



**HAL**  
open science

## Carbon Leakage in the Primary Aluminium Sector

Oliver Sartor

► **To cite this version:**

| Oliver Sartor. Carbon Leakage in the Primary Aluminium Sector. 2012. ⟨hal-00776451⟩

**HAL Id: hal-00776451**

**<https://hal.science/hal-00776451v1>**

Preprint submitted on 17 Jan 2013

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

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

Oliver Sartor, Research Fellow

CDC Climat Research

47 rue de la Victoire, Paris 75009, France

Email: [oliver.sartor@cdcclimat.com](mailto:oliver.sartor@cdcclimat.com)

September 2012

## **Abstract**

This paper provides an empirical analysis of the evidence of carbon leakage from the European primary aluminium industry during the first 6 ½ years of the European Union Emissions Trading Scheme (EU ETS). The findings suggest that while rising electricity prices in several major producer countries in the EU have played a critical role in the rise in net imports of EU primary aluminium into the EU in recent years, the role of CO<sub>2</sub> costs in this equation has been more limited than was expected in the ex-ante literature. Other factors, including rising primary energy prices and difficulties for primary smelters in obtaining long-term electricity-supply contracts, appear to have been more economically important factors than the relatively low CO<sub>2</sub> costs which have been witnessed so far.

**Keywords:** carbon leakage, European Union Emissions Trading Scheme (EU ETS), CO<sub>2</sub> pricing

## 1 - Introduction

Since the European Union Emissions Trading Scheme (EU ETS) began pricing CO<sub>2</sub> emissions within the European Community in 2005, the risk of industries off-shoring production and emissions to avoid the new regulatory cost has been a central preoccupation of its architects. To combat the risk of such “carbon leakage”, policy makers have sought to provide compensating state-aid to firms in energy-intensive industries, mainly by allocating a share of emissions allowances to industries for free. This policy is controversial, partly because of its distributive impacts, but also because decisions must be made based on asymmetric information: industry knows better than policy-makers how much state-aid it needs to avoid carbon leakage from occurring.

To best meet the challenges posed by the threat of carbon leakage, policy makers thus need access to reliable and relevant information concerning the extent of the risks for specific sectors. This paper seeks to shed some more light on the nature of these risks for a specific sector. It provides a quantitative, ex-post analysis of the evidence of lost competitiveness<sup>i</sup> of EU primary aluminium producers – as proxied by changes in net imports from non-EU ETS countries – during the first 6 ½ years of the EU ETS. It finds that large changes in domestic electricity prices, which have increased by to a large extent for reasons other than the introduction of the carbon price, combined with the effects of the global financial crisis, and the phase-out of long-term power-supply contracting in EU countries, appear to have been significantly more important than the price of CO<sub>2</sub> at explaining the decline in market share of EU primary smelters during the past 6-and-a-half years.

At the outset, however, it will be useful to define the meaning of the concepts of competitiveness and carbon leakage as used in this paper. “Competitiveness” is a distinct but related concept to “carbon leakage”. In this paper, carbon leakage shall refer to the net increase in emissions beyond the perimeter of a regulated carbon pricing regime, such as the EU ETS, though an increase in the market share of foreign producers and as a direct or indirect consequence of unequal carbon prices or costs. Competitiveness, on the other hand, refers to the capacity of firms to obtain and sustain market share in their relevant product market. A loss of competitiveness, so understood, due to carbon pricing can therefore easily lead to carbon leakage in many cases. And, since this is true of primary aluminium, it is in this sense that we shall focus on “competitiveness”, as measured by market share, in the analysis of this paper. However, we note that a loss of competitiveness is not necessarily equivalent to carbon leakage in all cases.

### *1.1. The Primary Aluminium Sector and the EU ETS*

The primary aluminium sector is a particularly interesting candidate for evaluating the extent to which carbon leakage has occurred as a result of the EU ETS. While the sector has not been explicitly included in the scheme so far<sup>ii</sup>, 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. Sijm et al (2006) found that in Germany and the Netherlands – two significant primary aluminium producing countries – average CO<sub>2</sub> 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 have been gradually coming off of long-term electricity supply contracts since 2007 (Reinaud, 2008), it follows

---

i

ii Direct emissions from aluminium production will be covered by the scheme from 2013.

that the aluminium sector should therefore have increasingly faced the pass-through of CO<sub>2</sub> prices in their electricity costs from 2008 onwards.

At the same time, because it was not included in the EU ETS directly in Phases I and II, the sector has not so far been eligible for free allowances or other compensation to mitigate these cost increases. 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 (cf. CITL, 2011) and hence the risks of early carbon leakage have potentially been mitigated.

Moreover, European aluminium producers have a relatively high exposure to foreign competition. As a product with a high value-to-weight ratio, and produced in many parts of the world, aluminium is traded extensively in competitive international markets. Hence, all else equal, EU aluminium producers would have had a more limited ability to pass through carbon costs in their final prices.

The structure of this paper is as follows. Section 2 offers a summary of the related literature on carbon leakage in the EU aluminium sector related to the EU ETS. Section 3 provides background information on the primary aluminium sector in Europe. Section 4 describes the quantitative methodology and data used to estimate whether carbon leakage has occurred. Section 5 summarises and interprets the results and section 6 concludes.

