The effects and side-effects of the EU Emissions Trading Scheme[a]

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Abstract :

As many countries, regions, cities and states implement emissions trading policies to limit CO_2 emissions, they turn to the European Union's experience with its Emissions Trading Scheme since 2005. As a prominent example of a regional carbon pricing policy, it has attracted significant attention from scholars interested in evaluating the effectiveness and impacts of emissions trading. Among the key difficulties faced by researchers is isolating the effect of the EU ETS on industry operation, investment and pricing decisions from other dominant factors such as the financial crisis, and establishing credible counterfactual scenarios against this backdrop. This article reviews the evidence, focusing on two intended effects (emissions abatement and investment in low-carbon technologies) as well as two side-effects (profits and price impacts). We find that the EU ETS cut CO_2 emissions by 40 million–80 million tonnes per year on average, or 2–4% of the total capped, while the evidence on innovation and investment impacts is inconclusive. There is strong empirical support for cost-pass through in electricity (20-100%), in diesel and gasoline (>50%), and some preliminary evidence of pricing power in other industrial sectors. Windfall profits have amounted to billions of Euros, and concentrated in a few large companies.

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Introduction

The EU Emissions Trading System (EU ETS) launched in 2005, is Europe's flagship climate change policy to meet its carbon mitigation objectives. Currently in its third phase of operation (2008- 2020), it encompasses over 11,500 installations across 30 countries (including Norway, Liechtenstein and Iceland) and covers over 40% of total EU emissions. Its first eight years of operation has been anything but smooth, and characterised by over-allocation of allowances and a series of price crashes. The large surplus of allowances in the system at the end of Phase II (2008-2012), set against the background of the decline in global economic activity due to the financial crisis, have led to a series of concerted efforts to buttress the system in future Phases, including proposals for backloading of allowances (the withdrawal of allowances from the system to reduce surpluses, before reintroducing the allowances at a later date) and wider structural reform.

Lessons learnt in the design and operation of the EU ETS, as the largest and most comprehensive emissions trading system, however, provide an invaluable toolkit for system design in other jurisdictions.[1] New Zealand, California, Australia, South Korea and Shenzhen already implement emissions trading markets, and many others are in the pipeline. There is keen interest from policy makers worldwide to understand outcomes that are both intended – reduced carbon emissions and greater investment in innovation and low-carbon technologies – and also 'unintended' outcomes such as price effects, competitiveness impacts and windfall profits.

With the wealth of data available has emerged a new and enormous wave of *ex-post* EU ETS evaluation studies examining the early evidence. Largely falling within the program evaluation strand of the environmental economics literature, they use creative and advanced approaches to work around methodological and data obstacles. Scores of papers have analysed the performance of the scheme in relation to a variety of aspects including allocation rules, electricity sector impacts, uncertainty and price volatility, and competitiveness. In parallel, on-going efforts to subject these studies to critical synthesis[2] [3] [4] [5] help draw out lessons, but at the same time highlight the difficulty in teasing out the effect of the nascent policy relative to many confounding factors such as economic shocks and rising fuel prices. Previous reviews also discuss aspects around regulatory and technical issues of emissions trading[6] and the historic context of its development.[7]

The EU ETS affects corporate actors through a number of different channels, both those intended by policy-makers, and unintended that have arisen through the scheme's evolution. Abatement, investment, innovation and profits have resulted as a result of these different channels, affecting the effectiveness and efficiency of the scheme. Along with the price signal, that changes decision-making regarding investments and operating processes authors have highlighted that the 'institutional weight' of the EU ETS has created attention, experimentation, learning along with investment with regard to low-carbon technologies and processes that otherwise would not have been employed.[8] These multiple of channels has created intended and unintended effects that have effected both the efficiency and the equality of the scheme.

