>60,000</td>
<td>82</td>
</tr>
<tr>
<td><strong>TOTAL excl Medway</strong></td>
<td><strong>12455</strong></td>
<td></td>
<td></td>
<td><strong>9,161,785</strong></td>
<td><strong>12,550</strong></td>
</tr>
</tbody>
</table>
Table 3.4 above allows the production volume at individual plant level in the UK to be compared against BCA data on plant capacity. The volumes have been inferred from CO$_2$ emissions data by installation$^{27}$ published by DEFRA for the 2005-07 National Allocation Plan (NAP).

The choice of manufacturing process type may have a significant effect on the plant’s cost structure, as explained in the Technical Annex. The comparison does not reveal any obvious systematic differences, and it would appear that virtually all the plants achieved a uniformly high level of utilisation during the UK’s NAP reference period. This may simply reflect the fact that there is no cement industry equivalent of a ‘peaking’ power station, given that prices have remained well above variable cost even for the less efficient plants, and for those using more costly fuels. However, the idea of a fuel-cost based merit order could be relevant during any industry shake-out, given that plants with higher variable costs would be more likely to close down.

Another industry characteristic which varies between Member States, and which may be relevant to product pricing, is the degree of vertical integration. Several of Europe’s leading firms have integrated their operations either upstream into the supply of aggregates, or downstream into the supply of ready-mixed concrete, or both. This may affect their bargaining power with major customers, and hence the ability to pass on cost increases on a timely basis.

Also relevant to product pricing is the established fact that the cement industry in parts of Western Europe has been characterised by collusive behaviour at various times. There have been a number of prosecutions, including one spectacular case in 2002 where German cartel members were collectively fined €600M by the competition authority.

The question of whether indirect price-drivers such as capacity utilisation, vertical integration, plant location and co-operative behaviour should somehow be included in the oligopoly framework of pricing in the cement sector will be discussed in Section 4.5.

$^{27}$ For simplicity, a uniform rate of CO$_2$ emissions per Tonne of cement has been assumed, ignoring any plant-specific differences in energy efficiency or fuel type.
4. EMPIRICAL APPROACH AND METHODOLOGY

The stated objective of the research described in this paper is an empirical estimate of the impact of EU ETS on profitability and competitiveness of firms operating in the European cement sector. One obvious starting point for developing a methodology was to consider the approach taken by Sijm et al (2005) for the power sector, adapting it where appropriate to the type of commercial data on cement which is readily available.

4.1 Comparison of power and cement industry pricing regimes

Although wholesale power markets and cement industries in Europe can both be considered oligopolistic, it is necessary to consider the following three differences in the characteristics of competition between producers.

- Indigenous supply and demand in a country’s wholesale power market generally clears on a real-time basis since the possibilities of producing electricity ‘for stock’ by pumped storage hydro-electricity are limited to a small fraction of daily demand. By contrast, the cement supply chain allows for several weeks of production to be stocked at factories, distribution depots, or in transit. Cement production may therefore adjust much more gradually to changes in demand.

- Wholesale power prices tend to be published, and can respond quickly to changes in input costs, or to changes in the marginal generation fuel. By contrast, there may not be a visible bidding process in the cement sector. Indeed, there may not even be a single market-clearing price for cement within each country, given the possibility of regional differences, and of bilaterally-negotiated discounts to larger cement users such as ready-mix concrete producers. Moreover, since some of the leading cement producers are vertically integrated, such discounts may also reflect intra-company transfer prices that are set for reasons of tax efficiency.

- The technical constraints on kilns switching between different types of fuels are less onerous than for electricity generators, being mainly concerned with materials handling and logistics rather than thermal efficiency. The concept of different plants being ranked in a merit order of fuel cost may therefore be somewhat less relevant to the cement sector than it is to the power generation sector.

The main points to draw from this are:

(a) that any time-series analysis of cement sector prices should aim to identify price changes from month to month rather than day to day; and

(b) since the prices of kiln fuel and of EU Allowances are observed to change on a similar (monthly) timescale, any time-series analysis may be complicated because the values of these variables (as regressors in any econometric model) may not be fixed under repeated sampling.
4.2 Choice of cement industry competition model

There are numerous proprietary models describing competition in the European power sector, but apparently none for the cement sector. It would be a major task to construct a realistic cement sector analogue of the COMPETES model. The admittedly simplistic Cournot model which Oxera has used would therefore appear to be the best option available at this time to model the profit and competitiveness impact of cement price changes arising from emissions trading costs.

The price elasticities of demand assumed by Oxera for cement (-0.27) and electricity (-0.25) are very similar. As a first approximation, therefore, it seems reasonable to assume that if a similar rate of cost pass-through were to be observed in the power and cement sectors, the same conclusions could be drawn about whether the cement sector is a net beneficiary from emissions trading. The analogy is not exact, given that the lump sum endowment of grandfathered permits in some Member States appears to be proportionately larger in the cement sector than the power sector. In such circumstances, the rate of cost pass-through required for firms to ‘break even’ would be lower.

4.3 Sources of data on cement prices

Since the German cartel judgement in 2002, Cembureau’s members across Europe have discontinued publishing list prices, and have generally refused to provide data in response to private requests, even from academic scholars. This may be because the firms wish to avoid doing anything that might be interpreted as facilitating collusive behaviour, or it may be that the information is now regarded as commercially sensitive.

Whatever the reason, the paucity of industry data poses a challenge for any researcher wishing to model the pass-through of factor costs into market prices. The research in this report has been based on data from three other sources, namely:

- the Eurostat Production database;
- estimates by a firm of construction industry sector analysts; and
- the Eurostat Trade database.

Each of these is discussed below.

4.3.1 Producer Price Data

The oligopoly model developed by Oxera (2004) specifically makes predictions about the impact of EU ETS on market prices within a country, based on the number of producers competing in that country, and the proportion which are subject to emissions trading. However, the domestic market price may differ substantially from the average factory gate price achieved by producers in each country. This is because producer prices
represent a weighted average of domestic and export sales. Although most cement exports from EU producers consist of deliveries to other European markets, there are also some exports into world markets, notably the US. An empirical assessment of the pass-through of CO₂ costs into market prices may therefore not capture the full effect on cement sector competitiveness. It would be worthwhile also to consider the pass-through into producer prices.

The majority of EU Members States oblige cement producers to submit financial and volumetric data each year to a Central Statistical Office (CSO) which in turn passes the collated data on to Eurostat. This data can be remotely extracted, free of charge, from Eurostat’s Production Database. For any given year, the ratio of annual production value to production Tonnage represents a direct measure of the average producer price of Portland cement in the relevant Member State. One drawback with this approach is that the Eurostat production data for each year is published several months after the year end. When this work was being undertaken during the second quarter of 2006, the production statistics for 2005 had not yet been made available.

4.3.2 Market Price Data

Chart 4.1, which is extracted from Pinatel and Godet (2006) provides a qualitative analysis by London based stock-broking firm BNP Exane Paribas of the regional cement prices understood to be prevailing in early 2006. In response to a private request, Exane BNP Paribas has also kindly provided quantitative estimates of annual cement prices (expressed in Euros per Tonne and Stg£ per Tonne) by country for the period 1995 to 2006.

4.3.3 Import Price Data

All EU Member States oblige cement importers and exporters to submit monthly volume and value figures to the relevant CSO. The collated monthly data is also passed on to Eurostat, and can be extracted free of charge from Eurostat’s Trade Database.

For any given month, the ratio of import value to import Tonnage represents a direct measure of the average price of cement for a particular import trade route. Trade data is generally available about three months in arrears. Data up to and including December 2005 was therefore available when this work was being undertaken.

One major advantage of using Eurostat Trade data to calculate EU ETS cost pass-through is that prices are calculated for each month, potentially allowing short term dynamic effects to be observed. Differences between import prices from different sources also allow estimates of regional variations in market price within each country, including the postulated effect of proximity to seaports. However, import prices could also be significantly affected by unobserved variables, such as market conditions in the country from where the imports originated. Moreover, the market prices prevailing in a particular border region or port region may not be reflective of the average prices achieved by an indigenous producer.

It should in any case be noted that different product classification codes are used by Eurostat for the Production and Trade databases. For the Eurostat data presented in this paper, the selected code for Production is 26511230 (Grey Portland cement including blended cement) while that for Trade is 252329 (Portland cement, excluding white).

4.4 Sources of data on cement input costs

The main variable costs of cement manufacture are kiln fuel, electricity, EU Allowances, limestone and a portion of the wages. The fixed costs of production (depreciation, finance and most of the wage bill) change slowly over time. Although they may have a long term effect on changes in cement price, the short term effects are assumed to be negligible.

4.4.1 Kiln Fuel

As noted in the Technical Annex, coal and petroleum coke account for 75% of fuel consumed by European cement kilns. Monthly and annual price trends for these two fuels can be obtained from a number of proprietary publications, but for this paper they have been inferred from Eurostat trade data.

Combustible waste materials account for much of the remaining 25% of kiln fuel consumption. Further research would be necessary to understand what drives the price of such materials in EU markets.
The specific fuel consumption quoted in the Technical Annex represents a hypothetical new Dry Process plant, designed according to Best Available Technique (BAT), operating on Heavy Fuel Oil. The published prices of Heavy Fuel Oil (HFO) and Natural Gas are readily available from commercial data sources such as Platts, but they may not be very relevant in determining cement input costs, given that they account for a very small proportion of total kiln fuel consumption.

Because bituminous coal and petroleum coke are close substitutes, their prices will be correlated over time. Any econometric model which included the price of both fuels as independent variables might therefore exhibit the problem of multi-collinearity. In other words, to include the price of both fuels as predictive variables might increase the explanatory power of a regression as measured by the R-squared statistic\(^{28}\), but the estimated coefficients of fuel cost pass through for each fuel would be subject to considerable uncertainty.

The analysis in Section 5 therefore assumes that the marginal fuel cost in cement production is determined primarily by the monthly wholesale market price of coal. For the purpose of modelling the fuel-related CO\(_2\) emissions of existing European plants, it was decided to use the Cembureau benchmark by assuming coal to be the default fuel, and the specific consumption to be 120kg (0.12 Tonnes) of coal per Tonne of finished Portland cement.

### 4.4.2 Electricity for materials handling and grinding.

Table A1 in the Technical Annex shows that kiln electricity consumption varies between 20kWh\(^{29}\) and 30kWh per Tonne of cement produced. However, this represents only a fraction of the total electricity usage. Much of the power consumed on site is required to pulverise coal prior to combustion, or to grind the granular clinker into a powder form for blending. The specific electricity consumption assumed in this study is the mid-range figure of 110kWh per Tonne quoted by Cembureau.

Electricity unit costs are assumed to reflect published tariffs for industrial users, rather than any traded wholesale price. The tariffs most relevant for this study are those applicable to the very largest users. For example, a medium sized cement plant consuming 110kWh per Tonne of cement and producing 0.6 Million Tonnes per annum of finished product would consume 66GWh of electricity per annum\(^{30}\).

Since 2002, Eurostat has published annual reports itemising the published tariffs for industrial users in each EU country. Since 2005, it has also published half-yearly updates.

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\(^{28}\) The value of R-squared can take any value between zero and one. A value of 0.5 would indicate that the model explains 50% of observed variation in the dependent variable. A related statistic, known as adjusted R-squared, may be used to compare models with different numbers of explanatory variables.

\(^{29}\) kWh refers to kilo-Watt hours of electrical energy

\(^{30}\) 1GWh (Gigawatt-hour) is equal to 1 Million kWh
Tariff data for 1995 -2003 was obtained from Eurostat (2003a, 2003b) with supplementary information from Goerten (2005a). The data for subsequent periods was obtained from Goerten (2004, 2005b and 2006). Some of the tariffs in earlier periods are broken out by regions within each country, although the treatment changes somewhat in later years. In any case the regional tariff variations within countries appear to be relatively small, and it was decided only to use national prices for regression purposes. Eurostat data for 1 January 2006 was not available when the work was being undertaken.

4.4.3 EU Allowances

The amount of CO\textsubscript{2} emitted from cement production will depend partly on the process energy efficiency, and partly on the clinker content of the finished cement product. For the purpose of modelling existing European plants, most of which are fired on coal or petroleum coke, it was decided to use the Cembureau benchmark figure of 730kg (0.73 Tonnes) of CO\textsubscript{2} per Tonne of finished cement.

The daily evolution of EU Allowance prices is available from Point Carbon’s website\textsuperscript{31}. Each Allowance corresponds to one metric Tonne of emitted CO\textsubscript{2}. Although each year’s Allowances are surrendered after the year end, it is reasonable to assume that the average opportunity cost for a given month will be proportional to the average published CO\textsubscript{2} price during that month. One possibility would be to take the un-weighted average for each day. Other options include simply using each mid-month price or month-end price.

4.4.4 Limestone (and/or Chalk)

Quarry gate prices for crushed limestone (typically in the region of €5.00/Te) tend to be quite small compared with the subsequent costs of road haulage. It is therefore understandable that cement plants tend to be located adjacent to large quarries. The corollary, however, is that any Eurostat data for delivered limestone prices could be seriously distorted by including a premium for the cost of transportation, and possibly also of grinding.