## **2. Related Literature**

### *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. Reinaud (2004) identified aluminium among the EU industries likely to be most affected in terms of cost increases from the EU ETS. She estimated that, for IEA countries in the EU, the average per tonne cost increase, if electricity generators passed through 100% of the carbon price, would be 2.4% at 10€/tCO<sub>2e</sub>, 3.6% at 15€/tCO<sub>2e</sub> and 7.2% at 30€/tCO<sub>2e</sub>. Assuming a price elasticity of demand of -0.86, the authors concluded that the EU would see between a 2.2% and 7.6% production drop if profit margins were to be maintained. Meanwhile, McKinsey et al. (2006) estimated higher cost impacts: at 20€/tCO<sub>2e</sub> 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 these conclusions. Hourcade et al. (2007) found that, with a carbon price of 20€/tCO<sub>2e</sub> 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<sup>iii</sup>. 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<sub>2e</sub> primary aluminium would experience an approximate 4% short-run marginal cost increase, while at 30€/tCO<sub>2e</sub> a 13% marginal short-run production cost increase would be expected. Turning to the effects on trade, they found that at 15€/tCO<sub>2e</sub> the 4% cost increase would be sufficient to drive both domestic smelters out of business almost immediately, to the benefit of non-EU competitors. Studies in Germany and the Netherlands, have also found similar results (cf. Graichen et al., 2008; CE Delft, 2008).

---

<sup>iii</sup> Calculation based on data at the SIC four digit level.

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

Author	Scope	Price €/tCO <sub>2</sub>	Pass- through cost €/MWh	% Cost increase variable costs/tAl	% Decline in production
Reinaud (2004)	EU (IEA)	10-30	5-15	2.4-7.6	2.2-6.7
McKinsey (2006)	EU	20	10	11.5	-
Carbon Trust (2004), Hourcade et al. (2007)	UK	20	10	10	-
Smale et al (2006)	UK	15-30	7.5-15	4-13	100
Graichen et al (2008)	DE	20	19	11.2	-
CE Delft (2008)	NL	-	-	6	-

Source: authors

Interestingly, though, the part of the literature that has focused on the longer-term competitiveness of the EU primary aluminium smelting industry has suggested that CO<sub>2</sub> costs are not likely to be as relevant as the shorter term literature suggests. Most notably, McKinsey (2006) concluded that on the then 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. CO<sub>2</sub> prices were not likely to be a determining factor in driving the long-run off-shoring of primary smelting production capacity in Europe, even if they could potentially hasten the process.

### **2.1. The ex-post literature**

To our knowledge, Reinaud (2008) is the only original ex-post analysis of the effects of the EU ETS carbon price on European primary aluminium production. The author provided an econometric analysis of the effects of the first two years of the EU ETS (2005-2006) on quarterly net exports of primary aluminium from the EU to non-EU countries. She found that the effect of both CO<sub>2</sub> prices and the existence of the EU ETS were not statistically significant in explaining these net export data.

This result may appear surprising, given that the ex-ante literature described above had consistently predicted such strong impacts on both costs and domestic production. To explain this discrepancy, Reinaud (2008) argued that most EU smelters were still on long-term power supply contracts in 2005 and 2006. Moreover, the entry into force of many of the long-term contracts that EU smelters have held during the period 2005 – 2007 predate the passage of the EU ETS Directive in 2003. Thus, the author estimated that only around 18% of EU smelting capacity was exposed to wholesale power price increases in response to the EU ETS during the a large part of the sample period.

In addition, Reinaud (2008) noted that the years 2005 and 2006 also saw a surge in wholesale power prices due to large primary energy cost increases and strong industrial demand, in addition to the introduction of the EU ETS. It was thus suggested that this may have led the

most inefficient plants to shut down anyway, thus drowning out any effect that CO<sub>2</sub> costs may have had on production in the absence of these other changes.

This paper therefore re-examines empirically the effects of the EU ETS carbon price on competitiveness of net imports of primary aluminium in the EU, as a proxy for evidence of carbon leakage. In particular, it aims to take advantage of a larger sample period than the empirical study mentioned above, in order to examine a period during which a large portion of aluminium sector electricity supply contracts have been expiring. According to Reinaud (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 2007.

But before doing so, a detailed overview of the industry context and some relevant trends related to the competitiveness of European aluminium smelters are provided in the next section, in order to better ground the econometric model to follow. Indeed, these turn out to be critical to understanding the risks of competitiveness losses due to carbon pricing and of carbon leakage in the primary aluminium sector in the medium term and in putting the econometric analysis into a broader context.

### **3 – Industry context**

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

Primary aluminium refers to aluminium which is produced from extracting the pure aluminium elements from aluminium oxide (Al<sub>2</sub>O<sub>3</sub> 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. This typically requires around 15MWh of electricity per tonne of primary aluminium (EAA, 2010). Secondary aluminium refers to aluminium produced using recycled scrap. It does not require 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 has historically represented between 30-40% of total unit production costs, depending on prices (Reinaud, 2008). For this reason smelting plants are usually located near, or have on-site, large electricity-generating plants.

Unwrought primary and secondary aluminium slabs, billets or ingots are subsequently turned into a variety of semi-finished shapes, before being turned into final products. These later steps are significantly less energy intensive, and require a higher level of labour input, depending on the complexity of the final product. This study therefore focuses on the production of unwrought, primary aluminium products, as the most energy and CO<sub>2</sub> cost-sensitive part of the value chain.

