

Article

# Analysis of Carbon Leakage under Phase III of the EU Emissions Trading System: Trading Patterns in the Cement and Aluminium Sectors

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**Abstract:** This paper contributes to the existing literature on carbon leakage by using a range of different publically available datasets in order to develop a systematic approach for identifying whether products are potentially at risk of carbon leakage. The scope of this paper focuses on the cement and aluminium sectors at different levels of product aggregation to demonstrate the variation in trade patterns that exist over time. The evolution of EU-28 trade flows with third countries for these sectors between 2000 and 2016 enables the selection of key third countries that could warrant further investigation via more quantitative techniques in order to determine the impact of carbon pricing on trade patterns. This systematic approach could be replicated for additional sectors in further research as part of a more regular assessment to provide evidence of carbon leakage for European industry. No evidence of carbon leakage is found in this paper for clinker and cement, while there is no conclusive evidence for unwrought non-alloyed aluminium and aluminium products.

**Keywords:** carbon leakage; emission trading; aluminium; cement; trade

## 1. Introduction

The European-Union Emissions Trading System (EU ETS) is a cap and trade scheme that requires participating installations to obtain allowances to cover their greenhouse gas (GHG) emissions. Energy intensive industries across Europe have long argued that it may be necessary to relocate their production activities to unregulated countries in order to avoid the competitive disadvantages associated with their participation in the EU ETS. The relocation of production to countries with laxer emission constraints is often referred to as carbon leakage due to the fact that it could lead to an increase in overall emissions [1].

To mitigate the risk that the cost associated with surrendering these allowances could competitively disadvantage European industry, relative to those that are not subject to the same carbon pricing, the majority of the allowances were initially issued for free (i.e., based mainly upon historic emissions or capacity) in the first two trading periods (2005–2012). However, major revisions to strengthen the EU ETS were undertaken for the third trading period (2013–2020), especially with respect to allowance allocation and included:

- The move to a single union-wide cap, instead of national caps, standardised the approach to improve the harmonisation of ambition between Member States and therefore the level of allocation to their industries.

- Auctioning became the default method for allowance distribution, reducing the number of allowances that are provided for free.
- Harmonised rules for free allocation based on (emission performance) benchmarks (for products and fallback approaches for heat and fuels) standardised the approach for installations within each sector or sub-sector.

Given these changes in the allocation method (i.e., resulting in a reduction in the number of allowances distributed for free), installations covered by the EU ETS may now be at a greater risk of carbon leakage than in the past, at least as long as other regions are not following rapidly which, nevertheless, is changing over recent times with South Korea (ETS start in 2015) and China (ETS start in 2017) establishing their own trading systems. Indeed, these countries are already starting to identify their own sectors at risk of carbon leakage for both ETS sectors [2,3] as well as non-ETS sectors [4]. Despite the increased efforts by third countries to implement more ambitious climate change policies, the European Commission concluded that no comparable action was being taken by third countries when determining the list of sectors that were considered to be exposed to significant risk of carbon leakage in the 2015 to 2019 period.

As a consequence, it was considered necessary to continue to protect those sectors or sub-sectors at risk of carbon leakage via the provision of a higher share of free allowances in the third trading period in comparison to other industrial installations. A sector or sub-sector is defined as being exposed to a significant risk of carbon leakage based on the outcome of the following two indicators (1) carbon cost (i.e., (direct carbon costs + indirect carbon costs)/gross value added) and (2) trade intensity (i.e., (imports + exports)/(turnover + imports)):

- The direct and indirect costs induced by the implementation of the ETS directive 2003/87/EC (and updates) would increase production cost, calculated as a proportion of the gross value added, by at least 5%; and;
- the sector's trade intensity with non-EU countries (imports and exports) is above 10%.

A sector or sub-sector is also deemed to be exposed if:

- the sum of direct and indirect additional costs is at least 30%; or;
- the non-EU trade intensity is above 30%.

Carbon leakage may take the form of production leakage (i.e., short term competitiveness effects and a loss in market share due to a difference in cost structure) and investment leakage (i.e., longer term impact resulting in eventual locational shifts in production) [5]. Evidence of carbon leakage has so far been very difficult to detect due, primarily, to the challenge in attributing changes in production levels and trade to EU-28 climate policy during a time of economic volatility caused by the economic recession. However, given the low carbon price as a result of the imbalance in the supply and demand of allowances, and the free allocation given to sectors or sub-sectors at risk of carbon leakage, it is unlikely that carbon leakage, at least with regards to production leakage, has occurred [6,7]. This evidence needs to be continually updated in light of changes to environmental policies both within the EU-28 and abroad and other factors (i.e., economic developments, technological changes, currency fluctuations and labour and transportation costs) that may influence levels of production and trade.

This study focuses on changes in trade patterns by providing a comparison between the following two very diverse sectors at different levels of product aggregation over time.

- (1) Cement manufacturing can be divided in two main steps: 'clinker manufacturing (90% to 95% of emissions, virtually all from direct emissions), and blending and grinding clinker with other materials to produce cement (generating indirect emissions due to electricity use)' [8]. Given that the majority of the emissions associated with the production of cement are embodied within an intermediate product, the import of clinker from non-regulated countries represents a carbon

leakage risk [8]. The fact that cement is a relatively homogenous product adds to this risk as producers of cement essentially compete on price alone due to the lack of product specialisation. However, according to estimates by [9] the average total production cost per tonne of cement for Egypt (47 €/t), the EU (48 €/t) and Ukraine (53 €/t) were similar in 2011/12. In the assessment, the energy costs of the EU were lower than both Egypt and Ukraine but this was offset by relatively higher raw material and labour costs. To date, high transportation costs relative to product value have led to the creation of regional markets largely protected from international competition; despite regional variations in production costs.