For simplicity, therefore the unit price of this raw material will be treated as effectively fixed through the period. The sole exception to this simplification is the inclusion of a dummy variable to allow for the once-off effect of an environmental tax on quarried limestone (equivalent to €2.50 per Tonne of cement) which was introduced by the UK Government in April 2002.

4.4.5 Variable Labour Costs

Minor elements of the labour cost of cement production (such as payments to subcontractors or lorry drivers) may be dependent on plant throughput. However, this study treats the overall labour cost of cement production as being entirely fixed. It seems a reasonable approximation, given that much of

\textsuperscript{31} www.poincarbon.com
the plant labour force is engaged in work of a supervisory nature, and that the labour costs of maintenance are largely independent of throughput.

4.5 Indirect Price Drivers

4.5.1 Capacity utilisation

Reference was made in Section 3 to the importance which leading European cement producers have traditionally placed on avoiding unduly high levels of unutilised capacity. The prevailing level of surplus production capacity within any European country might reasonably be expected to have a material impact on the position of the producers’ aggregate Supply Curve, and hence the market-clearing price of cement.

Oxera’s framework ignores any capacity effects. This raises the concern that any time-series analysis of changes in cement factor cost and market prices which fails to include capacity utilisation as a predictive variable might lead to biased estimates of cost pass-through rates. Unfortunately, it has proved difficult to identify any publicly available data on capacity utilisation suitable for inclusion in a quantitative econometric analysis. The estimates of surplus capacity published in Pinatel and Godet (2006) represent ranges rather than values, so are not sufficiently precise to allow for quantitative statistical analysis. Nevertheless, a linear regression of market price against the mid-range value of capacity utilisation for each country, as presented in Appendix 3, does suggest the existence of a positive correlation.

Quantitative time-series data on capacity utilisation in various EU Member States was purchased from the publishers of International Cement Review, but on examination the data exhibited numerous gaps and apparent inconsistencies. No meaningful analysis of the relationship between market price and capacity utilisation could be conducted. According to a representative of Irish Cement, there are currently no publicly available statistics on plant capacity utilisation within the EU. In the absence of such data, it does not seem feasible to quantify the degree to which historic price trends were the result of capacity effects.

4.5.2 Management of supply

The existence of a large capacity surplus in a market would be inconsistent with the conditions specified by Kreps and Scheinkman (1983) for Bertrand competition to result in Cournot equilibrium outcomes. Although transport costs might enable firms to maintain some control over local prices, one possible outcome in such circumstances would be a price war, leading to forced plant closures. There have been relatively few such closures in recent years, other than in the German market.

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32 www.comnet.co.uk
33 Private communication, April 2006
Another possible outcome would be for firms voluntarily to take out part of their capacity, or to buy out other firms. As previously mentioned, this did appear to take place in Eastern Europe some years ago. However, there is no evidence of it continuing today in the EU.

A third, possibly illegal, approach would be for firms to collude tacitly to restrict their output, thereby maintaining higher prices. The existence of collusion may be suspected where stable prices are maintained despite obvious surplus capacity. However, it is generally not feasible to assess or model the year-on-year effect of a continuing arrangement which by its very nature is secretive. The economic effects of such behaviour are most readily apparent after a break down of the arrangement.

The cement price data for Germany which is presented in Section 5 provides an illustration of this. German cement prices remained stable for several years prior to 2002 despite a long-stagnant construction sector. This was apparently achieved by the larger players covertly agreeing to restrict output and to share the market. The secret agreement was legally unenforceable, and there was a temptation for some of the smaller firms to ‘cheat’ by increasing their market share. By early 2002, one of the larger firms decided to punish them by expanding its own output. This precipitated a temporary price drop of circa nearly €20 per Tonne, heavy losses being made by all firms, the closure of some plants, and a gradual recovery of prices towards their former levels.

Despite a thorough investigation by German Cartel Authority, and guilty pleas being offered by some of the firms, the economic impact of the collusion is not known with certainty. For example, Blum et al (2004) have argued that the Authority’s economic logic was flawed, and that the true effect on prices of the industry collusion was rather less than its claimed figure of €10 per Tonne.

There are obvious reasons for the absence of any objective and readily observable variables that would allow an estimate of year-to-year changes in the degree of co-operative behaviour (if any) within an individual EU cement market. It was therefore considered impractical to address the issue in any econometric analysis of price trends, other than as a dummy variable (pre- and post-2002) for the German data.

4.5.3 Impact of sea-freight cargo rates

Marine freight rates for non-liquid bulk cargo vary by vessel size but are generally linked to the ‘Dry Index’ published by the Baltic Exchange. Sea-freight of the finished cement product does not represent an incremental cost of sales for producers in their home market, but it might nevertheless have a small indirect effect on market prices under conditions of Cournot competition. This is because a step change in freight costs would raise the importers’ delivered costs, thereby reducing the equilibrium market share of imports. The new equilibrium market price would be slightly higher than before, although it would not necessarily have increased by as much as the change in freight cost. In any case, a non-EU cement producer might be willing to absorb all or
part of its incremental freight cost in order to maintain a profitable long-term foothold in a given EU market.

The model used by Oxera would therefore imply little or correlation between sea-freight rates and EU cement prices. However, Oxera’s model would not necessarily be incompatible with a strong correlation between sea-freight rates and the net prices of exports by EU producers to non-EU markets. It is conceivable that EU cement producers would engage in ‘gentlemanly’ Cournot-type pricing behaviour within their domestic markets, but be willing to take lower margins on their exports to non-EU markets such as the USA.

As discussed in Section 2.4, a cement market with little or no import penetration might be characterised more accurately by a limit pricing model rather than by Cournot competition. In effect, the incumbent firms would be willing to sacrifice short-term profits as part of a longer-term strategy to deter potential (domestic or foreign) market entrants.

In such circumstances, it is feasible that any sustained increase in the cost of sea-freight would eventually be passed through into domestic market prices, reflecting the reduced competitiveness of imported cement. This would lead to the expectation of a stronger correlation between sea-freight rates and EU cement market prices.

It is worth noting, though, that the bituminous coal consumed in European cement kilns is typically imported from Colombia, Australia or South Africa, so the variable cost of clinker production is directly affected by freight rates. Although the introduction of freight rates as an additional variable might increase the overall explanatory power of an econometric model, the likely correlation between freight rates and coal import prices could make it more difficult to obtain an accurate estimate of the coefficient of fuel cost pass-through.

4.5.4 Locational variations in the intensity of competition

As discussed in Section 2, it seems reasonable to expect some regional variations in price cement, reflecting spatial Cournot competition within each EU country market. Perhaps the rate of emissions trading cost pass-through is, to some extent, specific to each individual plant. Unfortunately, since regional price data is not published, and proprietary data is very difficult to obtain, there is no obvious way of testing this empirically.

The Eurostat Trade database does allow a comparison of monthly prices for cement imported across land borders and sea borders. The analysis presented in Section 5 includes an assessment of whether (as expected) the regional cement prices in close proximity to seaports are generally lower than those in inland regions.

Care is needed in interpreting the monthly prices associated with a specific import route. For example, imports by sea are likely to consist of sizeable (10,000 Tonne) cargoes being brought into distribution depots. Such
transactions could well reflect international wholesale prices. By contrast, most imports recorded at land-borders are likely to consist mainly of relatively small (25 Tonne) loads of product being delivered to end-users from factories located close to the border. Such transactions would probably include a retail margin, and may be reflective of regional market prices. However, some imports at land-borders may consist of finished stock being transported in trainloads from factory to distribution depot. Such movements could be reported at transfer prices designed to maximise tax efficiency, or to be consistent with accounting procedures. In the latter case, the stock valuation could depend on the local accounting treatment of grandfathered allowances.

For these reasons, it is reasonable to expect the average import price levels to vary between trade routes. Moreover, because monthly import volumes are generally rather small compared with the size of a country market, there is greater scope for heterogeneity of product mix or regional effects. A degree of volatility in the monthly prices might therefore be expected.

Finally, Appendix 4 explores the implications for spatial price variation under the monopolistic competition model that was briefly conjectured by Smale (2006). It presents a simple framework of Bertrand competition with factory-gate pricing, assuming that the end-users are uniformly distributed in one spatial dimension. The two producers have identical production costs, but the cost of road transportation creates a downward-sloping demand curve for each firm, thereby circumventing the so-called Bertrand Paradox whereby prices would fall to variable cost, the gross profits of each firm would fall to zero, and both firms could incur net losses.

The prices predicted in Appendix 4 (based on Cembureau estimates of variable production cost) are substantially below those actually reported in most EU countries, which is consistent with Smale’s suggestion that Cournot competition probably represents a more appropriate cost/price framework for analysing capital-intensive industries.
5. RESULTS AND DISCUSSION

Sections 5.1 and 5.2 respectively analyse trends in the estimated price of Portland Cement, and in the estimated variable cost of production, for seven EU Member States, namely France, Germany, Italy, UK, Greece, Portugal and Spain.

Section 5.3 considers the impact of observed changes in some of the other indirect price drivers which were identified in Section 4.5.

Section 5.4 attempts to quantify trends in gross margin (calculated as market price less variable cost) for each country over the period 1995 to 2006. In particular, it examines the changes in margin that appear to have taken place since the introduction of the pilot EU ETS in January 2005.

By considering all the feasible rates of price pass-through for energy costs (0% to 100%), Section 5.5 infers a range of possible values for the short-run price pass-through rate of the CO$_2$ opportunity cost resulting from EU ETS.

Finally, Section 5.6 briefly considers whether it is feasible to estimate (rather than simply to assume) the rate of energy cost pass-through, and if so, whether it is also possible to distinguish between short-run and long-run rates.

5.1 Cement Prices

Appendices 5 - 11 are graphical summaries of price data obtained for each of the seven countries from three sources, namely:

- Eurostat’s Production Database (reported annual producer prices)
- Eurostat’s Trade Database (reported monthly import prices)
- Exane BNP Paribas (estimated annual market prices)

For all but one$^{34}$ the seven countries there are two charts in each Appendix.

The first chart is a scatter plot which superimposes the annual producer prices for 1995 to 2004 and the monthly import prices for January 1995 to December 2005. No monthly breakdown of the annual data on producer prices is available, for which reason the producer data for each year is represented as a sequence of 12 identical monthly prices, labelled ‘prodprice’. The prices are expressed as Euro per 100kg of cement, the same units used by Eurostat$^{35}$. These are nominal prices, and have not been adjusted for inflation. The UK data were translated from Sterling into Euro at the prevailing exchange rate for each year.

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$^{34}$ In the case of Greece, one of these charts is omitted because no cement imports were reported during the period.

$^{35}$ To convert prices from €/100kg to €/Tonne, simply multiply by 10.
The second chart is a scatter plot which allows a comparison of reported producer prices for 1995 – 2004 and the Exane BNP Paribas estimate of market prices up to 2006. The producer prices in this case are labelled as ‘Eurostat’ and expressed in Euros per Tonne of cement. Again the prices are nominal, and UK data has been translated at prevailing exchange rates.

5.1.1 French Cement Prices

Appendix 5 shows that annual producer prices (labelled ‘France_Eurostat’) remained flat between 1996 and 1999 at around €80/Tonne, before rising steadily to €93/Tonne by 2004.

BNPP’s estimated market price (labelled ‘France_BNPP’) initially remained flat at around €69/Tonne, before rising steadily to €82.50/Tonne by 2004, €85.80/Tonne in 2005 and finally €88.40/Tonne in early 2006.

A comparison of these trends up to 2004 suggests that market prices were consistently about €10/Tonne lower than average producer prices. This may reflect higher prices being achieved where in inland regions which are not threatened by imports. In any case, the close correlation means that year-to-year changes in producer prices are very similar to changes in market prices.

The pattern of reported import prices for the French cement market appears to be more complex. Appendix 5 identifies several import trade routes, each with a different price history and associated price volatility. Although it is difficult to draw unambiguous conclusions about year-to-year price changes in the French market from these data, they do provide some insights into spatial price variation. For example:

- The prices of imports into France from Greece (‘France_Greece’) and from Turkey (‘France_Turkey’) appear to have been maintained at a substantial discount to French producer prices (‘France_prodprice’). The prices of imports from countries such as Belgium and Spain, which share a land border with France, started at a similar discount. However, they appear to have converged with producer prices in recent years. This indicates a growing gap between the market prices in inland regions and the market price in the vicinity of Mediterranean seaports.

- The monthly prices of imports from Germany (‘France_Germany’) have been extremely volatile throughout the period, but are suggestive of a premium to French cement producer prices. The reasons for the volatility and the premium are not clear, although the volumes involved are rather small.

5.1.2 German Cement Prices

Appendix 6 shows that annual producer prices (‘Germany_Eurostat’) remained fairly flat between 1995 and 2001 at around €63/Tonne, before falling to €58/Tonne in 2003. There was a further sharp decrease (to €42/Tonne) in 2003, followed by a slight recovery in 2004.
The BNPP estimates show ex-works (factory gate) market prices remaining flat at around €63/Tonne between 1995 and 2000, rising to €65.20/Tonne in 2001. There was a sharp drop in 2002 to €43.40/Tonne, and a further decrease in 2003 to €35.30/Tonne, followed by a recovery to €45.00/Tonne in 2004, €53.00/Tonne in 2005 and €57.20/Tonne in 2006.