#### ***3.2. The EU as a producer of primary aluminium***

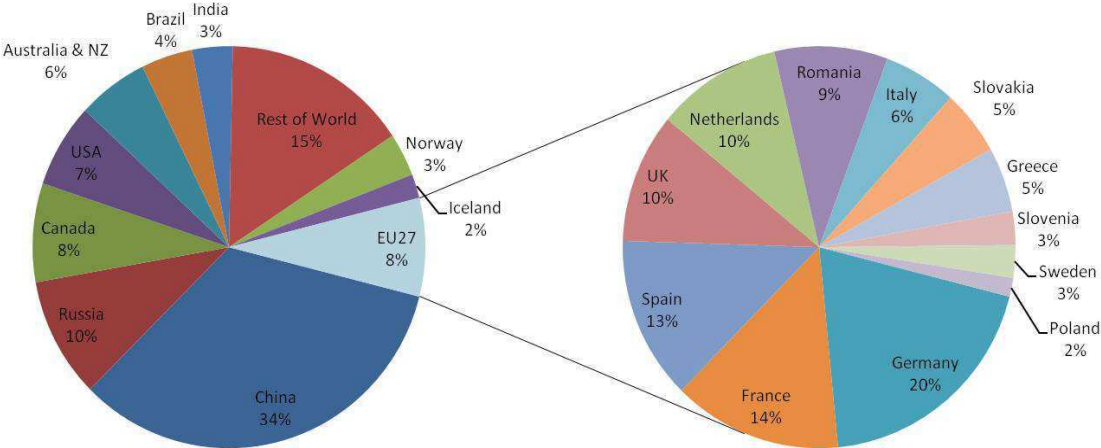
The global primary aluminium industry is concentrated in a relatively small number of countries in which a handful of multinational companies<sup>iv</sup> dominate. As Figure 1 shows,

---

<sup>iv</sup> 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)

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. But this appears to have begun to change over the past decade, 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.

**Figure 1. Relative shares of world and EU27 primary aluminium production**



Data source: ABARE, 2009 (2008 data)

The European Union accounts for only 8% of world production. The major production locations in Europe are correlated with high levels of domestic industrial production and with countries who have historically offered large sources of abundant, reliable and cheap power.

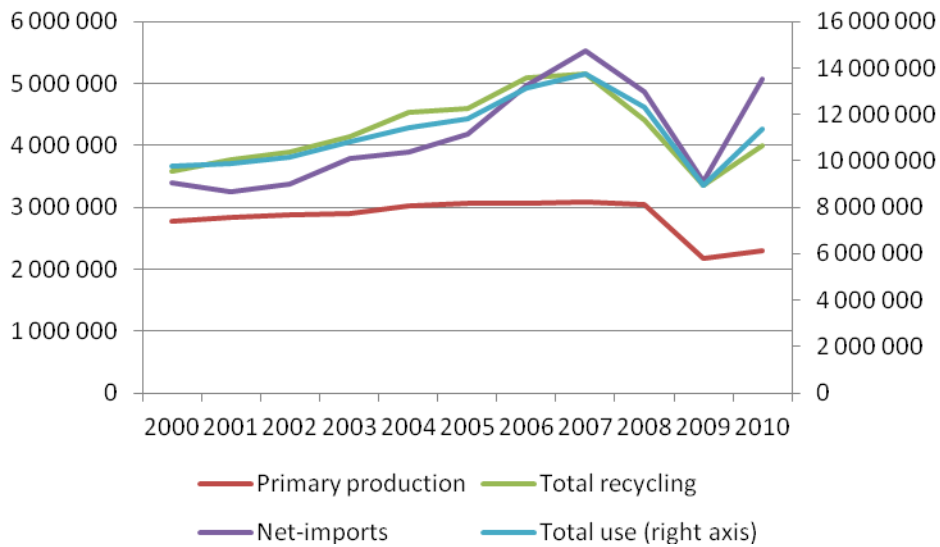
**3.3. Competitiveness trends of EU primary aluminium production**

Data on capacity investment and dis-investment in new primary aluminium smelters suggest that the primary production part of the industry has been in decline in many European countries since the late-1990s. EEA (2006) reported that, from 1989 to 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<sup>v</sup>. Thus, 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”<sup>vi</sup>. This trend has indeed been observed since 2006, with 6 more medium-sized primary smelters closing between 2008 and 2011 in 5 different countries (EAA, 2010).

<sup>v</sup> 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.

<sup>vi</sup> McKinsey et al, 2006, p.47 UK (2010, 2011)

**Figure 2. EU primary production versus substitutes for domestic use**

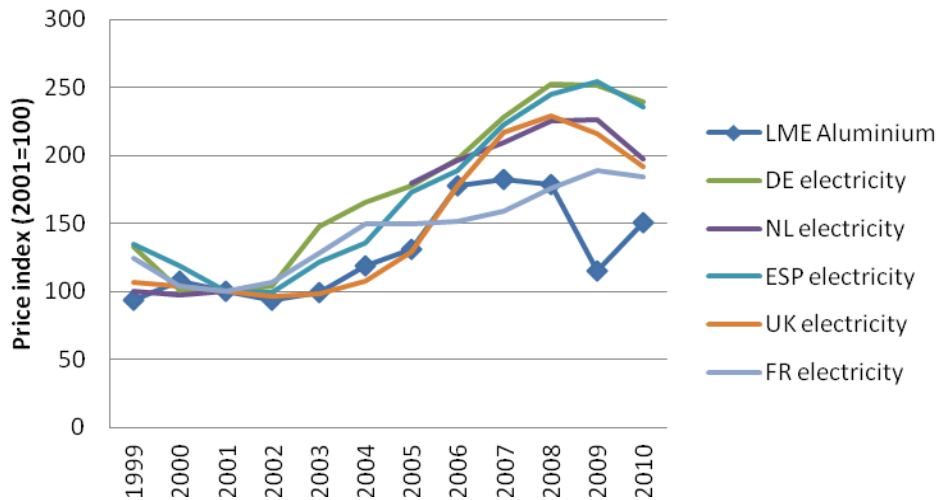


Source: EEA, 2010 ; figures in tonnes  
 Note: Figures reflect EU25 (2000-04) and EU27 (2005-10)

The general lack of investment in new capacity within the EU is well evidenced by the diverging trends in long-run domestic production and consumption since 2000. Figure 2 shows that, by and large, EU primary aluminium production is not maintaining its competitiveness – in the sense of its capacity to maintain or improve its market share – with foreign and domestic substitutes, such as imports and secondary aluminium. Although its output has been steady prior to 2009, its share of the market for domestic use has been declining, suggesting that new capacity investments in primary production are not being made despite rising demand.