In the current carbon leakage list, the manufacture of cement is defined as being at a significant risk of carbon leakage for reasons of induced carbon costs alone as it well exceeds the 30% threshold (i.e., 45.5%) [6]. Despite the potential risk of carbon leakage for the cement sector due to carbon costs, recent ex-post evaluations in the literature suggest that this risk has not, so far, been realised and that carbon pricing impacts are more limited than experienced in other industrial sectors [7,10,11].

- (2) Aluminium production refers to both upstream (i.e., production of primary aluminium from alumina, which is energy intensive and the production of secondary aluminium from refining recycled waste and scrap that is less energy intensive) and downstream (i.e., aluminium rolling and aluminium extrusion) processes. Given the energy intensive nature of primary aluminium production, there is a risk that the impact of the EU ETS on energy prices is undermining the competitiveness of the sector.

According to estimates by [9] the average cast aluminium prices 'during 2012 and 2013 were 1572 €/t and 1391 €/t, respectively and the average of the estimated production costs of the EU industry for those years 1411 €/t and 1295 €/t, respectively'. Several countries were estimated to have lower total production costs per tonne of cast aluminium than the EU in 2012/13 (i.e., Kazakhstan: approx. 700 €/t and Iceland: approx. 1200 €/t) primarily due to lower energy prices. Interestingly the assessment shows that production costs for China were slightly higher than in the EU in 2012/13 reflecting the large number of smaller inefficient plants that still operate to meet domestic demand in the country.

In the current leakage list, aluminium production is defined as being at a significant risk of carbon leakage for reasons of trade intensity alone as it exceeds the 30% threshold (35.9%) [6]. Evidence of carbon leakage effects in the aluminium sector is limited, so far, with several ex-post assessments [12,13] unable to observe beyond negligible effects of the EU ETS on trade patterns.

The aim of this study is to identify any changes in trade patterns that may have occurred at different levels of product aggregation for the cement and aluminium sectors, especially after the revision to the EU ETS at the start of the third trading period. Given the different characteristics of the assessed sectors, it is expected that any increase in carbon costs will have a greater impact on the competitiveness of the highly valuable and trade intensive aluminium products compared to the less valuable and less trade intensive cement products. The study will provide possible explanations for the observed trade patterns. The study will conclude with some reflections on the impact of the EU ETS on the competitiveness of the European cement and aluminium sectors and provide recommendations for future research.

## 2. Methodology

We analyse three different aspects:

- EU-28 production, extra-European import and extra-European export volume
- EU-28 extra import volume by trading partner
- EU-28 extra export volume by trading market

We carry out the analysis based on the following indicators:

- Ratio extra-EU-28 imports / production
- Ratio EU-28 extra and intra import volume
- Ratio EU-28 intra and extra export volume
- EU-28 share in its main export markets

The analysis is carried out both for cement clinker and unwrought non-alloyed aluminium, as well as for cement and overall aluminium production. In order to descriptively assess the development of trade patterns in the European cement and aluminium sectors and thus to identify any evidence of carbon leakage risk, it is necessary to use complimentary information that is publically available. A three-step approach evolved from the availability of data on trade from the following three sources:

- (1) PRODCOM: provides statistics on the production of manufactured goods together with related external trade data, which is obtained by the National Statistical Institutes who conduct a survey of enterprises. The survey is based on the PRODCOM List, consisting of about 3900 products. The eight digit codes used in the list are based on the six digit CPA headings (i.e., refers to the Statistical Classification of Products by Activity in the European Economic Community) and the four digit NACE rev 1.1 (i.e., refers to the Statistical classification of economic activities in the European Community). From 2008 onwards the PRODCOM code is linked to CPA 2008 and NACE Rev. 2 [14].

The dataset entitled, Sold production, exports and imports by PRODCOM list (NACE Rev. 2)—annual data, provides information on extra EU-28 imports and exports at an eight digit level of product disaggregation, which enables the assessment to observe the trade developments of specific products in the cement and aluminium sectors (i.e., cement clinker and unwrought non-alloyed aluminium, which were selected based upon the sector specific guidance document from the European Commission [15]). In addition, the dataset provides information on levels of sold production. Therefore this dataset can be used to consistently evaluate the relationship between domestic sold production, external imports and exports for products in the cement and aluminium sectors, and develop useful indicators to provide evidence of carbon leakage over time. However, if more reliable production data from industry is publically available then the assessment may include this information to ensure the production of a sector is accurately represented. In this first step, if we observe the ratio of imports to domestic production increasing for products in the European cement and aluminium sectors this may provide evidence of carbon leakage that would require further assessment to understand the explanatory factors driving this trend over the time period.

- (2) COMEXT: provides statistics on the international trade of goods. This statistical information is collected from traders on the basis of Customs (extra-EU) and Intrastat (intra-EU) declarations. Products are disseminated according to the Combined Nomenclature (CN8), which first six digit codes coincide with the Harmonised Commodity Description and Coding System (HS), products are disseminated as well according to the Standard International Trade Classification (SITC) and the Broad Economic Categories (BEC) [16].

The datasets entitled, EU Trade Since 1988 By CPA\_2008 and EU trade since 1988 by HS2, 4, 6 and CN8, provide information on both intra and extra EU-28 imports and exports at a four and eight digit level of product disaggregation. The datasets also provide information on the trade flows of both European cement and aluminium products with partner countries.

In this second step, we identify the key export markets for the European cement and aluminium sectors that will then be further assessed qualitatively in the third step (based on additional country specific information) to determine whether any changes in trade can be linked to the effects of carbon leakage. The development of internal trade amongst EU Member States will also

be considered by developing an indicator that tracks the share of internal EU-28 trade in relation to the total EU-28 trade for cement and aluminium products. This may provide further evidence of carbon leakage. For example, if the share of internal EU-28 imports declines, this may imply that the EU-28 is more dependent on imports from third countries (if domestic production does not increase).