This paper revisits the two central and intended objectives of the EU ETS: 1) to reduce GHG emissions efficiently, at a negotiated balance of cost and environmental gain and 2) to promote corporate investment in low carbon technologies, focusing on insights from the economics and political economy literature.[9] This literature has been arguably the most vocal in discussing the EU ETS though there are notable contributions in a number of other fields notably governance[10] and law – especially that regarding competitiveness aspects as reviewed succinctly by Branger and Quirion.[11]

The extent to which the EU ETS has contributed towards emissions reductions and carbon-intensity improvements remain key indicators of the System's environmental performance. There has been a large debate, predominantly in the policy space regarding the effectiveness of the EU ETS,[12] but there has been surprisingly little in the academic sphere.

The analysis of the two indicators of direct and intended effects of the ETS is complemented by an examination of the two unintended, indirect effects - impacts on profits and product prices. These unintended effects are key to understanding both important second-order effects such as carbon leakage and competitiveness, but also possible first-order effects such as changes in abatement behaviour and investment incentives that the evidence of the EU ETS has highlighted may arise in trading schemes.[13][14] In doing so, it tries to contribute to the rapid learning process around efforts to implement national and regional carbon prices in the absence of a global price.

The next section will focus on emissions and abatement impacts, separating studies that examine the pre- and post-financial crisis periods. The third section collects and scrutinises evidence from studies on investment and innovation using both data at the sector and firm level. The fourth section critically examines both *ex-ante* and *ex-post* studies that estimate the impact of EUA prices on prices, and the extent to which they give rise to windfall profits. Finally we offer concluding comments.

EMISSIONS AND ABATEMENT

The EU ETS guarantees the achievement of a cap on aggregate emissions from regulated installations. Yet were the emission reductions attributable to the EU ETS, or due to other factors such as energy prices and renewables support policies? The problem of isolating the impact of the EU ETS is difficult not only because of the numerous factors that influence emission levels, but is compounded by the lack of credible 'counterfactuals' against which to compare actual emissions.[15] A number of different methodological approaches have been adopted to produce counterfactual scenarios from pre-EU ETS data, including the extrapolation of various data sources such as that used to produce National Allocation Plans (NAPs),[16] UNFCCC reporting data[f][17] and Eurostat data.[18] These approaches require adjustment to fit the EU ETS data and thus suffer from a number of issues regarding the quality of the underlying data, especially for NAP

[f] The technique is outlined in Herold, A. 2007 Comparison of verified CO_2 emissions under the EU emission trading scheme with national greenhouse gas inventories for the year 2005, European Topic Center on Air and Climate Change, Technical Paper, 3:81

data, and the fact that they only offer aggregate estimates and are unable to delve into sectoral level differences.[19] The availability of greater data in Phase II has helped to improve the creation of counterfactuals and has allowed the extension of previous studies[20] and the employment of complementary data to control for economic activity.[21] A third stand of research has employed qualitative techniques to analyse the extent to which firms had undertaken abatement activity linked to the EU ETS.[22][23] Such studies help to complement quantitative studies by providing insights into the underlying mechanisms that drive abatement decisions, however they have only captured information from a very small subset of market participants, making it difficult to draw strong conclusions.

This history of the EU ETS can be punctuated by the major economic crisis that swept the EU in 2008 and 2009, hence this section separately assesses analyses that sought to quantify the abatement that has occurred prior to the financial crisis, and the subsequent analyses examining abatement after the shock.

The majority of studies on this issue cover the first four years of the ETS (Table 1). Two main methods have been utilised to estimate the abatement driven by the carbon price signal prior to the financial crisis: 'top-down' techniques which involve econometrically estimating scheme-wide emissions without the EU ETS and comparing verified emissions against this scenario;[24] [25] [26] [27] [28]and 'bottom-up' sector-specific techniques, involving either estimating business-as-usual emissions from specific industries and comparing against reported emissions,[29] utilising anecdotal evidence from EU ETS participants,[30] or using the shift from Phase I to II to evaluate whether companies changed their emission reduction strategies.[31] This latter study provides the interesting result that firms abatement decisions were a function of their initial allocation at the start of Phase I, and the change in allocation across the periods, seemingly challenging the 'independence property' of emissions trading[32], maybe because of the limited liquidity in the market or the conditionality of allowance allocations upon past emissions.[33]

