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Abstract

One of the central debates surrounding the design of the EU Emissions Trading Scheme is the approach to addressing carbon leakage. Correctly identifying the economic activities exposed to the risk of carbon leakage represents the first step in mitigating the risk effectively. Several metrics and methods have been proposed to separate sectors which are at risk from those which are not. This study sets out a simple analytical framework and several indicators to measure the relative potential exposure of manufacturing sectors to emissions leakage. These indicators are applied to detailed UK and German data. This illustrates that, when applied to high quality data, simple metrics can be used to identify carbon-intensive-trade-exposed sectors. We find that, of the 159 industrial sub-sectors examined, CO_2 cost impacts are focused on a few industrial sub-sectors. The 25 highest ranking sub-sectors collectively account for around 13% of total UK CO_2 emissions (from both direct and indirect energy use), 1% of total UK GDP, and 0.5% of total UK employment. For Germany, the equivalent figures are 22% of total CO_2 emissions, 2% of GDP and 1% of employment. That the vulnerable sectors account for small shares of emission, value-added and employment does not mean that their potential emissions leakage can be ignored. Rather, the focus on specific sub-sectors provides possibilities for tailored and technical solutions where leakage is a valid concern, thus improving robust economic performance and the credibility of the EU ETS as an instrument for delivering emissions reductions.

Key Words

JEL

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1. INTRODUCTION

Carbon leakage refers to emissions that are displaced rather than reduced, as a result of unilateral action on climate change in a region.[i] Concerns around the potential for carbon leakage has remained at the forefront of debate, as unilateral carbon pricing policies have proliferated globally including schemes in Europe[ii], Australia, South Korea, British Columbia, California and the US' North-East states.

Most of these schemes adopt a two-step strategy to addressing carbon leakage concerns. The first step involves identifying the sectors which are potentially vulnerable to the threat of carbon leakage to substitute domestic mitigation efforts – carbon-intensive-trade-exposed (CITE) sectors. The second step then involves designing special provisions or exemptions to be applied on the grounds of carbon leakage. The policy adopted under the EU Emissions Trading Scheme (EU ETS), the Californian GHG ETS and the Australian Carbon Price Mechanism (ACPM) has been to provide permits to CITE industries for free.

It is increasingly understood that these special provisions can have drawbacks, for example on the economic efficiency of the scheme (Hepburn et al 2006) and the impacts on innovation and investment incentives (Martin et al 2011). Moreover, as free allowance allocation constitutes an implicit subsidy for such sectors, this policy paved way for rent-seeking behavior and large-scale lobbying (Grubb and Neuhoff 2006). Indeed, the EU experience has moreover shown that large windfall profits have been generated from free allocation of allowances (CE Delft, 2010; Lise et al, 2010; Martin et al, 2010; Maxwell, 2011; Point Carbon and WWF, 2008; Sandbag, 2011) and can undermine the credibility of the scheme.

Separating out the sectors genuinely at risk through a transparent, analytically coherent and credible methodology is key to addressing the potential for carbon leakage effectively. Methodological robustness to back the selection of CITE sectors is important, because the process is inherently prone to political blunder. In addition to sectors' motives for potential windfall profits, policy makers may also be motivated by concerns other than carbon leakage – e.g. employment migration and competitiveness concerns – to protect sectors from the impact of carbon prices.

This analysis aims to contribute to these debates, by setting out a simple analytical framework and indicators to measure relative potential exposure of manufacturing sectors to carbon leakage. These indicators are applied to data on UK and German manufacturing sectors, specifically, 159 manufacturing sub-sectors defined using Standard Industrial Classification at 4-digit level. Furthermore, our results for the UK and Germany are contrasted with the results of the European Commission's assessment at the EU27 level, underpinning the provisions of the revised version (2009/29/EC) of the EU ETS Directive 2003/87/EC.

The analysis illustrates how simple metrics can be used to quantify and compare the effects of CO_2 pricing from the EU ETS, when applied to high quality data. The proposed approach allows identifying the most vulnerable sectors to carbon leakage in a transparent way. It also gives insights into the combined magnitude of potential leakage from the manufacturing industries, and how different effects from carbon

pricing may affect different channels of leakage (investment leakage and production leakage). The comparative approach also allows us to explore the robustness of the indicators and gives insight into the reasons why EU level results diverge from country-level results.

This study builds on the literature on the identification of leakage-exposed sectors. Anderson et al (2011) calculate marginal leakage probabilities based on responses to a comprehensive firm-level survey, which included questions on the "Future impact of climate change policies". Juergens et al. (2012) presents the CEC's undergone work behind the Directive 2009/29/EC which identifies CITE sectors using two criteria – value at stake and trade intensity – which adopts the evaluation methods used originally by Carbon Trust (2004) and subsequently Smale et al (2006), Hourcade et al (2006) and Graichen et. al. (2008). The purpose of this study is to provide the analytical framework underpinning the evaluation strategy, quantifying the relative first order effects of carbon pricing (impact on production cost relative to sector profitability) at a highly disaggregated level of sectoral definition. In doing so, it exposes how conducting this evaluation using aggregated data (sector and regional) mask cost impacts experienced at more disaggregated levels. It also highlights the key challenge of obtaining reliable and verifiable data, given the inherent problem of asymmetric information between the regulator and the firms.

This paper is organised as follows. Following a review of the literature in Section 1.1, Section 2 sets out the analytical framework used to assess effects on production cost. It then explains our approach to quantify relative exposure of different sectors to emissions leakage. It includes a brief discussion on the indicators of choice. Results are illustrated using data collected for the UK and Germany in Section 4. We also apply a "CO_2 cost screen" to identify the most vulnerable sectors and discuss the relevance and appropriateness of additional criteria proposed for assessing the level of carbon leakage risk. Section 5 then compares the UK and Germany results from this study to that of the EU 27 aggregated assessment under the ETS directive 2003/87/EC (European Parliament and the Council of the EU, 2009), and discusses reasons behind the differences. Section 6 offers some and suggests future work.

1.1 Literature

The examination of emissions leakage in the economic literature is rapidly growing. There are a number of distinct groups of surrounding debates, which interestingly come to conflicting conclusions.

Firstly, the carbon leakage effects have been examined using computable general equilibrium modelling frameworks. These studies estimate carbon leakage rates resulting from the implementation of the first-period Kyoto Protocol commitments through uniform carbon taxes (measured by the increase in CO_2 emissions outside of Annex I divided by reductions in Annex I) to be in the range 5% to 20% (e.g. Barker 2007; Babiker and Jacoby ,1999; Burniaux and Truong 2002; Burniaux and Oliveira-Martins, 2000, 2011; Kuik and Gerlagh 2003; Gerlagh and Kuik, 2007; Manne, A.S., Richels, R.G, 1998; Mc-Kibbin et al., 1999; Paltsev, 2001)[iii]. An exception is Babiker (2005) which uses the MIT-EPPA model with 7 regions, 7 goods and 3 industries

including assumptions of increasing returns to scale, homogeneous goods and strategic behaviour and estimates leakage rates up to 130%.

Secondly, the empirical literature also provides mixed evidence. Earlier studies found little evidence to support positive leakage rates are found (e.g. Oikinomou, 2006; IPCC, 2001; Sijm, et al 2004, Zhang and Baranzini, 2004). In their survey of spillover effects, Sijm et al (2004) compare results of empirical studies on the issue of relocation of energy-industries and find "no satisfactory explanation for the different outcomes between empirical studies". They conclude that if a relation between climate policy and relocation could exist, then it is statistically weak and insufficient for policy making. Reinaud (2008) examines the impact of the EU ETS on four heavy industrials sectors – primary aluminium, refining, iron & steel and cement – and finds "no significant changes in trade flows and production patterns were evident during the first phase (2005-2007)". They attribute this to the free allocation of allowances and the existence of long-term contracts for electricity.

More recent studies adopt new strategies to investigate carbon leakage empirically. One way to empirically assess carbon leakage impacts from heterogeneous carbon pricing policies, is to look at how historical differences in energy price impacts trade flows. Aldy & Pizer (2011)'s study on the US examine the relationship between industrial energy prices (which varies across sectors and States) and industry supply and demand, and finds a positive but small effect. They find that a unilateral US\$15/tCO$_2$ carbon price is associated with a 1.4% decline in domestic supply, and about two thirds of this is due to a reduction of domestic demand. Therefore, only one third of the decrease in domestic output is due to the rise in net imports, hence implying a very small trade impact, which are greater for more energy intensive sectors. Gerlagh & Mathys (2011) examines the variation in energy abundance across countries and finds that there is high correlation between energy abundance and price, and that energy abundant countries have a high level of energy embodied in exports relative to imports. These results therefore provide support to the existence of a carbon leakage effect.

Thirdly, explanations around the stark difference between the modelling analysis and the emerging empirical evidence have been sought in the wider pollution heaven hypothesis literature. Porter (1991), Grubb and Hope (2002) Barker et al (2007) among others put forward the argument that emissions leakage effects are offset by technology spillover effects. The latter, using an econometric approach to examining leakage effects from environmental taxation in Europe between 1995 and 2005, finds very small and sometimes negative leakage rates due to technological spillover effects. Using the same E3ME econometric model, Ekins (2007) also finds a reduction in fuel demand from energy taxation in Western European countries, with largest reductions occurring in countries with higher tax rates. Others have argued that environmental policy is endogenously determined – that is, that the implementation of regulatory measures are used as trade barriers to protect domestic industry (e.g. Ederington and Minier (2003) and Levinson and Taylor (2004) examine the link between US environmental regulations and trade patters and find a positive influence, when regulation is treated as an endogenous variable). Another argument is that environmental compliance costs (and related risks) represent a small proportion of a firm's total costs relative to other costs and risks. Production cost impacts of CO$_2$ pricing in general have been found to be modest for energy-intensive industry. Baron

and ECOEnergy (1997) carry out a statistical analysis on four energy-intensive sectors in nine OECD countries and estimate an average 3% increase in production costs from a CO_2 tax of ~$US30/tC0_2$. Andersen and Speck (2007) find that the cost burden of environmental tax reform in eight energy intensive sectors in Germany, Denmark and Sweden does not exceed 5% of gross operating service. When revenue recycling (e.g. recycling of employer's social security contributions) is taken into account, this figure falls to 2%. Finally, an argument put forward by Levinson and Taylor (2004) is that there are endogenous effects due to the changing composition of industry. Most existing studies examining carbon leakage aggregate sectors at two or three-digit level of sector classification. At this aggregated level, carbon leakage may not be detected, if it occurs at 4-digit level, as this in turn reduces the pollution intensity of the industry at 3-digit level. Findings in this paper will provide support to this argument.

A fourth strand of literature examines the microeconomic effects of a carbon price or other environmental price instrument on pricing and production behaviour. It provides insights into how pricing power in international markets (ability to pass carbon costs to product prices) vary across sectors.[iv] Earlier studies set out the principles of how in the short-run, sectors within the EU ETS have some degree of pricing power and are likely to adjust price and output and profit from free allocation (Carbon Trust (2004 and 2005), Reinaud (2005a), Smale et al. (2006) and McKinsey and Ecofys (2006)).[v] Subsequent studies provide empirical support, for example, Oberndorfer et al (2010)'s study on the UK finds evidence behind the influence of EUA prices on pricing in diesel (50%) and gasoline (75%) using weekly output price data. Evidence of cost pass through was also found for ceramic goods (>100%), low-density polyethylene film (>100%) and ammonium nitrate (50%) but not for container glass, and mixed for hollow glass (20-25%) and ceramic brick (30-40%). Alexeeva-Talebi (2010) used advanced time-series techniques to estimate cost pass-through rates in an oligopoly setting the long-run equilibrium in German energy-intensive sectors (mainly paper and chemicals). This paper found that most of the German EU ETS sub-sectors studied have a positive and flexible mark-up over marginal costs, and severe implications on profit margins are unlikely. They also found that the impact on the pass-through is ultimately determined by the interplay of individual effects working in different directions: for example, market power, market share, product substitutability and the degree to which firms capitalize on the opportunity to increase output price in response to their foreign competitor's mark-up.

Lastly, different approaches to addressing emissions leakage have been put forward. Several studies point out that the free allowance allocation approach currently adopted by the EU ETS is unlikely to address leakage as firms can cash in on the free allowances and still relocate abroad (e.g. Neuhoff 2008 and Alexeeva-Talebi, 2010). Several anti-leakage measures have been hotly discussed: output-based free allocation[vi], sectoral agreements[vii] and trade measures[viii]. There has been considerable discussion on the latter particularly on the legal aspects (e.g. Ismer & Neuhoff, 2007; Lockwood & Whalley, 2010; Holzer, 2010; Tamiotti, 2011; Zhang, 2010; Pauwelyn, 2007) and trade impacts (e.g. Monjon & Quirion, 2011; Dong & Whalley, 2010; Gros & Egenhofer, 2011; Fischer & Fox, 2009).

The underlying argument across these bodies of literature is that carbon leakage effects, as well as potential solutions are sector specific in nature. Yet the experience

in Europe and Australia has demonstrated the political di where there is relatively limited understanding is the question as to how focused is the potential emissions leakage - whether and to what degree the effect is focused on, for example, a specific sector, sub-sector, production process, product or geographic region. Olson (1965) has argued that the more narrowly focused the adverse impacts of a given policy, the more politically difficult it is to sustain that policy. It is understood that cost impacts and ability to pass on CO_2 costs to product prices are highly differentiated across, for example, sectors, production processes and products depending on factors such as the level of international competition and product homogeneity (Sato et al 2006). Some mapping of differentiated cost impacts across sectors are emerging for the US (Morgenstern et al, 2006; WRI, 2008) and for Australia (Citigroup, 2008).

2. METHODOLOGY, ASSUMPTIONS AND DATA

The economic effects of the EU ETS are felt by emitters, in a number of different ways. Production costs increase in two main ways. First, there is a direct CO_2 cost that is relative to the level of direct CO_2 emissions from the installation. This is usually proportional to the level of direct energy use. Second, there is an indirect CO2 cost for installations that consume electricity from the grid. This is a function of electricity consumption and the CO_2 cost-pass through rate in the power sector. Different sectors can make a series of adjustments in production to different degrees, in order to mitigate direct and indirect CO_2 cost effects in the short, medium and long run. Possible channels for reducing cost effects include the improvement of energy/electricity efficiency in production (through technology investment, changes in process management and logistics etc.), adjustment of output, replacement of upstream production processes with imports (e.g. coke in steel), fuel switch and recycling.

How the effect on production costs translates to effects on profits depends on the degree to which the sector can pass costs onto product prices which in turn depends on the degree to which the sectors are exposed to competitive environment in the product market.

Therefore the potential exposure of a sector to various emissions leakage effects (production leakage, investment leakage, leakage through effects on energy price) is likely to be a function of:
1. Carbon intensity of production
2. Electricity intensity of production
3. CO_2 abatement opportunities
4. Ability to pass-though CO_2 costs (level of competition, product homogeneity etc.)

