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Carbon Leakage in the Primary Aluminium Sector: What evidence after 6 ½ years of the EU ETS?

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Abstract

This paper provides an econometric analysis of the evidence of carbon leakage from the European primary aluminium industry during the first 6 ½ years of the EU ETS. The findings suggest that while rising electricity prices have played a critical role in reducing the competitiveness of EU primary aluminium smelting in recent years, no evidence of carbon leakage can be detected so far. Other factors, including rising primary energy prices and changes in EU competition law regarding long term contracts, appear to be more important factors explaining the rise in net imports of primary aluminium and the gradual closure of a number of European primary smelters during the past 6 ½ years. Our results suggest that the carbon leakage debate in this sector may therefore be better seen in terms of not accelerating the decline of the industry in Europe, rather than preventing it, and that any state-aid to the industry to prevent carbon leakage should therefore be applied accordingly.

CDC Climat Research is the research department of CDC Climat, a subsidiary of the Caisse des Dépôts dedicated to the fight against climate change. CDC Climat Research provides public research on the economics of climate change.

Contents

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1 - Introduction

Since the European Union Emissions Trading Scheme (EU ETS) began pricing CO_2 emissions within the European Community in 2005, the risk of industries moving production and emissions offshore to avoid the regulatory cost of compliance has been a central preoccupation of its architects. Thus far, EU policy makers have sought to use state aid measures, such as the allocation of free emissions allowances, to prevent such "carbon leakage" from occurring. For instance, in Phases I & II (2005-07 & 2008-12) of the EU ETS, these concerns led to the allocation free of charge of a large share of the required emissions allowances of industrial manufacturing participants in the scheme. Meanwhile, Phase III (2013-2020) will see the introduction of free allocation based on harmonised emissions performance benchmarks to sectors deemed to be at risk of carbon leakage. And Article 10a(6) of the Revised EU ETS Directive will allow for the provision of additional State Aid to energy intensive sectors deemed at risk of leakage, in order to compensate for increases in electricity prices created by the scheme. Electricity intensive sectors in countries where the carbon cost pass-through is relatively high, such as primary aluminium production in Germany, are therefore hoping for this state aid.

However, the provision of state aid to protect industries from going offshore as a direct consequence of carbon pricing policies remains a controversial issue. The underlying question of the right balance between mitigating genuine risks of carbon leakage and the inevitable welfare transfers to industry continues to be a subject of intense debate. On the one hand, to the extent that it prevents carbon leakage, state-aid measures can reinforce the environmental effectiveness of the scheme and can prevent economically inefficient reallocation of productive resources due to "policy arbitrage". Thus, state aid can in principle improve economic welfare, environmental effectiveness and arguably also stakeholder acceptability if it prevents avoidable carbon leakage.

On the other hand, excessively generous state aid measures may reduce scheme acceptability and the appearance of fairness to the general public, because of the potentially large welfare transfers from the public to private sector. To a certain extent, the emissions performance benchmarking approach to free allocation to be introduced in Phase III of the EU ETS can be understood as a response to such concerns about equity.

To best meet the challenges posed by the threat of carbon leakage, policy makers need access to reliable and relevant information concerning the extent of the risks of carbon leakage for specific sectors. This paper therefore seeks to shed some more light on the nature of the risks by providing a quantitative ex-post analysis of the evidence of carbon leakage from the primary aluminium production sector during the first 6 ½ years of the EU ETS. It also tries to shed further light on the likely role of carbon pricing – compared to other factors – in affecting the longer run economic competitiveness of European primary smelters via an overview of some broader trends currently being observed in the sector.

1.1. Why Aluminium?

The primary aluminium sector is a particularly interesting candidate for evaluating the extent to which carbon leakage has occurred during the first six years of EU ETS. While the sector has not been explicitly included in the scheme so far[1], as an extremely electricity intensive product, it has nevertheless faced the new carbon price indirectly. This is because the price of emissions allowances (EUAs) has tended to be passed on by generators into the price of wholesale electricity. For example, Sijm et al (2006) found that in Germany and the Netherlands – two significant primary aluminium producing countries – average CO_2 cost pass-through rates of roughly 90% and 70% (respectively) could be observed in Phase I. Since only a small percentage of EU primary aluminium smelters use auto-generation and a large share of them have been gradually coming off of long-term electricity supply contracts since 2007 (IEA, 2008), the aluminium sector should therefore have faced increases in operating costs in response to the EU ETS.

At the same time, because it was not included in the EU ETS directly in Phases I and II, the sector has not been eligible for compensation from the issuance of free EUAs. This distinguishes aluminium from other sectors like steel, cement, or pulp and paper, where a high share of the increase in carbon costs have been compensated with free allowances (CITL, 2011).

Moreover, European aluminium has a relatively high exposure to foreign competition. As a product with a high value-to-weight ratio, and which is produced in many parts of the world, it is traded extensively in competitive international markets. This suggests that domestic aluminium producers may have a more limited ability to pass-through unilateral cost increases in order to maintain profitability in the face of carbon cost increases.

The structure of this paper is as follows. Section I offers a summary of the related literature on carbon leakage in the EU aluminium sector related to the EU ETS. Section II provides background information on the production process, industrial organisation, and offers some perspectives on investment trends of the primary aluminium sector in Europe. Section III describes the quantitative methodology and data used to estimate whether carbon leakage has occurred. Section IV summarises and interprets the results and section V concludes.

[1] Direct emissions from aluminium production will be covered by the scheme from 2013.

2 – Previous studies

2.1. The ex-ante literature

The EU primary aluminium industry has long been recognised as one of a handful of specific industries exposed to a risk of off-shoring production in response to carbon prices. For example, IEA (2004) identified aluminium among the EU industries likely to be most affected in terms of cost increases from the EU ETS. It estimated that, for IEA countries in the EU, the average overall per tonne cost increase of the EU ETS, if electricity generators passed through 100% of the carbon price, would be 2.4% at 10€/tCO_2e, 3.6% at 15€/tCO_2e and 7.2% at 30€/tCO_2e. Assuming a price elasticity of demand of -0.86, it concluded that the EU would see between a 2.2% and 7.6% production drop if profit margins were to be maintained. McKinsey et al (2006) found slightly higher cost impacts: at 20€/tCO_2e the EU ETS would probably lead to an 11.5 % short-run operating cost increase via electricity prices for average EU smelters.