Comparing across the point estimates of particular years reported in studies surveyed in Table 1, the available literature collectively points to ***attributable*** annual average emission savings in the range 40 – 80 MtCO2 per year, or 2-4% of the total capped emissions. These results therefore suggest the EU ETS has nontrivial impact on emissions, relative to energy-environmental policy instruments in the past, such as the range of carbon taxes introduced across Scandanavia that have been dogged by industrial lobbying and exemptions,[34] and previous regulatory and voluntary initiatives in the EU.[35]

Largest emission reductions in Phase I were achieved in the power sector by encouraging the switch from coal to gas-based generation plants.[36] Evidence from other sectors is sparse, but evidence of abatement in the non-metallic minerals (cement) which contributes about 8% of EU ETS emissions, has been documented by several studies, as an example of a sector where the discovery of unexpected low-cost abatement opportunities are incentivised by the price signal created by emissions trading. Across kilns in Europe, improvements in carbon intensity of production occurred during Phase I through shifts towards low-carbon alternative fuels including waste and biomass as well as reductions in clinker content of cement, despite expectations of limited significant abatement opportunities.[37] [38] [39]

Difficulties in teasing out the impact of the EU ETS on emissions encountered new heights with the financial crisis that hit in 2008 and the consequent and dramatic fall in production and emissions relative to BAU trajectories. Moreover, initial evidence is emerging that the crisis changed the evolution of the EU economy so fundamentally that it caused a structural break in the evolution of both emissions and energy intensity of the EU.[40] Not to mention the lack of data available to assess the impacts due to the complexity and time persistent nature of the crisis, as well as the time-lag involved in releasing emission data.

It is therefore not surprising that the results from the literature evaluating the post-crisis emission impacts have been inconclusive. There is a general dearth of studies in the area although some evidence from the grey literature in 2009 indicated that the scale of reductions in emissions as a result of the financial crisis was less than that caused by the EU ETS.[41] Another study argued as the crisis developed, that the recession has served as a very useful tool for the EU to reduce its emissions, at least in the short-run. Lower electricity demand, lower fuel prices, offset slightly by the lower carbon price appears to have caused a reduction in emissions from the European power sector greater than the range of the abatement driven by Phase I of the Scheme.[42]

While so far the evidence is limited to the early years of the crisis, studies extending techniques used to estimate Phase I abatement to Phase II do not necessarily preclude an abatement effect from the EU ETS during the recession period. One study found stronger abatement in 2008-2009 than in 2006-2007, with emission-intensity improvements attributable to the EU ETS rising from 1% to 3.35% per year, with stronger abatement in combustion (predominantly related to power generation) than in industrial facilities.[43] Whether this abatement has continued throughout the duration of the crisis, especially with the worst of the price collapses in 2011 and 2012 remains to be seen and is an important topic for future research.

INVESTMENT AND INNOVATION

The environmental effectiveness of the EU ETS in the longer run, as well as its cost-effectiveness are both functions of the system's ability to influence decision-making regarding low-carbon technologies. Along with other climate policy measures and targets, by setting a price on carbon, the ETS is intended to play a role in driving short-term switching between fuel types, innovation in new low-carbon technologies, and investments in lower-carbon assets. Much of the investment required for the switch to a low-carbon economy is on the timescale of decades; hence it is believed that a "loud, long and legal" or credible price signal is required to induce these dynamic effects.

Again, aware of the elephant in the room – the financial crisis which swamped all other effects on firms' operation and investment decisions – and despite the additional barrier of the lack of public data on new low-carbon investments, brave attempts have been made to assess EU ETS impacts on innovation and investment.