2.1 Exposure indicators

To translate the analytics into quantitative insights, we develop two "exposure" indicators for CO_2 emissions leakage, focusing on 1, 2 and 4.

2.1.1 Cost exposure: Maximum and Net Value At Stake (MVAS and NVAS)

To identify the key exposed sub-sectors, we focus on the relative effects. The impact of the EU ETS on industrial production costs can be differentiated into indirect and direct effects. Installations that buy grid electricity at market prices incur an indirect cost, due to the increase in electricity prices with the EU ETS. This *indirect* effect on production costs affects all industrial production sites, regardless of whether or not it is covered under the EU ETS and regardless of the level of free allowance allocation granted. *Direct* CO_2 costs corresponding to the level of CO_2 emitted is incurred by installations regulated under the scheme. If an installation receives enough free CO_2 allowances to cover their emissions, the direct costs represent not a real cost but an opportunity cost.

To quantify the impact of carbon pricing on production costs, we are primarily interested for a sub-sector *j*, in the MWh electricity inputs $E_j = \varphi_{elec} u_{elec,j}$ (where φ_{elec} is the ttoe to MWh conversion factor) as well as the direct energy related inputs to production:

$$u_j^e = (u_{coal,j}, u_{manufacturedfuel,j}, u_{LPG,j}, u_{gasoil,j}, u_{fueloil,j}, u_{Natgas,j},).$$

For a CO_2 cost pass through of $\text{€}P_e$/MWh in the electricity sector, the indirect effect of carbon pricing on sector

(1) $NVAS_j = \dfrac{P_e E_j}{GVA_j}$ $\qquad\qquad$ *j*=1,2….*n*

Equation (1) - the Net Value At Stake (MVAS) - thus measures the *indirect* effect of CO_2 pricing on sector costs relative to sector GVA which is irrespective of participation in the EU ETS or allocation and assumes no abatement action is taken.

Combining the indirect and direct effect gives:

(2) $MVAS_j = NVAS_j + \dfrac{P_c C_j^D}{GVA_j}$ $\qquad\qquad$ *j*=1,2….*n*

Where $C_j^D = \sum_f \theta_{fj} u_j^e + C_j^P$. Here, θ_f is the carbon emission factor for fuel *f*, C_j^P is the process emissions attributing to sector *j* and P_c is the CO_2 price in euros per tonne of CO_2.

Equation (2) – the Maximum Value At Stake (MVAS) - therefore represents the combined effects of increase in electricity prices and the cost of carbon allowances whether it is a real cost or an opportunity cost. MVAS gives an indication of the effect of a carbon price on sectors' marginal costs and hence the potential impact on output prices.

Notice that a higher or lower P_e and P_c does not hamper the explanatory power of the results as the MVAS and NVAS would increase or decrease in a linear manner.

The effect of carbon pricing on production costs is measured relative to their gross value added to allow for comparison across subsectors. GVA as a denominator has several advantages over alternative metrics. Figure 1 illustrates the different

components of turnover of a sector for which data is typically available at four digit sector level. Their evolution over time is depicted at the example of basic iron and steel in Germany.
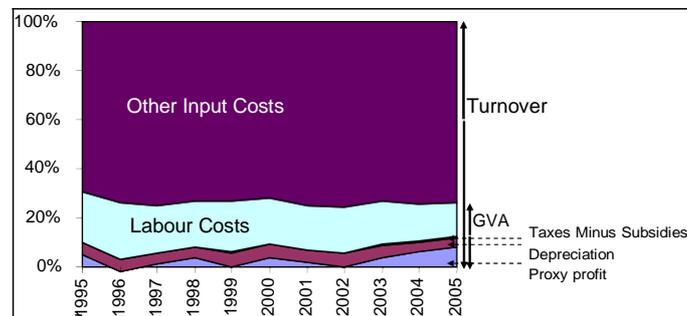
Figure 1 Composition of turnover in the Basic Iron, Steel and Ferro-Alloys (SIC 27.1)

Figure 1 suggests several different metrics that could be used: First, total sales revenue (i.e. turnover) of a sector could be used as comparator for cost increase. This includes, in addition to the value added, the costs for all input factors. Many of the inputs like coal and iron ore are priced in international markets; efficiency improvements in production still would not change the price of inputs, but will change the total expenditure on the input. It is therefore difficult to judge how flexible companies could respond to cost increases measured relative to turnover.
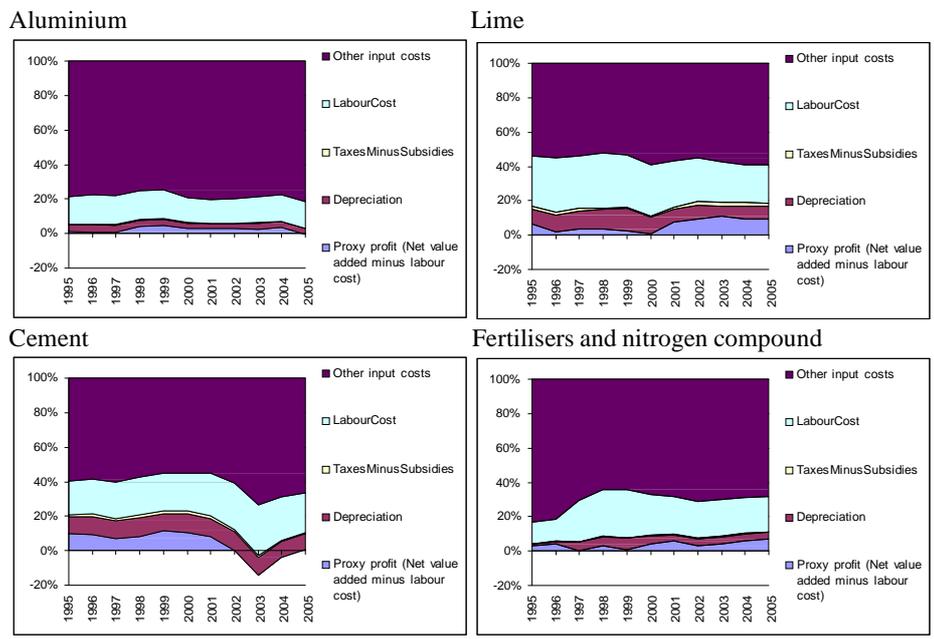
Figure 2 Composition of turnover in Aluminium, Lime, Cement and Fertilisers sectors.

Second, cost increase can be measured relative to profits. This raises several problems as demonstrated in Figure 1 and Figure 2. Profits are very volatile over years, and sometimes negative. Thus data over several years is required, and results are strongly influenced by the time frame. For any one year, the depreciation strategy of firms has a strong influence on the profit levels - depreciation levels allow for smoothing of profits across years. In addition, profit levels can be influenced by tax optimization policies. For example, multinational firms have the potential to "reduce" profits they

accrue in countries with high corporate tax levels, using transfer prices across countries that are biased in their favour. This will understate the profits but obviously varies across sectors and organizations. Finally, if firms incur costs from CO_2 pricing without passing them on to consumers, this reduces profits, however, as profits are the basis for many taxes it also reduces taxes. The reduced tax burden in turn implies that the cost impact on profits is reduced.

Third, earnings before interest, tax and depreciation and amortisation (EBITDA) could be used as comparator. From available data, it could be calculated as the sum of taxes, profits and depreciation. Thus cost increases would be measured relative to capital input into production. As labour inputs into production are not considered, the metric 'ignores' one important flexibility that firms can manage and optimise in response to cost increases. It also creates asymmetries across industry sectors - as a comparison across the different sectors illustrates (Figure 2), the relative importance of labour and capital input varies significantly. Finally, it does not address the question of potentially biased transfer prices across countries and segments in the value chain. (Unintended) distortions of transfer pricing are more relevant for this analysis, as leakage concerns relate to specific carbon intensive production steps.

The fourth option – CO_2 price impact on costs relative to sector GVA – has the attractive feature of being a stable metric over time, that reflects the fraction of costs that are under direct control of the firm and is less subject to strategic optimization (other than via allocation of labour cost as input costs with outsourcing of activities). It compares favourably against other metrics as the most robust. The metric is also helpful to understand the real economic value created by an industrial activity.

The choice of metrics affects estimations of carbon pricing's impact on relative cost increases experienced by subsectors. At the same time, we emphasise that the focus here is relative effects. We argue that measuring cost increase relative to value added provides a good indicator for the cost increases relative to other cost factors that are under control of the management of the firm.

2.1.2 Cost pass through ability: Trade Intensity

We now turn to the impact of carbon pricing on product prices. In theory, efficiency is achieved if producers pass-through the full cost increase induced by the carbon price, through to product prices. Passing down the full carbon price signal gives consumers the incentive to substitute away from the consumption of CO_2 intensive products. However, the degree to which producers can pass down the CO_2 costs to product prices may be constrained under "open" unilateral carbon pricing regimes such as the EU ETS, if producers compete in international markets. Distortions in competition induced by the unilateral carbon pricing policy may in the long run induce emissions leakage effects.

The biggest single constraint on ability to pass CO_2-related costs on to customers is therefore foreign competition from regions outside the EU ETS region, and the simplest measure of this is the existing degree of trade intensity. Obviously this is an imperfect indicator, and in response to large price differentials could change substantially over time. Econometric estimates of cost pass through are emerging for sectors other than electricity (e.g. Zachmann and von Hirschhausen 2008, Chernyavs'ka and Gulli 2008, CE Delft 2010 and Oberndorfer et al 2010). Yet trade

intensity remains the most practical indicator to screen all sectors for indication of whether they are traded or not.

As an indicator of the various barriers to a sectors' ability to pass through costs, we quantify the EU and Non-EU trade intensities respectively:

$$(3) \; X_j^{EU} = \frac{E_j^{EU} + I_j^{EU}}{ATO_j + I_j^{EU} + I_j^{NonEU}} \qquad j=1,2....n \quad \text{and}$$

$$(4) \; X_j^{NonEU} = \frac{E_j^{NonEU} + I_j^{NonEU}}{ATO_j + I_j^{EU} + I_j^{NonEU}} \qquad j=1,2....n$$

Here, for sector j, E_j^{EU} is the value of exports to EU, I_j^{EU} is the value of imports to the EU, and ATO_j is the Annual turn over. Equations (3) and (4) are therefore indicators to measure the intensity of foreign competition for industrial sectors. It relates the sum of traded goods to total market supply (the sum of domestic production and total imports). For the purpose of the EU ETS, the approach can meaningful be applied to asses the trade exposure of EU countries (such as Germany or the UK) with countries outside of the EU (non-EU) only, as all EU countries take part in the ETS.

The approach cannot reflect whether additional countries outside of the EU implement policies which would lead to a comparable increase in energy costs. If other countries implement similar policies like the EU ETS, competitors from these countries would have no advantage over domestic producers in terms of a CO_2 cost increase. In addition, this simple indicator aggregates the multiple trade barriers that deter relocation of industry. As such for key manufacturing sectors with high carbon cost impacts, the determination of carbon leakage risk begs more detailed assessment of the degree of exposure to foreign competition including factors such as product and service differentiation, import restrictions, transport costs, cost instability and exchange rate risk (see Hourcade et al 2007).

2.2 Sectoral coverage and mapping

The data for this study covers 159 manufacturing sectors using the Standard Industrial Classification (92)[ix] at 4-digit resolution. These 4-digit sectors belong to the broader manufacturing sectors shown in Table 1. The high resolution of sector information used allow us to understand cost impacts at a highly disaggregate level. As the intent is to examine potential effects of carbon pricing across the manufacturing sectors, no distinction is made between sectors covered under the EU ETS and other climate policy regimes.

SIC	Included in this analysis	Excluded
15, 16	Food, Drink and Tobacco	
17, 18, 19	Textiles and Leather	
20, 21, 22	Wood , Paper, Printing and Publishing	
23	Refining & fuels	
24	Chemicals	

25	Plastic and Rubber	
26.1-26.4	Glass and Ceramics	
26.5-26.8	Cement, Lime and Plaster	
27 excluding 27.4, 27.53, 27.54	Basic Metals (incl.) Iron & Steel	
27.4, 27.53, 27.54	Non-Ferrous Metals	
28		Fabricated metal products
29		Machinery and Equipment
30 - 33		Electrical and Optical Equipment
34, 35		Transport Equipment
36		Manufacture not elsewhere classified

Table 1 Manufacturing sectors covered in this analysis

2.3 Data

2.3.1 Direct and indirect CO_2 emission levels

For the UK, data on the energy and electricity inputs to production at the 4-digit level is obtained from BERR Energy Statistics Publication (2007) "Table 4.6: Detailed industrial energy consumption, by fuel, 2004" (updated in summer 2007). The data gives a representation of energy consumption by fuel for industrial sectors defined using SIC at 4 digit resolution.[x] Consumption of coal, manufactured fuel, LPG, gas oil, fuel oil, natural gas and electricity are reported separately. Hence cost effects from direct and indirect energy use and electricity consumption can be separated. To convert energy inputs into CO_2 emissions, we use emission factors from USA EPA (2004). For Germany, energy and electricity inputs into production have been obtained from the German Statistical Office, emission factors are based on the German GHG inventory and AG Energiebilanzen information.

Several data and methodological challenges need to be addressed. First, attribution of industrial activities and energy use can raise issues for disaggregated data. Indeed some significant classification errors in earlier UK data before updated in summer 2007. Second, data based upon energy expenditure surveys is subject to price uncertainties. Third, consumption of fuel for non-energy purposes, e.g. for the reduction of iron ore in steel production, is not reported and hence process emissions have to be identified from other sources.

To overcome data constraints, the analysis and results has involved an extensive stakeholder consultation conducted via the Department for Environment, Farming and Rural Affairs and the Emissions Trading Group. In Germany, the results were presented to key industry stakeholders in the government, federal agencies and research arena.

The stakeholder consultation process helped reduce the uncertainty around the data. The data provided by industry data on emissions, except for a few sectors had a systematic tendency to over-estimate emissions compared to 2005 verified emissions data, to varied but sometimes remarkable degrees. These were scrutinised against a range of estimates available (BERR 2007, DEFRA 2007, UNFCCC 2006, European Commission CITL verified emissions, 2006). In the end we believe we have obtained a reasonably consistent and accurate representation of emissions for the sectors studied.

2.3.2 Gross Value Added data and Annual Turnover Data

Approximate GVA at basic prices (£million, 2004) are obtained from UK Office of National Statistics Annual Business Inquiry (ONS ABI) reports (2006). [xi] For subsectors where GVA data is not available for the year 2004, data for the latest previous available year (or an average of several years), is obtained from the same source. In a few cases, they are obtained from other data sources Annual turnover is also obtained from ONS ABI. For Germany, GVA at factor costs and annual turnover data have been obtained from the German Statistical Office for the year 2005.