Other ex-ante studies at the country specific level have broadly supported the IEA and McKinsey's initial conclusions. In the UK, Climate Strategies (2007) found that with a carbon price of 20€/tCO_2e and a power cost pass-through equal to 10€/MWh, UK aluminium would face carbon costs equivalent to around 11% of gross value added – with 90% of the cost effect due to the electricity price[2]. These results were in line with those of Carbon Trust (2004, 2008). Also focusing on the UK, Smale et al (2006) performed a partial equilibrium analysis with imperfect competition and found that at 15€/tCO_2e primary aluminium would experience an approximate 4% short-run marginal cost increase, while at 30€/tCO_2e a 13% marginal short-run production cost increase would be expected. Turning to the effects on trade, they found that at 15€/tCO_2e the 4% cost increase would be sufficient to drive both domestic smelters out of business almost immediately, to the benefit of non-EU competitors.

In Germany, where the marginal electricity producers have historically burnt coal, but increasingly are shifting to natural gas, Oeko Institute (2008) reported that carbon pricing of 20€/tCO_2e would be expected to result in a cost increase equivalent to 14% of sector gross value added[3], of which around 80% would be from electricity cost increases. The authors also noted that the market for German aluminium and aluminium products have significant trade intensity[4] with non EU countries of between 20-30%, suggesting that higher domestic costs due to carbon pricing could feasibly lead to foreign competitors winning a larger share of the German market. Meanwhile, in the Netherlands, CE Delft (2008) reported an expected increase in operating costs due to the EU ETS of around 6% for Dutch smelters – which they also noted would not be able to be met through price pass-through due to strong

[2] Calculation based on data at the SIC four digit level.
[3] i.e. profit margins plus labour costs
[4] Trade intensity was defined as (imports + exports) / (turnover + imports)

international competition. This in turn implied that margins and hence profitability would need to be reduced to maintain market share.

Table 1. Summary of (electricity price) cost-impacts estimated in the literature

Author	Scope	Price €/tCO_2	Pass-through cost €/MWh	Cost increase % variable costs/tAl
IEA (2004)	EU (IEA)	10-30	5-15	2.4 - 7.6% *Causing 2.2-6.7% decline in prod.*
McKinsey (2006)	EU	20	10	11.5
Carbon Trust (2004), Climate Strategies (2007)	UK	20	10	10%
Smale et al (2006)	UK	15-30	7.5-15	4 -13% *Causing 100% decline in prod.*
Oeko Institute (2008)	DE	20	19	11.2%
CE Delft (2009)	NL	?	?	6%

The long-run competitive prospects of the EU primary aluminium smelting industry have also been commented upon by a number of publications (e.g. McKinsey (2006), CE Delft (2008) and EAA (2006)). Among these, the conclusions offered by McKinsey are representative. They concluded that on current trends in relative power prices, the majority of remaining EU primary smelting capacity could be expected to shut down by 2025, irrespective of carbon costs. They therefore concluded that CO_2 prices were not likely to be a "determining factor" in driving the long-run off-shoring of primary smelting production capacity in Europe; however they could potentially hasten the process.

2.2. The ex-post literature

To our knowledge, IEA (2008) is the only original ex-post analysis of the effects of the EU ETS carbon price on European primary aluminium production. In it, the author provided an econometric analysis of the effects of the first two years of the EU ETS (2005-2006) on net exports of primary aluminium from the EU to non-EU countries. She found that the effect of both carbon prices and the existence of the EU ETS were statistically not significant in explaining quarterly net export data for the EU.

This result may appear surprising, given the conclusions of the ex-ante literature. However, to explain it, the author concluded that the results were probably due to the fact that most EU smelters were still on long-term power supply contracts as of 2005 and 2006. Long-term contracting is important to any analysis of carbon leakage in this sector, since it has (in the past) allowed aluminium smelters to agree long-term deals with power or energy suppliers which guarantee them electricity supply at a given price over long periods of time. Since electricity represents such a large part of the costs of primary aluminium production, long-term contracting has allowed smelters to insulate themselves to a considerable degree from risks to electricity prices, including carbon pricing.

Many of the long-term contracts EU smelters have held during the period of the EU ETS predate the passage of the EU ETS Directive in 2003. In fact, the author estimated that only around 18% of capacity was exposed to wholesale power price increases in response to the EU ETS, which probably explains why their analysis did not find any impact of carbon pricing on competitiveness of EU smelters, during the period 2005-2006.

In addition, the author noted that the years 2005 and 2006 saw a surge in wholesale power prices due to large primary energy cost increases. The simultaneous rise in electricity costs has been attributed by owners of smelters in Germany, France and Hungary who together represented 6.5% of EU capacity as the reason for shutting down (Ellerman et al, 2009). The author of IEA (2008) thus suggested that this may have led the most inefficient plants to shut down anyway, implying that those remaining may have been less vulnerable to electricity and presumably also CO_2 costs.

This paper aims to make two contributions to the above literature. Firstly, it seeks to re-examine empirically the effects of the EU ETS carbon price on net imports of primary aluminium in the EU. In particular, it aims to take advantage of a larger sample period than the existing IEA (2008) study mentioned above, in which a much larger portion of aluminium sector electricity supply contracts have expired. According to IEA (2008) and discussions with industry participants, roughly 65% of 2006 capacity should have seen their contracts expire by 2010, a process which has occurred gradually since approximately 2007.

Secondly, this paper aims to provide some reflections on long-run trends affecting the market share of European aluminium smelters, as well as factors that appear to be guiding future capacity investments, since we believe that these are critical to understanding the risks of carbon leakage in the primary aluminium sector in the medium term.

3 – Industry context

3.1. Primary aluminium production: the most energy intensive part of the value chain

This study focuses on the production of unwrought *primary* aluminium products – both alloyed and non-alloyed. Primary aluminium refers to aluminium which is produced from extracting the pure aluminium elements from aluminium oxide (Al_2O_3 or “alumina”). The process, also known as electrolysis, involves dissolving the raw alumina in a bath of molten cryolite and then passing large amounts of electric current through the bath via carbon anodes in order to separate the bonds between oxygen and aluminium elements in the alumina. This typically requires around 15MWh of electricity per tonne of primary aluminium (EAA, 2010). For this reason smelting plants are usually located near, or have on-site, large electricity-generating plants.

Secondary aluminium, on the other hand, refers to aluminium produced using recycled scrap. Secondary aluminium therefore does not require either the use of electrolysis and as such its electricity intensity is roughly 5% of that required to produce primary (McKinsey et al, 2006).