Initial assessments relied on the use of intermediate metrics, anecdotal evidence, as well as through survey[44] [45] and interview data from senior managers at firms regulated under the EU ETS. Some evidence has been reported in this literature (Table 2), of impacts on marginal decision-making on investment and innovation patterns, chiefly by helping move the issue of carbon into the realm of key decision-makers at boardroom level[46] or by incentivizing energy or GHG saving measures relating to their manufacturing or core processes.[47] Anecdotal accounts also link the EU ETS to the cancellation of investments in highly carbon-emitting generation plants,[48] increased corporate CCS research, incentives to retrofit coal plants,[49] and inducing small-scale investment decisions with short amortization times.[50] Preliminary econometric analysis on Swedish firms finds no significant effect of the EU ETS on either small or large investment decisions.[51]

An annual assessment of the German companies regulated by the EU ETS has been conducted since 2009, with its latest version highlighting the increasing engagement of firms in trading activity, though almost a third remain outside the process due to the extent of free allocation and in-house regulatory restrictions.[52] The vast majority of surveyed firms had carried out investments, or amended production processes, leading to emissions reductions, but the majority of these investments were carried out for other reasons, for which CO_2 abatement was only a side-effect.

Recent studies using matching econometric techniques and firm-level data contribute significantly to the evidence pool on the relationship between the EU ETS and innovation. Increased patenting activity in low-carbon innovation was found during the period 2005-2009 for firms regulated under the EU ETS (relative to non-regulated, similar firms).[53] Further research along the lines of these studies, using the new emerging data is crucial to understand the full effects of the EU ETS, and thus to understand how best the system can be buttressed and improved.

There is an overwhelming general consensus that the scale of impact so far is limited to a fraction of what is necessary to deliver the types of long-term capital projects needed to meet the long-term targets that the EU has set out. Other factors such as access to fuel, public perception, technology-specific support policies and other elements of the regulatory framework remain far dominant in the investment decisions of EU industry.

PRICES AND PROFITS

When a firm faces an increase in input costs, three options are open in the short-run: (1) absorb the cost by reducing profit margins; (2) decrease costs by improving the efficiency of their operations; or (3) pass the additional costs to the consumer by increasing prices. The latter is desirable from the perspective of reducing emissions as it drives demand side mitigation via demand substitution.[54] Where prices are passed through to consumers they have the incentive to use less high-carbon products and move towards low-carbon ones. Conversely, where prices are absorbed by industry, firms still have incentives to reduce their carbon content but consumers do not receive the price signal needed to shift to lower-carbon alternatives.

Assessing the extent to which firms regulated by the EU ETS pass on carbon costs to product prices is interesting, not only to understand distributional impacts between the producers and consumers but also the firms' exposure to risk of carbon leakage and competitiveness impacts. Relatedly, the degree of cost pass through also gives insight into whether compensation measures to address such risks (e.g. free allowance allocation) are indeed justified, or results in windfall profits being granted to industry - an unintended[55] but highly controversial outcome of the EU ETS.

Price adjustment behaviour of firms under the EU ETS has been studied using both modelling and econometric techniques, drawing on the literature on exchange rate pass-through,[56] [57] and based broadly on the simple mark-up model of imperfect international competition.[58] [59] Earlier studies using static and dynamic bottom-up (engineering economic) models to simulate the effect of the EU ETS to product prices and windfall profits find, in general, that a significant part of the costs of CO_2 emission allowances are passed through to product prices resulting in higher electricity prices for consumers (Table 3). Econometric analysis became more commonplace following the introduction of the EU ETS in 2005 and find compelling empirical evidence to support the existence of pricing power in the form of CO_2 opportunity cost pass-through, not only in electricity but also in industrial sectors. They support the theory that companies exhibit ability to pass-through carbon costs, particularly in markets where demand is more inelastic whether due to high product differentiation or other trade barriers.[60]

Studies on the power sector find compelling evidence of cost-pass through (Table 3). The degree of price impact vary considerably across European markets with degree of market power.[61] Econometric estimates from the surveyed literature vary widely in both scope and quality with estimates varying between 20-100%. Rising EUA prices have been found to affect electricity prices more strongly than falling EUA prices in Germany.[62] In addition, cost pass-through rates are influenced by structural factors including the degree of market concentration (higher in monopolistic / oligopolistic markets), the available capacity, the power plant mix and the power demand level (peak vs. off-peak hours);[63] and auctioning has no impact on electricity prices but merely secures the revenue for the public rather than for firm profits.[64] Cost pass-through is often restricted by regulatory measures: the large power utilities in France (holding market power) are subject to tight price controls, for example.