BNPP price estimates are in close agreement with reported producer prices up to 2001, and again for 2004. There is a significant divergence during 2002 and 2003, possibly due to timing effects during a period of rapid price changes. The generally accepted reason for depressed prices during 2002-03 was the collapse of a collusive arrangement which had previously placed artificial limits on production output. The observed recovery of market prices from 2004 onwards does not imply the return of collusive behaviour, but rather a reduction in spare production capacity following plant closures. It should be noted that this industry rationalisation, and a consequent upward shift in the aggregate Supply Curve, may mask the price impact of any changes in variable cost since 2002.

Analysis of German import prices again reveals some insights into the spatial variation of prices.

- Reported monthly prices of cement imported into Germany from France (‘Germany_France’) and from the Netherlands (‘Germany_NL’) have remained very close to annual producer prices (‘Germany_prodprice’) over the period 1995 to 2004. Prices of imports from Belgium have followed the same general trend as those from France, but have been considerably more volatile. It seems reasonable to expect that the observed price increases in 2005 for these imports will be reflected in producer prices.

- During the same period, the price of imports from Czech consistently remained about €15/Tonne lower than producer prices. The reason for this substantial and sustained difference between import prices at different land borders is not clear; one possibility is that it reflects conditions in the Czech market. Imports from nearby Slovakia were originally about €15/Tonne below producer prices, but have gradually converged with producer prices over the period.

5.1.3 Italian Cement Prices

Appendix 7 shows that annual producer prices (‘Italy_Eurostat’) rose from €41/Tonne in 1995 to €51/Tonne in 1996, then remained flat until 1999 before rising steadily to €65/Tonne in 2004.

The BNPP estimates show a steady increase from €41/Tonne in 1995 to €63.10/Tonne in 2004, dipping to €60.00/Tonne in 2005 before recovering to €67.20/Tonne in 2005. There is an increasingly close correlation between the two datasets.
Analysis of the import data again reveals some insights about spatial price variations. Reported monthly prices of imports to Italy from Croatia (‘Italy_Croatia’) were consistently about €18/Tonne below producer prices (‘Italy_prodprice’) during the period 1995 to 2004. The prices of imports from Greece were very similar to those from Croatia up to 2002, but appeared to command a €5/Tonne premium during 2003 and 2004. The prices of imports from Turkey follow a similar trend, but with higher volatility.

However, the import data for calendar 2005 reveals no consistent pattern of price changes during the first year of pilot EU Emissions Trading. Prices of Croatian cement appear to be unchanged from the previous year, prices of Turkish imports appear to be up sharply, whereas imports from Greece appear if anything to be priced slightly lower.

5.1.4 UK Cement Prices

Appendix 8 shows annual producer prices (‘UK_Eurostat’) increasing from €65/Tonne in 1995 (after a dip in 1996) to a peak of €90/Tonne in 2001, then decreasing steadily to €81/Tonne in 2004.

BNPP estimates of market price showed the ex-works price initially at Stg£41/Tonne, rising to Stg£45/Tonne by 2001, dipping to Stg£43/Tonne in 2004, and then rising to Stg£46/Tonne in 2005 and Stg£50/Tonne in 2006. In Appendix 8 these prices are converted to Euros/Tonne at the following average exchange rates, consistent with those used by Eurostat.

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>Stg£/Euro conversion</th>
</tr>
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<tbody>
<tr>
<td>1995</td>
<td>1.22</td>
</tr>
<tr>
<td>1996</td>
<td>1.25</td>
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<tr>
<td>1997</td>
<td>1.45</td>
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<td>1998</td>
<td>1.48</td>
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<td>1999</td>
<td>1.52</td>
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<td>2000</td>
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<td>2001</td>
<td>1.61</td>
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<td>2002</td>
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<td>2003</td>
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<td>2004</td>
<td>1.47</td>
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<tr>
<td>2005</td>
<td>1.46</td>
</tr>
<tr>
<td>2006</td>
<td>1.45</td>
</tr>
</tbody>
</table>

Other than in 1996, the BNPP price estimates appeared to be at a consistent discount of €15/Tonne to producer prices up to 2000. For reasons which are not clear, in 2001 the discount increased to €19/Tonne. It then remained
virtually unchanged up to 2004, resulting in an estimated market price of €63/Tonne. Prices climbed to €67/Tonne in 2005 and to €72/Tonne in 2006.

The UK import data reveal little about spatial variation of prices. For reasons of commercial confidentiality, monthly cement imports to the UK from individual EU Member States have not been reported to Eurostat since 1998. The monthly prices for aggregated import data ('UK_EU27') fluctuated considerably up to 1998, although from 1999 to 2004 they appeared to maintain a discount of roughly €18/Tonne to producer prices.

5.1.5 Greek Cement Prices


The BNPP estimates of Greek market prices show a steady upward trend from €47.40/Tonne in 1995 to €68.20/Tonne in 2004. There were further small increases in 2005 (€70.30/Tonne) and 2006 (€72.00/Tonne). It is noteworthy that, apart from 2002, Greek market prices appear to have remained at a premium, rather than a discount, to producer prices. This is possibly due to the impact of competitively-priced export sales.

There were no cement imports during the period, so no inferences can be drawn about spatial variation of Greek market prices.

5.1.6 Portuguese Cement Prices

Appendix 10 shows Portuguese producer prices ('Portugal_Eurostat') rising steadily from €59/Tonne in 1995 to €69/Tonne in 2002, then falling back to €62/Tonne by 2004.

The BNPP estimates of Portuguese market prices show a steady increase from €59.60/Tonne in 1995 to €71.40/Tonne in 2002, thereafter remaining flat up to 2005, before falling to €70.00/Tonne in 2006.

The observed premium of market prices over producer prices therefore increased from €1/Tonne in 1995 to €9/Tonne by 2004. Since Portugal was not a major cement exporter during the period, it is not clear why this premium should exist.

Marine imports to Portugal from Turkey have been recorded since 1999, apparently displacing marine imports from Italy. In 2003 the Turkish imports were at a discount of €20/Tonne to producer prices. Increases in Turkish import prices during 2004 and 2005 appear to have virtually eliminated this discount. The driver for these price increases remains unclear, although it may simply reflect a decrease in the surplus cement production capacity in Turkey, and hence a less aggressive attitude towards export markets in
Europe. In this regard, it should be noted that there have been similar recent increases in the price of Turkish cement imported to Italy.

5.1.7 Spanish Cement Prices

Appendix 11 shows Spanish producer prices (‘Spain_Eurostat’) remaining flat at €55/Tonne from 1995 to 1997, rising slightly for the next two years before dropping back in 2001, and then recovering strongly to €64/Tonne in 2002, where they remained flat up to 2004.

Although the BNPP estimates of market prices in 1995 and 1996 were similar to producer prices, in later years they appeared to be at a consistent discount of about €5/Tonne, reaching €59.10/Tonne by 2004. Prices rose to €63.20/Tonne in 2005 and to €67.00/Tonne in 2006.

Cement imports to Spain from Turkey (‘Spain_Turkey’) were priced at €38/Tonne in 1995, representing a discount of €18/Tonne to producer prices. This discount was virtually eliminated by 2000, as import prices rose to a peak of €55/Tonne, but it subsequently opened up again as the import prices eased back to €45/Tonne in 2002, where they remained unchanged up to 2004.

A similar picture emerges for imports to Spain from Greece (‘Spain_Greece’), except that these prices were particularly low in 2002 and 2003. It is also interesting to observe imports to Spain from Russia. These were competitively priced at €40/Tonne throughout the period 1997 to 2001, before rising to €45/Tonne by 2004.

In all of these three cases, there appears to have been a €10 per Tonne increase in import prices during 2005. As previously discussed, this may reflect changes in market conditions in the country of origin as well as those in the destination market.

5.2 Variable Costs of Production

5.2.1 Kiln Fuel

According to Cembureau, the main source of coal and petroleum coke used by European cement producers are bulk imports from countries located outside the EU. For this reason, it seems sensible to use Eurostat trade data to estimate the monthly prices of each fuel into each country.

Appendix 12 show the Eurostat price data for bituminous coal delivered into various European destinations by Panamax (20,000Te) or Capesize (60,000Te) cargo vessel from three major (southern-hemisphere) exporting countries. The coal prices do not vary much between exporters, or between import destinations, suggesting that European average prices can prudently be used as a proxy for local coal prices in cases where the latter data is incomplete.
Appendix 13 shows the corresponding delivered cost of un-calcined Petroleum Coke, delivered from oil refineries in the US Gulf. The spread of petroleum coke prices is somewhat wider than that for coal, although this may simply reflect unobserved product heterogeneity in the Eurostat data.

In this regard, Chart 5.1, extracted from Energy Argus (2004) shows the monthly price of petroleum coke to depend on whether the fuel Sulphur content is 4.5% or 6.0%. During 2003, there appeared to a consistent price premium for the 4.5% grade. It is worth noting that the premium grade was quoted for delivery to North West Europe, whereas the high Sulphur grade was quoted for delivery to the Mediterranean region. However, the difference may not be due to freight costs. A feasible alternative interpretation is that the combustion installations within each country market that opted to burn petroleum coke in 2003 were sourcing the cheapest grade permitted in their Integrated Pollution Prevention and Control Licences.

**Chart 5.1. Argus prices for US Petroleum Coke exports.**

The first chart in Appendix 14 confirms, as expected, a strong relationship between coal import prices and petroleum coke import prices derived for the period 1995 to 2005. The second chart shows that coke/coal price ratio over this 132 month period appears to be stationary at around 90%, although there were some short-run variations of ±20%.

Since both fuels are extensively used in cement kilns, it might be argued that a composite fuel price should be used to assess any changes in fuel cost over an extended period. However, this ignores the potential for fuel switching by cement producers. In any case, for the purpose of calculating kiln fuel cost increases since the introduction of EU ETS, it may not matter whether the fuel is assumed to be coal, petroleum coke, or a mixture of both. The prices of both these fuels (expressed in €/Tonne) appear to have changed by a similar amount between 2004 and 2005.
5.2.2 Electricity

Appendix 15 includes two charts, the first of which shows trends in electricity retail prices by country for Eurostat category I-I. This corresponds to very large industrial electricity users, typically consuming circa 70GWh per annum. The trends in electricity unit prices do vary considerably between countries, possibly reflecting different regulatory environments or differences in the prevailing type of power generation. The second chart shows trends in electricity unit price for users in Eurostat category I-G, consuming 24GWh per annum. Where country data for both Eurostat tariff categories is available, there appears to have been a similar evolution of unit costs for users in each category in any given country.

Although cement producers would normally be categorised as I-I, the relevant data is not available in all of the seven countries considered. For this reason, price data from category I-G has been used as a proxy to calculate year-on-year changes in cement production costs.

Although it would be possible to obtain data on the traded price of wholesale electricity, they would probably not be relevant for analysis of cement production costs. Nevertheless, they could give some indication of how retail tariffs are likely to change. As noted by Newbery (2006) the wholesale price of UK electricity rose sharply towards the end of 2005, apparently driven by rising gas prices.

Because the Eurostat electricity tariff data for 2006 were not available when this research was conducted, it remained unclear how fully the wholesale increase had been translated into retail prices for the first quarter of 2006. It should be noted that since no change in retail electricity tariffs was assumed for 2006, the pass-through rate of other variable costs (fuel and CO₂ emissions) may, if anything, be slightly over-estimated.

5.2.3 EU Allowances

As explained in the Technical Annex, the leading European cement firms have been co-operating since mid-2002 to develop an agenda for mitigating various harmful externalities (including greenhouse gas emissions) associated with cement production. However, apart from a general desire to be seen as acting in an environmentally responsible manner, they arguably faced no marginal cost in respect of their CO₂ emissions prior to 1 January 2005. It is therefore unlikely that cement prices prior to 2005 included any specific provision for the recovery of emissions abatement costs.

Cement producers would have been able to hedge the cash cost of any expected EU Allowance shortfall at the outset of 2005, given that a shadow market for these Allowances developed during the second half of 2004.

36 A number of UK electricity suppliers did announce increases in March 2006 ranging between 10% and 20%.
However, there is no evidence of this happening. Indeed, according to Redmond and Convery (2005) the overall traded volumes during 2004 and early 2005 appeared to be very small compared with the total number of 2005 vintage EU Allowances being put into circulation.

In any case (as previously discussed) the opportunity cost of CO\textsubscript{2} emissions associated with cement production in a given month may not depend on whether or an individual firm's grandfather allocation is sufficient to cover its requirements. Nor, in principle, does it depend on any price hedging which may be undertaken on the shortfall amount. An economic cost arises because the Allowances effectively ‘used up’ in each month’s production could instead have been sold on the traded market at prevailing spot prices\textsuperscript{37}. Because the Allowances are freely traded, there is effectively a common spot price for all participants in EU ETS.