2.3.3 Trade Data

Trade Data are obtained from the "Trade in Goods Industry BOP MQ10" published by UK ONS (2004). For Germany, trade data have been obtained from the German Statistical Office for 2005. There is uncertainty over the reliability of this data as: A) it relies on trade data collected using a self-reporting approach; B) for most subsectors, there are no alternative sources to verify this data[xii]; and c) if emission trading induces large price differentials, the trade flows could change. Trade intensity is treated as a secondary indicator as a dimension of further assessment where a sector is deemed to have a high carbon cost impact.

3. RESULTS

3.1 First step - sectoral mapping and interpretation

To illustrate the assessment method, we first apply the exposure indicators to 2004 UK data, assuming a carbon price of €20/tCO$_2$ and an electricity pass-through resulting in wholesale electricity cost increase of €10/MWh. This assumes marginal electricity generation costs are set by natural gas emitting 500g CO$_2$/kWh electricity generated. In Germany, the marginal price is set by hard coal; hence the electricity price increase would be closer to €20/MWh. For comparison purpose, in both countries, we take €10/MWh to be the electricity cost pass-through rate.

Figure 3 and Figure 4 plots the NVAS and MVAS values on the vertical axis and the trade intensity on the horizontal. Each bar represents a UK sub-sector defined using SIC at 4-digit level. A total of 159 subsectors were analysed.

26.1- 26. 4 Glass & glass products, ceramic & ceramic products and bricks
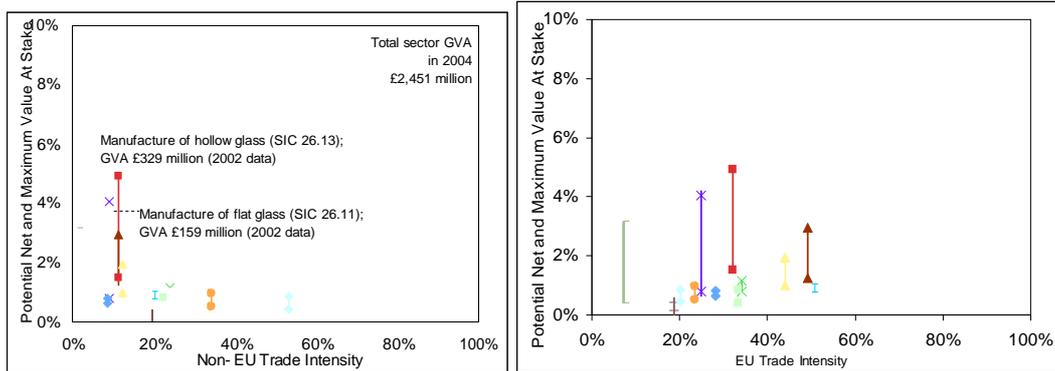
**26.5 – 26.8 Cement, lime & plaster; articles of concrete, plaster & cement**
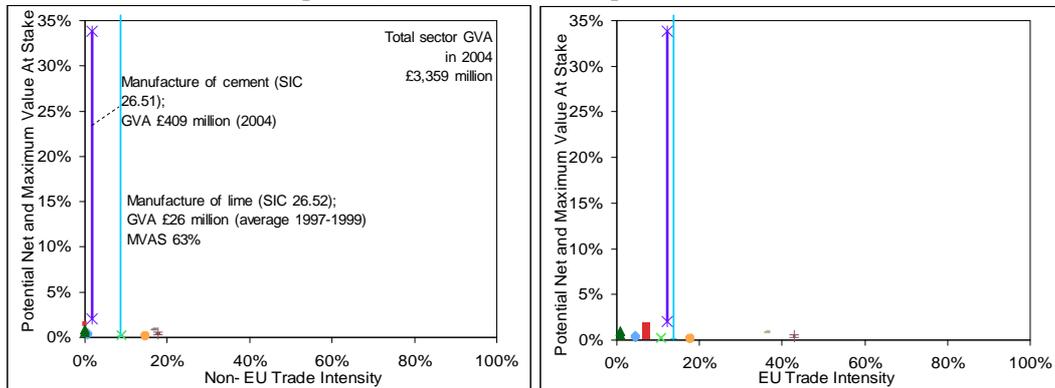
Figure 3 Value at stake for UK "Manufacture of other non-metallic mineral products" sectors against trade intensity from non-EU and EU

Graphically plotting sectors on the two dimensions highlights the differentiation in cost impacts experienced at sub-sector level. Take cement for example. Typically in studies using aggregate definition of sectors, cement is grouped together with glass, ceramics, bricks, lime, plaster, concrete products and so on. For example under the Standard Industrial Classification system at 2-digit level, cement is represented under Sector 26: "Manufacture of other non-metallic mineral products". The SIC at 4-digit resolution level separates Sector 26 into 25 separate subsectors as can be seen in Figure 3.

Here, the lower end shows the *indirect* cost effect from electricity price increase as a consequence of CO_2 price pass through in the electricity sector, irrespective of participation or allocation. This is the highest for *Manufacturing of cement* (SIC 26.51) – attributed the electricity used for the grinding process - for which an electricity price increase of €10/MWh would increase production costs by 2% relative to GVA. For all other sub-sectors, the NVAS is less than 2%.

The upper end shows the total potential cost increase of a carbon cost of €20/t CO_2 relative to GVA. In this respect and for the case of the subsectors in discussion, four stand out: *Manufacture of flat glass* (SIC 26.11), *Manufacture of hollow glass* (SIC 26.13), *Manufacturing of cement* (SIC 26.51) and *Manufacturing of Lime* (SIC 26.52). They represent the basic and upstream products in this sector. In particular, MVAS for *Lime* and *Cement* are 63% and 34% respectively. This reflects the CO_2 intensity of

production and low GVA; collectively they account for 78% of total sector direct CO_2 emissions but 8% of GVA. In contrast are high value added secondary products such as *Manufacture of concrete products for construction purposes* (SIC 26.61) and *Manufacturing of concrete products for construction purposes* and *ready-mixed concrete* (SIC 26.63).

The MVAS gives an indication of the impact of the carbon price on marginal cost, which in turn gives some interesting insights. Firstly, if firms price at or close to the marginal cost of the last unit produced, the MVAS gives a rough indication of the corresponding potential effect on product prices. In general, if a sector (such as *Lime* and *Cement)* receives free allowance allocations, they have the potential to profit by passing on the marginal CO_2 cost. However, such behaviour may cause leakage and the degree to which free allocation addresses this risk of leakage is unclear. The higher the marginal cost differentials with producers outside the EU, the greater the potential emissions leakage. In the short-run, domestic producers receiving free allowances have the incentives to benefit from the high marginal cost differential via production leakage (replacing domestic production with imports). Subsectors with high marginal cost differentials against producers outside the region, are also exposed to higher risk of investment leakage in the long-run. On the other hand, if measures are introduced to prevent leakage, then the subsectors with high MVAS values are likely to respond quickly in contributing towards emissions reductions whether via emissions abatement measures or demand side response.

Focusing on the x-axis, Figure 3 shows the same value at stake range set against the import intensity *from outside of the EU* and also *from other EU* countries. The former is relevant for analysis of the distortions from the EU ETS that may induce emissions leakage. Comparing across the sectors in Figure 4 shows the intensity of competition with producers from other countries differs significantly among subsectors. Some are predominantly produced for, and consumed by, national markets. International trade is negligible in these cases and, thus, international competition, or distortion thereof, is no matter of concern even if production costs increased due to unilateral policy measures. The case is different for industrial sectors which export large shares of their domestic production or which face high competition from imports for their domestic sales.

The latter is of interest from the perspective that high intensity of trade *within* Europe implies that differential allocation methods and volumes during phase I and II of EU ETS (2005-2007 and 2008-2012) between Member States increase competitive distortions in the EU regional market. Closer trade relationships among European countries for all sectors indicate the priority for harmonisation of allocation methodologies and volumes. Since January 2013 across the EU ETS allocation for industrial installation is based on European benchmarks. Sensitivity to inter-EU competitiveness for sectors, however, are likely to be as much on electricity differences (for participating installations) as on allocation differentials. For *Manufacture of flat glass* (SIC 26.11), *Manufacture of hollow glass* (SIC 26.13), *Manufacturing of cement* (SIC 26.51) and *Manufacturing of Lime* (SIC 26.52), the relatively low external trade intensity suggests a high degree of CO_2 cost pass through. The trade barriers for the cement sector are discussed extensively in Hourcade et al. (2007).

15 – 16 Food, beverages and tobacco
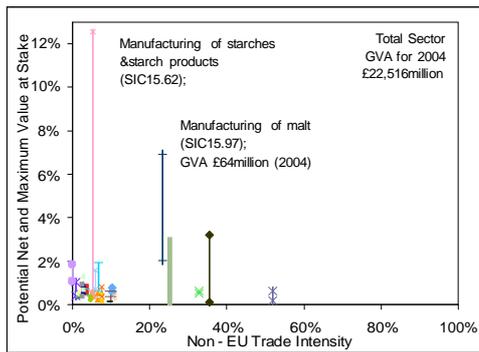
17 -19 Textiles, leather &- - products
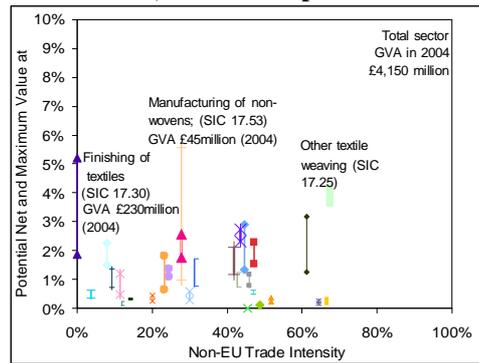
20-22 Wood, pulp, paper, -products& printing
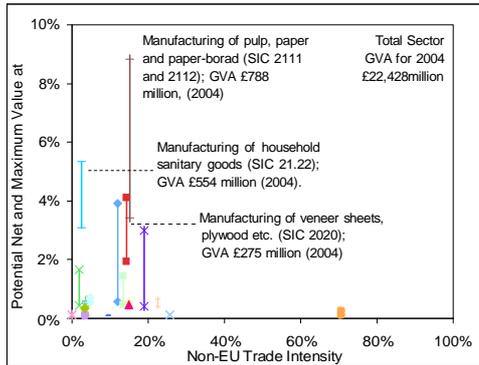
23 Coke and refined petroleum products
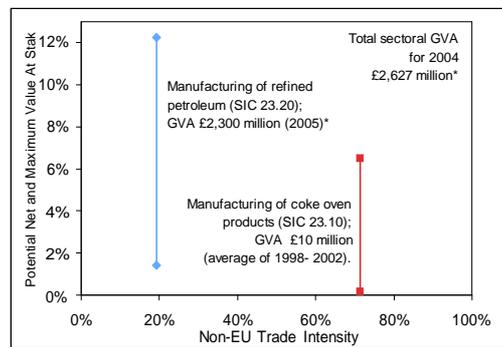
24Chemicals,-products &man-made fibres
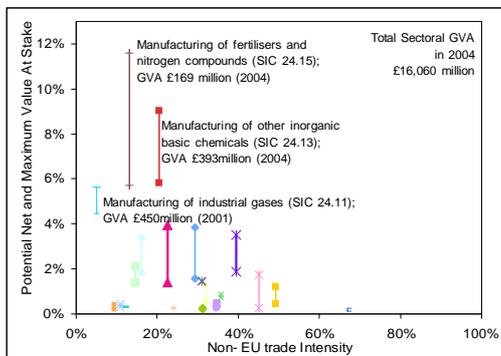
25 Rubber and plastic products
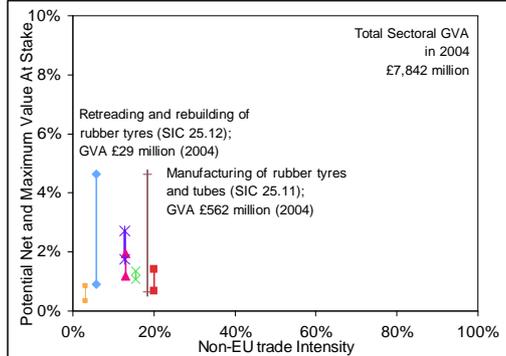
27Basic metals & fabricated metal products (excl. 27.4, 27.53, 27.54)
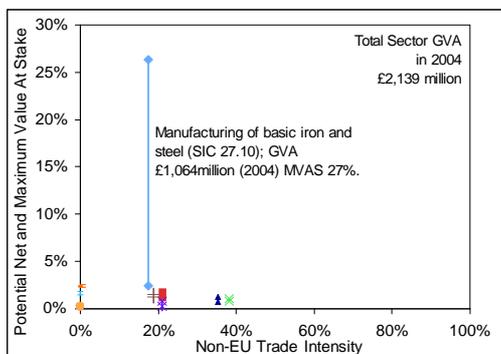
27.4, Basic precious&other non-ferrous metals 27.53, 27.54
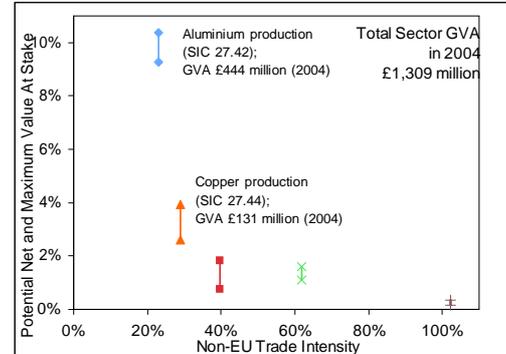
Figure 4 Value at stake for UK manufacturing sectors against trade intensity from non-EU

3.2 Second step – CO₂ cost screen and comparison

Having applied the indicators, now a "cost screen" is placed on the performance of the 159 4-digit SIC subsectors examined for the UK and Germany. We refer to Graichen et al (2008) for further information on the screening process conducted for Germany's sectors. Applying a minimum threshold levels of MVAS and NVAS at 4% and 2% respectively filters out all but 25 subsectors in both cases. This screening process therefore helps identify those subsectors for which further investigation can be warranted on grounds of potential cost exposure.

Figure 5 and Figure 6 plots for the UK and Germany, the top 25 subsectors with the MVAS and NVAS on the y-axis, and the share of contribution to national GDP[xiii] on the x-axis. The area under the histogram is proportional to the level of CO_2 emissions (direct and indirect). For the purpose of comparison, taking only the 25 identified subsectors from the UK screening process, Table 2 gives the key data for these subsectors including share of domestic emissions, GDP and employment in both the UK and Germany. Notice therefore that the same set of subsectors represented in Figure 5 (UK) and Table 2, but not in Figure 6 (Germany).