Rising power costs in Europe are typically cited as the main reason behind these trends (EAA, 2006; Ellerman et al, 2009). Figure 3 provides support for this argument: large industrial consumer electricity prices have indeed been rising faster than the global reference price of primary aluminium in the EU’s largest producer countries since 2001. However, it also shows that the global financial crisis appears

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



Data: IMF after the London Metals Exchange, EUROSTAT

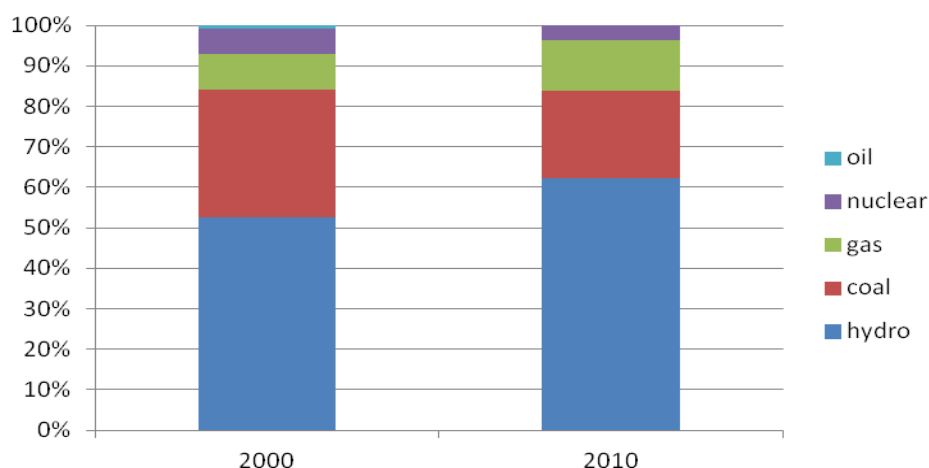
Note: electricity prices refer to average annual industrial consumer prices converted from national currencies into USD/kWH incl. tax.

to have contributed to the destruction of margins for producers in these countries, by lowering the global aluminium price more than domestic electricity prices. The combination of high electricity prices and the effect of the global recession on prices (Figure 3) and volume demand (Figure 2) therefore appears likely to have been a key factor weighing the profitability of the EU aluminium sector post-2008.

In interviews conducted during the preparation of this paper, European producers and industry representatives also commented that the increasing difficulty of securing new long-term contracts with power generators within the EU was also a key issue for 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 (European Commission, 2012). As old contracts have begun to expire from 2008 onwards, and as primary energy and hence electricity prices have become more volatile (with the CO<sub>2</sub> price but one factor), it has thus simultaneously become harder to hedge these costs for EU smelting operations.

Data on primary smelting capacity and production during the first decade of the 21<sup>st</sup> century indicates that investors in new smelting operations 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 (ABARE, 2010; IAI 2010). Such investment trends appear consistent with reports of aluminium companies seeking to hedge increasingly volatile energy costs by tapping abundant local energy reserves and the availability of special pricing arrangements no longer open to them in the EU. For example, electricity sources are increasingly based on hydro-power, for example in Iceland, Norway, Russia, and some parts of Africa and Latin America, while others seek to exploit cheap and abundant gas supplies in Middle Eastern countries (see Figure 4). Anecdotal reports from industry publications also suggest that another motivation in the location of new investment outside of Europe is to gain geographical and supply chain advantages with respect to new emerging markets, which will increasingly consume aluminium as incomes rise (Global Industry Analysts, 2012)

**Figure 4. 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 have been somewhat affected by changes in tariffs which took place in 2007. Between 1999 and 2007, the EU applied a 6% value-added tariff 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, which has since joined the World Trade Organisation in 2012.

Therefore, based on the foregoing preliminary analysis, carbon pricing appears to be only one potential factor among several influencing the relative economic attractiveness of investment in new EU smelting capacity. It is therefore against this backdrop of several factors driving broader industry trends that any analysis of the impact of CO<sub>2</sub> prices on sectoral competitiveness must be conducted.

## **4 – Methodology & data**

### **4.1. Econometric Model**

To estimate the effect of the EU ETS carbon price on EU primary aluminium producers’ international competitiveness, we focused on EU27 net imports. This variable was chosen, as it should in general reflect the relative attractiveness of purchasing primary aluminium produced abroad versus EU-produced aluminium in both the European and international market. It is in this sense, therefore, that we define competitiveness for the purposes of this analysis – our conception of competitiveness is therefore closely related to the idea of EU producers being able to win or maintain market share.

Obtaining unbiased estimates of the impact of carbon prices on the competitiveness of EU primary aluminium production thus requires controlling for the effects of simultaneous changes in other variables that may be correlated with both EU/extra-EU trade in aluminium and the CO<sub>2</sub> price. We therefore use the econometric technique of Multiple Linear Regression to control for these factors in order to obtain unbiased estimates of the part of the change in

net imports that would be caused by CO<sub>2</sub> prices alone. We thus specified the following model:

$$\begin{aligned} \text{Net Imports}_t &= \alpha + \beta_1.PCO2_t + \beta_2.IndProd_t + \beta_3.EUR/USD_t \\ &+ \beta_4.PCoal_t + \beta_5.PNatGas_t + u_t \quad (1) \end{aligned}$$

Where,

$NM_t$  = The level of net imports of primary aluminium products<sup>vii</sup> by the EU27 from non-EU ETS countries, in economic quarter t, measured in 100kg units. This represents EU27 imports from, minus exports to, all countries outside the EU27 to non-EU ETS countries<sup>viii</sup>.