- (3) United Nations Commodity Trade Statistics (UN COMTRADE): The dataset is the largest depository of international trade data and relies upon over 170 reporter countries/areas providing the UNSD (United Nations Statistics Division) with their annual international trade statistics data according to commodities/service categories and partner countries. Commodities are reported in the current classification and revision (HS 2012 in most cases as of 2016) [17].

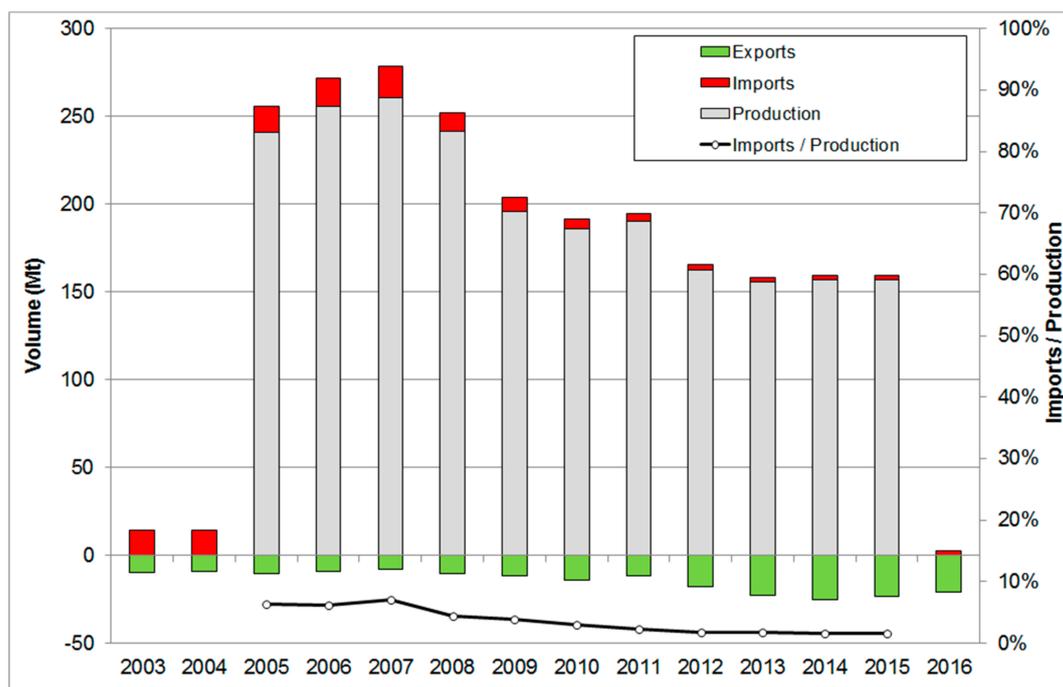
The dataset complements the other datasets in this final step by providing information on the trade flows of third countries, which is used to assess the imports of the third countries that were previously identified as key EU-28 export markets for the European cement and aluminium sectors. The identification of such third countries furthers any discussion on carbon leakage as it is possible to track how the share of EU imports in these key markets changes over time and to put forward reasons for why other countries may be more competitive (i.e., geographical proximity, competitive production costs) and whether or not similar environmental policies are implemented in these third countries. However, changes in trade patterns before and after the introduction of the EU ETS may occur for many longer term reasons (i.e., loss/gain in competitiveness independent from carbon markets) and shorter term reasons (i.e., economic cycles in different parts of the world resulting in different levels of capacity utilisation).

This paper contributes to the existing literature on carbon leakage by using a range of different publically available datasets in order to develop a systematic approach for identifying whether products are potentially at risk of carbon leakage. The scope of this paper focuses on the cement and aluminium sector at different levels of product aggregation to demonstrate the variation in trade patterns that exist over time. The evolution of EU-28 trade flows with third countries for these sectors between 2000 and 2016 enables the selection of key third countries that could warrant further investigation via more quantitative techniques in order to determine the impact of carbon pricing on trade patterns. This approach could be replicated for additional sectors in further research as part of a more regular assessment to provide evidence of carbon leakage for European industry.

### 3. Results

#### 3.1. Cement

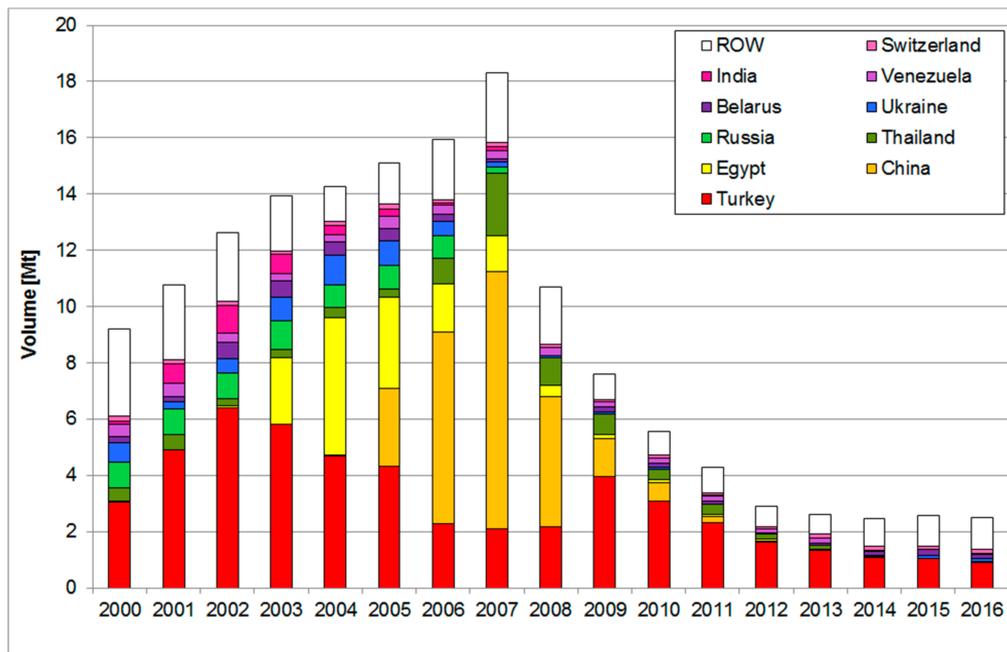
The analysis of the cement sector focuses on products classified under NACE code 2351, which includes the manufacture of clinkers and hydraulic cements, including Portland, aluminous cement, slag cement and superphosphate cements. Figure 1 shows production, extra import and export volumes for EU-28 cement products between 2003 and 2016. The majority of cement products are produced and consumed domestically by the EU-28 over the time period with international trade accounting for smaller volumes. Production and imports of cement products by the EU-28 peaked in 2007 at 260.3 million tonnes (Mt) and 18.3 Mt respectively. However, demand declined sharply following the financial crisis. This lack of demand for cement production was related to the decline in construction as a consequence of stalled growth in the European economy. Due to the low demand domestically, exports of cement products have increased in recent years reaching a peak volume of 25.2 Mt in 2014.