A few striking features emerge from this comparison. First is the similarity of the sectors with significantly high MVAS. *Lime, Cement, Basic Iron & Steel, Starch & Starch Products, Refined Petroleum, Fertilisers & Nitrogen, Aluminium, Other Inorganic Basic Chemicals, Pulp* and *Paper & Board* rank within the top 10 in both UK and Germany in terms of total production cost effects, although the ranking order may differ slightly. Note that due to data availability, there are some differences in the level of sector disaggregation. For example, *Coke, Refined petroleum products and Nuclear fuel* (SIC 23) is disaggregated in the UK but included at 2-digit level for Germany. Similarly, *Pulp, Paper & Board* (SIC 21.1) is represented at 3-digit level for the UK and disaggregated for Germany.

Secondly, overall the NVAS and MVAS for sectors are comparable between the two countries. The comparison also reveals some interesting differences. Notably, the MVAS for *Cement* and for *Fertilisers & Nitrogen* is higher in Germany than in the UK, whereas the opposite is true for *Lime* and for *Basic Iron & Steel*. The differences reflect national sectoral characteristics. The share of recycled steel in Germany is higher, reducing the average carbon content and thus MVAS. In Germany cement prices were lower during the reference period after the cartel was dissolved, reducing the GVA and thus increasing the MVAS. These aspects are discussed in more detail in section 4.
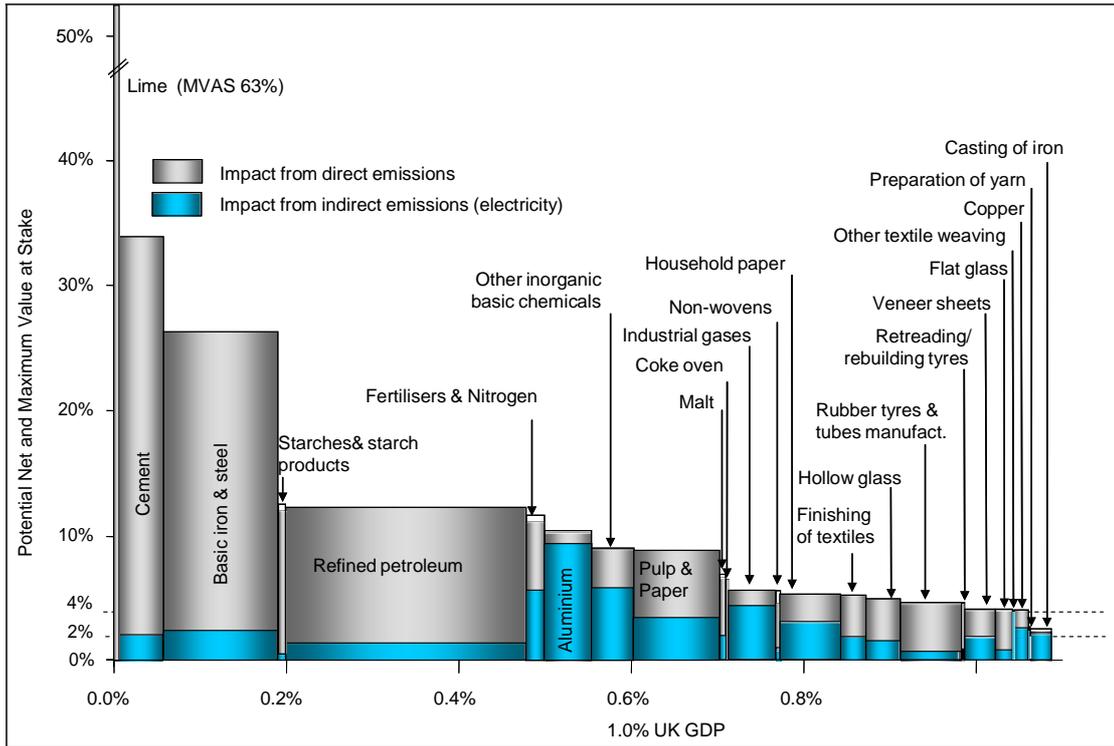
Figure 5 CO$_2$ cost screen: sectors potentially exposed under unilateral CO$_2$ pricing, based on 2004 UK data.

The German data give comparable results.
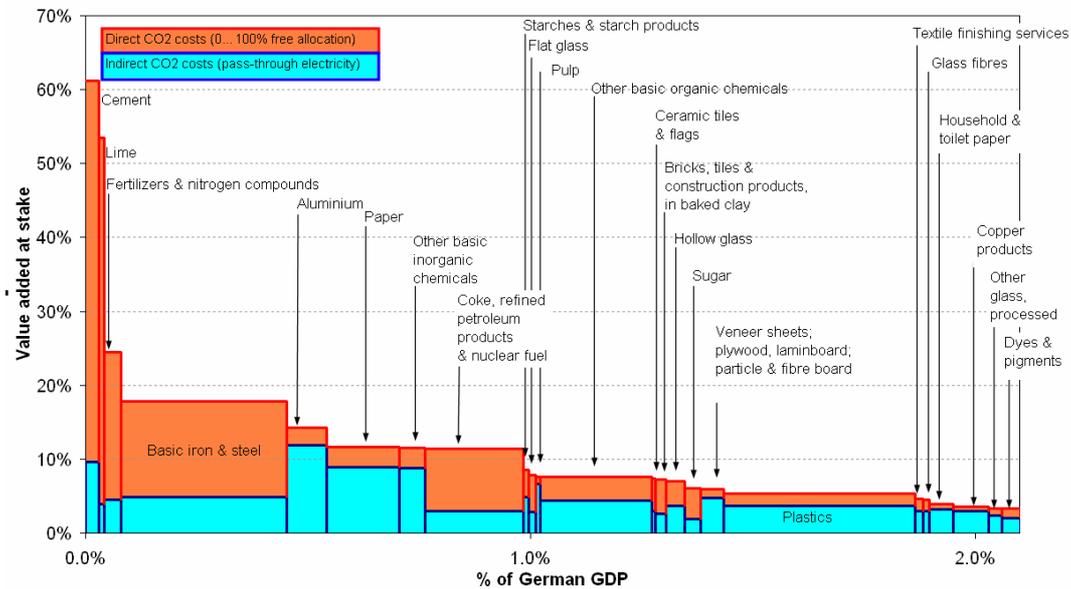
Figure 6 CO$_2$ cost screen: sectors potentially exposed under unilateral CO$_2$ pricing, based on 2005 German data

SIC sector code		[1] UK MVAS	[2] DE MVAS	[3] UK NVAS	[4] DE NVAS	[5] UK EU trade intensity	[6] DE EU trade intensity	[7] UK Non-EU trade-intensity	[8] DE Non-EU trade-intensity	[9] % of UK CO2 emissions	[10] % of DE CO2 emissions	[11] % of UK GVA	[12] % of DE GVA	[13] % of total UK Employm.	[14] % of total DE Employm.
2652	Lime	62.80%	55.68%	0.08%	2.14%	7.08%	16.04%	4.42%	0.80%	0.43%	0.72%	0.01%	0.01%		0.01%
2651	Cement	33.88%	57.94%	2.01%	5.08%	12.18%	20.98%	1.79%	1.65%	1.80%	2.19%	0.05%	0.03%	0.02%	0.02%
2710	Basic iron & steel	26.36%	15.68%	2.39%	1.84%	47.11%	51.94%	17.39%	14.48%	3.62%	7.23%	0.13%	0.36%	0.08%	0.22%
1562	Starches & starch products	12.56%	4.46%	0.48%	0.92%	40.23%	43.43%	5.25%	10.82%	0.11%	0.08%	0.01%	0.01%	0.00%	0.01%
2320	Refined petroleum products	12.26%	-	1.40%	-	19.27%	-	19.27%	-	3.63%	2.31%	0.29%	-	0.04%	-
2415	Fertilizers & nitrogen compounds	11.61%	21.13%	5.72%	1.09%	23.48%	49.28%	13.22%	18.86%	0.24%	1.03%	0.02%	0.04%	0.01%	0.03%
2742	Aluminium & -products	10.38%	8.60%	9.28%	6.20%	47.48%	52.91%	23.16%	25.67%	0.51%	0.98%	0.06%	0.09%	0.04%	0.09%
2413	Other basic inorganic chemicals	9.03%	7.92%	5.82%	4.16%	40.65%	51.45%	20.57%	31.78%	0.42%	0.57%	0.05%	0.06%	0.02%	0.04%
2111, 2112	Pulp, Paper & bord	8.84%	6.08%	3.42%	3.26%	56.24%	63.25%	15.08%	20.86%	0.85%	1.32%	0.10%	0.17%	0.06%	0.13%
1597	Malt	6.93%	12.91%	2.03%	3.62%	5.33%	26.23%	23.37%	12.44%	0.06%	0.03%	0.01%	0.00%	0.00%	0.00%
2310	Coke oven products	6.48%	-	0.15%	-	23.81%	-	71.43%	-	0.01%	0.02%	0.00%			-
2411	Industrial gases	5.60%	-	4.44%	-	8.15%	-	5.03%	-	0.29%	0.34%	0.06%	-	0.02%	-
1753	Nonwovens and -articles except apparel	5.58%	1.46%	0.97%	1.08%	0.00%	68.30%	0.00%	20.06%	0.03%	0.03%	0.01%	0.02%	0.00%	0.02%
2122	Household & toilet paper	5.32%	2.29%	3.06%	1.46%	18.06%	51.60%	2.56%	8.14%	0.35%	0.15%	0.07%	0.05%	0.04%	0.05%
1730	Textile finishing services	5.20%	3.11%	1.88%	1.44%	0.00%		0.00%		0.15%	0.07%	0.03%	0.02%	0.03%	0.03%
2613	Hollow glass	4.92%	5.41%	1.52%	1.97%	32.09%	39.92%	11.32%	15.93%	0.20%	0.28%	0.04%	0.04%	0.06%	0.05%
2511	Rubber tyers and tubes	4.65%	0.85%	0.66%	0.58%	37.93%	47.55%	18.49%	15.32%	0.33%	0.09%	0.07%	0.08%	0.03%	0.07%
2512	Retreading & rebuilding of rubber tyres	4.64%	0.51%	0.90%	0.51%	12.50%	69.73%	5.68%	8.84%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%
2020	Veneer sheet,plywood, lamin board, particle -, fibre-	4.09%	2.82%	1.94%	1.65%	35.32%	44.27%	14.29%	19.28%	0.14%	0.18%	0.03%	0.05%	0.02%	0.05%
2611	Flat glass	4.06%	6.62%	0.80%	1.47%	24.94%	42.48%	8.98%	15.31%	0.08%	0.13%	0.02%	0.02%	0.01%	0.01%
1725	Other textile weaving	4.04%	0.92%	3.75%	0.92%	105.66%	-	67.37%	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2744	Copper	3.93%	2.18%	2.61%	1.54%	57.46%	51.30%	28.87%	26.38%	0.06%	0.18%	0.02%	0.06%	0.01%	0.05%
1715	Preparation of yarn	2.74%	-	2.32%	-	67.86%	-	43.57%	-	0.00%	0.00%	0.00%	-		-
2751	Casting of iron	2.48%	4.01%	2.20%	2.71%	0.00%	-	0.00%	-	0.06%	0.37%	0.03%	0.07%	0.02%	0.08%
	TOTAL									**13.39%**	**18.73%**	**1.10%**	**1.40%**	**0.52%**	**1.01%**
23	Coke, refined petroleum products & nuclear fuel		8.82%		0.40%		16.16%		4.92%		2.48%		0.22%		0.06%

Table 2 Summary key data for UK and Germany top 25 sub-sectors

Thirdly the combined impact on GDP is small in both countries. All together, the top 25 account for just above 1% of UK GDP. For Germany, this figure is 2% using Germany's top 25 subsectors (see Figure 6) and 1.4% using the UK top 25 subsectors (see Table 2). In employment terms, the share is even smaller at 0.5% for the UK and 1% for Germany (using UK top 25). The small share of these sectors to GDP and employment does not mean that they can be ignored. On the contrary, the fact that the impact and potential leakage is focused on few specific subsectors allows for tailored and technical solutions to address potential leakage concerns.

Overall, there is striking similarity in MVAS and NVAS performance across the UK and German manufacturing subsectors. In addition to the strength of the indicator over time (See section 2.12), this comparison gives further confidence to the strength of these indicators for measuring relative cost impacts of carbon pricing on these subsectors.

3.3 Third step – further dimensions for assessing exposed (high value at stake) subsectors

Sectors identified by the carbon cost screen can also be assessed and compared in terms of their trade exposure (Equations 3 and 4). Figures 7 and 8 indicate the value at stake and the trade intensity with countries outside of the EU for the UK and Germany respectively, for the top exposed sub-sectors identified in Section 3.1.

Overall trade intensity is comparable in Germany and the UK. As one would expect from the geographical location and Commonwealth affiliation of the UK, for many of the exposed subsectors identified in Section 3.1, the UK exhibits higher trade intensity with non-EU countries while share of intra-EU trade intensity is far higher for Germany.
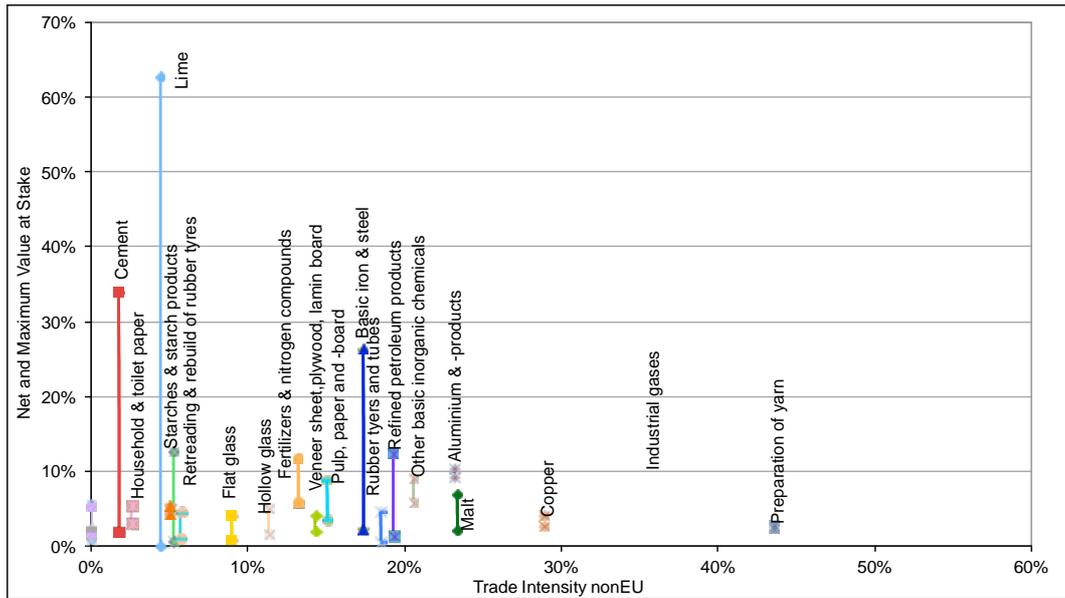
Figure 7 Trade intensity and value at stake (relative to GVA) for UK's top 25 sectors