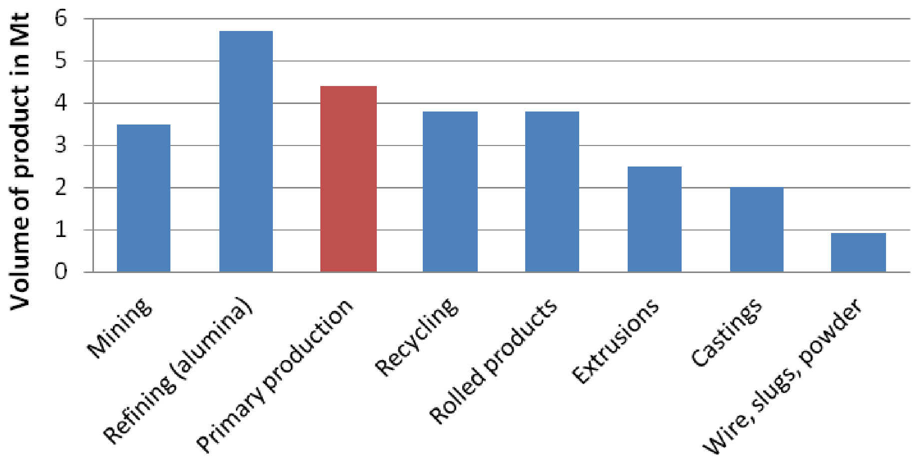
In terms of production costs of primary aluminium, the largest unit variable cost factor is electricity, which can represent between 35-50% of total unit production costs, depending on prices. Obtaining refined alumina also typically accounts for a roughly 30-35% of unit costs (IEA, 2008).

Once primary aluminium has been made, the resulting molten aluminium is syphoned off and cast directly into simple “unwrought” forms, such as ingots, slabs or billets. These may be made purely of non-alloyed aluminium or can be mixed with other elements, such as zinc, magnesium, etc, to produce alloys, which can have a range of different mechanical properties. Unwrought primary and secondary aluminium slabs, billets or ingots are subsequently turned into a variety of semi-finished shapes, such as rolled cast or extruded products, before being turned into final products. These later steps are significantly less energy intensive than the earlier stages of the production process.

3.2. EU production of primary aluminium

Primary production is only one area where the European aluminium industry participates in the aluminium value chain. As Figure 1 shows, primary aluminium production accounts for around 16.5% of volume (by weight) of primary and semi-finished products made in Europe (including Norway and Iceland). As a share of industry value added, this is certainly a much smaller percentage, since recycling and so-called “mill products”, such as rolled products, extrusions, wire and castings, generally require a higher level of labour input and are often tailor-made products for speciality industrial purposes. They can thus command a higher market price and have a greater ability to absorb cost increases. Therefore, to the extent that producers of downstream products are not dependent on being vertically integrated with upstream primary producers, they are less vulnerable to carbon leakage.

Figure 1. Production of primary and secondary aluminium products - Europe 2009



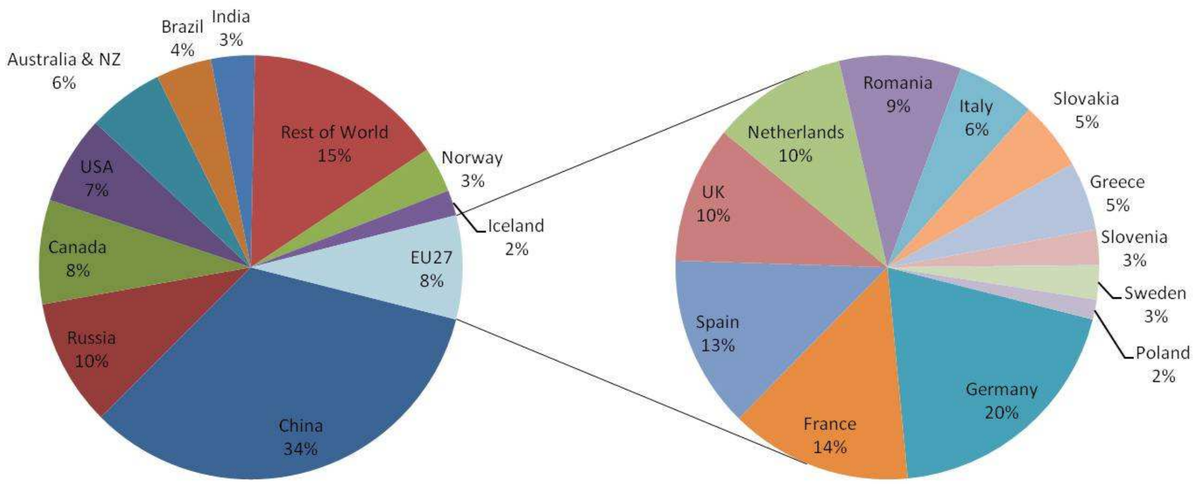
Data: EAA, 2010
Figures include Norway & Iceland, but exclude Russia

The global primary aluminium industry is concentrated in a relatively small number of countries in which a handful of multinational companies[5] dominate. As Figure 2 shows, China, Russia, Canada, USA, Australia & New Zealand, Brazil, Norway and India currently account for 75% of global production. This concentration is largely due to the natural advantages offered by these countries, most importantly in the form of a large, cheap and reliable power supply. Historically, access to bauxite reserves and elevated domestic consumption has also provided incentives for vertical integration in some countries. This has changed somewhat in the past decade or so as primary prices have risen relative to transport costs and as companies seek to be geographically well positioned to gain a foothold in emerging markets such as Asia and Latin America.

Figure 2 also shows that the European Union accounts for only 8% of world production. The major production locations in Europe are correlated with large levels of industrial production – particularly those who have historically offered large sources of abundant, reliable and cheap power.

[5] The largest global companies and their market share as of 2010 are Rusal (12.4%), Alcoa (11.9%), Alcan (11.4%), Chalco (6.1%), Norsk Hydro (4.7%), BHP Billiton (4%) - http://www.aluminiumleader.com (accessed 09/2011)

Figure 2. Relative shares of world and EU27 primary aluminium production (2008 data)



Data: ABARE, 2009

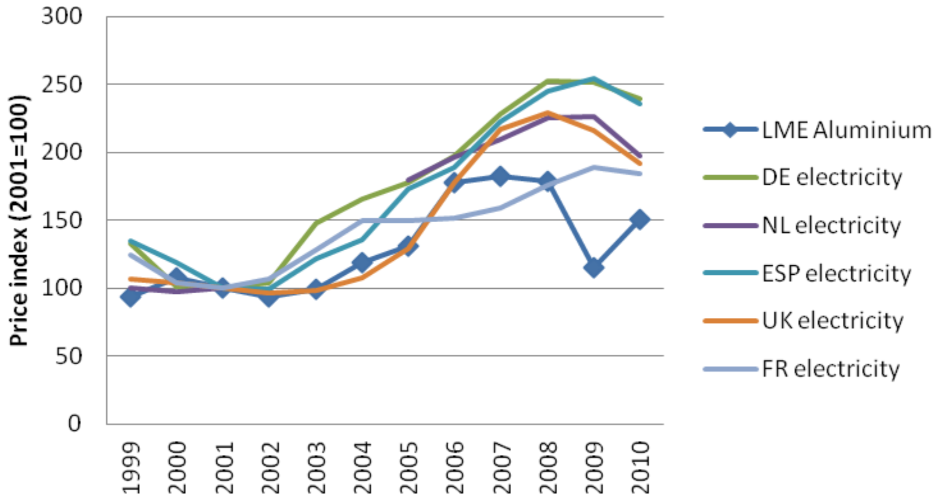
3.3. Competitiveness trends of EU primary aluminium production