Appendix 16 shows the mid-monthly spot price of EU Allowances for the period January 2005 to March 2006. The mid-January price of €6.80/Tonne was similar to levels previously observed in the shadow market. Allowance prices rose sharply in March and April, and again in June. By July they appeared to have peaked at around €23.70/Tonne, easing back slightly by mid-December. Further increases occurred in the first quarter of 2006, with prices exceeding €27/Tonne in March.\textsuperscript{38}

Based on Cembureau’s specific CO\textsubscript{2} emissions figure (0.73Te per Tonne of finished cement) the emissions opportunity cost in January 2005 would have been €5.00 per Tonne of cement. By December 2005 (for which the mid-month spot price was €21.95/Tonne) the opportunity cost would have risen to €16.00 per Tonne of cement.

5.3 Non-cost variables potentially affecting market prices

5.3.1 Capacity Utilisation

As discussed in Section 5.1, some of the import price trends may reflect a reduction in the level of surplus production capacity controlled by cement producers outside the EU.

It also seems likely that the evolution of producer prices and market prices in Germany from 2003 onwards may reflect a reduction of surplus domestic production capacity. However, it has not yet been possible to obtain data of sufficient quality to enable such a hypothesis to be quantitatively tested.

\textsuperscript{37} The author is personally of circumstances where an Irish fertiliser producer ignored this economic logic, by consuming natural gas under favourable contracts when it would have been more profitable to close down operations and sell back the gas in the market. Although the shareholders of the firm might have benefited, the firm’s managers and employees would effectively have been redundant.

\textsuperscript{38} EU Allowance prices collapsed by more than 50% during the second quarter of 2006, following the revelation that the overall allocation to the Traded Sector in some EU Member States had been overly generous. This does not impact on the analysis of cost pass-through up to the first quarter of 2006.
5.3.2 Freight Costs

The two charts presented in Appendix 17 provide some empirical evidence for freight cost absorption by European exporters to the US market.

The upper chart shows prices for cement exports to the US market from three European countries\textsuperscript{39}. These prices are reported Free on Board (FOB\textsuperscript{40}) at the port of origin, and hence are net of sea-freight costs. The ‘netback’ price of exports from Sweden steadily increased from around €25/Tonne in 1995 to a peak of €37/Tonne in 2002, then declined to around €27/Tonne in 2004, before recovering slightly in 2005.

A similar pattern is observed for Greek exports, although the prices are more volatile. A similar trend is also initially observed for exports from Spain, although its exports to the US appear to cease in 2002. These prices are well below the average producer prices and market prices in most European domestic markets. Indeed, they are somewhat lower than the recorded import prices from Turkey into European markets.

One interpretation of this is that European producers with surplus capacity are willing to discount their prices more aggressively for exports to the US market than they are for exports within Europe. Perhaps this is because the leading European producers all have operations in several Member States, and would be concerned about the overall impact on profits.

The lower chart shows the evolution of the Baltic Dry Index over the same period. It was fairly stable up to 2002, but rose five-fold to peak at 6100 points over the next two years, before falling back in 2005. It is noteworthy that the FOB prices of European cement exports destined for the US market remained stable when freight rates were stable, declined when freight rates increased, and started to recover as freight rates eased in 2005.

Chart 5.2 below compares movements in the Baltic Dry Index during 2004/05 against published long haul freight rates. The peak of 6100 points corresponds to a freight rate of US$34/Tonne, which suggests that long haul freight rates increased by US$28/Tonne (circa €22/Tonne) between 2002 and 2004. Cement export prices declined by €10/Tonne during the same period, which would be consistent with nearly half of the freight cost increase being absorbed by exporters.

If European producers exporting to the US market were unable to pass through the full cost of increases in freight rates, it is likely that they would also struggle to pass through the full opportunity cost of CO\textsubscript{2} emissions, since they would be competing against firms that are not subject to EU ETS. However, the overall effect on EU producer prices is relatively small, because exports from EU to non-EU countries represent only a small fraction of total production, even in the case of Greece.

\textsuperscript{39} Extracted from the Eurostat Trade Database
\textsuperscript{40} A standard commercial term meaning that title and risk pass from vendor to purchaser when the cargo has been loaded onto the ship.
5.4 Margin of cement market price over estimated variable cost

Appendices 18 – 24 summarise the trends in monthly market prices and marginal costs of energy and CO₂ emissions for the period 1995 to early 2006 for each of the seven countries under consideration. In accordance with estimates discussed in the Technical Annex, the average consumption of kiln is assumed to be 0.12 Tonnes of bituminous coal per Tonne of finished Portland Cement. The associated electricity consumption is assumed to be 110kWh, and the associated direct CO₂ emissions are assumed to be 0.73 Tonnes.  

For reasons discussed in Section 4.4.4, the unit cost of crushed limestone rock is assumed to be fixed throughout the period, at €5 per Tonne of rock, equivalent to €5.50 per Tonne of finished cement. The variable cost of grinding the limestone rock into powder is included in the process electricity consumption. Therefore, the estimated difference between market prices and energy/CO₂ costs should represent the cement producers’ average gross profit margin plus a consistent €5.50/Tonne premium.

Sections 5.4.1 to 5.4.7 below estimate the combined pass-through of fuel and emissions costs in each country market. The feasibility of estimating individual pass-through rates of energy and CO₂ costs will be considered in Section 5.5.

41 The appended charts continue to follow Eurostat Database nomenclature, by expressing costs and prices in units of €/100kg. However, throughout Sections 5.4.1 to 5.4.7, all costs and prices will be discussed in units of € per Tonne.
5.4.1 Cost Pass-through in French Market

The upper chart in Appendix 18 shows that, between 1995 and 2004, there were fluctuations in the unit cost of kiln fuel usage, and a slight reduction in the unit cost of electricity consumption, but the variable cost (excluding limestone) remained at around €11 per Tonne of cement. During 2005, the energy unit cost increased steadily to €14/Tonne, primarily due to higher coal prices. During the first half of 2005, the opportunity cost of CO$_2$ emissions rose sharply from €5 to €16 per Tonne of cement, where it remained approximately constant during the second half of the year.

The lower chart in Appendix 18 shows that, between 1997 and 2004, the mark-up between market price and energy/CO$_2$ cost increased steadily from €59.00 to €72.50 per Tonne of cement. By the end of 2005, this mark-up had fallen to €55.80 per Tonne. In early 2006 it appeared to have had recovered to €58.40 per Tonne.

If, as suggested by Pinatel and Godet (2006) the market prices tend to be adjusted at the start of each calendar year, the following interpretation of cost pass-through is feasible.

- In the sales contract negotiations for 2005, French cement producers may not have anticipated the increase in energy costs, but would have anticipated an incremental cost of €5 per Tonne of cement resulting from EU ETS.
- In the contract negotiations for 2006, producers would have factored an observed energy cost increase of €4 per Tonne, and an expected cost of €16 per Tonne arising from EU ETS.

A comparison of the observed French market price increase of €5.90 per Tonne between 2004 and 2006, and the corresponding marginal cost increase of €20 per Tonne, suggests a marginal cost pass-through rate of no more than 33%. Moreover, given that market prices had been increasing by about €2 per annum prior to 2005, other (unobserved) factors could have contributed to the market price increases observed in 2005 and 2006. For this reason, the underlying rate of cost pass-through of combined energy/CO$_2$ costs could be less than 30%.

5.4.2 Cost Pass-through in German Market

The upper chart in Appendix 19 shows a pattern of fuel, electricity and emissions costs between 1995 and 2006 which is similar to that observed in France. By the same reasoning, in their sales contracts negotiations for 2006, German cement producers would have factored an energy cost increase of €4 per Tonne and an increase of €16 per Tonne arising from EU ETS, compared with the costs prevailing in 2004.
The lower chart in Appendix 19 shows, however, a very different pattern of gross margin compared to that observed in France. Between 1995 and 2000, the mark-up over energy cost was remarkably stable at €52 per Tonne. It rose slightly in 2001, but collapsed in 2002, bottoming out in 2003 at just €24 per Tonne. The mark-up subsequently recovered to about €31 per Tonne by the end of 2004, with prices increasing faster than energy costs. By the end of 2005, the mark-up had reduced to €21 per Tonne, but in early 2006 it again recovered to €25 per Tonne.

A comparison of the observed German market increase of €12.20 per Tonne between 2004 and 2006, and the corresponding marginal cost increase of €20 per Tonne, might suggest a marginal cost pass-through rate of up to 64%. However, as previously discussed in Section 5.1.2, it is likely that most of the observed price increase was due to competitors exiting from the market, and surplus production capacity being taken out of commission, in response to the price war which occurred in 2002 and 2003.

The intensity of price competition in 2003 was arguably consistent with a period of Bertrand (price setting) competitor behaviour. If this is the case, then the observed price recovery which began in 2004 could represent a gradual transition to more Cournot-like outcomes which, according to Kreps and Scheinkman (1983), result under Bertrand competition with constrained capacity. Given the structural changes in the market that have occurred since 2003, it is very difficult to gauge with any accuracy the underlying rate of marginal cost pass-through during 2005-06. Nevertheless, the true figure is arguably likely to be lower than 30%.

5.4.3 Cost Pass-through in Italian Market

The upper chart in Appendix 20 shows a similar pattern of fuel costs as observed in France and Germany. However, unlike those countries, the cost of Italian electricity shows a rising trend, reflecting a steady increase in published tariffs. Italian cement producers, when negotiating their sales contracts for 2006, would have factored in an energy cost increase of €1 per Tonne, and an incremental cost of €16 per Tonne arising from EU ETS, compared with a 2004 base case.

The lower chart in Appendix 20 shows the mark-up of market price over combined energy/CO$_2$ cost increasing steadily from €30 per Tonne in 1995 to €48 per Tonne in 2003. It remained unchanged in 2004, but fell sharply to €26 per Tonne in 2005, before recovering to €34 per Tonne by early 2006.

A comparison of the observed Italian market price increase of €4.10 per Tonne between 2004 and 2006, with the corresponding marginal cost increase of €20 per Tonne, suggests a pass-through rate of up to 10%.

5.4.4 Cost Pass-through in UK Market

The upper chart in Appendix 21 shows a pattern of fuel, electricity and CO$_2$ costs broadly similar to observed in France and Germany.
The lower chart in Appendix 21 the price mark-up increasing from €41 per Tonne in 1995 to a peak of €62 per Tonne in 2000, remaining unchanged up to 2002, and dropping to €53 per Tonne the end of 2004. It dropped further to €47 per Tonne by the end of 2005, before recovering to €53 per Tonne in early 2006.

It should be noted, however, that the 46% increase in Euro-denominated UK market prices over the period 1995-2000 coincided with a 32% appreciation of Sterling against the Euro. Conversely, the 9% price decrease observed in between 2002 and 2004 coincided with an 8% depreciation of Sterling against the Euro. The observed decrease in Euro-denominated prices may have been a transient effect. It is therefore conceivable that the recovery in (Euro-denominated) UK market prices since 2004 includes a delayed adjustment of up to €3.50 per Tonne in respect of the earlier currency exchange rate depreciation. Commercial rigidity of this type might reasonably be expected to occur where contract prices are largely determined by annual rounds of bilateral negotiations between UK cement producers and their domestic customers in the ready-mixed concrete sector.

A comparison of the observed UK market price increase of €9.30 between 2004 and 2006, with the corresponding marginal cost increase of €19 per Tonne, suggests a pass-through rate of up to 46%. However, this represents an upper limit. If one-third of the €9.30 increase were to be attributed to currency effects, the apparent cost pass-through rate would be up to 31%.

5.4.5 Cost Pass-through in Greek market

The upper chart in Appendix 22 shows a pattern of energy and CO₂ costs similar to those in France, Germany and the UK. The lower chart shows a steady increase in mark-up of prices over these costs, from €38 per Tonne in 1995, to €57 per Tonne by the end of 2004. The mark-up fell to €41 per Tonne in 2005, before recovering to €43 per Tonne in early 2006.

A comparison of the observed Greek market price increase of €3.80 per Tonne between 2004 and 2006, and the corresponding marginal cost increase of €19 per Tonne, suggests a cost pass-through rate of up to 11%.

5.4.6 Cost Pass-through in Portuguese Market

The upper chart in Appendix 23 shows a similar pattern of energy and CO₂ costs to those observed for France, Germany and the UK. The lower chart shows a steady increase in mark-up, from €49 per Tonne in 1995, to €61 per Tonne in 2003. The mark-up remained unchanged in 2003, but fell to €59 per Tonne in 2005. By the end of 2005 the mark-up had fallen to €40 per Tonne, where it remained until early 2006.

A comparison of the observed market price decrease of €1.40 between 2004 and 2006, and the corresponding marginal cost increase of €19 per Tonne, suggests that the cost pass-through was effectively zero. (There is no
particular reason to suppose that the estimated reduction in Greek cement market prices was due to an increase in marginal costs.)

5.4.7 Cost Pass-through in Spanish Market

The upper chart in Appendix 24 shows a similar pattern of Spanish energy and CO₂ costs to those of producers in the other countries considered. The lower chart shows the price mark-up fluctuating between €41 per Tonne and €45 per Tonne during the period 1995 to 2001. It rose to €47 per Tonne in 2003, where it remained until the end of 2004. It had reduced to €34 per Tonne by the end of 2005, but in early 2006 it recovered to €38 per Tonne.