Notes: Three subsectors lie on the verticle axsis (zero non EU trade) and these are: Casting of iron; Textile finishing service and Non-woven articles except apparel.
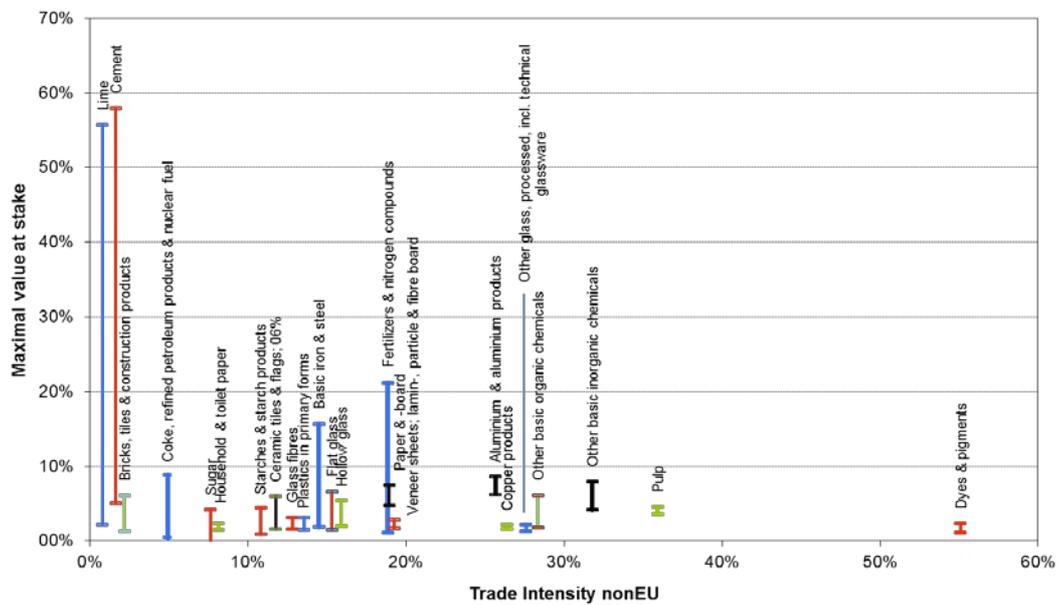
Figure 8   Trade intensity and value at stake (relative to GVA) for Germany's top sectors

Source: Data from German Statistical Office, calculations Öko-Institut

A number of other sectors reveal a high intensity of trade but low value at stake (dyes, for example). This is also an indication that the increase in production costs due to the EU ETS is relatively small and therefore may be passed through. Sectors with high EU ETS related cost effects but low trade intensity are not expected to be significantly threatened by international competition. Considered to be vulnerable are those sectors with both significant carbon cost and high trade exposure.

For the sectors that reveal high values at stake and high trade intensities, market positions are likely to change under the EU ETS due to increased production costs and high exposure to international competition. Depending on the allocation mechanism, firms may face high CO_2-related costs and will need to adjust their activities.

To illustrate the effect of the allocation mechanism, we compare the two extreme cases of MVAS (no free allocation) and NVAS (free allocation for direct emissions) and apply the EU Directive's combined threshold for trade intensity and value at stake which is applied to determine the sectors and subsectors at risk of carbon leakage. The combined threshold is set at 10% for the indicator of trade intensity and 5% for carbon costs. For the UK, we identify *fertilizer and nitrogen compounds*, *aluminium and aluminium products* and *other basic inorganic chemicals* to fulfil these criteria in the case of free allocation (NVAS), while additionally *basic iron and steel*, *refined petroleum products*, *pulp, paper and paperboard*, *malt* and *coke oven products* meet the criteria in the case of no free allocation (MVAS). For Germany, the picture looks similar. In the case of free allocation (NVAS), only *aluminium and aluminium products* would meet the threshold, while in the case of auctioning (MVAS) more sectors than in the UK would meet the thresholds, i.e. additional to the ones identified for the UK, in Germany *starch and starch products*, *hollow and flat glass* would meet the combined threshold. As pointed out above, a number of sectors do not provide sufficient data to allow for an analysis.

It should be noted that the two cases of full free allocation and no free allocation for direct emissions are of illustrative nature and provide the respective ends of the range. With an allocation system that is based on benchmarks, as it has been implemented within the EU ETS Directive, or any other approach that would lead to free allocation for a share of direct emissions, the induced carbon costs would lie somewhere in the middle of the MVAS and NVAS cases. Applying the combined threshold of 5% and 10% would then imply that at least the sectors identified under the NVAS above would meet the threshold, complemented by some (but not all) of the sectors that are additionally identified under the MVAS case. For each sector there is a break-even point that could be derived depending on the share of free allocation.

In general, it must be noted that even though the selected indicators (trade intensity and value at stake) provide a consistent illustration of the effects of different allocation schemes, they do not present information on companies' actual decision making schemes, i.e. they do not allow immediate conclusions on whether firms may consider full or partial relocation to countries outside the Emissions Trading Scheme.

One should also keep in mind that all of these approaches, including the trade intensity or the value at stake approach, neglect non-price aspects that may reduce the effects on international competitiveness and thus reduce leakage concerns in some sectors. This includes specialty products, close cooperation with domestic/European partners, exchange rate risks, transport costs and other trade barriers as noted in Section 2.1.2.

Approaches to address competitiveness effects and leakage concerns would need to be considered on a sector by sector basis. As the number of exposed sectors is limited a focussed treatment of these sectors should be possible. A more in-depth analysis of

the exposed sectors should be carried out to identify reasons for national differences and whether all products of the mentioned sectors are exposed or whether the exposure is limited to some products.

4. How does the UK and German results compare with the EU27 average?

Under the ETS directive 2003/87/EC (European Parliament and the Council of the EU, 2009), the assessment of a sector's risk of carbon leakage is conducted at the level of the EU. Under this approach, averaged data are used, therefore sector heterogeneity across Member States is not considered.

Table 3 provides a comparison of our results for the UK and Germany and the results of the Commissions' quantitative assessments for the EU27 for our 25 sectors. The comparison is conducted for four indicators 1) total cost exposure 2) direct cost exposure; 3) indirect cost exposure and 4) trade intensity.

To enable a comparison, several adjustments are made to the UK and German indicator assessments reported in Section 3. The carbon price assumption is adjusted to 30 Euros (from 20 Euro used for Section 3), we standardise the electricity carbon intensity factor with the EU average, and a 75% free allocation rate is embedded in the direct cost exposure calculation (compared with the 0% free allocation assumed in the MVAS indicator and 100% free allocation for direct emissions in the NVAS indicator). Furthermore, calculation of the trade intensity indicator is adjusted to adhere to the definition used by the Commission.[xiv] The implication of the different definitions used by the Commission and this study (Equations 3 and 4) are further discussed below.

Differences in the results can occur due to a number of reasons. Reasons behind the diverging sectors are likely to fall under the following six broad types:
- Difference in production processes, technologies and fuel mix
- Process emissions
- Recycling rate differences
- Product mix differences
- Sector classification, statistical boundaries, activity allocation differences
- Data quality

#	SIC sector code		Value at stake			Direct emissions contribution to VAS			Indirect emissions contr. to VAS			Trade Intensity (COM approach)		
			UK	DE	EU27	UK	DE	EU27	UK	DE	EU27	UK	DE	EU27
			2004	2005	2005/06	2004	2005	2005/06	2004	2005	2005/06	2004	2005	2005/06
1	2652	Lime	84.03%	83.30%	85.90%	83.89%	80.32%	83.10%	0.14%	2.98%	2.80%	4.55%	0.84%	2.60%
2	2651	Cement	45.96%	86.38%	59.20%	42.62%	79.29%	54.90%	3.34%	7.09%	4.40%	1.99%	1.75%	6.80%
3	2710	Basic iron & steel	36.02%	23.33%	12.30%	32.05%	20.76%	8.70%	3.97%	2.57%	3.60%	22.28%	19.81%	32.30%
4	1562	Starches & starch products	16.96%	6.59%	8.80%	16.16%	5.32%	6.90%	0.80%	1.28%	1.90%	7.48%	14.87%	14.50%
5	2320	Refined petroleum products	16.85%	-	15.20%	14.52%	-	14%	2.33%	-	1.20%	20.74%	-	16.10%
6	2415	Fertilizers & nitrogen compounds	17.37%	31.58%	92.40%	7.88%	30.06%	18.7% (+69.9% process)	9.49%	1.52%	3.70%	15.51%	23.95%	27.40%
7	2742	Aluminium & -products	16.87%	12.25%	15.30%	1.47%	3.60%	2.3% (+2.7% process)	15.39%	8.65%	10.30%	30.83%	34.40%	35.90%
8	2413	Other basic inorganic chemicals	13.95%	11.45%	13.90%	4.29%	5.64%	6.4%(+1.4% process)	9.66%	5.80%	6.00%	24.67%	38.71%	31.70%
9	2111	Pulp,	12.92%	6.40%	<5%	7.26%	1.43%	3,9%	5.67%	4.97%	<5%	26.86%	70.95%	46.10%
10	2112	Paper & bord		10.71%	11.90%		4.13%	7,1%		6.58%	4.80%		26.93%	25.70%
11	1597	Malt	9.92%	18.99%	6.80%	6.56%	13.95%	3.30%	3.36%	5.04%	3.50%	24.01%	14.68%	30.90%
12	2310	Coke oven products	8.72%	-	53.60%	8.48%	-	49.10%	0.24%	-	4.60%	80.65%	-	>30%
13	2411	Industrial gases	8.91%	-	9.40%	1.55%	-	1.90%	7.37%	-	7.50%	5.23%	-	4.20%
14	1753	Nonwovens and -articles except apparel	7.78%	2.08%	<5%	6.17%	0.57%	<5%	1.60%	1.51%	1.80%	-	27.33%	30.90%
15	2122	Household & toilet paper	8.10%	3.29%	3.60%	3.02%	1.26%	0.70%	5.08%	2.03%	2.90%	2.87%	10.24%	12.80%
16	1730	Textile finishing services	7.56%	4.52%	1.50%	4.45%	2.51%	0.60%	3.11%	2.01%	1.00%	-	-	-
17	2613	Hollow glass	7.06%	7.92%	8.80%	4.55%	5.16%	6.30%	2.51%	2.75%	2.60%	14.78%	18.19%	24.30%
18	2511	Rubber tyers and tubes	6.43%	1.21%	1.50%	5.33%	0.41%	0.60%	1.10%	0.81%	0.90%	24.88%	20.38%	37.10%
19	2512	Retreading & rebuilding of rubber tyres	6.50%	0.71%	<5%	5.01%	0.00%	<5%	1.49%	0.71%	0.70%	5.95%	11.02%	7.10%
20	2020	Veneer sheet,plywood, lamin board	6.09%	4.05%	4.00%	2.88%	1.74%	1.50%	3.21%	2.31%	2.60%	20.55%	22.72%	23.80%
21	2611	Flat glass	5.68%	9.77%	10.10%	4.36%	7.72%	8.30%	1.33%	2.06%	1.80%	10.71%	18.06%	21.00%
22	1725	Other textile weaving	6.60%	1.28%	<5%	0.38%	0.00%	<5%	6.22%	1.28%	1.10%	143.42%	-	58.30%
23	2744	Copper	6.10%	3.11%	6.20%	1.77%	0.96%	2.80%	4.33%	2.15%	3.40%	42.01%	34.13%	34.60%
24	1715	Preparation of yarn	4.41%	-	<5%	0.56%	-	<5%	3.85%	-	2.40%	101.67%	-	40.50%
25	2751	Casting of iron	2.51%	5.73%	>5% and < 30%	1.25%	1.95%	<5%	1.26%	3.78%	3.60%	-	-	-
*	23	Coke, refined petroleum products & nuclear fuel		13.18%			12.63%			0.55%			5.44%	

The UK production of *basic iron and steel* (2710) occur in three blast furnace plants, the more carbon intensive of the two steel processes. Germany's steel production portfolio is less skewed with a mix of blast furnace and the cleaner electric arc furnace technology. Across Europe as a whole, the cleaner electric arc furnace technology is more widely adopted, and this goes a long way to explain the large differences in cost exposure for this sector in Table 3. Similarly, the *pulp and paper* sectors (2111 and 2112) also use two distinct processes – mechanical and chemical pulp production. The UK relies solely on the more carbon intensive chemical process, whereas Germany employs a mix of the two technologies. Using the EU average to assess sectors with significantly different production processes therefore appears problematic.

Carbon intensity can vary considerably across Member States due to differences in the fuel mix. For example the UK's *Fertilizer and nitrogen compounds* (2415) sector has markedly low carbon intensity relative to the EU 27 average as they are fuelled by natural gas and electricity rather than coal. The fuel mix for the production of *rubber tyres and tubes* (2511 an 2512) is fuelled by oil in the UK and natural gas in the Germany, and hence the latter has a much lower total cost exposure.

Relatedly, large differences appear more likely to occur where process emissions play a role, usually from the use of coal in production. Notably, the process emissions reported for the EU27 for the *Fertilizer and nitrogen compounds* (2415) sector is very high, relative to our results for the UK and Germany. Part of this may be due to the difference in fuel mix. The low cost impact for the UK is likely attributable to the reliance on gas and electricity, yet the large divergence between Germany and the EU27 results cannot be easily explained. However, the EU27 results are based on confidential data (Juergens 2013) to which we have no access, therefore we cannot further assess the discrepancy between the results.

Differences in recycling rates may also vary across Member States. This is particularly important for subsectors including *aluminium* (2742), *pulp and paper sectors* (2111 and 2112), *household and toilet paper* (2122), *flat glass* (2611) and hollow glass (2613).

Several sectors in the list of 25 are characterised by heterogeneous products and numerous product grades. These include the *other basic inorganic chemicals* (2413) as well as *paper and paper board (*2112). The former sector includes the production of electricity-intensive chlorine. The high share of chlorine in the UK sector's output may explain the relatively high indirect cost exposure, compared to Germany and the EU27. The differences in the results for the sector *Nonwovens and nonwoven articles except apparel* (1753) may also be due to a different product mix. This is in part a product category issue – different countries include different products into categories (such as this) which represents a residual or 'others' category.

The *coke oven products* (2310) sector is often an integral part of blast furnace steel works and usually represents a residual activity of the iron and steel production. This sector demonstrates an example of difficulties with attribution of both energy inputs and product outputs to sectors, more generally, issues relating to statistical boundary and classification, which make it prone to data errors. In the UK, two of the three

coke plants are owned by steel manufacturers and in order to avoid double counting, the GVA and trade data for the remaining independent plant was used. For Germany, it was not possible to achieve the disaggregation of the 2-digit sector "coke, refined petroleum products and nuclear fuel". Similarly, the separation between pulp and paper was not possible for the UK.