Capacity investment trends in new primary aluminium smelters indicate that the primary production part of the industry is in decline in many advanced European countries and that this was the case prior to the introduction of the EU ETS. EEA (2006) reported that between 1989 and 2005 the EU25 saw 21 primary smelting plant closures and only 2 new openings – in 1991 and 1995 respectively. With the exception of these 2 new plants, the vast majority of the remaining 19 plants were commissioned pre-1980[6]. Indeed, McKinsey et al (2006) argued that "most of the primary smelting capacity in Europe and the United States is likely to be shut down over the next 20 years due to increased power prices and the search for cheaper, stranded energy"[7]. And this trend has indeed been observed, with 6 more medium-sized primary smelters closing between 2008 and 2011 in 5 different countries[8].

Rising power costs in Europe are typically cited as the main reason behind this trend (e.g. EAA, 2006; Ellerman et al, 2009). Moreover, according to IEA (2008), approximately 49% of production capacity was supposed to be coming off long-term contracts between 2007 and 2012. The decision to shut down therefore corresponds with the worsening of margins due to rising power prices and tighter margins as these contracts are expiring (see Figure 3).

[6] The average primary smelting plant is typically depreciated over a lifetime of 30 years, although lifetimes can be extended by up to 20 years via major maintenance investments.
[7] McKinsey et al, 2006, p.47 UK (2010, 2011)
[8] Germany (2009), France (2008), Italy (2009), Poland (2009), UK (2010 & 2011)

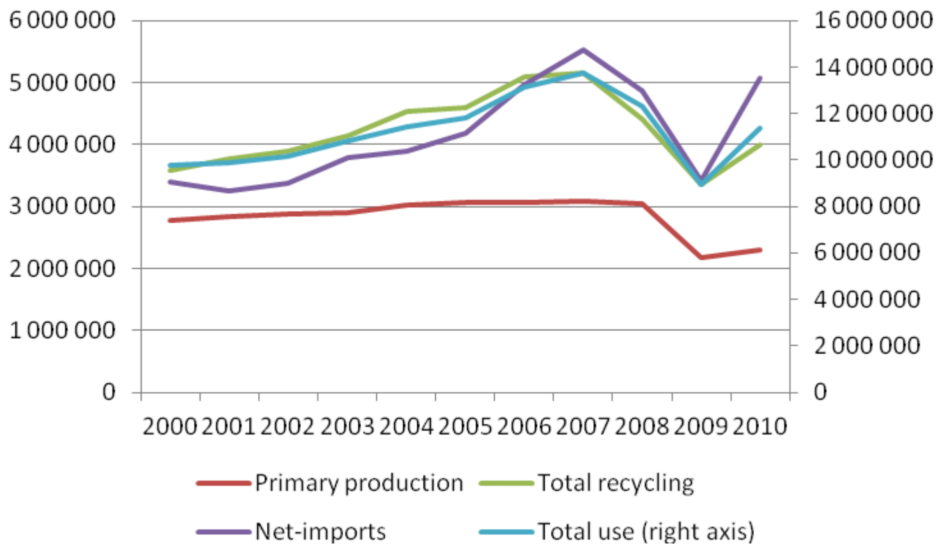
Figure 3. Industrial electricity costs for major EU producers vs. LME primary aluminium price



Data : IMF after the London Metals Exchange, EUROSTAT
Note: electricity prices refer to average annual industrial consumer prices converted from national currencies into USD/kWH incl. tax.

The general lack of investment in new capacity within the EU is well evidenced by the diverging trend in long-run domestic production and consumption since 2000. Figure 4 shows that, by and large, EU primary aluminium production is not maintaining its competitiveness with substitutes, such as imports and secondary aluminium. Although its output has been steady prior to 2008, its share of the market for domestic use has been declining, suggesting that new capacity investments are not being made despite rising demand.

Figure 4. EU primary production versus substitutes for domestic use



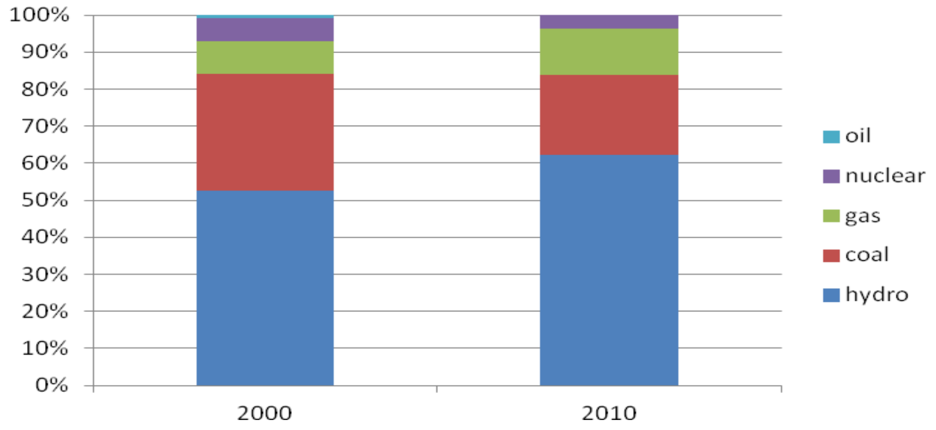
Source: EEA, 2010 ; figures in tonnes
Note: Figures reflect EU25 (2000-04) and EU27 (2005-10)

Conversations with representatives of European producers also suggests that the increasing difficulty of securing new long-term contracts with power generators at internationally competitive power prices appears to have been a key factor in new investment decisions. This difficulty has arisen in large part due to the stricter enforcement of EU anti-trust and competition law which has been interpreted as disfavouring long-term contracting, as well as increasing volatility in primary energy prices and other production and investment costs for European generators (of which the CO_2 price is but one factor).

During the past 5-10 years, investment trends in the sector have favoured large-scale new capacity investments outside of Europe's borders, in Iceland, Norway, the Middle East, Russia, and some parts of Africa and Latin America. In these locations, increasingly volatile energy costs are increasingly being "hedged" by tapping abundant local energy reserves and the availability of special pricing arrangements. Interestingly, these energy reserves are increasingly based on hydro-power, for example in Iceland, Norway, Russia, and some parts of Africa and Latin America, while others may also be gas in the Middle East.

Another motivation in the location of new investment is to gain geographical and supply chain advantages with respect to new emerging markets, which will increasingly consume aluminium as incomes rise. The desire to hedge carbon price risk is therefore only one factor among several influencing the broad global trends in investment in the sector.