$Ind-Prod_t$  = 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.

$PNatGas_t$  = 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.

$\alpha$  = Constant term

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

The underlying logic of the model is that the higher the cost of CO<sub>2</sub> in any given economic period, the higher will be electricity prices for EU smelters and so the greater the probability they will reduce production (either marginally or by shutting down) and that domestic demand will be met by imports. Consequently, if CO<sub>2</sub> prices have indeed led to a loss in competitiveness during the period of investigation, there should be an observable correlation between the CO<sub>2</sub> price and the quarterly level of net imports. Moreover, this correlation should be independent of changes in energy prices, exchange rates, and industrial production.

The explanatory variables were chosen with the aim of providing an unbiased estimate of the effect of quarterly CO<sub>2</sub> prices on the dependent variable. Thus all variables which could *a priori* be considered to be correlated with both the CO<sub>2</sub> 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<sub>2</sub> emissions via industrial production and therefore potentially the CO<sub>2</sub> price by increasing demand for emissions allowances. 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.

<sup>vii</sup> Specifically, primary aluminium data were calculated as the sum of HS codes: 760110 (Aluminium, not alloyed, unwrought) + 7601201 (Aluminium, alloyed, primary)

<sup>viii</sup> Norway, Iceland, and Liechtenstein have been included in the EU ETS since 2008 and are hence excluded as non-EU traded partners in the calculation of this variable.

The nominal EUR/USD exchange rate was also included as a further measure of the relative cost of imports and the relative value of exports. 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 EUR/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 have been empirically shown to be a fundamental driver of the EU ETS carbon price (Ellerman et al, 2009). We expected them to have a positive relationship to net imports. Many of the countries that export to the EU do not rely on coal-or gas-fired electricity to produce aluminium, or else do not share the same cost-exposure because of imperfectly competitive market conditions. But many EU producers now operate in relatively liberalised markets and are exposed to these prices as the marginal generating fuel in their respective electricity markets (e.g. via the German, British and Nordpool markets).

In addition to the above variables, we constructed two additional variables as robustness checks to the findings of the basic model described above. Firstly, to account for the possible effect of a significant percentage of long-term contracts beginning to end in 2007, we also tested structural break variables for the post-2007 part of the sample and interacted them with respect to the CO<sub>2</sub> price. Secondly, we used annual EU recycling production data (since quarterly recycling data was not available) and we tested whether quarters belonging to years of higher recycling levels witnessed different reactions to the CO<sub>2</sub> price. Finally, we also controlled for the effects of the global financial crisis in 2009 using a dummy variable.

## **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 “spurious regression”. We therefore sought to use the so-called cointegration approach to overcome this risk. Johansen cointegrating-rank tests confirmed the existence of a single cointegrating relationship between the variables, which implied that there was a stable long-run relationship between net imports and the set of dependent variables. 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 data and hence 50 quarterly observations, of which CO<sub>2</sub> prices were only present for 6 ½ years (26 quarterly observations), we must be clear that this analysis is limited to a relatively short sample period for evaluating the long-run effects of carbon pricing. Nevertheless, the sample size was sufficient for evaluating the evidence of the effects of EU carbon prices over the 6 ½ year period during which the EU ETS has been in operation.

One challenge posed by the data was that the prices of coal, gas and our measure of industrial production volumes turned out to be jointly highly correlated. Since the sample size was relatively small, this posed an identification problem to including all three variables in the model. This problem 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. The results of each are reported in Table 2.

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, it was also appropriate to control for secondary aluminium consumption. Since 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 estimate the model without secondary aluminium consumption. Then, as a robustness check, we re-estimated the model including the secondary aluminium data by using a “quarterised” average of the annual data for each calendar year. These data came from the European Aluminium Association. The relevant coefficient estimate appears in the results below next to the variable name “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. 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. Annex I describes some further features of the data and the estimation procedure.

## 5 – Results

### 5.1. Regression results

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

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

<b>Variable</b>	(1)	(2)	(3)	(4)
<b>Constant</b>	201964 (.)	255195 (.)	57405 (.)	199971 (.)
<b>PCO2</b>	-314 (270)	-1154*** (290)	-1053*** (278)	-361 (219)
<b>IndProd</b>	0.454*** (0.08)	0.634*** (0.08)	0.174** (0.09)	0.497*** (0.10)
<b>EUR/USD</b>	48339*** (13363)	6615.9 (17770)	32546*** (12809)	41851*** (10771)
<b>PCoal</b>	-	492*** (101)		

<b>PNatGas</b>	-	-	123*** (31.5)	
<b>RecyProd</b>	-	-		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 5% level

\*\*\* Statistically significant at 2.5% level

In all four model specifications, the coefficient estimate representing the effect of the price of CO<sub>2</sub> on net imports of primary aluminium was either not statistically significant or was the wrong sign (i.e. negative rather than positive). We therefore did not find any statistical 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.