A comparison of the observed market price increase of €7.90 between 2004 and 2006, and the corresponding marginal cost increase of €18 per Tonne, suggests a cost pass-through rate of up to 37%.

5.5 Individual pass-through rates for Energy and Emissions costs

The analysis presented in Section 5.4 identifies feasible ranges for the aggregate pass-through of energy costs and CO₂ opportunity costs into cement prices within each of the seven EU markets considered. However, it should not be assumed that the pass-through rates for energy and EU Allowances are the same. Changes in energy prices represent an immediate cash cost for producers, whereas changes in EU Allowance prices do not, given that most of the emissions by EU cement producers are covered by grandfathered Allowances. An individual firm may or may not include the value of grandfathered EU Allowances in its management accounts, and this may influence affect the perceived economic value of such assets. It is reasonable to posit that at least some firms might seek to achieve a higher rate of pass-through for energy costs than for CO₂ emissions costs.

As previously discussed, Sijm et al (2005) assumed 100% pass-through of fuel cost increases in order to infer a value of 50%-70% for the pass-through rate of EU Allowance costs into wholesale electricity prices. By analogy, the marginal pass-through rate for fuel cost into cement prices could reasonably be assumed to lie in the region of 100%.

Table 5.2 presents feasible ranges for the percentage pass-through rate of EU Allowance costs into cement prices within each country market between 2004 and 2006. It does so by considering fuel cost pass-through rates of 50% and 100%. It turns out that because the EU Allowance cost increase was about four times larger than the energy cost increase in this period, the estimated rates of CO₂ cost pass-through between 2004 and 2006 appear to be lower than 50%, regardless of the assumed rate of energy cost pass-through.
Table 5.2.
Sensitivity of EU Allowance Cost Pass-through to Energy Cost pass-through

<table>
<thead>
<tr>
<th>Country</th>
<th>Market Price Dec 2004 €/Tonne</th>
<th>Price Increase to Jan 2006 €/Tonne</th>
<th>Marginal Cost Increase €/Tonne</th>
<th>Allowance Cost Pass-Through Rate (1)</th>
<th>Allowance Cost Pass Through Rate (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>€59.10</td>
<td>€7.90</td>
<td>€16.00</td>
<td>37%</td>
<td>24%</td>
</tr>
<tr>
<td>Italy</td>
<td>€63.00</td>
<td>€4.10</td>
<td>€16.00</td>
<td>10%</td>
<td>1%</td>
</tr>
<tr>
<td>Portugal</td>
<td>€71.40</td>
<td>€0.00</td>
<td>€16.00</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Greece</td>
<td>€68.20</td>
<td>€3.80</td>
<td>€16.00</td>
<td>11%</td>
<td>0%</td>
</tr>
<tr>
<td>UK</td>
<td>€63.20</td>
<td>€9.30</td>
<td>€16.00</td>
<td>46%</td>
<td>33%</td>
</tr>
<tr>
<td>Germany</td>
<td>€45.00</td>
<td>€12.20</td>
<td>€16.00</td>
<td>64%</td>
<td>51%</td>
</tr>
<tr>
<td>France</td>
<td>€82.00</td>
<td>€5.90</td>
<td>€16.00</td>
<td>33%</td>
<td>12%</td>
</tr>
</tbody>
</table>

(1) Assuming 50% of an estimated €4.00/Tonne energy cost increase was passed through into January 2006 prices
(2) Assuming 100% of an estimated €4.00/Tonne energy cost increase was passed through into January 2006 prices

Table 5.2 allows tentative conclusions to be drawn about the accuracy (or otherwise) of theoretical predictions made in Oxera (2004) about the EU Allowance cost pass-through rate in the UK cement sector. Given the above-stated assumption of 100% energy cost pass-through rates in each country, the apparent pass-through rates of 15% - 30% for CO₂ opportunity cost are substantially lower than the value of 80% predicted by Cournot competition theory for a market with four profit-maximising producers facing the same costs. Indeed, the pass-through rates are lower than the value of 60% which would be expected if one of those four producers was not subject to costs from EU ETS.

Crucially, the same inferences remain valid even if the energy cost pass-through rate is assumed to be only 50%. This implies that the impact of EU ETS on cement firms’ EBITDA in 2005 was substantially less than predicted by Oxera, regardless of the exact value of fuel cost pass-through. It also suggests that any windfall profits in the cement sector were proportionately less than those in the electricity sector.

5.6 Econometric estimation of energy cost pass-through

Notwithstanding the apparent robustness of the findings on emissions trading cost pass-through implied by Table 5.2, it would be helpful to have a better understanding of the longer-term relationship between changes in energy costs and changes in cement prices. For example, the required time period for market price or producer adjustment following an energy cost shock might shed some light on how quickly such prices might adjust to the introduction of
EU ETS. In particular, it might resolve the issue of whether, by early 2006, European cement prices had fully adjusted to the CO\textsubscript{2} opportunity costs observed during the second half of 2005. In turn, this might allow an early evaluation of two alternative explanations for the rather low observed rates of pass-through. These are:

- that EU cement producers believe the cost of emitting CO\textsubscript{2} to be somewhat less than the forgone opportunity of selling EU Allowances in the market, due to the expected impact of current production on future grandfather allocations; or

- that EU producers do believe the cost of emitting CO\textsubscript{2} to be the forgone opportunity to sell unused EU Allowances, but their contract prices are slow to adjust fully to this new marginal cost.

5.6.1 Selection of Price and Cost Data for Analysis.

In order to isolate the pricing effect of energy cost from that of emissions trading cost, data was analysed for the period January 1995 to December 2004. Two sets of data were analysed, namely the annual market price estimates provided by BNPP, and the monthly import prices calculated from the Eurostat Trade Database.

Although it might be possible in principle to measure different pass-through rates for kiln fuel and electricity costs, it was not considered necessary or appropriate to introduce this level of complexity in the analysis. Instead, a composite energy cost variable was calculated for cement producers in each country market.

5.6.2 Specification of Models for Testing

Four linear models have been econometrically tested for each of the individual time series. Regressions were run using the STATA statistical analysis software package\textsuperscript{42}.

The first (and simplest) model assumes that the observed price of cement in period ‘t’ depends on only the composite variable cost in that time period.

This can be stated mathematically as follows:

\textit{Model 1:}
\[ cem\_price_t = B1 + B2 \times var\_cost_t + e_t \]

where B1 and B2 are constants, and \( e_t \) is a random error.

This assumes there are no time lags incurred in passing through costs into prices, and that there is no price ‘stickiness’ from one period to the next. The short term and long term rates of pass-through are both equal to B2.

\textsuperscript{42} www.stata.com
The second model assumes that the observed price of cement in period $t$ depends on the variable cost in that period, but also on the variable cost in the previous period, which may be interpreted as a smoothing of the cost pass-through. Stated mathematically:

**Model 2:**  
\[ \text{cem\_price}_t = B1 + B2^* \text{var\_cost}_t + B3^* \text{var\_cost}_{t-1} + e_t \]

where $B3$ is a constant. In this case, the short term pass-through rate would be given by $B2$ but the long term rate would be equal to $(B2 + B3)$.

The third model assumes that the observed price depends on the variable cost in this period, but also on the observed price in the previous period, implying a degree of stickiness. Stated mathematically:

**Model 3:**  
\[ \text{cem\_price}_t = B1 + B2^* \text{var\_cost}_t + B4^* \text{cem\_price}_{t-1} + e_t \]

where $B4$ is a constant. In this case, the short term pass-through rate would be given by $B2$, but the long term rate would be equal to $B2/(1 – B4)$.

The fourth model assumes that the observed price in period $t$ depends on the current and previous variable costs, as well as the previous observed price. Stated mathematically:

**Model 4**  
\[ \text{cem\_price}_t = B1 + B2^* \text{var\_cost}_t + B3^* \text{var\_cost}_{t-1} + B4^* \text{cem\_price}_{t-1} + e_t \]

In this case, the short term pass-through rate would be $B2$, but the long term rate would be equal to $(B2 + B3)/(1 – B4)$.

Model (1), since it does not involved any lagged variables, is also amenable to a Fixed Effects panel data regression, where the geographic price differences are assumed to exist, but to be time invariant. The price in market $i$ for period $t$ therefore depends on the variable cost in that period for that country. Stated mathematically:

**Model 1 (panel)**  
\[ \text{cem\_price}_{ti} = B1_i + B2^* \text{var\_cost}_{ti} + e_{ti} \]

where $B1_i$ is a time-invariant parameter whose value is specific to country $i$.

Dummy variables were included in the regression models to allow for the impact of a quarry tax introduced in the UK in 2002, and also to allow for the effect of a cartel arrangement collapsing in Germany in 2002. For the panel data regressions on import price data, an additional dummy variable was included to distinguish between trade involving land borders from that involving sea-freight.
Consideration was also given to the idea of conducting Fixed Effects panel data regressions on Models (2) – (4). This would have required the identification and use of suitable ‘instrumental’ variables\textsuperscript{43} in place of the lagged energy cost and lagged cement price. However, no such variables could be readily identified.

5.6.3 Statistical Problems with the Data

There are several reasons why the regression results presented in Section 5.7 below should be treated with considerable caution.

\textit{Omitted Variable Bias}

The unavoidable omission of any variable allowing for changes in capacity utilisation within each market may lead to the estimated coefficients of other variables being biased. This is particularly the case for Germany, where there was a shake-out of surplus capacity during and after the 2002-03 price war. A bias may also exist in the UK data because of delayed pricing effects arising from changes in the Stg£/€ exchange rate.

\textit{Autocorrelation}

Since all of the above models involve time-series regressions, there is a possibility of autocorrelation (sometimes known as serial correlation) whereby the error terms $e_t$ may not be identically and independently distributed. This would be a violation of the classical assumptions under which Ordinary Least Squares (OLS) regression is the Best Linear Unbiased Estimator (‘BLUE’). If autocorrelation is believed to be first order\textsuperscript{44}, the problem may be rectified by regressing first differences of the variables. STATA’s Prais-Winsten\textsuperscript{45} command allowed this to be done without losing the first data point. The Durbin-Watson statistic, which is a widely-used diagnostic test for first-order autocorrelation, has been applied to Models (1) and (2). However, STATA does not permit this tool to be used for models which include a lagged dependant variable. A more general diagnostic tool for autocorrelation, namely the Breusch-Godfrey test, was therefore used for Models (3) and (4).

\textit{Stochastic regressors}

It was previously noted in Section 4.1 that the observed monthly energy cost for a cement producer is itself a random variable. Its sampled value will not be fixed under repeated sampling, and may be correlated with the random error term $e_t$. This would violate one of the assumptions under which Ordinary Least Squares regression is BLUE.

\textsuperscript{43} Instrumental Variables are used in a statistical technique known as the Generalised Method of Moments, of which OLS is a special case. See Bond (2002) or Wooldridge (2002).

\textsuperscript{44} First order serial correlation would imply that $e_t = \lambda e_{t-1} + \nu_t$, where $\lambda$ is a constant and $\nu_t$ is an independently and identically distributed random error term.

\textsuperscript{45} For further information on Prais-Winsten, Dublin-Watson and Breusch-Godfrey, see Gujarati (2003)
Panel data analysis

As discussed in Hogan (2004) and Arellano (2003) the use of stochastic regressors can lead to particular problems in panel data analysis. Pesaran and Smith (1995) have proposed an alternative (Mean Group) estimator for long panels which may be less efficient than the standard Fixed Effects panel estimator, but which (unlike Fixed Effects) would be consistent in dynamic models in the presence of heterogeneity and autocorrelation. Consideration was given to using this instead of the Fixed Effects estimator. However, the Mean Group estimator does not appear to be available in STATA, even as a user-written upgrade. In any case it is unclear whether 10 years of annual cost and price data would be considered a sufficiently long period for a dynamic model of the cement industry.

Heteroskedasticity

It is not known whether the distribution of random errors is independent of the value of each of the regressors in models (1) to (4). The STATA regressions have been run using ‘robust’ options (which allow for heteroskedasticity) in models (1) and (2) but not in models (3) or (4) because the robust option is incompatible with the Breusch-Godfrey test. Consideration was briefly given to the use of an alternative estimator (known as Newey-West) which allows for both Heteroskedasticity and Autocorrelation. However, the Newey-West tool was not considered appropriate, due to an insufficiently large sample size.

5.7 Results from STATA regressions

Annual market price data for individual countries

The results from individual STATA runs for Exane BNP annual price data for the period 1995 to 2004 are summarised in Appendix 25. For ease of comparison, they are listed by country, and also by model. For each of the seven countries, there are five regressions, namely:

- Model 1 – OLS (which assumes no autocorrelation)
- Model 1 – Prais-Winsten (which corrects for first order autocorrelation)
- Model 2 – OLS (which includes first lag of energy cost)
- Model 3 – OLS (which includes first lag of cement price)
- Model 4 – OLS (which includes lags of energy cost and cement price)

The results for Model 1 (OLS) show a wide variation in the estimated coefficient of energy cost across the seven countries. The implied rates of cost pass-through vary from -42% in Portugal to +736% in the UK. Only in the case of Germany (+81%) and Spain (+101%) do the figures make any intuitive sense in the context of a Cournot competition framework. In both these cases, though, the value of the t-statistic is less than 1.0, so the coefficients of energy cost are statistically insignificant at the 5% confidence level. Although the explanatory power of Model 1 for Germany appears to be quite high ($R^2 = 0.95$) this may be largely due to the presence of the dummy
variable ‘post cartel’ which distinguishes data before and after the start of the 2002-03 price war.