Figure 5. Share of global primary aluminium production by electric fuel source



Source: IAI website (accessed June 2011)
Figures do not include Middle Eastern countries (therefore the "gas" percentage is underestimated)

In addition to the prospect of coming off of long-term contracts in the face of soaring power prices, the EU's primary aluminium industry may also be negatively affected by changes in tariffs which took place in 2007. Between 1999 and 2007, the EU applied a 6% value added tariffs on imports of primary aluminium products from tertiary countries without preferential agreements – essentially this related to countries outside the European Economic Area. These were reduced to 3% for non-alloyed products in late 2007, while imports of alloyed products retained their 6% tariff. The reduction was expected to benefit Russian imports in particular.

4 – Methodology & data

4.1. Econometric Model

Estimating the effect of the EU ETS carbon price on EU primary aluminium producers' international competitiveness requires controlling for the effects of simultaneous changes in other variables influencing EU/extra-EU trade in primary aluminium. The econometric technique of Multiple Linear Regression can overcome this difficulty. A well-specified regression model allows for the estimation of the individual effect of each explanatory variable on a dependant variable, after controlling for its possible correlations with other relevant variables.

This approach thus allowed us to estimate whether, after controlling for other factors, the EU ETS carbon price has contributed to a loss of competitiveness in so far as it may have contributed to higher net imports of primary aluminium products by the EU during the period of investigation (1999Q1 – 2011Q2). The underlying logic is that, on average, the higher the cost of CO_2 in any given economic quarter, the higher are electricity prices for EU smelters (who are not on long-term contracts) and hence the greater the chances they will reduce production (either marginally or by shutting down) and hence that domestic demand will be increasingly met by imports from non-EU ETS countries. The model described below therefore allowed us to observe whether there was any statistically robust evidence of this phenomenon:

$$Net\ Imports_t = \alpha + \beta_1.PCO2 + \beta_2.IndProd_t + \beta_3.EUR/USD_t$$
$$\beta_4.PCoal_t + \beta_5.PNatGas_t + u_t$$

Where,

NM_t = The level of net imports of primary aluminium products[9] by the EU27, in economic quarter t, measured in 100kg units. This represents EU27 imports from, minus exports to, all countries outside the EU27[10].

$Ind\text{-}Prod_t$ = The volume of industrial production in the EU27 in economic quarter t, measured in millions of Euros via chain-linked prices.

$PCO2_t$ = The average spot price of EUA emissions allowances in the EU ETS carbon market during economic quarter t.

$PCoal_t$ = The average spot price of Rotterdam coal during economic quarter t, measured in USD/tonne.

[9] Specifically, primary aluminium data were calculated as the sum of HS codes: 760110 (Aluminium, not alloyed, unwrought) + 7601201 (Aluminium, alloyed, primary)

[10] This variable was constructed expressly excluding trade with Norway, Iceland, and Liechtenstein, who are also included in the EU ETS since 2008. However, since Norway and Iceland are important producers of primary aluminium, a separate regression was performed in which trade with these countries was included in the NM variable – this did not meaningfully change the results.

$PNatGas_t$ = The average price of “EU Natural Gas” according to the IMF during economic quarter t, measured in USD/thousand cubic metres.

EUR/USD_t = The average effective exchange rate of the EU27 during economic quarter t.

α = Constant term

u_t = Random disturbance term, representing the effect of unobserved factors

The explanatory variables were chosen with the aim of providing an unbiased estimate of the effect of quarterly CO_2 prices on the dependent variable. Thus all variables which could *a priori* be considered to be correlated with both the CO_2 price and EU27 net exports of primary aluminium were included in the model. For example, EU27 real industrial production data were used. This variable affects CO_2 emissions via industrial production and therefore potentially the CO_2 price. Moreover, it also proxies the level of domestic demand, which affects demand for imports and also spare capacity available for producing exports of primary aluminium. We therefore expected it to yield a positive coefficient estimate.

The nominal EUR/USD exchange rate was also included as a measure of the relative cost of importing and value of exporting. A priori we expected a positive relationship with net imports, since a higher euro implies that imports are cheaper and exports are more attractive to undertake, all else held equal. Since the EURO/USD exchange rate has fluctuated significantly since the introduction of the carbon market this was also included as a control variable.

The Rotterdam CIF coal price and Zeebrugge Hub natural gas price variables were included to control for their effect on the price of EU electricity for smelters. These variables are also known to have an impact on the EU ETS carbon price (Ellerman et al, 2009). We expected them to have a positive relationship to net imports, since many of the countries that export to the EU do not rely on coal-or gas-fired electricity to produce aluminium while many EU producers are exposed to these prices as the marginal generating fuel in their respective electricity markets (e.g. via the German, British and Nordpool markets).

Moreover, to account for the effect of long-term contracts beginning to end in 2007, we tested structural break variable for the post 2007Q4 part of the sample with respect to the CO_2 price. This was constructed by multiplying a post-2007 dummy variable by the average CO_2 price in each quarter. This variable allowed us to test the potentially changed effect of the CO_2 price post-2007 just after the proportion of capacity without long term contracts moved from 18 to 38%.

4.2. The Data

A preliminary analysis of the data revealed that several key variables were non-stationary data series, implying that there was a risk of the so-called "spurious regression" problem. We therefore performed a Johansen cointegrating rank test to confirm the presence of a cointegrating relationship between the dependent and independent variables (see Annex II). This revealed the existence of a single cointegrating relationship between the variables, which implies that there is a stable long run relationship between net imports and the set of dependent variables. In this case, this relationship largely reflects the strong relationship between the level of demand for aluminium (i.e. industrial production) and the level of imports, as well as the exchange rate. We therefore proceeded to estimate our model using the Johansen cointegration method.

The regression was based on quarterly data with a sampling period from 1999Q1 to 2011Q2. Thus, given that we had only 12 ½ years of quarterly observation, of which CO_2 prices were only present for 6 ½ years, we must be clear that this analysis has a limited capability to accurately measure the full long-run effects the EU carbon price might have in shifting investments with long-lead times away from the EU. This limited sample size effect was compounded by the fact that long-term contracts have only just begun to expire in 2007 for a high percentage of EU producers. This leaves a somewhat limited period of quarterly observations for the model to capture the distinct effects of CO_2 prices as opposed to other causes of longer run investment shifts. However, the model does allow for any such shifts of investment or marginal reductions in production capacity that have occurred *during the sample period* to be captured, assuming they had an effect on net imports.

Secondly, since the price of coal, gas and industrial production turned out to be highly correlated, and the sample size was relatively small, this posed a small identification problem. This was resolved by estimating three separate equations – one which controlled only for industrial production, one which controlled for industrial production and coal prices, and a third which controlled for industrial production and gas prices.