The evidence is growing, that carbon costs pass-through is not restricted to the electricity sector, but also in the industrial sectors (Table 4). Understanding the extent to which these sectors were able to pass through costs in Phase I and II holds the key to EU ETS reforms in Phase III and beyond, particularly in terms of the number of free allowances that will be distributed for free. Quantifying pass-through for industrial sectors is difficult, however, due to the lack of detailed price information in contrast to electricity. The exceptions here are diesel and gasoline, for which robust econometric evidence of cost pass through has been found (>50%). Yet using innovative methods to overcome data availability constraints, econometric studies on a variety of industrial sectors have also emerged in recent years and report positive cost-pass through rates for some sectors including cement, steel, plastic and some chemicals.[65][66] Here again, the impact on the pass-through is determined by the interplay of individual effects working in different directions; thus cost-pass through behaviour differ across sectors and products in terms of both asymmetry (impacts of ascending and descending EUA price) [67] and dynamics (time-lags present in cost pass-through).[68] [69]

The findings of these studies on the EU ETS are in line with similar studies that investigate industrial sectors' cost pass through capabilities in other policy or geographical contexts. For example, in the context of EU environmental tax reform, the non-metallic minerals sector (cement, lime) were found to have the greatest pricing power whereas the basic metals sector and chemicals emerged as price-taker.[70] Studies in Japan found evidence of price-setting behaviour particularly in domestic markets largely due to product differentiation abilities in high-grade steel,[71] and to a lesser degree in paper and pulp and glass, but not in automobiles, chemicals, solar panels and home electronics.[72] This growing evidence of pricing power supports the case for increasing allocation by auctioning in the industrial sectors as has already occurred for the electricity sector.

Although cost-pass through is necessary to induce demand side response in carbon intensive products, it has a downside when combined with free allowance allocation, in the form of windfall profits to heavy emitters. Although windfall profits were foreseen by economists and are often understood as a political compromise made in order to get industry on board, the sheer scale of windfall (see Table 5) has drawn heavy criticism, damaging public perception and credibility of the scheme. It is therefore rather more complex than a truly unintended effect. Evidence in Phase II that a surplus of 240 million EUAs were held by the top ten benefiting companies (the top five firms being ArcelorMittal, Lafarge, Tata Steel, ThyssenKrupp and Riva Group), with an estimated value of 4.1billion EURs (four times the entire EU environment budget over the same period) made scandal.[73]

Windfall profits in essence represent a transfer of income with a few emissions-intensive producers making profits at the expense of consumers (Electricity consumers are losers relative to a scenario where windfall profits are collected as auction revenue, and redistributed to the consumers or invested in efforts to meet the emissions reduction cap). Furthermore, greater windfall profits tend to be accrued by installations with more carbon intensive production under the current allocation procedures, and not surprisingly, the opportunity to gain windfall profits has attracted heavy lobbying activity by the industry. To address the issue of windfall profits, Phase II allocation plans have made a move away from free allowance allocation, with all power generation installations in the UK required to buy their permits in auction. The EU ETS as a whole is moving in this direction and will move away from free allocation in the power sector, virtually completely, by Phase III.

Conclusion

The EU ETS continues to spark curiosity of researchers, the literature continues to grow, and a number of important lessons for design of emissions trading schemes are emerging from it. This paper has contributed by means of synthesis of the discussions and findings in the political economy and economics literature in three main areas: abatement, investment and innovation, and profits and prices.