The results for Model 1 (Prais-Winsten) also show a wide variation in the estimated energy cost pass-through rate across countries, ranging from -11% in Germany to +453% in the UK. Only in France (20%) and Spain (50%) do the magnitudes of the figures make intuitive sense. Again, neither of these coefficients of energy cost is statistically significant at the 5% confidence level.

The results for Model 2 (OLS) show a similarly wide variation in the coefficients of energy cost and of lagged energy cost. In no case do the values make any intuitive sense, and in five out of seven cases the coefficients are statistically insignificant at the 5% confidence level.

The results for Model 3 (OLS) show a wide variation in the estimated short term energy cost pass-through rate across countries, ranging from -69% in France to 294% in the UK, with only one (Germany, 216%) being statistically significant at the 5% confidence level. The estimate coefficient of lagged price for Germany is 24%, implying a long term pass energy cost pass-through rate of (216%/0.76) ie. 284%. Such a high pass-through rate seems likely to be the result of a spurious correlation. Model 3 does result in high values of R-squared for all the countries, although this may simply be because prices do not change much from year to year.

The results for Model 4 (OLS) show a wide range of coefficients for energy cost, lagged energy cost, and lagged cement price. Only in the case of Germany (259%) is the coefficient of energy price statistically significant at the 5% confidence level. However, the coefficient of lagged energy price in Germany is strongly negative, which indicates a possibly spurious result.

Overall, therefore, the analysis of market price data for 1995-2004 does not provide any evidence to support either of the two interpretations proposed to explain the lower-than-predicted value of the cost pass-through rate.

Monthly import price data for individual countries

The results from 21 individual STATA runs on monthly price data for a representative selection of marine and land border import trade routes are shown in Appendix 26. For ease of comparison, they are listed by destination market, and also by model. In only three of these regressions is the estimated coefficient of energy cost statistically significant at the 5% confidence level. For some reason, all of these are for marine imports to Italy, namely:

- Model 1 (OLS) - Greek cement (for which the estimated coefficient of cost pass through is 320%)
- Model 1 (OLS) – Croatian cement (for which the estimated coefficient of cost pass-through is 280%)
• Model 1 (Prais-Winsten) – Croatian cement (for which the estimated coefficient of cost pass-through is 264%)

Perhaps these particular correlations are statistically significant simply because the Italian import prices (Appendix 7) and Italian electricity costs (Appendix 15) both exhibit a strong upward trend over the period 1995-2004. To eliminate the possibility of a spurious correlation between these two non-stationary variables, it would be necessary to establish whether they are co-integrated. However, it was decided not to attempt this, given that the coefficients are not intuitively sensible, and that other (unobserved) factors could be biasing the results.

Panel data regressions

The two tables in Appendix 27 respectively show results from Fixed Effects panel data regressions of BNPP annual market price data and of Eurostat monthly import price data. In each case, two STATA runs are reported; the first is a regression against the energy costs specific to each country, while the second is a regression against an un-weighted average of energy costs across the seven countries considered. The reason for including the latter is that fuel price data is incomplete for some of the countries. These models are static, in that they do not allow for lagged cost or price to influence the annual or monthly cement price. Regardless of the result, therefore, they cannot provide evidence to support either of the two explanations for the low cost pass-through rate.

The panel regression coefficient of annual energy costs on annual market prices is observed to be 259% or 352%, depending on whether local or averaged costs are considered. The t-statistics (4.7 and 5.9 respectively) suggest that the results are statistically significant, although the overall explanatory power of the model is only 8%-10%. The energy cost coefficients are significantly higher than predicted by Cournot competition theory, or even by Bertrand theory. Indeed, since the market prices during the period in question were typically three to four times higher than the energy cost, the regression results would appear to be more consistent with a fixed percentage margin over variable cost. However, this interpretation is unlikely to be correct, since it would imply an average short-term pass-through rate for CO₂ costs significantly lower than the 15%-30% range that is implied by 100% fuel cost pass-through. The energy cost pass-through rate would therefore be about twenty times higher than the implied EU Allowance opportunity cost pass-through rate. An alternative, and perhaps more likely interpretation, is that the panel data include country-specific effects which invalidate the Fixed Effects assumption.

The panel regression coefficient of monthly energy costs on selected monthly import prices is observed to be 93% or 112% depending on whether local or averaged costs are considered. The z-statistics (4.6 and 5.1 respectively) indicate that the coefficients are statistically significant, with the model

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46 As previously noted, the POLES model explicitly assumes a constant margin over variable costs.
explaining about 21%-25% of observed price variation. This result seems intuitively reasonable in the context of Cournot or Bertrand competition, although it should be noted that the selected imports represent only a small proportion of market demand in the seven countries considered.

The value of the coefficient for the dummy variable ‘Marine’ is -1.92 or -2.00 (depending on which energy cost data is used) suggesting that prices of marine imports are, on average, about €19 to €20 per Tonne lower than those of land-based imports. This would be consistent with the conjectures made by Martin (1999) and Reinaud (2005) about the potential exposure of cement producers located in coastal regions to competition from non-EU imports.
6. CONCLUSIONS.

6.1 Findings

This study has presented empirical data on Portland cement production for firms operating within the EU. It has also discussed the nature of competition in the cement industry, and the likely impact of EU Emissions Trading on the international competitiveness of leading cement producers operating in seven EU markets. In order to do so, it has sought to quantify the marginal cost increases faced by producers, and the corresponding market price increases achieved, since the start of Emissions Trading. Although a similar empirical exercise was previously undertaken for the wholesale electricity market, this appears to be the first such study for the European cement sector.

Calculations of variable production cost were based on energy price data obtained from Eurostat and Allowance price data obtained from Point Carbon. They indicate that immediately prior to the start of the pilot EU Emissions Trading Scheme on 1st January 2005, the unit variable cost (excluding limestone) for a typical European producer was about €10 per Tonne of cement, but by the end of 2005 it had risen to about €35 per Tonne. Some of this increase was attributable to rising fuel costs (coal and petroleum coke being the dominant in the fuel mix) and rising to electricity tariffs, but most of it was due to a completely new cost element, namely the opportunity cost of emitting CO\textsubscript{2} gas from the cement kiln. Prior to EU ETS, the environmental cost of such emissions was rightly regarded as an externality.

A review of the literature identified one particular study that had made specific predictions about the likely impact of EU ETS on the competitiveness of UK cement firms. The study, reported in Oxera (2005) assumed that cement firms would pass through to their customers whatever portion of the incremental cost was consistent with short-term profit maximising behaviour under the assumption of Cournot equilibrium. It also assumed that firms would regard any free (grandfathered) allocation of EU Allowances as equivalent to a lump sum cash endowment, and would therefore behave as if 100% of Allowances needed to be purchased in the market. Oxera’s theoretical framework can be readily extended to make predictions about the impact in other EU markets. It also provides a benchmark to compare against any empirically observed rate of emissions trading cost pass-through.

Other studies of the impact of EU ETS on international trade in cement, also based on the Cournot competition framework, have considered the possibility that firms may regard the long-run opportunity cost of emissions to be lower than the short-run cost. For example, Demailly and Quirion (2006) suggest that the prospect of emissions baseline updating (relevant for any subsequent grandfather allocation) may reduce the opportunity cost to below the market price of EU Allowances.

It is also worth noting that the cement firms, in lobbying for more generous treatment in the full EU ETS period 2008-12, would not wish to be seen to be
benefiting from windfall profits. In such circumstances, the underlying rate of CO$_2$ cost pass-through for 2005-07 would be higher than the figure estimated from EU Allowance prices. The Cournot competition framework suggested by Oxera could remain valid, provided that it was reformulated in terms of longer term profit maximisation. In considering the likely economic efficiency and environmental effectiveness of any post-Kyoto emissions trading policy, it would be advisable to consider the effects of grandfathering (and in particular baseline updating) on the behaviour of cement firms.

The empirical data shows, with reasonable certainty, that the aggregate pass-through rate of energy and emissions opportunity costs in early 2006 was significantly lower than the figure of 80% predicted by Oxera’s theoretical framework. Although, due to statistical difficulties, it has proved impractical to distinguish the pass-through rates of energy and emissions trading costs, it seems likely that significantly less than 50% of the opportunity cost arising from CO$_2$ emissions was being passed through to cement customers after the first 12 months operation of the pilot Emissions Trading Scheme.

It has not, so far, been possible to judge between the two interpretations previously proposed to explain this observation. It is also unclear whether additional time-series data will unambiguously answer the question of whether the prices in early 2006 represented a new equilibrium, or whether the prices were still adjusting to EU ETS. Unchanged cement prices in 2007 would suggest that equilibrium had been reached in early 2006. However, a sharp increase in cement prices in 2007 could either be the result of delayed cost pass-through, or a change in the perceived long-run opportunity cost of CO$_2$ emissions. (The level of grandfather allocations to each cement installation for the period 2008-12 would have been finalised by the end of 2006, and would be unaffected by firms’ pricing or production behaviour.)

A third possibility is that the some of major European cement producers, by tacit co-operation over their aggregate production levels, and/or the levels of surplus production capacity, have maintained prices at a level that are effectively cushioned from the impact of fuel cost changes, and from CO$_2$ allowance shortfalls. This need not involve anything illegal. In such circumstances, though, producers might not wish to ‘rock the boat’ by being seen to achieve super-normal profits from grandfathered allowances. For obvious reasons it would be difficult even to discuss such a hypothesis with the industry, let alone obtain any data to test it.

6.2 Further work

The empirical methodology which has been developed to quantify emissions trading cost pass-through may be equally applicable to other industries in the Traded Sector, notably steel refining. This may lead to co-operative research with other academic institutions over the next 12 months. However, as Demailly$^{47}$ has noted, the econometric issues could prove to be formidable.

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$^{47}$ Private communication, September 2006.
Steel is a globally traded commodity, for which reason European market prices can be strongly affected by freight rates, or by the growth of product demand outside the EU.

The main focus of research will therefore continue to be in the cement sector. One possible line of enquiry would be to seek a better understanding of how the price of cement varies between countries, and over time. This might lead to a more accurate estimate of the individual cost pass-through rates, and hence the impact of EU ETS on profitability. The same may be true, to a lesser extent, of regional price variations within each country. However, the data on costs and prices currently in the public domain would not be sufficiently detailed. Further analysis would therefore need to be based primarily on field work, and progress would be contingent on securing access to (possibly confidential) data at the level of individual firms, or even individual plants. From experience to date, it seems likely that European cement producers would be very reluctant to divulge such data, even on a confidential basis.

Two further lines of research are currently being considered.

- An investigation of whether the level of planned capacity investment in Europe (net of planned closures) is consistent with recent claims by cement producers that EU ETS will increasingly result in carbon leakage, with production of cement (or clinker) migrating to countries that are not subject to EU ETS.

- An investigation of whether EU ETS provides adequate incentives for emissions abatement to cement firms, whether by clinker content reduction, use of alternative fuels (such as bio-mass and combustible waste), or process efficiency improvements.

These can be considered as complementary approaches to address the conjecture that firms will not indefinitely be willing or able simply to pass on the incremental cost of emissions trading to their customers. Some firms will increasingly devote effort to abate their process-related and/or fuel-related emissions, consistent with the environmental policy objective of EU ETS. However, other firms may find it more attractive to relocate their cement (or clinker) production outside the EU altogether, resulting in carbon leakage rather than emissions abatement.
Overview of Portland Cement Manufacturing Process

Chart A1 below is a schematic of the so-called ‘Dry’ process for manufacturing Portland cement. The raw materials (limestone or chalk, plus small amounts of sand, clay and other minerals) are ground into a powder and blended to achieve a uniform chemical composition before being fed as ‘raw meal’ into a rotary kiln. Fuel is burnt at the outlet end of the kiln, with the combustion gases travelling counter-current to the raw meal. Some of the heat energy is required to drive chemical reactions, but a significant amount leaves the kiln as sensible heat, which can be usefully extracted from the flue gases before they are vented to air. In a modern plant this is normally achieved by allowing the hot gases to come into contact with the raw meal in a series of cyclone heat-exchange chambers.

Chart A1. Schematic of Cement Production Plant.