A third challenge posed by the data was the fact that it was not possible to obtain quarterly data on secondary aluminium consumption in the EU. Since secondary aluminium is a substitute for primary imports, we did nevertheless find it appropriate to control for secondary aluminium consumption. Unfortunately, only annual production data was available, this did not allow us enough observations to create a statistically robust sample size. It was therefore decided to omit the secondary consumption variable from the main estimation. However, as a robustness check, we constructed a "quarterised" average of the annual data points for each calendar year based on data provided by the European Aluminium Association and used this as a rough proxy variable for quarterly secondary aluminium consumption. This variable appears in the results below as "RecyProd". Including it in our regressions did not significantly change the results with respect to the carbon price impact.

Finally, to take account of the fact that in 2008 Norway and Iceland (two large aluminium producers) joined the EU ETS, the EU27 data were recalculated to net out trade between the EU27 and these two countries for the entire sample period. Thus, the net imports variable effectively reflected net imports by the EU27 countries from non-EU27 countries excluding Iceland and Norway. Annex I describes some further features of the data and the estimation procedure.

5 – Results

5.1. Regression results

The results of the four main cointegrating regressions estimated are summarised in Table 2.

Table 2. Results of cointegrating regressions on net imports of EU27

Variable	(1)	(2)	(3)	(4)
constant	201964 (.)	255195 (.)	57405 (.)	199971 (.)
PCO2	-314 (270)	-1154*** (290)	-1053*** (278)	-361 (219)
IndProd	0.454*** (0.08)	0.634*** (0.08)	0.174** (0.09)	0.497*** (0.10)
EUR/USD	48339*** (13363)	6615.9 (17770)	32546*** (12809)	41851*** (10771)
PCoal	-	492*** (101)		
PNatGas	-	-	123*** (31.5)	
RecyProd	-	-		0.002 (0.004)
	N=50 P>Chi2=0.000	N=50 P>Chi2=0.000	N=50 P>Chi2=0.000	N=50 P>Chi2=0.000

* Statistically significant at 10% level
** Statistically significant at 5% level
*** Statistically significant at 2.5% level

In all four model specifications, the coefficient estimate representing the effect of the price of CO2 on net imports of primary aluminium was either not statistically significant or was the wrong sign (i.e.

negative rather than positive). We therefore concluded that we did not find any evidence that the carbon price has caused a rise in net imports of primary aluminium during the first 6 ½ years of the EU ETS.

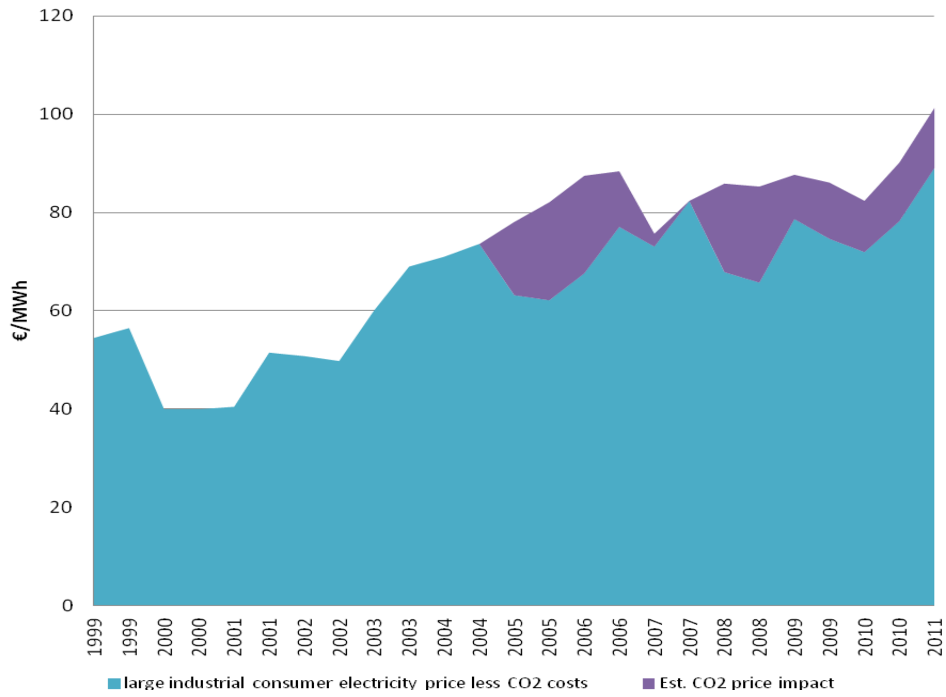
Among the variables found to be statistically significant explanators of EU net imports of primary aluminium were: the level of industrial production (i.e. European demand), the price of coal, the EUR/USD dollar exchange rate, and the price of natural gas in Europe. In addition to being statistically significant, these variables' coefficient estimates were also found to be correlated with net imports in the expected way (i.e. positively).

5.2. Interpretation and uncertainty

The fact that carbon price did not prove to be statistically significant suggests that so far the EU ETS has not been a significant factor behind the steady rise in the share of EU consumption which is being met by net imports from outside the EU ETS countries. This result can probably be explained by a combination of factors. First and foremost, of course, is the fact that most smelters have only recently begun to come off of long term contracts, which would be expected to limit the responsiveness of their production decisions to the carbon price up until that point. The sample size post-long term contracts therefore remains relatively small for the purposes of detecting the carbon price effect, especially in the context of an unusually volatile energy prices and demand.

Secondly, primary aluminium production has a technical constraint limiting its ability to vary production levels in the short run. Failure to run a smelting "pot" on a 24-hour, 7-day a week basis leads to freezing of the aluminium bath inside the pot, resulting in costly repair work necessitating a wait of up to 6-12 months to return production to full capacity. Thus, for those producers who have been off of long term contracts and facing carbon costs in their electricity prices, carbon prices would need to be sufficiently high to incentivise such a costly operation. However, since carbon prices have so far been relatively low as a share of wholesale electricity prices (see Figure 6), they have probably not been high enough to incite this activity. Thus it is theoretically possible that the true effect of carbon prices on EU production will not be seen until the reduced per unit margins induced by higher carbon and electricity prices makes itself evident when capital stock expires and is not replaced.