On emissions, over-allocation (in Phase I) and in particular the recession (in Phase II) have reduced the direct impact of the EU ETS on emissions, but the combination of rigorous monitoring and awareness, together with a positive carbon price, has driven some abatement. Disentangling the impact of the EU ETS from other factors is complex, but academic studies with both "top down", and sector-based “bottom up” evaluations point to attributable emission savings in the range 40 – 80 $MtCO_2$/yr, about 2-4% of total capped emissions. Crucially it is important to note that this abatement has occurred even with surpluses in the system.

On investment, there are no quantitative (monetised) studies of investment impacts, but a series of studies focusing on managerial interviews suggest that the EU ETS has affected investment decisions, but so far only in limited ways: mainly small-scale efficiency related investments rather than being sufficiently clear to drive large long-term investment decisions. On innovation the volatile price – and lack of clarity beyond 2020 - has undermined the potential of the EU ETS to drive the large, long-term investments that decarbonisation ultimately requires. For this, more targeted supports – notably the renewable energy policies –may be more directly impactful.

On profits, free allocation combined with trading creates the potential for ‘windfall’ profits. The evidence from Phase I and Phase II is that significant windfall profits only endure for a limited time, as policy can and will respond once the evidence is clear – as with the move to auctioning in the EU power sector. Price, and the value it creates, also of course carries the risk of abuse and sometimes fraud, and thus demands strong governance.

It remains unclear whether the EU ETS will have to wait until Phase IV to solve the outstanding problems regarding abatement, investment and windfall profits. Efforts from researchers on policy evaluation are making important contributions to providing evidence to support these debates and developments and as new data is starting to emerge new and interesting lessons from the EU ETS are emerging – crucial for system design elsewhere.

Table 1: Estimates of emissions abatement from the EU ETS pre-financial crisis

Study	Methodology	Key Results
Ellerman and Buchner (2008)[74]	Econometric modelling	Abatement from Phase I in the range of 120-300MtCO_2
Delarue et al (2008)[75]	Econometric modelling	Power sector emissions reductions of 90MtCO_2 in 2005 and 60MtCO_2 in 2006
Anderson and Di Maria (2011)[76]	Dynamic Panel data model	Total abatement in Phase I 247MtCO_2
Deutsche Bank (2010)[77]	Econometric modelling	Residual abatement in 2008 of 38MtCO_2; 2009 emissions below BAU
New Carbon Finance (2009)[78]	Econometric modelling	40% of the 3% fall in 2008 emissions due to the EU ETS
Abrell et al (2011)[79]	Econometric modelling	2007-2008 emissions reductions 3.6% larger than 2005-2006 reductions
Egenhofer et al (2011)[80]	Econometric modelling	2008-2009 emission intensity improvements attributable to the EU ETS 3.35% per annum.
Point Carbon (2009)[81]	Anecdotal evidence	60% of firms reported abatement or planned abatement in 2008 or 2009

Table 2: Studies estimating impact of EU ETS on investment and innovation activities

Study	Methodology	Results
Martin et al (2011)[82]	Survey of manufacturing companies	• Large proportion of firms pursued some measures to reduce GHG emissions • Strong positive association between firms' expectation regarding stringency of the cap and overall innovation in GHG saving processes or products.
Rogge et al (2010)[83]	Survey of German power sector	• Limited impact on innovation due to its lack of stringency in its early Phases and its relatively lower importance than other context factors • Impact on investment has been small so far, CO_2 has now become a part of the investment appraisal of power sector construction

Hoffman (2007)[84]	Survey of managers in German power sector	• EU ETS has become a main driver for small-scale investment decisions with short amortization times • Little impact on large scale investment decisions in power plants or research and development
Petsonk and Cozijnsen (2007)[85]	Case studies in France, Germany, Netherlands and UK	• Innovative activity in a number of sectors both within the EU ETS driven by the carbon price directly, and in sectors outside, for which the potential to sell offsets into the scheme was driving innovation
Kenber et al (2009)[86]	Survey of firms within and outside the EU ETS	• 'all other effects are being swamped by the credit crisis' • EU ETS had moved the climate debate into the boardroom
Aghion et al (2009)[87]	Investigation of responses to EU Community Innovation Survey	• Found that energy efficiency and reducing environmental impact were ranked lowest of innovation motivation
Anderson et al (2011)[88]	Survey of Irish EU ETS firms	• Find that EU ETS had been successful in stimulating moderate technological change
Hervé-Mignucci (2011)[89]	Survey of corporate investment communications for 5 most carbon-constrained EU firms	• During the early years of the EU ETS non-climatic considerations • In Phase II of the scheme there were clearer investment-related responses