The chemical reactions take place in two stages. Firstly, the limestone or chalk component is chemically decomposed from Calcium Carbonate into Calcium Oxide (‘Lime’) and Carbon Dioxide (CO$_2$) at a temperature of 900°C. In modern plants, this takes place in a separate preheating chamber, before the material enters the kiln. The CO$_2$ escapes to atmosphere, and the calcined Lime passes into the kiln along with the other components of the raw meal. As the kiln slowly rotates, these materials pass along the kiln, taking about 30 minutes to reach the burner, where they temporarily attain a temperature of circa 1450°C, causing them to sinter.
The granular product, known as ‘clinker’, is composed of Calcium Silicate\(^{48}\). The clinker is cooled before being blended with circa 5% Gypsum (Calcium Sulphate) and up to 5% of raw meal, and is then milled into a fine powder. Each Tonne of finished Portland cement therefore contains 90%-95% clinker by weight. Portland Composite cements may, however, contain significantly less than 90% clinker, as a result of further blending with other cementitious materials such as powdered Blast Furnace Slag, which is a by-product of steel refining.

The calcination stage unavoidably generates a fixed amount of process emissions of CO\(_2\) per Tonne of clinker. The amount of CO\(_2\) additionally emitted from fuel combustion depends both on the kiln energy efficiency and carbon intensity of the fuel. Chart A2 shows a heat and mass balance (excluding electricity consumption) per kilogram (kg) of Portland Composite cement containing 75% Clinker.

**Chart A2. Heat and Mass Balance for Dry Kiln with Pre-calcining.**

It depicts what the European Commission (2001) considers to be the Best Available Technique (BAT). The CO\(_2\) emissions are calculated assuming the use of Heavy Fuel Oil (HFO). However, the European Commission (2001) also acknowledges that HFO accounted for only 7% of European cement kiln fuel consumption in 1995. It quotes a Cembureau submission which indicated that the most commonly used fuels at that time were petroleum coke (39%), coal (36%), and various waste materials (10%). The residual fuel consumption was reported to be from brown lignite coal (6%) and natural gas (2%). The burning of carbon-rich fuels such as coal and petroleum coke naturally results in significantly higher specific fuel emissions of CO\(_2\) than those associated with HFO combustion.

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\(^{48}\) Clinker is the active ingredient in Portland cement. It is ‘hydraulically active’, in that the silicate compounds rapidly form hydrated salts when mixed with water, forming crystalline bridges between the particles, and causing the cement powder to set into a solid. Gypsum is added to the clinker primarily in order to regulate the rate of this hydration, and hence the speed of setting.
Table A1 below lists the fuel factors and oxidation factors which the Irish EPA obliged cement kilns and other installations to use in order to estimate their 2005 greenhouse gas emissions.

Table A1. Specific Emissions Factor by Fuel Type.

<table>
<thead>
<tr>
<th>Fuel Factors</th>
<th>t CO₂/TJ</th>
</tr>
</thead>
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<tr>
<td>Coal</td>
<td>Site specific</td>
</tr>
<tr>
<td>Kerosene</td>
<td>71.76</td>
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<tr>
<td>HFO/RFO</td>
<td>76.38</td>
</tr>
<tr>
<td>LPG</td>
<td>64.13*</td>
</tr>
<tr>
<td>Diesel / Gas Oil</td>
<td>73.67</td>
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<tr>
<td>Natural Gas</td>
<td>67.28**</td>
</tr>
<tr>
<td>Pet Coke</td>
<td>100.8***</td>
</tr>
<tr>
<td>Crude Oil</td>
<td>Site specific</td>
</tr>
</tbody>
</table>

*Source: Flugas Ireland Ltd. analysis data for commercial propane (LPG).

**Source: Average for 2000-2003 only, from EPA weighted average of BGE analysis of Interconnector and Kilnace gas.

***IPCC 1996.

<table>
<thead>
<tr>
<th>Net Calorific Values</th>
<th>NCV (TJ/kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Site specific</td>
</tr>
<tr>
<td>Kerosene</td>
<td>44.29</td>
</tr>
<tr>
<td>HFO/RFO</td>
<td>41.24</td>
</tr>
<tr>
<td>LPG</td>
<td>46.88*</td>
</tr>
<tr>
<td>Diesel / Gas Oil</td>
<td>43.31</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Not required, use bills**</td>
</tr>
<tr>
<td>Pet Coke</td>
<td>31.00***</td>
</tr>
<tr>
<td>Crude Oil</td>
<td>Site specific</td>
</tr>
</tbody>
</table>

*Source: Flugas Ireland Ltd. analysis data for commercial propane (LPG).

**Note BGE Gas bills show kWh based on Gross Calorific Value - convert to Net Calorific Value by multiplying by 0.903 and then convert to TJ by multiplying by 3.6 x 10^9

***Source IPCC 1996.

Tier 1 Oxidation Factors to be applied for all combustion (except cement kilns)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Oxidation factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.99</td>
</tr>
<tr>
<td>Kerosene</td>
<td>0.995</td>
</tr>
<tr>
<td>HFO/RFO</td>
<td>0.995</td>
</tr>
<tr>
<td>LPG</td>
<td>0.995</td>
</tr>
<tr>
<td>Diesel / Gas Oil</td>
<td>0.995</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.995</td>
</tr>
<tr>
<td>Pet Coke</td>
<td>0.99</td>
</tr>
<tr>
<td>Crude Oil</td>
<td>0.995</td>
</tr>
</tbody>
</table>

(From Annex II of the Monitoring and Reporting Guidelines, Commission Decision 2004/156/EC)

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49 The emissions from any particular grade of coal would depend on its Fixed Carbon content, which can vary anywhere between 50% and 80%. Coals with higher FC content tend to have significantly higher calorific values (MJ/kg) but nevertheless emit more CO₂ per MJ. [www.chemistryexplained.com/ce-co/coal.html](http://www.chemistryexplained.com/ce-co/coal.html)
Chart A3, reproduced from Szabo et al (2003) describes six variants of the rotary kiln process, along with an alternative (Shaft) process which is still commonly used in China and India. Szabo et al note that, according to Cembureau, 33% of worldwide installed capacity in 1997 was the ‘Dry with Pre-calciner’ variety, and a further 21% was ‘Dry with Preheating’. They also suggest that there are a number of commercially feasible retrofitting options for converting existing Wet, Semi-Wet or Semi-Dry capacity into one or other of the more energy efficient Dry processes.

**Chart A3. Comparison of Energy Efficiency of Different Kiln Processes.**

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Slurry</th>
<th>Filter cake</th>
<th>Pellet</th>
<th>Dry raw meal</th>
<th>Dry raw meal</th>
<th>Dry raw meal</th>
<th>Pelets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content of raw material</td>
<td>28-43</td>
<td>16-21</td>
<td>10-12</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
<td></td>
</tr>
<tr>
<td>Kiln type</td>
<td>Long</td>
<td>Long/Leopol</td>
<td>Long/ Leopol</td>
<td>Long</td>
<td>Short</td>
<td>Short</td>
<td>Shaft</td>
</tr>
<tr>
<td>Heat exchange device</td>
<td>Cylcone/ grate preheater</td>
<td>Cylcone/ grate preheater</td>
<td>-</td>
<td>Cylcone Preheater</td>
<td>Cylcone Preheater</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

The proportion of installed European capacity operating the Dry process is higher than the world average of 54%, although as previously noted in Table 3.4, a significant amount of Semi-Wet and Wet Process capacity is still operated in the UK. It may be the case that the UK plants are commercially constrained from retrofitting, possibly because the locally-available raw materials are unsuitable for homogenisation except in slurry form.

The choice of fuel may depend somewhat on what is locally available, as well as the infrastructure for preparing it. For example, a typical bituminous coal ‘as received’ contains 10% moisture and it would normally need to be dried and milled before being burnt in a kiln. The use of alternative fuels such as waste materials (eg. packaging, solvents oils and tyres) or biomass (eg. meat and bone meal) varies considerably across Europe, presumably reflecting what the Environmental Protection Agency in each country considers to be acceptable.\(^{51}\)

Cembureau (1997, 1999) has put forward environmental and economic arguments to justify what it calls the ‘valorisation’ of such non-fossil fuels in cement manufacture, and to allay potential concerns about gaseous emissions of toxic or carcinogenic substances such as dioxins or volatile metals such as Barium, Chromium, Cadmium, Lead, Thallium and Mercury.

\(^{50}\) The figure for electricity consumption refers only to the kiln.

\(^{51}\) The share of non-fossil kiln fuels ranges from 1% in Spain to 26% in France.
Nevertheless, it would be fair to say that the increasing use of waste incineration by cement producers remains a highly controversial issue in several European countries. In the UK, for example, it is the norm for local residents to campaign against any planning decisions allowing the use of alternative kiln fuels.

Cembureau members are strongly represented on the Cement Sustainability Initiative (CSI). Its five-year agenda, as outlined by the World Business Council for Sustainable Development (2002) includes the development of guidelines for climate protection and for the responsible use of fuels.
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3 Market Price versus Capacity Utilisation in 2005
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6 Cement Price Data – Germany (11 year trend)
7 Cement Price Data – Italy (11 year trend)
8 Cement Price Data – UK (11 year trend)
9 Cement Price Data – Greece (11 year trend)
10 Cement Price Data – Portugal (11 year trend)
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14 Comparative Prices of Coal and Petroleum Coke (11 year trend)
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18 Trend in mark-up of French cement price over energy and CO₂ costs
19 Trend in mark-up of German cement price over energy and CO₂ costs
20 Trend in mark-up of Italian cement price over energy and CO₂ costs
21 Trend in mark-up of UK cement price over energy and CO₂ costs
22 Trend in mark-up of Greek cement price over energy and CO₂ costs
23 Trend in mark-up of Portuguese cement price over energy/CO₂ costs
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Appendix 1.

Derivation of Cournot equilibrium cost pass-through formula

The assumptions made in Oxera (2005) for the purpose of modelling oligopoly competition are:

- non-co-operative simultaneous quantity setting game for N firms each producing a homogeneous product
- A linear downward-sloping demand curve $P = (a - b.Q)$
  Where:
  - $P$ represents the market price
  - $q_i$ represents the quantity produced by firm $i$
  - $Q$ represents the sum of $q_i$ over all N firms
- a constant marginal cost ($c_i$) for each firm

The profit for firm ‘$i$’ is defined as:

$$\Pi_i = (P - c_i)q_i = (a - b.q_1 - b.q_2 - \ldots - b.q_N - c_i).q_i$$  \hspace{1cm} (1)

The First Order Condition assumes that firm $i$ will choose a production quantity which maximises its profit, taking the quantities of the (N-1) other firms as given:

$$\frac{\partial \Pi_i}{\partial q_i} = a - b \sum_{j \neq i} q_j - 2b.q_i - c_i = 0$$

The resulting reaction curve for firm ‘$i$’ represents its best production decision ($q_i$), given the quantities decided by all the other firms:

$$q_i = a/2b - \left( \sum_{j \neq i} q_j \right)/2 - c_i/2b$$  \hspace{1cm} (2)

Summing the N reaction curve equations gives:

$$\sum q_i = Q = N.a/2b - (N-1).Q/2 - \sum c_i/2b$$  \hspace{1cm} (3)

Now define $C$ as the arithmetic mean of firms cost $c_i$.

$$N.C = \sum c_i$$  \hspace{1cm} (4)

---

52 For the more general case of oligopoly competition involving a non-linear demand curve, and non-constant marginal costs for each firm, see Ten Kate and Niels (2005) which discusses the implications of industry structure on the pass-through rate to customers of cost savings from company mergers.
Combining (3) and (4) and rearranging gives:

\[ Q = \frac{N \cdot a}{b(N+1)} - \frac{N \cdot C}{b(N+1)} \quad (5) \]

Substituting for \( Q \) in the demand curve gives the equilibrium price:

\[ P = a - \frac{aN}{(N+1)} + \frac{NC}{(N+1)} \]

\[ = \frac{a}{(N+1)} + \frac{C \cdot N}{(N+1)} \quad (6) \]

If a set of \( X \) firms (where \( X \leq N \)) face the same incremental marginal cost \( \Delta m \), the change in value of the unweighted mean cost is given by \( \Delta C = \Delta m \cdot \frac{X}{N} \).

Hence the increase in equilibrium price is given by:

\[ \Delta P = \frac{\Delta m \cdot X}{(N+1)} \quad (7) \]

which may also be written as

\[ \frac{\Delta P}{\Delta m} = \frac{X}{(N+1)} \quad (8) \]

The ratio of price change to marginal cost change is, by definition, equal to the cost pass-through rate.

Equation (8) confirms that this ratio does not depend on the price elasticity of demand for the product, provided that the demand curve is downward sloping.

This result may seem counter-intuitive to anyone familiar with the Lerner equation, which states that a monopolist’s mark-up on marginal cost (when calculated as a percentage of total price) turns out to be equal to the reciprocal of elasticity.
Appendix 2.

Location and Type of UK Cement Production Plants.

Source of CaCO$_3$ raw material:
LST = Limestone
CHK = Chalk

Kiln Process:
D = Dry
SD = Semi-Dry
SW = Semi-Wet
W = Wet

Producer:
Lafarge
Castle (Heidelberg)
Rugby (Cemex)
Buxton (Tarmac Group)
Appendix 3.