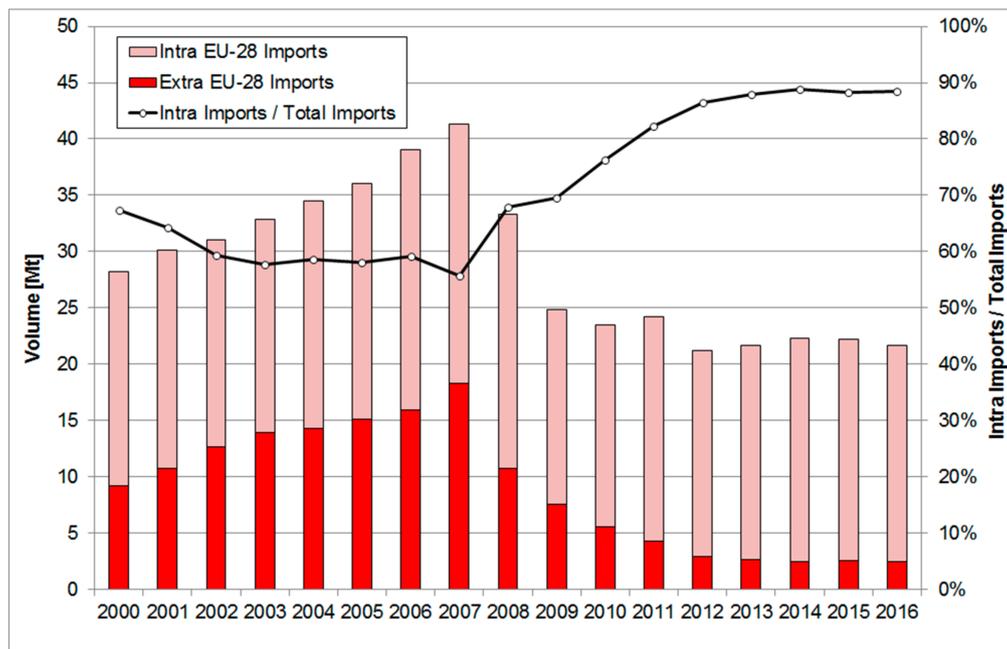
**Figure 1.** EU-28 production, extra import and extra export volumes (Mt) for cement products. Note: Aggregate of PRODCOM codes 23511100, 23511210 and 23511290. Production volume is taken from industry data (i.e., Getting the Numbers Right (GNR) project) and is not available for the years 2003, 2004 and 2016. The production data may not be fully consistent with the trade data from PRODCOM. Source: [18,19].

The ratio between extra EU-28 imports and domestic production has declined since the economic recession from a peak of 7% in 2007 to 2% in 2015. Based upon this indicator there is no evidence of carbon leakage for cement products at an aggregate level. The trend may not however continue into the future and may have been caused by shorter term circumstances (i.e., overcapacity following the collapse in domestic consumption after the economic crisis) [9]. Nevertheless, the evolution suggests that extra EU-28 imports were less competitive compared to domestic production, as they were divided by more than a factor of five from before the economic crisis. The opposite would have been expected, if domestic industries were becoming less competitive, especially during an economic crisis: while in a booming market competitive differences may be masked, they would appear more clearly in a stagnating market.

Figure 2 shows the extra EU-28 import volume of cement products by trading partner between 2000 and 2016 whilst Figure 3 puts this external trade into perspective by comparing the volume of extra EU-28 imports to the volume of intra EU-28 imports over the same time period. The majority of cement imports occur between the Member States of the EU-28, which reflects the low value to weight ratio of cement. For example, in 2016 intra EU-28 imports accounted for 88% of the total import volume. Prior to the economic recession, this value was considerably lower with the EU-28 also importing cement products from both China and Turkey. After the economic recession, however, the demand for cement products within the EU-28 declined and this is reflected by the lower import volumes. In recent years Turkey has continued (albeit to a lesser extent) to export cement products to the EU-28. Turkey benefits from an attractive location for cement production with the availability of viable limestone deposits, low labour costs, access to import demand markets and relatively short transport distances [20].



**Figure 2.** EU-28 extra import volumes (Mt) of cement products by trading partner. Note: CPA 2008 code: 2351. ROW: Rest of World. Source: [21].