Lastly, difference can occur due to data quality. In general, country-level data, being closer to source, are likely to benefit from higher quality. As mentioned, the quality of the data for UK and German sectors was ensured in this study through industry consultations and by cross-checking with both industry and public data. Yet data quality and availability can pose problems at the country-level data, for example, for small sectors for which confidentiality rules apply. For example, there are only two copper installations in Germany which makes the sector subject to confidentiality rules. It is possible that our results underestimate the true cost impact for Germany's copper sector because data on its brown coal use cannot be obtained.

The numbers for trade intensity calculated in chapter 3 cannot be directly compared to the Commission approach. Whereas for the EU as a whole internal trade can be disregarded as it does not influence the size of the domestic market (and thus in the Commissions approach does not enter the denominator), for individual EU Member States imports from other EU Member States play a significant role and influence the size of the domestic market. When the assessment is conducted at the MS level using the papers approach the trade intensity is underestimated and when using the Commissions approach is overestimated. The difference is highest for countries and sectors receiving a large share of imports from other EU MS. For example in the case of SIC 25.11 *Rubber, tyres and tubes* both in the UK and in Germany intra-EU imports are large leading to a difference of over 5 percentage points in trade intensity depending on the approach taken.

The comparison shows that sectoral trade intensity estimates for the UK and Germany can diverge considerably from the EU27 average. For example, *Starches* (1562) are in the UK below the threshold of 10% and would therefore unjustifiably be benefiting from free allocation under the EU assessment, whereas the opposite is the case for *Retreading & rebuilding of rubber tyres* (2512) in Germany. The differences highlight the limitation of trade intensity to measure the ability to pass through costs as it does not take into account other country specific sector characteristics such as transport costs, cost absorption potential or product differentiation according to local demand. All in all, it can be concluded that intra-sectoral differences might play a major role – both for the emission intensity and its exposure to competition from countries without similar carbon constraints.

5. Conclusions

In summary, this analysis has shown that the impacts of emission trading on competitiveness concerns and carbon leakage are focused on a few areas of economic activity.

The detailed data also shows that concerns about emission trading results, involving leakage of emissions and relocation of production, are best analysed and addressed by

focusing on the small set of subsectors that exhibit strong cost impacts and produce internationally traded commodities.

To identify these sectors we explored various metrics. Comparing the German, UK and EU data, we show that cost increase relative to gross value added provides a robust metric across countries and across time. The cross-country analysis illustrates however the short-comings due to aggregation across various processes.

First, a higher level of aggregation mixes energy and carbon intensive activities with other activities and results in a lower indicator for cost increase relative to value added. Second, recycling of materials like steel or aluminium is less carbon (energy) intensive than their primary production. Usually both processes are attributed to the same sub-subsector of standard industrial classification. Different shares of recycled materials can explain cross-country differences.

These observed variations point to the difficulty of assessing the risk of leakage for a sector based on indicators that measure cost increase at an aggregate level. The aggregate indicators can instead be used as a screen to identify sectors that might contain processes that are potentially at risk of leakage. For such individual sectors a more detailed analysis can help to understand the integration of the processes with the wider value chain. The specific circumstances will vary across sectors, but might include physical integration of a production process or organisational integration linked to the need of close coordination.

One prominently mentioned indicator for leakage concerns is the trade-intensity. We find for some very carbon intensive activities like the production of cement, lime, brick and industrial gases, consistently less than 10% are traded with countries outside of EU (and EU ETS). This is no proof that trade volumes could not change should significant carbon price differentials prevail over a long period of time, but indication that for short periods – relative to the investment cycles of the industry – carbon price differentials can be more easily maintained.

As the confidence of market participants that similar levels of carbon prices will be implemented globally is declining since the UN conference in Copenhagen, measures to address leakage concerns receive increasing attention. Initially allowances were allocated for free to industrial actors so as to temporarily bridge the concern. As a longer-term strategy the distortions created by such free allocation need to be weighted against the challenges of alternative policy responses, including the combination of full auctioning with border adjustments for imports, or the use of consumption based charging for carbon intensive commodities. Such measures are likely to be best tailored to the specific circumstances of a sector. For example the low trade-intensity of clinker and cement could be a criterion to prioritise the implementation of full auctioning of allowances to domestic producers and inclusion of (potential) imports into the domestic emission trading scheme so that domestic consumers face the full price of carbon.

The results of our analysis can also inform the on-going discussion of carbon embedded in trade: As a result of changing trade flows, increasing emission shares associated with consumption of products and services are not domestic to the final consumer, but are embedded in imports and occur in other countries. Our comparison

points to the uncertainties that can occur if the carbon embodied in such trade is inferred from aggregate indicators, as this might mask the differences of products and recycling shares.

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REFERENCES

Aldy, J. E. & Pizer, W. A. (2011). The competitiveness impacts of climate change mitigation policies. NBER Working Papers 17705, National Bureau of Economic Research, Inc. Available from: http://www.nber.org/papers/w17705.pdf.

Andersen, M. S. and Speck (2007). *WP6: Environmental tax reform in Europe: Stabilisation, mitigation and compensation.* In Publishable Final Report to the European Commission, DG Research and DG Taxation and Customs Union. Available at < http://www2.dmu.dk/cometr/COMETR_Final_Report.pdf >

Armington, P. (1969) *A theory of demand for products distinguished by place of production* IMF Staff papers 16. 159-178.

Athukorala, P. and Menon, J. (1994). 'Pricing to market behaviour and exchange rate pass-through in Japanese exports.' Economic Journal, vol. I 04, pp. 2 7 1-81.

Babiker, H. (2005) *Climate change policy, market structure, and carbon leakage* Journal of International Economics 65, 421-445.

Babiker, M. H., P. Criqui, et al. (2003) *Assessing the Impact of Carbon Tax Differentiation in the European Union*, Environmental Modeling and Assessment 8(3), 187-197.

Babiker and Jacoby (1999). Babiker, M., Jacoby, H., 1999. Developing country effects of Kyoto-type emissio 1s restrictions. MIT Joint Program on the Science and Policy of Global Change, Report No. 53, Cambridge, MA.

Barker, T. and Junankar, S., Pollitt, H., and Summerton, P. (2007). *Carbon leakage from unilateral environmental tax reforms in Europe, 1995-2005'*, Energy Policy, 35, 2007, 6281–6292.

Barnett, J., S. Dessai, et al. (2004) *Will OPEC lose from the Kyoto Protocol?* Energy Policy 32 (2004) 2077-2088.

Baron, R. and ECON-Energy (1997) *Economic/fiscal instruments: competitiveness issues related to carbon/energy taxation* Policies and Measures for Common Action Working Paper 14. A. I. E. G. o. t. UNFCCC. Paris, OECD/IEA.

Baron, R, J Reinaud, M. Genasci and C. Philibert (2007) Sectoral Approaches to Greenhouse Gas Mitigation: *Exploring Issues for Heavy Industry.* Available from http://www.iea.org/textbase/papers/2007/Sectoral_Approach_Info_WEB.pdf

Baron, Richard and Jane Ellis (2006). Sectoral Crediting Mechanisms for Greenhouse Gas Mitigation:Institutional and Operational Issues. COM/ENV/EPOC/IEA/SLT(2006)4. OECD/IEA information paper.

BERR (2006) Detailed UK Energy Statistics (DUKES). Available from http://www.dti.gov.uk/energy/statistics/source/electricity/page18527.html.

BERR (2007) Energy Statistics Publication, UK energy Consumption, Energy consumption tables: industrial energy consumption tables, **URN No:** 07/455. Available from:
<http://www.dti.gov.uk/energy/statistics/publications/ecuk/industrial/page18171.html>

Betz, R., K. Rogge and J. Schleich (2006) EU emissions trading: an early analysis of national allocation plans for 2008–2012. Climate Policy 6(4) 361-410.

Biermann, F. and R. Brohm (2003) *Implementing the Kyoto Protocol without the United States: The Strategic Role of Energy Tax Adjustments at the Border*, Working Paper of the
Global Governance Project.

Bishop, J. (2004) *Substitution Elasticities and the Costs of Protectionism: Evidence from the 2002 U.S. Steel Tariffs* Working paper, University of Minnesota.

Blok, K., de Jager, D., Hendriks, C., Kouvaritakis, N., Mantzos, L. (2001) *Economic evaluation of sectoral emission reduction objectives for climate change – Comparison of top-down and bottom-up analysis of emission reduction opportunities for CO2 in the European Union* Ecofys, AEA and NTUA, Report for European Commission, DG Environment.

Bodansky, D. (2007). International Sectoral Agreements in a Post-2012 Framework. <http://www.pewclimate.org/docUploads/International%20Sectoral%20Aggreements%20in%20a%20Post-2012%20Climate%20Framework.pdf>.

Bosi, M. and J. Ellis (2005) Exploring *Options for "Sectoral Crediting Mechanisms"* OECD Environment Directorate, IEA. Paris, OECD/IEA.

BP Statistics (2007). Available from:
<http://www.bp.com/productlanding.do?categoryId=6848&contentId=7033471>

BT [Business Today] (2007) *Steely Resolve* http://www.businesstodayegypt.com.

Burniaux, J.-M., Oliveira-Martins, J., 2000, Carbon Emission Leakages, A General Equilibrium View, Working Papers No. 242, Economics Department, Organisation for Economic Co-operation and Development, Paris.

Burniaux, J.-M., Oliveira-Martins, J., 2011, 'Carbon Leakage: a general equilibrium view', Economic Theory 9 (January), DOI: 10.1007/s00199-010-0598-y.

Burniaux J. -M., & Truong, T. P. (2002). *GTAP-E: An energy-environmental version of the GTAP Model*. GTAP Technical Paper n.16 (www.gtap.org).

Burtraw, D., K. Palmer, et al (2001) *The Effect of Allowance Allocation on the Cost of Carbon Emissions Trading* RFF Discussion Papers 01-30.

Burtraw, Dallas, Karen Palmer, Ranjit Bharvirkar, and Anthony Paul. 2002. The Effect on Asset Values of the Allocation of Carbon Dioxide Emission Allowances. RFF Discussion Paper 02-15. Washington, DC: Resources for the Future, March.

Burtraw, D., K. Palmer and D. Kahn (2005) Allocation of CO2 Emissions Allowances in the Regional Greenhouse Gas Cap-and-Trade Program. *RFF Discussion Papers*(05-25).

Carbon Trust, The (2004). *The European Emissions Trading Scheme: Implications for Inducstrial Competitiveness*, The Carbon Trust.

Carbon Trust, The (2005). *The UK climate change programme: potential evolution for the business and public sector*, The Carbon Trust.

CE Delft, (2010) Sander de Bruyn, Agnieszka Markowska,Dagmar Nelissen Will the energy intensive industry profit from the EU ETS under Phase 3? Delft : CE Delft, 2010

Cembureau (1999) Environmental *Benefits of Using Alternative Fuels in Cement Production: A Life Cycle Approach* Brussels, Cembureau.

Cembureau (2000) *Best Available Techniques for the Cement Industry*, Cembureau

Cembureau (2006) *Climate Change – CO2 Emissions Trading: Points of Convergence within the Cement Industry*. Position paper, available at: http://www.cembureau.be/Cem_warehouse/POINTS%20OF%20CONVERGENCE%20WITHIN%20THE%20CEMENT%20INDUSTRY.PDF

CE Delft, (2010) Sander de Bruyn, Agnieszka Markowska,Dagmar Nelissen Will the energy intensive industry profit from the EU ETS under Phase 3? Delft : CE Delft, 2010

CEPI (2003) *The European Paper Industry's Views and Action Plan on Climate Change*. C.O.E. P. Industries.

CEPI (Confederation of European Paper Industries) (2002) *Annual Statistics 2002 European Pulp and Paper Industry*, CEPI

CEPI (Confederation of European Paper Industries) (2005) Annual *Statistics 2005 European Pulp and Paper Industry*, CEPI.

Chernyavs'ka L, and Gulli F (2008) Marginal CO2 pass-through under imperfect competition in power markets. Ecol Econ 68(1–2):408–421

Citigroup (2008): Carbon Pollution Reduction Scheme - Impacts reviewed for ASX100 Companies and More. Thematic Investing Focus, Australia, 22 July 2008.

Cole, M.A., R.J.R. Elliott, and K. Shimamoto, (2005).Why the grass is not always greener: the competing effects of environmental regulations and factor intensities on US specialization. Ecological Economics 2005, 54: p. 95--109.

Commission, E. (2001) *Intergrated Pollution Prevention and Control. Reference Document on Best Available Techniques in the Pulp and Paper Industry*. Commission. Brussels.

De Beer, J., D. Phylipsen, et al (2001) *Economic Evaluation of Carbon Dioxide and Nitrous Oxide Emission Reductions in Industry in the EU*. Final Report. Ecofys, Utrecht. accessible at: http://europa. eu. int/comm/environment/enveco/climate_change/sectoral.

Datastream (2007) Available from http://www.datastream.net/English/Default.aspx.

DEFRA (2007) Compliance and Results, Analysis of the UK Results. Accessed from <http://www.defra.gov.uk/environment/climatechange/trading/eu/operators/compliance.htm>

Demailly, D., Quirion, P. (2007a). *Changing the allocation rules for EU greenhouse gas allowances: impact on competitiveness, revenue distribution and economic efficiency*. Conference of the European Association of Environmental and Resource Economists, Thessalonique, 27-30 June 2007.

Demailly, D., Quirion, P. (2007b) *Allocation of CO_2 allowances and competitiveness: A case study on the European iron and steel industry*. Forthcoming in Energy Economics.

Demailly, D., Quirion, P. (2006a). *CO_2 abatement, competitiveness and leakage in the European cement industry under the EU ETS: grandfathering versus output-based alloc*ation.
Climate Policy 6 (1), 93-113.

Demailly, D. and P. Quirion (2006b). *Leakage from climate policies and border tax adjustment: Lessons from a geographic model of the cement industry*, CIRED Working Paper.

Demailly, D. and Quirion, P. (2005) *The competitiveness impacts of CO_2 emissions reductions in the cement sector*. Report for the OECD, available at: http://appli1.oecd.org/olis/2004doc.nsf/linkto/com-env-epoc-ctpa-cfa(2004)68- final

Dong, Y. & Whalley, J. (2010). Carbon, trade policy, and carbon free trade areas. The World Economy, 33(9), 1073–1094.

Ederington J. and Minier J., (2003). Is environmental policy a secondary trade barrier? An empirical analysis, *Canadian Journal of Economics* **36** (2003), pp. 137–154.