Figure 6. Estimated contribution of CO_2 price to rise in German industrial power costs



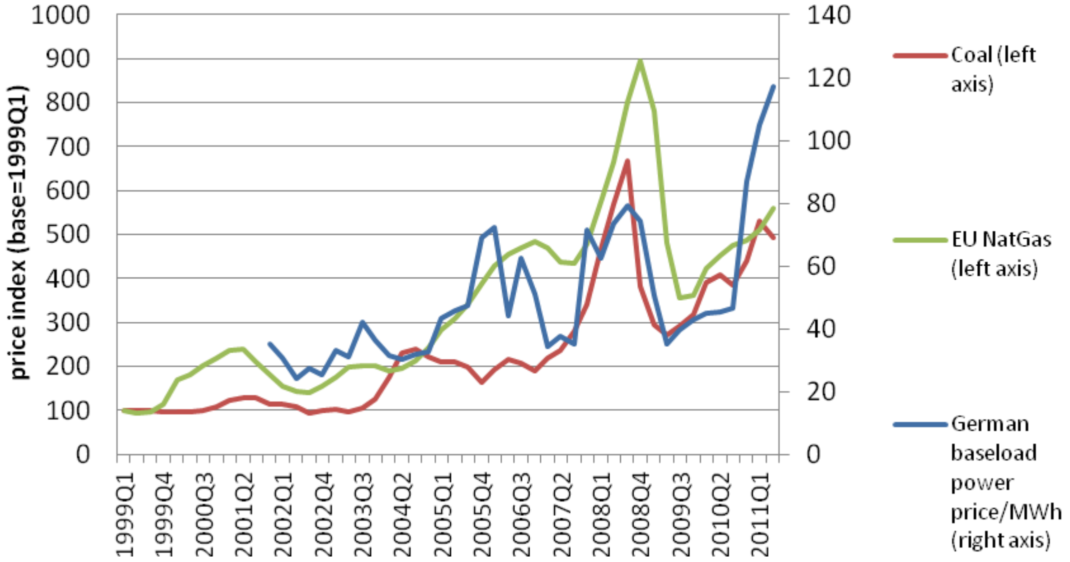
Data : Bluenext, EUROSTAT, own calculation

Note: electricity prices refer to average annual industrial consumer prices in €/MwH incl. tax. The industrial consumption price quoted refers to large industrial consumers consuming 70-150 000MwH/yr. Prices exclude VAT. CO_2 cost component assumes a pass-through of 90% of EUA price for coal-fired power and 0.9 tCO_2 emitted per MwH.

It is also possible that, to some extent, the hope of industry compensation for indirect emissions from 2013 onwards under Article 10a(6) of the ETS Directive may be influencing decision to remain in the market for the time being. A conversation with industry representatives suggested that the combination of the economic downturn and terminating long-term contracts coupled with higher electricity prices has left some smelters running at marginal profitability. Smelters in this category are therefore waiting to see how the business environment evolves in the coming year or two before making decisions about whether to continue operations. One part of this equation is the amount of state-aid which they will receive for indirect carbon costs under Article 10a(6). For example, one interviewee commented, "if we received no state aid, then that would probably make our decision [about whether to continue operating the smelter] for us". This "wait and see" approach to the carbon policy environment is therefore a caveat on our findings.

Interestingly, our results with respect to the positive influence of coal and gas prices suggest the importance of factors other than the CO2 price which help to explain the gradual rise of foreign imports as a share of the EU aluminium consumption since 1999. To illustrate, Figure 7 gives a graphical representation of the correlation between the sharp rise of the price of EU natural gas, EU coal, and German wholesale electricity prices. It suggests that a large part of the rise in German wholesale power prices appears to be explained by rising primary energy costs for marginal electricity producers.

Figure 7. EU coal, gas and Germany base-load power prices

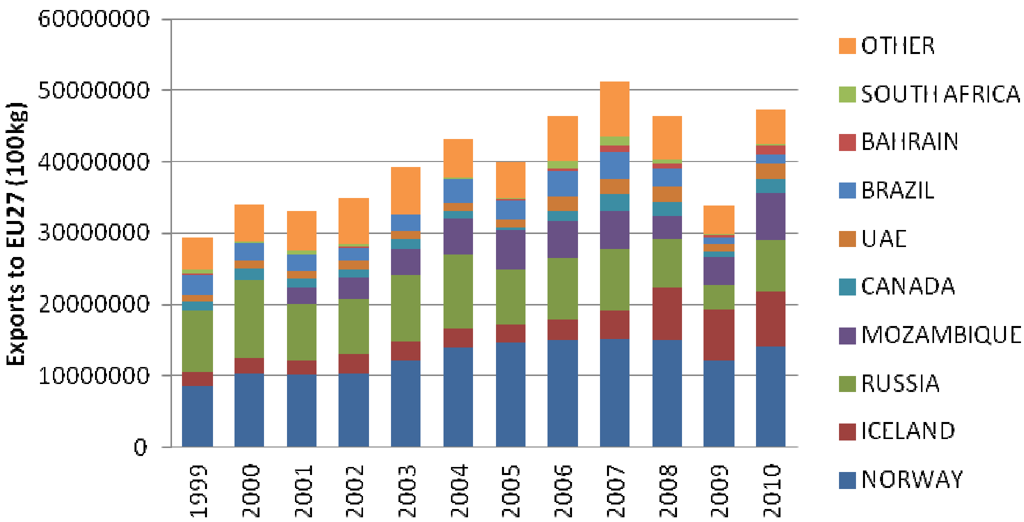


Source: IMF, Reuters; quarterly data

Assuming that both coal and gas prices are responsible for increased power pricesraises the question of why high coal and gas prices would disproportionately disadvantage the EU27's production of aluminium compared to that of competitors overseas. The answer is that the EU's main competitors are not as exposed to the prices of coal and gas-fired electricity for a variety of reasons. Firstly, Figures 8 and 9 show that during the period of rising coal and gas prices since roughly 2003, the major exporters to the EU have been countries relying mainly on hydro-power for aluminium production – namely Norway (100%), Iceland (100%), Russia (~80%), Canada and Brazil (~80%). Moreover, these countries and others such as Mozambique, UAE and Bahrain (which use electricity from coal and gas) operate under less competitive conditions than several of the main markets in Western Europe. For instance, they have the advantage of still being able to sign long-term arrangements with power companies, regulated power prices or auto-generation – all of which limit marginal price pass-through of rises in fossil fuel prices via electricity markets in the short term. Of course, in the long run this may change. But for the period of the sample, the coal and gas intensity of the EU's marginal power generating facilities has been a disadvantage for EU smelters coming off of long-term deals.