**Figure 3.** EU-28 extra and intra import volumes (Mt) of cement products. Note: CPA 2008 code: 2351. Source: [21].

Figure 4 shows the extra EU-28 export volume of cement products by trading partner between 2000 and 2016 whilst Figure 5 puts this external trade into perspective by comparing the volume of extra EU-28 exports to the volume of intra EU-28 exports over the same time period. The majority of cement product exports also occurs between the Member States of the EU-28, which again reflects the low value to weight ratio of cement. For example, in 2007 intra EU-28 exports accounted for 77% of the total export volume. In particular, EU-28 cement exports to Algeria have increased substantially in

recent years following a large capital spending programme to address their housing shortages by the Algerian government, which has resulted in their demand for cement products being unable to be met by domestic production alone. However, this trend is likely to change as the country produces more domestically [22].

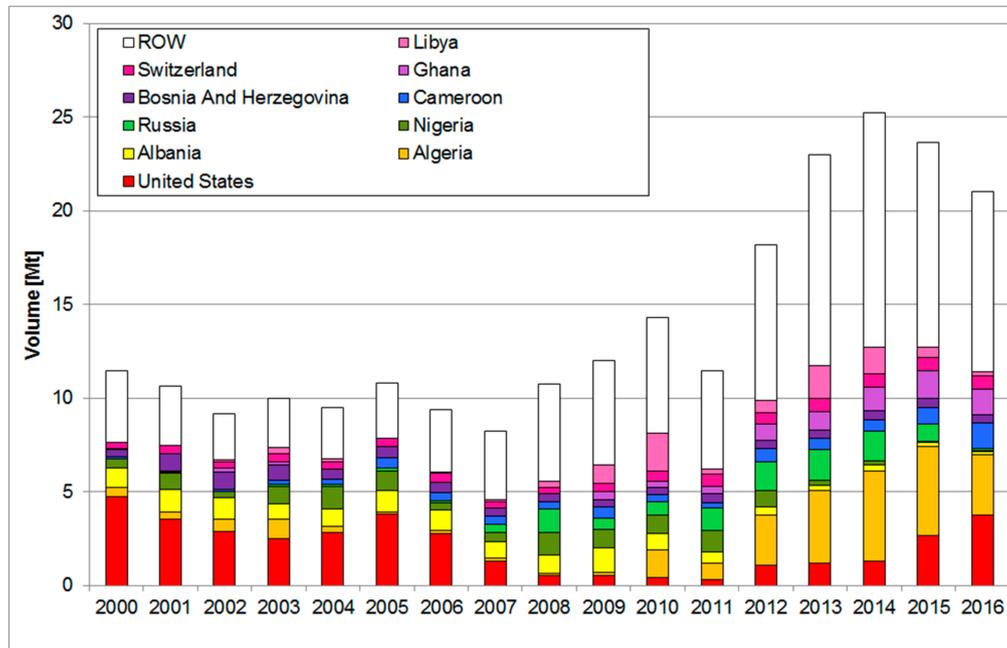


Figure 4. EU-28 extra export volumes (Mt) of cement products by trading partner. Note: CPA 2008 code: 2351. Source: [21].

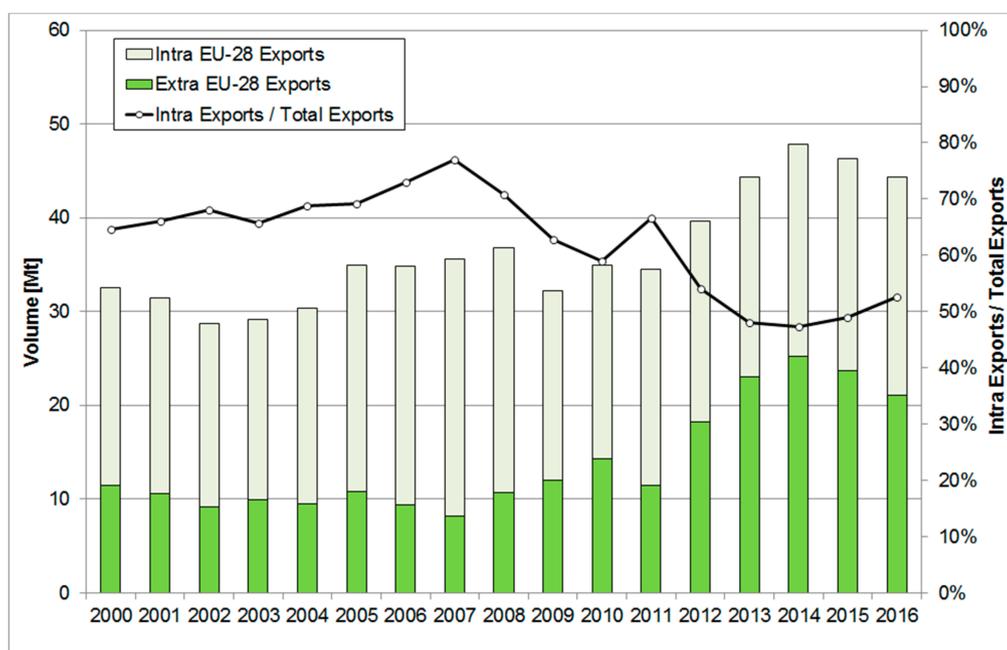
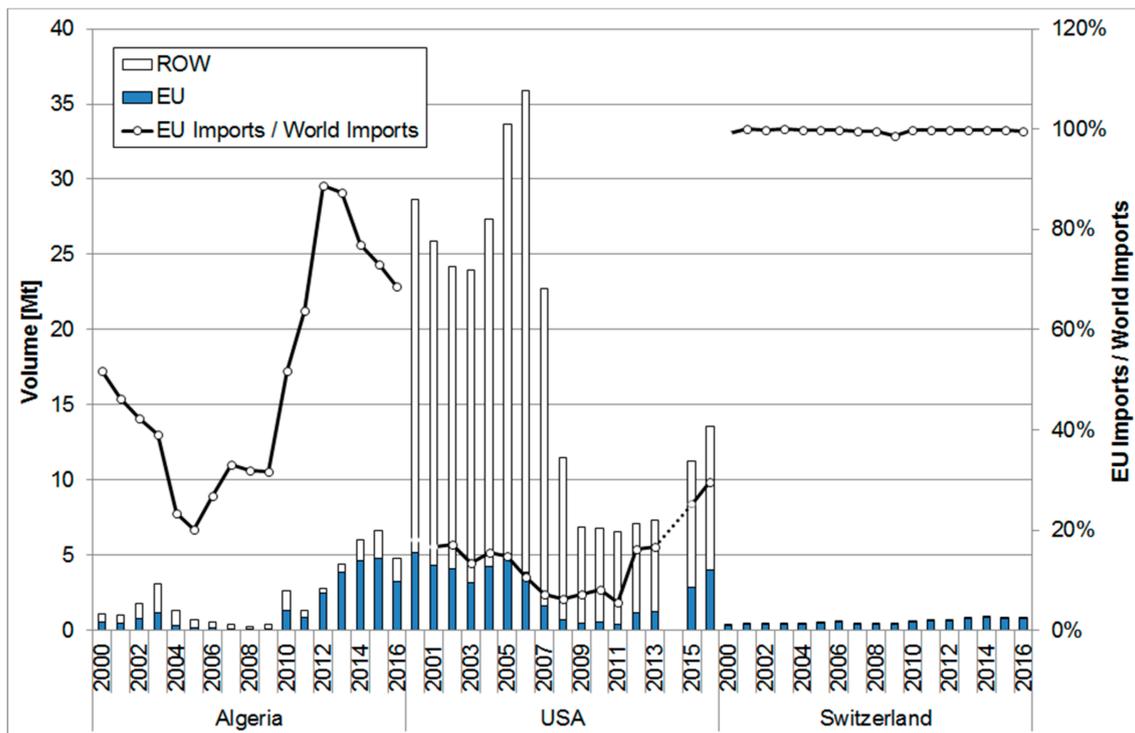