Ellis J., Baron R. (2005): Sectoral Crediting Mechanisms: An Initial Assessment of Electricity and Aluminium, OECD/IEA Information Paper, November, http://www.oecd.org/env/cc

Entec and NERA (2005) *EU Emissions Trading Scheme Benchmark Research for Phase 2*. http://www.berr.gov.uk/files/file27734.pdf

ETUC [European Trade Union Confederation] (2007) *Study on climate change and employment*. Commissioned by the European Commission, DG environment.

Ekins, P. (2007). WP4: The effects of ETR on competitiveness: modelling with E3ME. In Publishable Final Report to the European Commission, DG Research and DG Taxation and Customs Union(Summary report). Available at <http://www2.dmu.dk/cometr/COMETR_Summary_Report.pdf>

European Commission (2006) Community Independent Transaction Log. Available at <http://ec.europa.eu/environment/ets/>

European Commission (2007). Second Report of the High Level Group on Competitiveness, Energy and the Environment Contributing to an integrated approach on competitiveness, energy and environment policies <http://ec.europa.eu/enterprise/environment/hlg/doc_06/second_report_30_10_06.pdf >

European Parliament and the Council of the EU, 2009, 'Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emis- sion allowance trading scheme of the Community', Official Journal of the European Union I140, 63–87.

Eurofer (2005*) The greenhouse gas challenge: how the EU steel industry competitiveness could be affected?* Position paper, available at http://www.eurofer.org/positionpaper/compet/OECD12-01-2005doc.pdf

Eurostat (2007a) National Accounts, NACE Division 15: Manufacture of food products and beverages - Output indicators. Available from http://epp.eurostat.ec.europa.eu

Eurostat (2007b) CN8 database. Available from: http://fd.comext.eurostat.cec.eu.int/xtweb/setupdimselection.do

Financial Times (2007) INTERNATIONAL NEWS: China averts EU trade dispute with short-term coal exports deal, By Daniel Dombey in Brussels, Published: May 31, 2004 Available from: http://search.ft.com/ftArticle?sortBy=gadatearticle&queryText=chinese+coke+&y=0 &aje=true&x=0&id=040531000841&ct=0&page=7

Fischer, C. & Fox, A. K. (2009). Comparing policies to combat emissions leakage: Border carbon adjustments versus rebates. Discussion Paper 09-02, Resources for the

Future, Washington. Available from: http://www.rff.org/rff/documents/RFF-DP-09-02.pdf.

FONDDRI [Fondation pour le Développement Durable et les Relations Internationales] (2007) *Scénarios « REF » et « F4 mimétique », Résultats des simulations harmonisées POLES / IMACLIM-R*. Etude « Scénarios sous Contrainte Carbone », Avril.

Gallaway, M., McDaniel, C. (2003) *Short-run and long-run industry- level estimates of U.S. Armington elasticities*. North American Journal of Economics and Finance 14, 49–68

Gaulier G., Lahrèche-Révil A., Méjean I. (2006) *Exchange-Rate Pass-Trough at the Product Level*. CEPII Working paper 2006 (2).

Gerald, J.F., Scott, S. (2007) *The market structure and sector vulnerability*. Working paper for the COMETR Research Project. http://www2.dmu.dk/cometr/

Gerlagh and Kuik, 2006 Gerlagh, R., Kuik, O., 2006. Carbon Leakage with international technology spillovers. Working Paper draft, November.

Gerlagh, R., Kuik, O., 2007, Carbon Leakage With International Technology Spillovers, Working Paper No. 33.2007, Fondazione Eni Enrico Mattei (FEEM), Venice.

Gerlagh, R. & Mathys, N. A. (2011). Energy abundance, trade and industry location. Nota di Lavoro 003.2011, Fondazione Eni Enrico Mattei, Milan. Available from: http://www.feem.it/ userfiles/attach/20111171430134NDL2011-003.pdf.

Graichen, V., Schumacher, K., Matthes, F., Mohr, L., Duscha, V., Schleich, J., & Diek- mann, J. (2008). Impacts of the EU Emissions Trading Scheme on the industrial competitiveness in Germany. Technical Report 3707 41 501, Environmental Research of the Federal Ministry of the Environment, Na- ture Conservation and Nuclear Safety, Berlin, Germany.

Gritsevskyi, A. and Nakicenovic (2000) *Modelling uncertainty of induced technological change.* Energy Policy 28, 907-921.

Groenenberg, H., D. Phylipsen, et al (2001) *Differentiating commitments world wide: global differentiation of GHG emissions reductions based on the Triptych approach - a preliminary assessment*. Energy Policy 29: 1007-1030.

Gros, D. & Egenhofer, C. (2011). The case for taxing carbon at the border. Climate Policy, 11(5), 1262–1268.

Grubb, M., C. Hope, et al (2002) *Climatic Implications of the Kyoto Protocol: The Contribution of International Spillover*. Climatic Change 54, 11-28.

Grubb, M. & Neuhoff, K. (2006). Allocation and competitiveness in the EU emissions trading scheme: policy overview. Climate Policy, 6(1), 7–30. Available from: http://www. tandfonline.com/doi/abs/10.1080/14693062.2006.9685586.

Grubler, A., N. Nakicenovic, et al (1999) *Dynamics of energy technologies and global change*. Energy Policy 27(5): 247-280(34).

Gundimeda, H. (2004). *How 'sustainable' is the 'sustainable development objective' of CDM in developing countries like India*" Forest Policy and Economics 6: 329-343.

Hepburn, Grubb, Neuhoff, Matthes and Tse (2006). *Auctioning of EU ETS Phase II allowances: how and why?* Climate Policy 6(1). pp137-160.

Hertel T. W. (1997) *Global Trade Analysis Using the GTAP Model.* New York: Cambridge University Press.

Hidalgo, I., L. Szabo, et al. (2005). *Technological prospects and CO2 emission trading analyses in the iron and steel industry: A global model.* Energy 30: 583-610.

Holcim (2006) *Resource Utilization and CO2*, available at: http://www.holcim.com/CORP/EN/oid/47529/module/gnm50/jsp/templates/editorial/editorial.html Volume, DOI:

Holzer, K. (2010). Proposals on carbon-related border adjustments: Prospects for WTO compli- ance. The Carbon & Climate Law Review (CCLR), 2010(1), 51–64.

Hourcade et al. (2007): Differentiation and dynamics of EU ETS industrial competitiveness impacts. Climate Strategies Report, Climate Strategies 2007

House of Commons Select Committee (2005). *Memorandum from Corus. Science and Technology - Memoranda*. H.O. Commons.

Humphreys, K., M. M., et al. (2002). *Toward a Sustainable Cement Industry: Substudy 8: Climate Change.* W. B. C. f. S. Development. Battelle.

IEA [International Energy Agency], (2007). *Sectoral Approaches to GHG mitigation. Exploring issues for heavy industry*. Forthcoming.

IISI [International Iron and Steel Institute] (2007) *World Steel in Figures*. http://www.worldsteel.org

IPCC (2001). *IPCC Third Assessment Report* 2001.

IPCC, Climate Change (2007).: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. O.R.D. B. Metz, P.R. Bosch, R. Dave, L.A. Meyer. 2007, Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Ismer, R. and K. Neuhoff (2004). *Border tax adjustments: a feasible way to address nonparticipation in emission trading*. Cambridge working papers in economics ; CWPE 0409. Cambridge, Department of Applied Economics.

Johnston, A. (2006). *Free allocation of allowances under the EU Emissions Trading System – legal issues*. Climate Policy 6(1).

Juergens, I., Barreiro-Hurlé, J., & Vasa, A. (2013). Identifying carbon leakage sectors in the EU ETS and implications of results. Climate Policy, 13(1), 89–109. Available from: http://www. tandfonline.com/doi/abs/10.1080/14693062.2011.649590.

Kemfert, C. (2002). *An Integrated Assessment Model of Economy-Energy-Climate – The Model Wiagem*. Integrated Assessment 3(4): 281-298.

Kemppi, H., J. Honkatukia, et al. (2002). *EU-laajuisen päästökaupan toteuttamisvaihtoehdot ja vaikutukset Suomen kannalta*. V. G. I. f. E. Research.

Kettner C., Köppl A., Schleicher S., Thenius G. (2007). *Stringency and Distribution in the EU Emissions Trading Scheme – The 2005 Evidence*. WIFO, Vienna, February

Knetter, M., (1993). *International Comparisons of Pricing-to-Market Behavior*. The American Economic Review, Vol. 83, No. 3, pp. 473-486.

Korppoo, A. (unpublished). *Drivers and barriers to modernisation of Russian pulp and paper industry*. Centre for Environmental Policy, Faculty of Natural Sciences. London, Imperial College London. Phd.

Krugman, P. (1994). *Competitiveness: a dangerous obsession*. Foreign Affarirs 73(2).

Kuik, O. and R. Gerlagh (2003). *Trade Liberalization and carbon Leakage*. The Energy Journal 24(3): 97-120.

Kylä-Harakka-Ruonala (2004). *Teollisuus ja ilmastopolitiikan eri vaiheet*. T. energiankatsaus

Levinson, A., Taylor, M.S., 2004. Trade and the Environment: Unmasking the Pollution Haven Hypothesis. Mimeo, University of Georgetown.

Lise, W., Sijm, J. and B.F. Hobbs (2010), The Impact of the EU ETS on Prices, Profits and Emissions in the Power Sector: Simulation Results with the COMPETES EU20 Model, *Environmental and Resource Economics* 47, 23–44.

Lockwood, B. & Whalley, J. (2010). Carbon-motivated border tax adjustments: Old wine in green bottles? World Economy, 33(6), 810–819.

Manne, A.S., Mathiesen, L. (1994). *The Impact of Unilateral OECD Carbon Taxes on the Location of Aluminium Smelting*. International Journal of Global Energy Issues, 6, 52-61.

Manne A S and Richels R G. 1998 **On Stabilizing CO2 Concentrations -- Cost-Effective Emission Reduction Strategies**. *Environmental Modeling and Assessment* **2**: 251-265.

Martin, N., E. Worrell, et al. (1999). *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Cement Industry*. Berkeley, Lawrence Berkeley Natl. Lab.

Martin, R., Mirabelle Muûls and Ulrich J. Wagner. 2010. "Still time to reclaim the European Union Emissions Trading System for the European tax payer", Policy Brief, Centre for Economic Performance, London School of Economics

Martin, R., Muuls, M, and Wagner, U., (2011) Climate Change, Investment and Carbon Markets and Prices – Evidence from Manager Interviews, *Climate Policy Initiative and Climate Strategies*

Mathiesen and Maestad (2004) Climate Policy and the Steel Industry: achieving global emissions reductions by an incomplete climate agreement. The Energy Journal 25, 91-114.

Maxwell, D 2011. *Hot Air: The carbon price floor in the UK* London: IPPR; McCabe, J 2011. "£7bn windfall for UK utilities from carbon price floor" *Environmental Finance*, 28 June.

McKibbin et al. (1999). McKibbin, W.J., Ross, M., Shackleton, R., Wilcoxen, P.J., 1999. Emissions Trading, Capital Flows and the Kyoto Protocol. The Energy Journal (Special Issue on "The Costs of the Kyoto Protocol: A Multi-model Evaluation"), 287–334.

McKinsey & Ecofys (2006). *EU ETS review. Report on International Competitiveness*. European Commission, DG environment.

McKinsey (2007). *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*, Industrial Sector.

Monjon, S. & Quirion, P. (2011). A border adjustment for the EU ETS: Reconciling WTO rules and capacity to tackle carbon leakage. Climate Policy, 11(5), 1212–1225.

Morgenstern, R. D., M. Ho, J.S. Shih, and X. Zhang (2006). The Near Term Impacts of Carbon Mitigation Policies on Manufacturing Industries. *Energy Policy*. November 2006, Vol. 32, No. 16 , pp 1825-1841.

Neuhoff, K., Keats, K., Sato, M. (2006). *Allocation, incentives and distortion: the impact of EU ETS emission allowance allocations to the electricity sector*. Climate Policy 6(1).

Neuhoff, K. (2008). Tackling Carbon. Available at http://www.eprg.group.cam.ac.uk/wp-content/uploads/2009/03/tackling-carbon_final_3009082.pdf.

Neumayer, 2001 E. Neumayer, Greening trade and investment: environmental protection without protectionism, Earthscan, London (2001).

New Scientist (2002) "Green Foundations". Article. 13 July 2002. Magazine issue 2351.

Oberndofer et al. (2006) *The Impacts of the European Emissions Trading Scheme on Competitiveness and Employment in Europe - A Literature Review* (A report commissioned by World Wide Fund for Nature - WWF)

Oberndorfer, U., Alexeeva-Talebi, V. and A. Löschel (2010), Understanding the Competitiveness Implications of Future Phases of EU ETS on the Industrial Sectors, *ZEW Discussion Paper* 10-044, ZEW, Mannheim.

Oikonomou, v. M Patel, E Worrell (2006) **Climate** Change: Bucket or Drainer, Energy Policy, VoL. 34 (18), pp 3656-3668.

Olson, Mancur. 1965. The Logic of Collective Action. Cambridge: Cambridge University Press.

Oxera (2004). *CO2 emissions trading: How will it affect UK industry*? Report prepared for the Carbon Trust. Oxford.

Oxera (2005). *The Economic Impact of Carbon Policies on UK Companies. Report prepared for The Carbon Trust*. Oxford.

Paltsev. 2001. *The Kyoto Protocol: Regional and Sectoral Contributions to the Carbon Leakage* THE ENERGY JOURNAL, Vol. 22, No. 4.

Palmer, K., Burtraw, D., Kahn, D. (2006). *Simple Rules for Targeting CO2 Allowance Allocations to Compensate Firms*, Climate Policy, 6 (5).

Pauwelyn, J. (2007). US federal climate policy and competitiveness concerns: The limits and options of international trade law. Working Paper NI WP 07-02, Nicholas Institute for Environmental Policy Solutions, Duke University. Available from: http://goo.gl/XO5wc.

People's Daily Online (2005) "China will control coke exports even after canceling coke export quota, official of SDRC" UPDATED: 09:52, May 16, 2005. Available from < http://english.peopledaily.com.cn/200505/16/eng20050516_185227.html>.

Pershing, J. and F. Tudela (2004). *A Long-Term Target: Framing the Climate Effort. Beyond Kyoto: Advancing the international effort against climate change*, PEW Center on Global Climate Change.

Peterson, E. and J. Schleich (2007) Economic and Environmental Effects of Border Tax Adjustments <http://www.isi.fraunhofer.de/e/working%20papers/BTA_Peterson&Schleich_final.pdf>

Phylipsen, G. J. M., K. Blok, et al. (1998). *Handbook on International Comparisons of Energy Efficiency in the Manufacturing Industry*, Department of Science, Technology and Society. Utrecht University.

Porter, M. E (1991). *Towards a Dynamic Theory of Strategy*, Strategic Management Journal, (12) pp. 95-117.