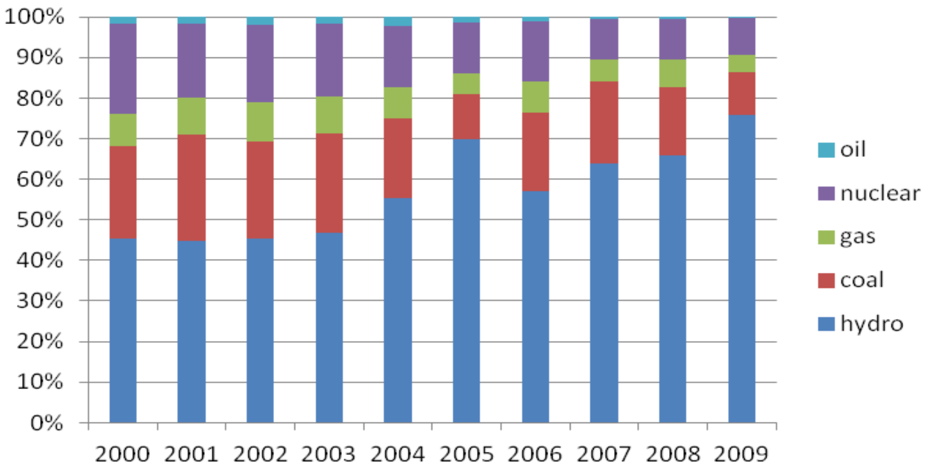
Thus, our regression results and on further analysis of the data would seem to provide further support for the claim made in McKinsey (2006) and elsewhere that the EU primary aluminium sector faces some significant medium term competitive challenges that go beyond carbon pricing. Our results suggest that exposure to primary energy prices in several traditional producer countries accompanied with the difficulty of signing long term contracts is one such difficulty. In addition, IFRI, (2011) has persuasively argued that rising network infrastructure, maintenance and capacity investment costs have been another significant contributor to rising electricity prices in Germany and in other European countries. Rising VAT rates since 2000 and growing demand relative to available capacity may also have made a contribution to rising power costs in several EU countries.

Figure 8. Major exporters of unwrought non-alloyed and alloyed primary aluminium to the EU27



Data : EUROSTAT

Figure 9. Share of European primary aluminium production by electric fuel source



Source: IAI website (accessed June 2011)
Figures includes Russia, Norway, Iceland as "European production"

6 – Concluding remarks

In summary, our results found no hard evidence for the hypothesis that the level of the carbon price created by the EU ETS between 2005 and 2011Q2 have led to carbon leakage in the EU primary aluminium sector as measured via changes in net imports of aluminium. Our findings therefore confirm those of IEA (2008) but over a longer period of investigation and in which a significant share of long-term power contracts had expired. Nevertheless, we believe that these results need to be interpreted with caution, given that our sample period examined is relatively short and given technical constraints on short-run production shifting in this sector. It is thus possible that the signs of carbon leakage in the sector are not yet visible.

Furthermore, the empirical evidence presented in this paper suggests that the international competitiveness of the Europe's primary aluminium sector – as measured by the share of the domestic consumption which is being met through local production – is in long-run decline for reasons which go beyond the introduction of the EU ETS. While the carbon price is a contributing factor to these cost rises, our estimates suggest that it is not the most important factor driving electricity costs and pressure on margins for the industry. Since competitiveness losses are not the same thing as carbon leakage, it follows that the debate about carbon leakage should therefore be about not unnecessarily accelerating the speed of delocalisation of existing production capacity, rather than preventing this delocalisation, which looks likely to continue in the near future based on current trends, irrespective of CO_2 prices. From a policy maker's perspective, it is therefore important that the CO_2 price is not used as an argument to compensate industry for a simultaneous loss of competitiveness which is due to other factors.

Moreover, to the extent that state aid is given, it will need to take account of long term contracts which will remain in existence in some EU ETS countries such as Norway for a number of years after Phase III of the EU ETS has begun. If these smelters have indeed locked in pre-existing power prices, then CO_2 prices should not affect their competitiveness until those contracts expire.

Annex I. Further comments on data

I. Data Sources

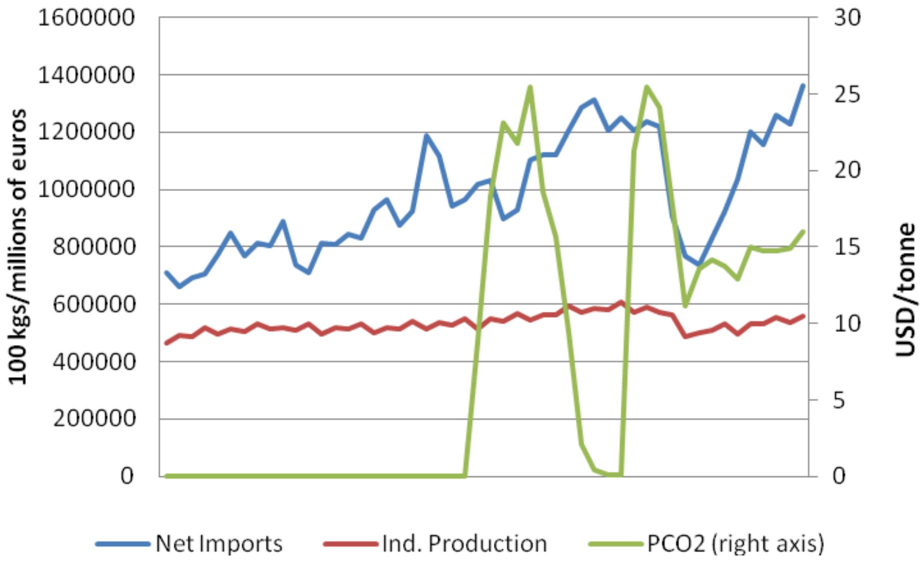
The data used to estimate the model came from a variety of sources. Trade data was obtained from EUROSTAT's Comext database. Industrial production and nominal exchange rate data also came from EUROSTAT's economic and industrial statistics databases. EU ETS CO_2 spot price data came from BlueNext. EU coal and natural gas cost data was obtained from the IMF world commodities database.

Nominal price data such as natural gas, coal and CO_2 prices were converted into US dollars. This was done to reflect the fact that aluminium sold in the international market – including Europe – is typically priced in US dollars. Hence it was assumed that changes in input costs should affect the marginal competitiveness of EU producers to the extent that they reduce the USD value of their margins.

II. Estimation

As Figure 10 shows, the dependent variable was a non-stationary time-series variable, implying that in the absence of a co-integrating relationship with the dependent variables, a simple linear regression would provide spurious results.

Figure 10. Net imports vs. Price of CO2



The table below provides the results of the Johansen cointegrating rank test for the first of the four models reported in the results section. Against the null hypothesis that the maximum cointegrating rank is 0, it reveals that that at a 95% significance level, the trace statistic is superior to the critical value, allowing us to reject the null. However, we fail to reject the null hypothesis of a cointegrating rank greater than 1, 2 or 3. Thus we conclude that there is only one cointegrating equation.

Table 3. Johansen cointegration tests for NM = F(Ind-Prod, EURUSD, PCO2)

Maximum rank	Trace statistic	5% critical value
0	50.18	47.21
1	**17.88***	**29.68**
2	8.20	15.41
3	0.737	3.76
Lags = 1 N = 49 Trend: constant		

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