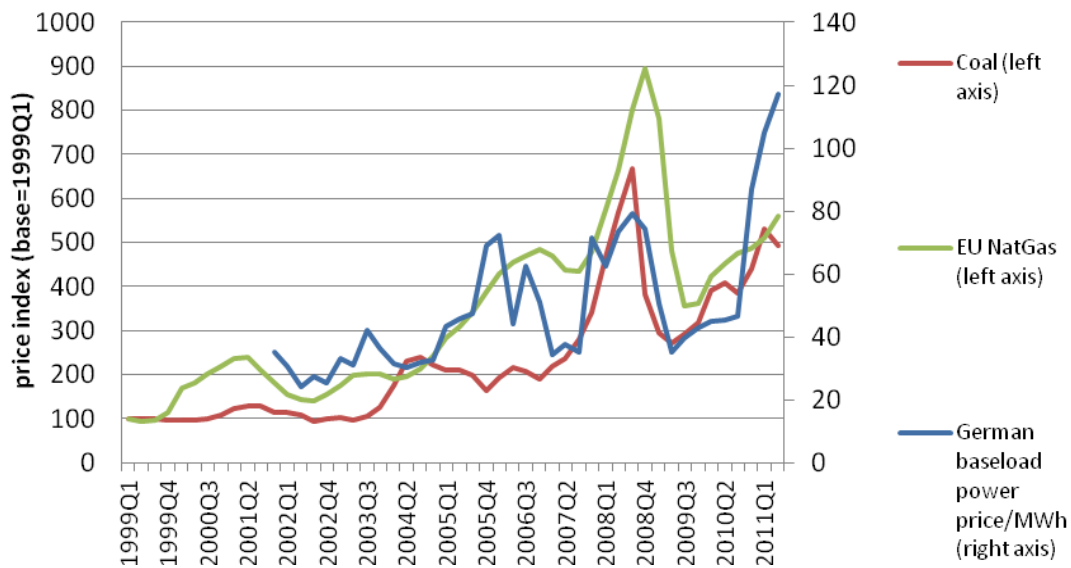
Among the variables found to be statistically significant explanators of EU net imports of primary aluminium were: the level of industrial production (i.e. European demand), the price of European coal, the price of European natural gas, and the EUR/USD dollar exchange rate. In addition to being statistically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

## 5.2. Interpretation

The fact that carbon price did not prove to be statistically significant suggests that, during the period of investigation, the EU ETS has not been a significant factor in explaining 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 reasons.

First and foremost, our results with respect to the positive influence of coal and gas prices, the exchange rate and domestic industrial production, demonstrate the greater importance of factors other than the CO<sub>2</sub> price. With respect to the significance of primary energy prices, a plausible explanation is that sharp rises in primary energy costs has, along with other factors, explained a more significant part of the rises in electricity costs for EU aluminium smelters than CO<sub>2</sub> prices. To help illustrate this point, Figure 5 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 shows that the rise in German wholesale power prices appears to be strongly – although not perfectly – correlated with very sharp rising trend and the increases volatility of primary energy costs for electricity producers.

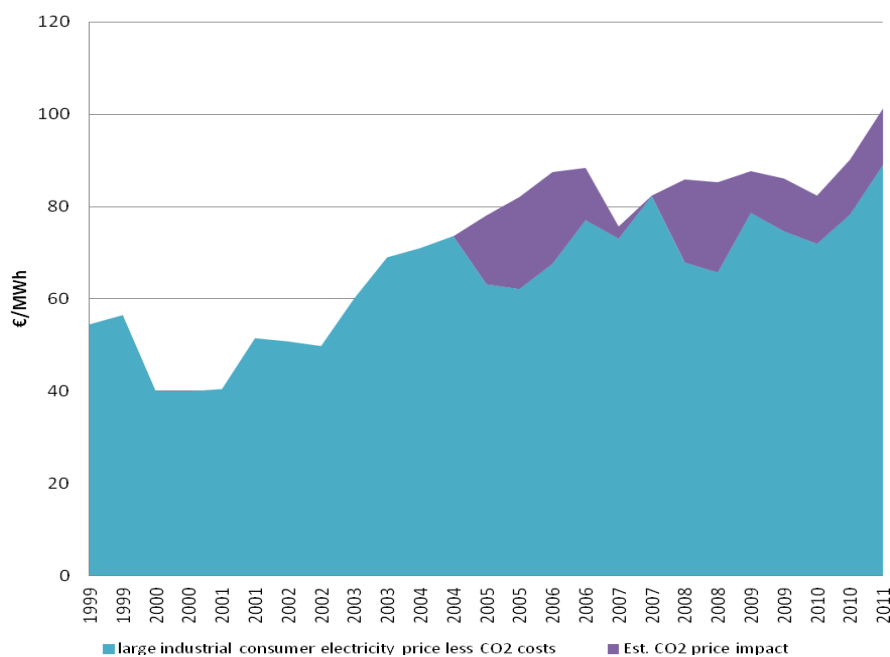
**Figure 5. EU coal, gas and Germany base-load power prices**



Source: IMF, Reuters; quarterly data

In order to provide further support for this interpretation of the driving factors behind electricity prices being more important than simply CO<sub>2</sub> costs, Figure 6 presents the results of an additional calculation. It shows the estimated contribution of CO<sub>2</sub> costs to wholesale German industrial electricity prices before VAT, based on the CO<sub>2</sub> price pass-through estimates of Sijm, et al. (2006). The figure confirms our hypothesis, that CO<sub>2</sub> costs have generally not been the biggest contributor to rising power prices – at least in Germany, a key aluminium producer.

**Figure 6. Estimated contribution of CO<sub>2</sub> price to rise in German industrial power costs**



Data : Bluenext, EUROSTAT, own calculation

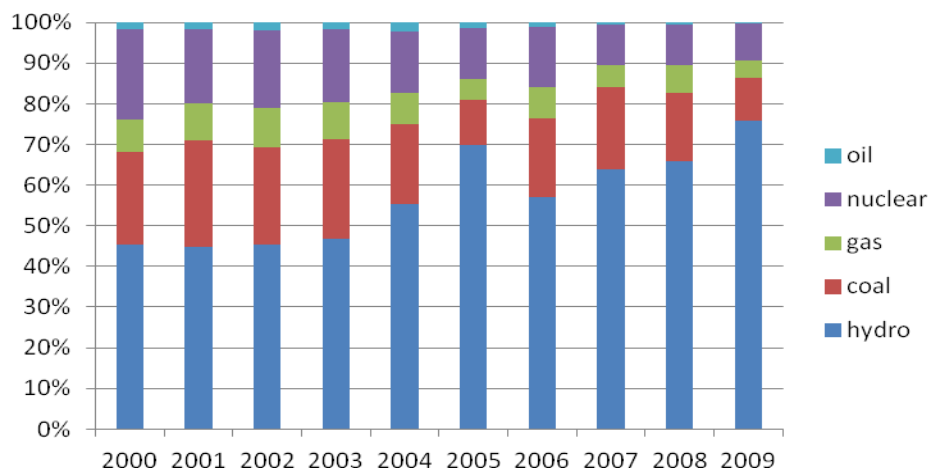
Note: electricity prices refer to average annual industrial consumer prices in €/MWh incl. tax. The industrial consumption price quoted refers to large industrial consumers consuming 70-150 000MWh/yr.