Point Carbon (2008) EU ETS Phase II – The potential and scale of windfall profits in the power sector: A report for WWF By Point Carbon Advisory Services.

Quirion, P. (2003). Allocation of CO2 allowances and competitiveness: A case study of the European iron and steel industry. CORE Environmental Seminar, Louvain-la-neuve.

Reinaud, J. (2005a) *Industrial Competitiveness under the European Union Emission Trading Scheme*, IEA Information Paper.

Reinaud, J. (2005b) *The European Refining Industry under the EU Emission trading scheme,* IEA Information paper.

Reinaud, J. (2008) Issues Behind Competitiveness and Carbon Leakage: Focus on Heavy Industry. EA Information Paper. Paris, France: International Energy, 2008

Romalis J. (2004). *NAFTA's and CUSFTA's impact on North American trade*, Graduate School of Business, University of Chicago, Working Paper

Rosendahl, K. (2004). *Cost-effective environmental policy: implications of induced technological change*, Journal of Environmental Economics and Management 48(3): 1099-1121.

Saddler, H., F. Muller, C. Cuevas (2006). *Competitiveness and Carbon Pricing Border adjustments for greenhouse policie*", The Australia Institute Discussion Paper 86.

Sandbag (2011) Carbon Fat Cats 2011: The companies profiting from the EU Emissions Trading Scheme. Sandbag report, June 2011.

Schmidt, J., N. Helm, et al. (2006). *Sector-based Approach to the Post-2012 Climate Change Policy Architecture,* Centre for Clean Air Policy, FAD Working Papers.

Shiells, C.R., Reinert, K.A. (1993). Armington *models and terms-of-trade effects : some econometric evidence for North America*. The Canadian Journal of economics, vol26, N°2, May, 1993, pp299-316.

Siitonen, S. and P. Ahtila (2002). *Possibilities of Reducing CO2 Emissions in the Finnish Forest Industry*. F. F. I. Federation. Helsinki.

Sijm, J. P. M., S. J. A. Bakker, et al. (2005). *CO2 Price Dynamics: The implications of EU emissions trading for the price of electricity*. Petten, Energy Resaerch Centre of the Netherlands.

Sijm, J. P. M., Y. Chen, et al. (2006). *CO2 Price Dynamics: A Follow-up Analysis of the Implications of EU Emissions Trading for the Price of Electricity*. Petten, The Netherlands, Energy Research Council of The Netherlands.

Sijm, J. P. M., O. J. Kuik, et al. (2004). *Spillovers of Climate Policy An assessment of the incidence of carbon leakage and induced technological change due to CO2 abatement measures*. Netherlands Research Programme on Climate Change Scientific Assessment and Policy Analysis, ECN.

Sijm, J. P. M., K. Neuhoff, et al. (2006). *CO$_2$ cost pass through and windfall profits in the power sector*. Climate Policy 6(1), 49-72.

Smale, R., Hartley, M., Hepburn, C., Ward, J., Grubb, M. (2006). *The impact of CO$_2$ emissions trading on firm profits and market prices*. Climate Policy 6(1), 31–48.

Statistisches Bundesamt (2007). German Industry Statistics. Available from <http://www.destatis.de/jetspeed/portal/cms/>

Stennek, J., Verboven, F. (2001). *Merger Control and Enterprise Competitiveness: Empirical Analysis and Policy Recommendations*. European Economy, European Commission Directorate-General for Economic and Financial Affairs, No. 5, pp. 129-194.

Swedish Forest Industries Federation (2005). *Pulp and Paper Statistics*. Stockholm.

Szabo, L., Hidalgo, I., Ciscar, J.C., Soria, A., Russ, P., (2003). Energy Consumption and CO$_2$ Emissions from the World Cement Industry. DG JRC-IPTS Report, Technical Report Series, EUR 20769 EN.

Szabo, L., Hidalgo, I., Ciscar, J.C, Soria, A. (2006). *CO$_2$ emission trading within the UE and Annex B countries: the cement industry case*. Energy Policy , 34(1), pp. 72-87

Tamiotti, L. (2011). The legal interface between carbon border measures and trade rules. Climate Policy, 11(5), 1202–1211.

Tanaka, K., R. Matsuhashi, et al. (2006). *CO$_2$ Reduction Potential by Energy Efficient Technology in Energy Intensive Industry*, Retrieved 17 October 2006, from http://eneken.ieej.or.jp/en/data/pdf/324.pdf.

Ten Kate, A., Niels, G. (2005). *To what extent are cost savings passed on to consumers? An oligopoly approach*. European Journal of Law and Economics 20, 323–337.

Thomas, C. D., A. Cameron, et al. (2004*). Extinction risk from climate change*. Nature 427: 145-148.

USA EPA (2004). Unit Conversion, Emissions Factors, and Other Reference Data. Available from http://www.epa.gov/appdstar/pdf/brochure.pdf.

UNFCCC (2006) National emissions reported to the UNFCCC, available from < http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=991>.

UK Office of National Statistics (2004). Trade in Goods Industry BOP MQ10 <http://www.statistics.gov.uk/statbase/tsdtables1.asp?vlnk=mq10>

UK Office of National Statistics (2005). Input-Output: UK National Accounts 2004. Available   from <http://www.statistics.gov.uk/about/methodology_by_theme/inputoutput/>.

UK Office of National Statistics (2006) Annual Business Inquiry Reports. Available from: < http://www.statistics.gov.uk/abi/>

UK Steel (2004) The Westminster Steel Bullitin, Issue 5, July 2004. Available from: http://www.uksteel.org.uk/appg/wsb5.pdf

US Trade Representative (2004) 2004 Report to Congress on China's WTO Compliance. Available from < http://www.ustr.gov/assets/Document_Library/Reports_Publications/2004/asset_uplo ad_file281_6986.pdf>.

Vieillefosse, A. (2007). *Des Accords Sectoriels dans les Engagements Post-2012? Série Etudes 07-E02*, Ministère de l'Ecologie et du Développement Durable, direction des études économiques et de l'évaluation environnementale.

Walker N. (2006). *Concrete Evidence? An Empirical Approach to Quantify the Impact of EU Emissions Trading on Cement Industry Competitiveness*. School of Geography, Planning and Environmental Policy, University College Dublin. Working Paper.

Watson, C., Newman, J., Upton, R.H.T., Hackmann, P. (2005). *Can Transnational Agreements Help Reduce GHG Emissions?* Round Table on Sustainable Development, OECD, Paris.

WBCSD [World Business Council For Sustainable Development] (2002). *Toward a Sustainable Cement Industry – Climate Chang*e. Report Commissioned to Batelle.

Wood Mackenzie (2007) Review of UK Oil Refining Capacity for Department of Trade and Industry. Available from: <http://www.berr.gov.uk/files/file39390.pdf>.

World Resource Institute (2007). Climate Analysis Indicator Tools, version 4.0. Accessed from <http://cait.wri.org/>.

World Resource Institute (2008) *Leveling The Carbon Playing Field: International Competition and U.S. Climate Policy Design.* Available from < http://www.wri.org/publication/leveling-the-carbon-playing-field>

Worrell, E., L. Price, et al. (2001). *Energy efficiency and carbon dioxide emissions reduction opportunities in the US iron and steel sector,* Energy 26(5): 513-536.

Worrell, E., L. Price, et al. (2001). *Carbon Dioxide Emissions From The Global Cement Industry*, Annual Review of Energy and the Environment 26: 303-329.

Zachmann, G. and C. von Hirschhausen (2008), First Evidence of Asymmetric Cost Pass- Through of EU Emissions Allowances: Examining Wholesale Electricity Prices in Germany, *Economics Letters* 99(3), 465–469.

Zhang, X. and A. Baranzini (2004). *What do we know about carbon taxes? An inquiry into their impacts on competitiveness and distribution of income*, Energy Policy 32 (2004): 507-518.

Zhang, Z. (2010). The US proposed carbon tariffs, WTO scrutiny and China's responses. International Economics and Economic Policy, 7(2), 203–225.

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[i] Emissions leakage is a secondary effect of carbon pricing, and a measure of the effectiveness of a unilateral carbon price. It is usually expressed in percentage terms, for example for EU's unilateral action, dividing the increased emissions outside the EU and the decrease in emissions within the EU (see IPCC, 2007).

[ii] The world's largest CO_2 market, covering around 40-45% of EU emissions.

[ii]. Directly subject to the CO_2 price are some 12 000 installations covered by the scheme, usually belonging to the power iron and steel, cement, pulp& paper, glass, chemicals & refining industries.

[iii] Gerlagh and Kuik (2006) survey the estimated leakage rates in the CGE literature and conducts a meta analysis to test the effect and sensitivity of various model assumptions on the results.

[iv] These are based principally on the economic theory from the literature on exchange rate pass-through (e.g. Knetter, 1993; Goldberg and Knetter, 1997; Stahn, 2006; and Gaulier et al., 2008), based broadly on the simple mark-up model of imperfect international competition (Dixit and Stiglitz, 1977, Dornbusch, 1987).

[v] In theory, a profit maximising firm adds the costs of CO_2 emission allowances to its other marginal (variable) costs when making (short-term) production or trading decisions, hence pass on the cost of CO_2 allowances onto product prices, even if allowances are allocated to them for fee (Burtraw et al. 2002 and 2005; Reinaud 2005). This is because as long as allowances can be sold on the market for a positive price, using allowances to cover its emissions carries an opportunity cost. Transmitting the CO_2 price signal throughout the economy is an important and desired effect, necessary to achieve emissions reductions via the demand side substitution effect. The CO_2 pass through has been empirically established in the electricity sector, where high carbon impact, hourly pricing decisions and wholesale markets with public information on spot and forward prices allowed for robust assessments despite the short time frame of less than two years of high carbon prices (Sijm, Neuhoff et al 2006). Other sectors might have more difficulty to pass through opportunity costs because of exposure to international competition and potential loss of market share in reaction to higher prices.. However, even if such cost pass through occurs, it is more difficult to analyse when (i) the carbon component of prices is small and (ii) pricing decisions are confidential and available perhaps only on annual basis.

[vi] Output-based allocation (whereby firms are allocated allowances according to proportion of production) in theory reduces product prices and increases production relative to the grandfathering approach. This approach is frequently advocated by producers of CO_2 intensive products because it would reduce the cost increase of CO_2 intensive products and delays substitution effects towards less CO_2 intensive alternatives (Eurofer 2005; Cembureau 2006). Indeed, studies using sector models to quantify impacts (Burtraw, Palmer et al. 2001; Quirion 2003; Demailly and Quirion 2006b) estimate that compared with allocation by grandfathering or auctioning, the impact on leakage of production (fall in domestic production and rise in imports) to non-EU regions is less under output based allocation, and profits are also less. However, CO_2 abatement is also less under this approach because prices do not reflect the CO_2 externality and therefore substitution effects towards less CO_2 intensive (intermediary) products is reduced.

[vii] Both government-lead and voluntary global sectoral agreements covering sectors with high international exposure, is discussed widely in the literature (Groenenberg, Phylipsen et al. 2001; Thomas, Cameron et al. 2004; Bosi and Ellis 2005; Watson, Newman et al. 2005; Schmidt, Helm et al. 2006; Baron and Ellis, 2006; Bodansky 2007). They are advocated by sector associations – for example, International Iron and Steel Institute (IISI), International Aluminium Institute (IAI), Cement Sustainability Initiative (WBCSD). Also the International Petroleum Industry have put forward proposals as means to support technological improvements and raise energy efficiency sector-wide. However, their role in providing sufficient CO_2 price signals necessary for investment decisions is uncertain. Sectoral crediting mechanisms are also explored in the literature e.g. OECD/IEA (Baron and Ellis 2006; Bosi and Ellis 2005) and CCAP (Schmidt and Helme 2005). Here, baseline levels/rates and certified emissions are defined as a sector and emissions reductions are linked to the ETS. Main issues include baseline data and data collection and governance issues (Baron and Ellis 2006).

[viii] The use of border adjustments is explored in the literature as an instrument to address leakage for specific CO_2 intensive products traded widely (Biermann and Brohm 2003; Hoerner 1998; Ismer and Neuhoff 2004; Saddler and Muller et al. 2006; Demailly and Quirion 2006b). It has the advantage that there is no trade-off between addressing the leakage problem and maintaining functioning of efficient CO_2 price signals domestically. While economically desirable and from a WTO most likely viable, the challenge for the implementation are political sensitivities associated with trade related measures. A joint international approach is therefore desirable to ensure alignment with the wider efforts of cooperation on climate policy. Discussions are emerging in Europe, US and Australia (Sadler et al, 2006; CEC, 2007; Peterson, and Schleich, 2007).

[ix] Standard Industrial Classification is the standard reporting format for industry data. Data is readily available at high resolution disaggregation and can thus enable detailed evidence-based cross-sectoral analysis. The number of manufacturing classes

increase from 23 at 2-digit resolution, to 101 at 3-digit resolution and 239 at 4-digit resolution. SIC definitions are end-product driven, however, and often do not capture distinctions between manufacturing processes and carbon intensities, for example that between BOF and EAF processes in steel. For sectors where differentiation between processes is key to competitiveness and leakage impacts, explicitly looking at examination of the production or value chain is required. In addition, some sectors are covered under different Classification (SIC) codes (e.g. Mineral Wool is defined under 26.14 for Glass Wool and 26.82 for Rock Wool).

x This is estimated by BERR based on annual company reports of fuel consumption to the Annual Business Inquiry collected by the Office for National Statistics, using average price data and then scaled to the aggregate volumes reported for12-sector figures published in Detailed UK Energy Statistics(DUKES) by BERR (2006).

xi The UK ONS states that "Gross value added (GVA) represents the amount that individual businesses, industries or sectors contribute to the economy. Broadly, this is measured by the income generated by the business, industry or sector less their intermediate consumption of goods and services used up in order to produce their output. GVA consists of labour costs (e.g. wages and salaries) and an operating surplus (or loss). The latter is a good approximation to profits, and out of which the cost of capital investment, financial charges and dividends to shareholders are met." (http://www.statistics.gov.uk/abi/variable_info.asp)

xii For some subsectors, trade data was verified during the industry consultation period.

xiii Here, GVA and GDP are used interchangeably. According to UK Office of National Statistics, "GVA is used in the estimation of Gross Domestic Product (GDP). GDP is a key indicator of the state of the whole economy. In the UK, three theoretical approaches are used to estimate GDP: 'production', 'income' and 'expenditure'. When using the production or income approaches, the contribution to the economy of each industry or sector is measured using GVA.

xiv Under the Commission's assessment, trade intensity for sector i is defined as the sum of the value of EU-27 exports to outside the EU-27 and the value of imports from outside the EU-27 for sector i, divided by the sum of total annual turnover of sector i plus the value of imports from outside the EU-27 (see Jürgens et al 2013). As shown in Equation 4, the definition used in this paper, as it considers both the EU imports and Non-EU imports in the denominator.