<table>
<thead>
<tr>
<th>Country</th>
<th>Cap Utilisation</th>
<th>Price 2005</th>
</tr>
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<tbody>
<tr>
<td>France</td>
<td>95.0%</td>
<td>68</td>
</tr>
<tr>
<td>Germany</td>
<td>67.5%</td>
<td>53</td>
</tr>
<tr>
<td>UK</td>
<td>98.0%</td>
<td>67.16</td>
</tr>
<tr>
<td>Italy</td>
<td>77.5%</td>
<td>50</td>
</tr>
<tr>
<td>Spain</td>
<td>95.0%</td>
<td>63.2</td>
</tr>
<tr>
<td>Greece</td>
<td>77.5%</td>
<td>70.3</td>
</tr>
<tr>
<td>Portugal</td>
<td>77.5%</td>
<td>71.4</td>
</tr>
</tbody>
</table>

**SUMMARY OUTPUT**

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<thead>
<tr>
<th>Regression Statistics</th>
<th>France</th>
<th>Germany</th>
<th>UK</th>
<th>Italy</th>
<th>Spain</th>
<th>Greece</th>
<th>Portugal</th>
</tr>
</thead>
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<tr>
<td>Multiple R</td>
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<td>0.363</td>
<td>0.272</td>
<td>0.473</td>
<td>0.673</td>
<td>0.573</td>
<td>0.453</td>
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<tr>
<td>R Square</td>
<td>0.432</td>
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<td>0.357</td>
<td>0.450</td>
<td>0.327</td>
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**ANOVA**

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**Possible Relationship Between Capacity Utilisation and Cement Price in 2005**

![Graph showing the relationship between capacity utilisation and cement price in 2005](graph.png)
Appendix 4.

Two-firm model of Bertrand competition in the Cement sector.

Smale (2006) conjectured that a monopolistic competition model might be a viable alternative to the Cournot model that was assumed by Oxera (2004). Monopolistic competition assumes that each firm in the market has an advantage in serving local customers. Each producer’s demand curve is therefore downward-sloping, allowing it some discretion over price-setting. Bertrand price-setting competition between spatially separated cement producers can be regarded as a form of monopolistic competition.

The following analysis explores this idea by considering a simple Bertrand model where:

- two cement producing firms compete on the basis of factory-gate price plus transportation costs;
- the customers of these two are uniformly distributed along the road connecting these two plants; and
- either firm is capable of serving the entire local market\(^{53}\).

Model assumptions:

The total market size (prior to the start of emissions trading) is assumed to be 1.0 Million Tonnes.

The variable costs (assuming both plants to be Semi-Dry Process) are:

- Fuels, electricity, minerals €18.79/Te cement
- EUA (opportunity cost) €16.06/Te cement
  €34.85/Te cement

The factories are separated by 100km, so the initial market demand is 10,000Te per annum per linear kilometer (km). The road transport cost is assumed to be €0.08/Te per \(^{54}\).

---

\(^{53}\) A more realistic variant of this model might involve a capacity constraint whereby neither firm would have sufficient capacity to serve the entire market.

\(^{54}\) The road freight assumption is based on the author’s previous personal experience as Group Supply Chain Manager for Irish Fertilizer Industries Ltd.
In the Base Case scenario, assume that:

- factories (A and B) have the same variable costs
- neither factory faces any emissions trading obligation.

If the factory gate prices at A and B are equal, a cement customer located exactly half way between the two plants would be indifferent between the two suppliers. All customers located to one side of this customer would purchase from A, while all those on the other side would purchase from B. However, if factory A then unilaterally increased its price, the ‘point of indifference’ would shift towards A, and its linear share of the market would shrink accordingly. Each factory therefore sees a locally downward sloping demand curve, consistent with monopolistic competition.

The following variables are defined:

- \( P^A \) = factory gate price charged by A (€ per Tonne)
- \( P^B \) = factory gate price charged by B (€ per Tonne)
- \( Q^A \) = quantity supplied by A (Tonnes per annum)
- \( Q^B \) = quantity supplied by B (Tonnes per annum)
- \( \Pi^A \) = gross profit earned by A (€ per annum)
- \( \Pi^B \) = gross profit earned by B (€ per annum)
- \( X \) = distance from A to the point of indifference (km)

At the point of indifference, the customer’s delivered price (including the cost road haulage) must be the same from each factory, hence

\[
(P^A + 0.08X) = (P^B + 0.08[100-X])
\]

which can be rearranged to:

\[
X = 50 + 6.25[P^B - P^A] \tag{1}
\]

Provided that the absolute value of \([P^B - P^A]\) is less than €8.00/Te, it follows that:

\[
Q^A = 500,000 + 62,500[P^B - P^A]
\]

and by symmetry:

\[
Q^B = 500,000 - 62,500[P^B - P^A]
\]
The Gross Profit earned by factory A can be expressed as:

\[ \Pi^A = P^A Q^A - 18.79 Q^A \]

Substituting for \( Q^A \) in this equation gives

\[ \Pi^A = P^A (500,000 + 62,500P^B - 62,500P^A) - 18.79(500,000 + 62,500P^B - 62,500P^A) \]

The profit-maximising First Order Condition for factory A is obtained by differentiation of this equation with respect to \( P^A \).

\[ 500,000 + 62,500P^B - 125,000 P^A + 1,174,375 = 0 \] (2)

Rearranging this, factory A’s upward-sloping ‘reaction curve’ can be expressed as:

\[ P^A = P^B/2 + €13.40 \] (3)

This equation defines the optimal pricing decision for factory A for any given price charged by factory B.

By symmetry, Factory B’s reaction curve is:

\[ P^B = P^A/2 + €13.40 \] (4)

A unique, stable Bertrand equilibrium exists where the two reaction curves intersect. Each firm is behaving optimally given the other firm’s decision, so neither firm has an incentive to change its pricing. Equations (3) and (4) can be solved simultaneously to give:

\[ P^A = P^B = €26.80/Te \]
\[ Q^A = Q^B = 500,000Te \]

Hence the annual Gross Profit (before deducting fixed costs) earned by each producer is given by:

\[ \Pi^A = \Pi^B = (€26.80/Te - €18.79/Te) \times 500,000Te = €4.05M \]

The predicted price level €26.80 is substantially lower than that observed in most European markets. Moreover, according to Reinaud (2005), the factory fixed costs (excluding depreciation) in each case are likely to be in the region of €20.0M per annum, so the EBITDA of each factory would be strongly negative. Such losses would be unsustainable, suggesting that the Bertrand/Monopolistic competition model may be unrealistic where the typical separation of competing firms is no more than 100km.

Nevertheless, the model may be used to predict the price impact of a variable cost change at one or both factories. The equilibrium price analysis proceeds exactly as before, except that the marginal production cost of cement at one or both factories will increase from €18.79/Te to €34.85/Te.
Two additional Bertrand outcomes will be considered, as shown in the following diagram.

**Impact of Incremental Variable Costs on Bertrand Equilibrium.**

**Equilibrium 1** is the base case where neither factory is subject to EU ETS. 
$P_A = €26.80$ and $P_B = €26.80$.

**Equilibrium 2** is where both factories are subject to EU ETS. 
$P_A = €42.86$ and $P_B = €42.86$. 
The industry-wide cost increase of €16.06 results in a common factory gate price increase of €16.06, hence a pass-through rate of 100%.

**Equilibrium 3** is where Factory B is subject to EU ETS but Factory A is not. 
$P_A = €32.15$ and $P_B = €37.50$. 
The cost increase of €16.06 for B results in a factory gate price increase of €10.70 for B, hence a pass-through rate of 67%. Firm A also increases its prices in response to Firm B’s decision, but by a lesser amount, so it captures a higher share of the local market. (In the context of Emissions Trading, this could be regarded as carbon leakage.)
Appendix 5.

Cement Price Data - France (11 year trend)

*Eurostat Production and Trade Database Prices*

French cement producer and import prices 1995-2005 (excl outliers)

Eurostat Production Database versus Exane BNP Paribas Estimated Prices

Comparison of Portland cement producer prices (Ex-works)
Appendix 6

Cement Price Data – Germany (11 year trend)

Eurostat Production and Trade Database Prices

German cement producer and import prices 1995-2005 excluding outliers

Eurostat Production Database versus Exane BNP Paribas Estimated Prices

Comparison of Portland cement producer prices (Ex-works)
Appendix 7
Cement Price Data - Italy (11 year trend)

Eurostat Production and Trade Database Prices

Italian cement producer and import prices 1995-2005

Eurostat Production Database versus Exane BNP Paribas Estimated Prices

Comparison of Portland cement producer prices (Ex-works)
Appendix 8.

Cement Price Data - UK (11 year trend)

Eurostat Production and Trade Database Prices

UK cement producer and import prices 1995-2005

Eurostat Production Database versus Exane BNP Paribas Estimated Prices

Comparison of Portland cement producer prices (Ex-works)
Appendix 9.

Cement Price Data – Greece (11 year trend)

Eurostat Production and Trade Database Prices

Not applicable – no imports recorded.

Eurostat Production Database versus Exane BNP Paribas Estimated Prices

![Comparison of Portland cement producer prices (Ex-works)](chart.png)
Appendix 10.

Cement Price Data – Portugal (11 year trend)

Eurostat Production and Trade Database Prices

Eurostat Production Database versus Exane BNP Paribas Estimated Prices
Appendix 11.
Cement Price Data – Spain (11 year trend)

*Eurostat Production and Trade Database Prices*

**Spanish cement producer and import prices 1995-2005**

**Eurostat Production Database versus Exane BNP Paribas Estimated Prices**

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Appendix 12.

Eurostat Data – Coal Import Prices (11 year trend)

Imported prices for bituminous coal 1995-2005

- Price_Germany_Australia
- Price_Germany_Colombia
- Price_Germany_S.Africa
- Price_Spain_Australia
- Price_Spain_Colombia
- Price_Spain_S.Africa
- Price_France_Australia
- Price_France_Colombia
- Price_France_S.Africa
- Price_UK_Australia
- Price_UK_Colombia
- Price_UK_S.Africa
- Price_Italy_Colombia
- Price_Italy_S.Africa

Price of Coal Imported from Australia, Colombia and South Africa 1995-2005

- Price_Germany
- Price_Spain
- Price_France
- Price_UK
- Price_Italy
- Price_Greece
- Price_Portugal
- Price_Europe
Appendix 13.

Eurostat Data - Petroleum Coke Import Prices (11 year trend)

Prices of US Petroleum Coke imported to Europe 1995-2005
Appendix 14.

Comparative prices of Coal and Petroleum Coke (11 year trend)

Unweighted average European import prices for bituminous coal and uncalcined petroleum coke
1995-2005

Coke-Coal average price ratio
Appendix 15.

Country Trends in Electricity Tariffs

European electricity prices 1995-05 - large users

Electricity tariffs for Eurostat group I-G (24GWh per annum) 1995-2005
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(As reported by Point Carbon at the mid-point of each month.)
Appendix 17.

Cement Export Prices to the USA versus Sea-Freight Costs

The Baltic Dry Index is a published indicator of freight rates for bulk cargo vessels used for the marine transportation of commodities such as grain, coal, and cement.
Appendix 18

Trend in mark-up of French cement price over energy and CO$_2$ costs

Energy and emissions costs of Grey Portland cement production - France

French Market Price (BNPP estimate) versus Energy cost plus CO2 opportunity cost
Appendix 19.

Trend in mark-up of German cement price over energy and CO₂ costs

Energy and emissions costs of Grey Portland Cement production - Germany

German Market Price (BNPP estimate) versus Energy cost plus CO₂ opportunity cost
Appendix 20.

Trend in mark-up of Italian cement price over energy and CO\textsubscript{2} costs
Appendix 21.

Trend in mark-up of UK cement price over energy and CO₂ costs
Appendix 22.

Trend in mark-up of Greek cement price over energy and CO$_2$ costs

Energy and emissions costs of Grey Portland Cement production - Greece

Greek Market Price (BNPP estimate) versus Energy cost plus CO2 opportunity cost
Appendix 23.

Trend in mark-up of Portuguese cement price over energy and CO$_2$ costs

Energy and Emissions costs of Grey Portland Cement production - Portugal

Portuguese Market Price (BNPP estimate) versus Energy cost plus and CO2 opportunity cost
Appendix 24.

Trend in mark-up of Spanish cement price over energy and CO₂ costs

Energy and Emissions costs of Gray Portland Cement Production - Spain

Spanish Market Price (BNPP estimate) versus Energy cost plus CO₂ opportunity cost
### Appendix 25

**Individual regressions using Exane BNP annual price estimates. (units are Euro/100kg)**

#### 1. REGRESSION RESULTS SORTED BY COUNTRY

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Selected individual regressions using Eurostat monthly import price estimates. (units are Euro/100kg)

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<th>Const</th>
<th>Energy cost</th>
<th>Post cartel</th>
<th>Quarry tax</th>
<th>Marine Import</th>
<th>t-value</th>
<th>R-squared within groups</th>
<th>R-squared between groups</th>
<th>R-squared overall</th>
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<td>-2.57</td>
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<td>5.9</td>
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<td>0.09</td>
<td>0.08</td>
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Panel regression using Eurostat monthly price estimates. (Euro/100kg)

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<th>Model No</th>
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<th>Energy cost</th>
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<th>Quarry tax</th>
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