Figure 5. EU-28 intra and extra export volumes (Mt) of cement products. Note: CPA 2008 code: 2351. Source: [21].

Figure 6 shows several of the EU’s main export markets for cement products between 2000 and 2016. The EU has become the dominant player in the Algerian market (i.e., accounting for 69% of

Algeria's import of cement products in 2016), which is due to a combination of over-supply of cement in Europe and increasing demand for cement products in the construction industry in Algeria. Indeed, the share of EU imports in the Algerian market increased rapidly between 2004 and 2013. The dominant position of the EU in this growing market will be dependent upon future capacity utilisation rates in Europe and the extent to which current investment in Algeria removes their dependency on cement product imports. Although the EU is less dominant in the more competitive US market (i.e., accounting for 30% of US imports of cement products in 2016) the share of EU imports has increased in recent years despite strong competition from Canada, which benefits from lower transportation costs given its geographical proximity.

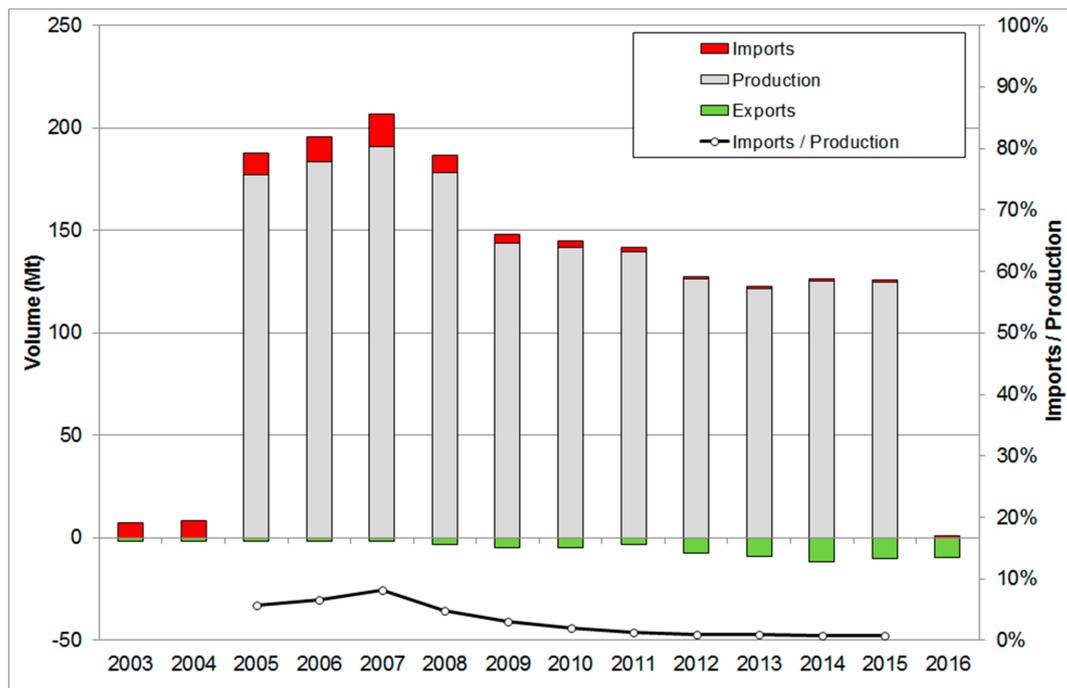


**Figure 6.** EU's share of selected export markets for cement products. Note: Harmonised Commodity Description and Coding System (HS) commodity code 2523. Source: [23].