Prices exclude VAT.

CO<sub>2</sub> cost component assumes a pass-through of 90% of EUA price for coal-fired power and 0.9 tCO<sub>2</sub> emitted per MWh, consistent with econometric estimates by Sijm et al (2006).

Furthermore, Figure 7 shows that since 2004, when rising fossil fuel prices began to become noticeable, the share of EU production sourced from non-fossil fuel-based electricity generation in Europe, Norway, Iceland and Russia, rapidly began to increase. This provides further evidence that fossil fuel prices have indeed been a factor effecting the competitiveness of European aluminium production.

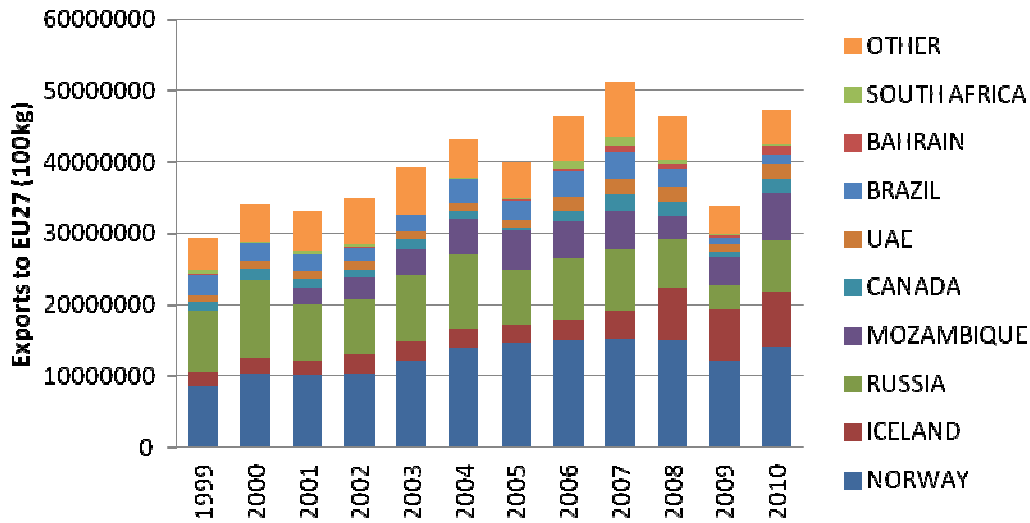
**Figure 9. Share of European primary aluminium production by electric fuel source**



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

However, arguing that both coal and gas prices are responsible for increased power prices raises 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, hinted at above, is that the EU's main competitors in the aluminium sector are not necessarily as exposed to the prices of coal and gas-fired electricity for a variety of reasons. Figure 8 shows that during the period of rising coal and gas prices since roughly 2004, the major exporters to the EU have been countries relying mainly on hydro-power for aluminium production – namely Norway (100%), Iceland (100%) but also Russia (~80%), Canada and Brazil (~80%). Moreover, producers in other key competitor countries, such as Mozambique, UAE and Bahrain (which use electricity from coal and gas), are often able to operate under less competitive-market conditions for both primary energy and generated electricity than several of the main markets in Western Europe. For instance, long term contracting is now an option available to aluminium producers in the outside Europe but not inside. It is highly plausible that as a consequence, the coal and gas intensity of the EU's marginal power generating facilities, is now an increasing disadvantage for EU smelters as they come off of long-term deals.

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



Data : EUROSTAT

Our results therefore appear to suggest the relatively much greater importance of factors other than the carbon price – relative energy prices, electricity market contracting arrangements, other factors driving domestic electricity prices higher<sup>ix</sup> and exchange rate movements – in determining the relative competitiveness of imports as opposed to domestic production for EU aluminium smelters.

Nevertheless, we believe that these results need to be interpreted with due caution, given that our sample period examined is relatively short compared to investment time-frames in the aluminium sector and given short-run 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.

## 6 – Conclusions

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.

Furthermore, the empirical evidence presented in this paper suggests that the international competitiveness of Europe’s primary aluminium sector is in long-run decline for reasons which go well 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 policy debate about carbon leakage should therefore be about not unnecessarily accelerating the

<sup>ix</sup> IFRI (2011) has 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 thus also have made a contribution to rising power costs in several EU countries.

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<sub>2</sub> prices. From a policy maker's perspective, it is therefore important that the CO<sub>2</sub> price is not used as an argument to compensate industry for a simultaneous loss of competitiveness which is due to other factors.

## Bibliography

Australian Bureau of Agriculture and Resource Economics (ABARE), 2009, *ABARE World Aluminium Statistics 2009*, Commonwealth of Australia.

Carbon Trust, 2004, *The European Emissions Trading Scheme: Implications for Industrial Competitiveness*, Carbon Trust, UK.

Carbon Trust, 2008, *The EU ETS Impacts on profitability and trade: a sector by sector analysis*, Carbon Trust, UK.