Table 3 Estimates of cost pass through in the electricity sector

Study	Country/ Year	Method	Pass through rate estimate
Oranen (2006)[90]	Nordic	Model (static)	<40%
Linares et al. (2006)[91]	Spain	Model (dynamic)	30% - 40%
Kara et al (2008)[92]	Finland	Model (static)	75%
Chen et al. (2008) [93]	Multiple, electricity	Model (static)	10% - 95%
Lise et al (2010)[94]	Multiple, electricity	Model	5% - 50% in Norway; 95% in

		(dynamic)	Poland; 50% - 65% average
Sijm et al (2006)[95]	Phase I Germany Netherlands	Econometric	60% - 100%
Fell (2010)[96]	Phase I Nord Pool market	Econometric	near 100%
Honkatukia et al. (2006)[97]	Phase I Finland	Econometric	75%- 95%
Bunn and Fezzi (2007)[98]	Phase I UK	Econometric	42%
Chernyavs'ka and Gulli, (2008)[99]	Phase I Italy	Econometric	20% -30%
Fabra & Reguant (2013)[100]	Phase I Spain	Econometric	80%
Cummins et al. (2010)[101]	Phase II in Poland, Germany ,Austria, Italy, Spain and Netherlands	Econometric	Evidence of interaction between EUA and regional gas and oil prices.
Fell et al (2013)[102]	Phase II Germany, France, the Netherlands, Nord Pool market and Spain	Econometric	Near or above 100%

Table 4 Estimates of cost pass through for industrial sectors

Study	Country/ Sector/ Year	Method	Pass through rate estimate
CE Delft (2010) [103]	8 countries, 8 sectors, 2005 to 2009	Model	Range from 33% (for polystyrene) to over 100% for diesel, gasoline, hot- and cold-rolled metal products.
Oberndorfer et al (2010)[104]	UK's refining, glass, chemicals and ceramics sectors.	Econometric estimation of EUA prices on pricing	Diesel (50%) and gasoline (75%)
		Using input price shocks rather than EUA prices	ceramic goods (>100%), low-density polyethylene film (>100%) and ammonium nitrate (50%), no evidence for container glass, and

			mixed results for hollow glass (20-25%) and ceramic brick (30-40%).
Alexeeva-Talebi (2010)[105]	Germany, 14 manufacturing sectors including paper, chemicals, fertlisers, plastics, cement, glass and rubber .	vector error correction models (VECMs),	Most of the German EU ETS sub-sectors studied have a positive and *flexible* mark-up over marginal costs

Table 5 Estimates of windfall profits accrued by power and non-power sectors

Study	**Sector/ Year**	**Carbon price assumption**	**Windfall profit estimate**
IPA Energy Consulting (2005)[106]	UK Phase I	€15-25/tCO_2	£800 million /year
Sijm and Neuhoff (2006)[107]	DE, UK, FR, BE and NLPower sector in Phase I	€20/tCO_2	€5.3-7 billion per year
Martin et al (2012)[108] and Martin et al (2013)[109]	EU all sectors in Phase III	€30/tCO_2	€3-7 billion per year
Maxwell (2011)[110]	UK Power sector in Phase II		£1 billion per year
Point Carbon, WWF (2008)[111]	German and UK Power sector in Phase II	€21-32/tCO_2	€14-34 bn for Germany €6-15 bn for UK
Lise et al (2010)[112]	EU 20 Power sector	€20/tCO_2	€35 billion

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