### 3.2. Cement Clinker

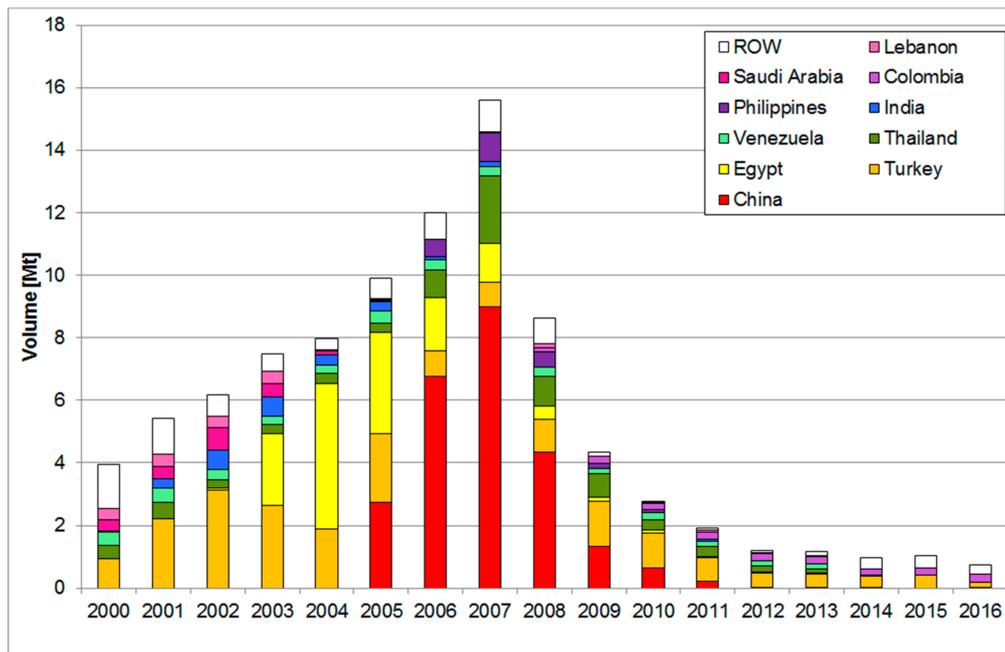
Within the sector specific guidance from the European Commission [15] that describes the product benchmarks, which determine free allocation in the third trading period of the EU ETS, the product entitled 'cement clinkers' is referred to as a relevant PRODCOM code for the grey cement clinker benchmark. It is therefore the focus of our analysis in order to see if the carbon leakage indicators differ at the product level of disaggregation. Figure 7 shows production, extra import and export volumes for EU-28 clinker products between 2003 and 2016. The EU-28 has changed from being a net importer before, to a net exporter after, the economic crisis.

This is illustrated by the decline in the import to production ratio. The import volume of clinker peaked in 2007 at 15.7 Mt. With the onset of the economic recession, the volume of clinker imports into the EU-28 declined to only 0.7 Mt by 2016. Simultaneously exports of clinker grew and accounted for a volume of 9.5 Mt by 2016. Over-capacity in the European cement sector following the economic recession is likely to have driven the current trends observed in the trade pattern.

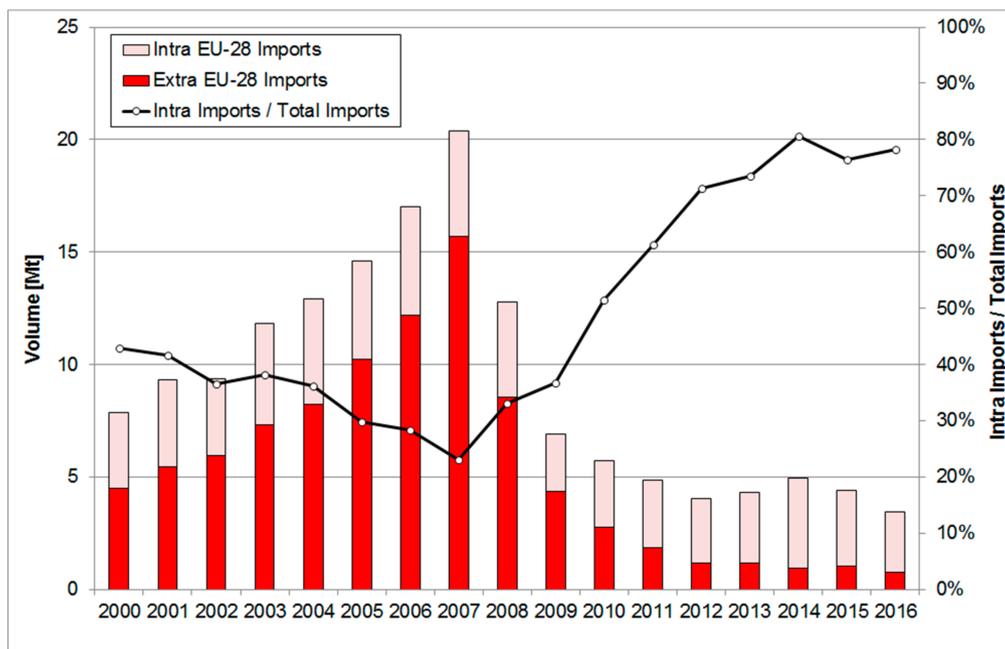


**Figure 7.** EU-28 production, extra import and extra export volumes (Mt) for cement clinker. Note: PRODCOM code 23511100. Production volume is taken from industry data (GNR project) and is not available for the years 2003, 2004 and 2016. The production data may not be fully consistent with the trade data from PRODCOM. Source: [18,19].