CE Delft, 2010, *Does the energy intensive industry obtain windfall profits through the EU ETS?* CE Delft, Netherlands, Research commissioned by the European Climate Foundation.

De Bruyn, S., Nelissen, D., Korteland, M., Davidson, M., Faber, J., van de Vreede, G., 2008, *Impacts of Competitiveness from the EU ETS – An analysis of Dutch industry*, CE Delft, Netherlands.

Community Independent Transaction Log (CITL), accessed 2011, maintained by Environment Directorate-General of the European Commission, <http://ec.europa.eu/environment/ets/>

Hourcade, J.-Ch., Demailly, M., Neuhoff, K., Sato, M., 2007, *Differentiation and dynamics of EU ETS competitiveness impacts*, Climate Strategies Report, Climate Strategies, UK.

DIW Berlin, Pahle M., Fan, L., Schill, W.P., 2011, *How Emissions certificate allocations distort fossil investments: The German Example*, Working Paper 1097, Germany

ECOFYS, 2011, *Competitiveness in the EU non-ferrous metals industries: final report*, a report commissioned by the European Commission, Directorate-General Enterprise and Industry

Ellerman, A.D., Convery, F.J., de Perthuis, C., 2009, *Pricing Carbon: The European Union Emissions Trading Scheme*, Cambridge.

European Aluminium Association (EAA), 2010, *Activity Report 2010*, EAA

European Aluminium Association (EAA), 2006, *Aluminium Sustainability Report 2006*, EAA, available at <http://www.alueurope.eu/>

European Commission, DG Competition website (accessed September 2012), [http://ec.europa.eu/competition/sectors/energy/electricity/electricity\\_en.html](http://ec.europa.eu/competition/sectors/energy/electricity/electricity_en.html)

Eurostat, (accessed 2011), [http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search\\_database](http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database)

Reinaud, J., 2004, *Industrial Competitiveness under the European Union Emissions Trading Scheme*, IEA information Paper, OECD/IEA, International Energy Agency, France.

Reinaud, J., 2008, *Climate Policy and Carbon Leakage: Impacts of the European Emissions Trading Scheme on Aluminium*, IEA information Paper, OECD/IEA, International Energy Agency, France

Cruciani, M., 2011, *Evolution des prix d'électricité aux clients domestique en Europe occidentale*, IFRI, Paris.

International Aluminium Institute Website (accessed 2011), <http://www.world-aluminium.org/>

International Monetary Fund (IMF), (accessed 2011), <http://www.imf.org/external/np/res/commod/index.aspx>

Global Industry Analysts, 2012, *Aluminium: A Global Strategic Business Report*, [http://www.strategyr.com/Aluminum\\_Market\\_Report.asp](http://www.strategyr.com/Aluminum_Market_Report.asp)

Graichen, V., Schumacher, K., Matthes, F.-Chr., Mohr, L., Duscha, V., Schleich, J., Diekmann, J., 2008, *Impacts of the EU Emissions Trading Scheme on the industrial competitiveness in Germany*, Oeko Institute for Deutsches Umweltbundesamt.

McKinsey & Company, Ecofys, 2006, *EU ETS Review: Report on International Competitiveness*, European Commission Directorate General of Environment, Belgium.

Sijm, J., Neuhoff, K., Chen, Y., 2006, CO2 cost pass-through and windfall profits in the power sector, *Climate Policy*, Vol. 6 Issue 1, UK.

Smale, R., Hartley, M., Hepburn, C., Ward, J., Grubb, M., 2006, *The impact of CO2 emissions trading on firm profits and market prices*, *Climate Policy*, Vol. 6 Issue 1, UK.

UNCTAD, 2010, *Review of Maritime Transport 2010*, United Nations, Geneva18

**Annex I. Data sources**

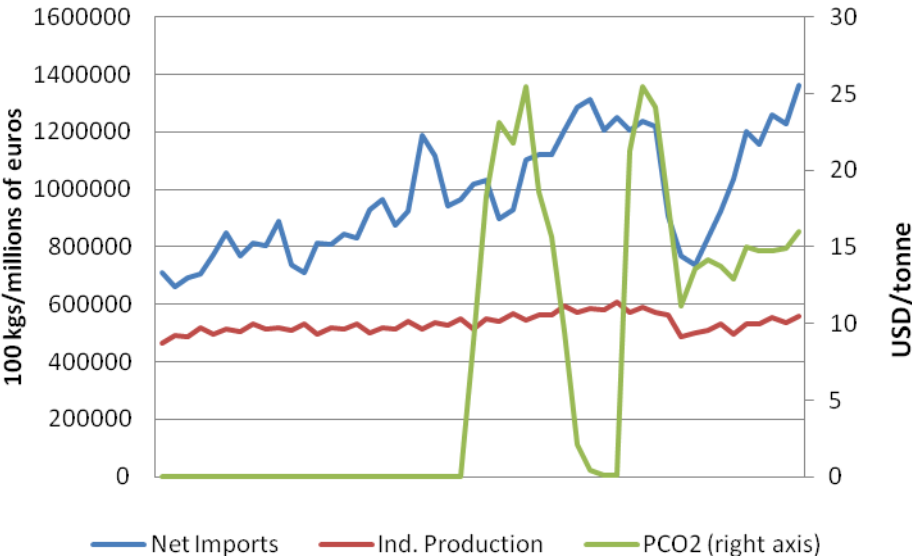
The data used to estimate the model came from a variety of sources. Trade data was obtained from EUROSTAT’s Comext database. Industrial production and nominal exchange rate data also came from EUROSTAT’s economic and industrial statistics databases. EU ETS CO<sub>2</sub> spot price data came from BlueNext. 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<sub>2</sub> 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.

**Annex II: Results of econometric tests**

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 CO<sub>2</sub>**



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)**

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