Figure 8 shows the import volume of clinker products by trading partner between 2000 and 2016, whilst Figure 9 puts this external trade into perspective by comparing the volume of extra EU-28 imports to the volume of intra EU-28 imports over the same time period. Prior to the economic recession, China accounted for 57% of the total EU-28 import volume of clinker products in 2007. Indeed, the overwhelming majority of the cement products that China exported to the EU-28 over the time period were in the form of clinker as it was economically viable to transport the lower weight product over long distances. Following the economic downturn, demand for clinker products in the EU-28 was considerably lower and China no longer accounts for a large share of EU-28 imports. Given that the share of intra EU-28 imports of clinker has increased following the economic crisis, the trend suggests that evidence for carbon leakage is limited.



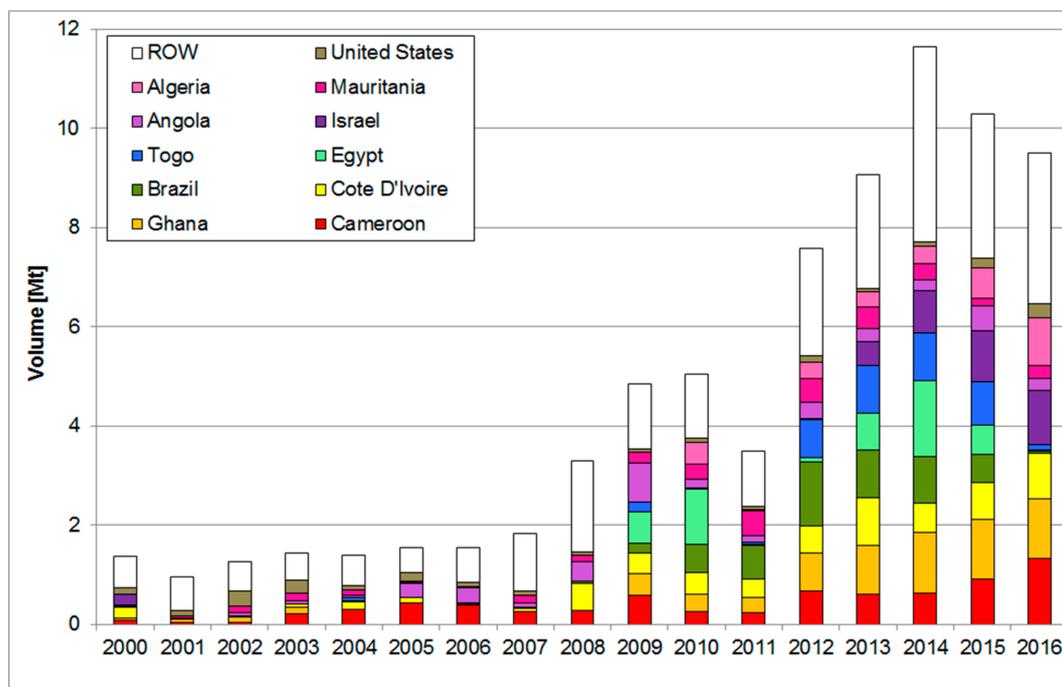
**Figure 8.** EU-28 extra import volumes (Mt) of cement clinker by trading partner. Note: Combined Nomenclature (CN) code 25231000—Cement clinkers. Source: [24].



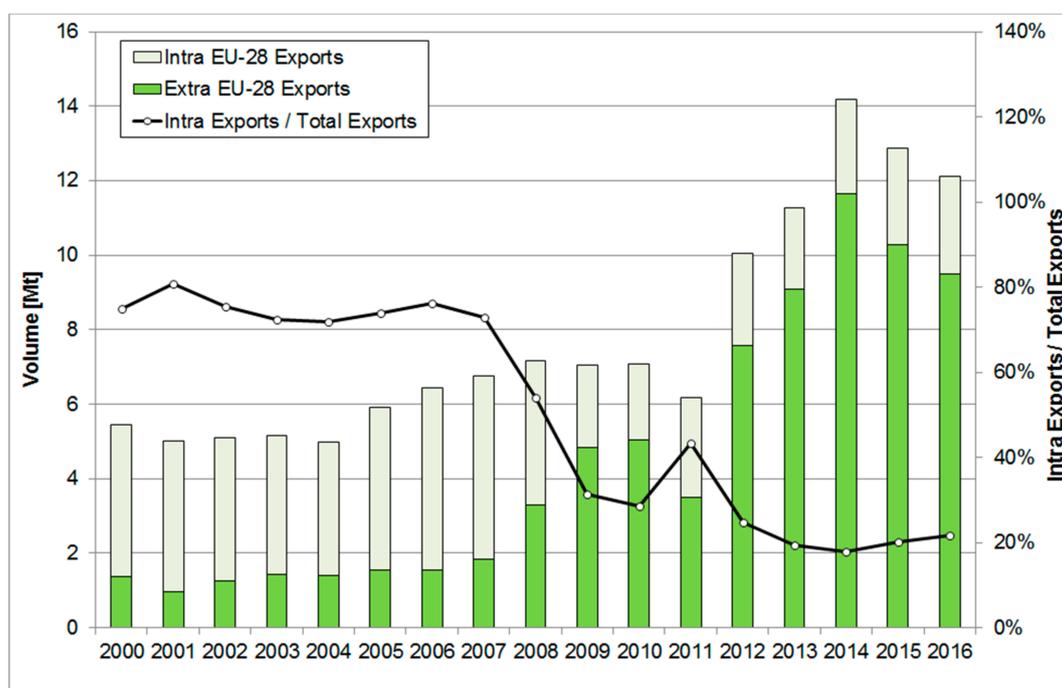
**Figure 9.** EU-28 extra and intra import volumes (Mt) of cement clinker. Note: CN code 25231000—Cement clinkers. Source: [24].

Figure 10 shows the export volume of clinker products by trading partner between 2000 and 2016; whilst Figure 11 puts this external trade into perspective by comparing the volume of extra EU-28 exports to the volume of intra EU-28 exports over the same time period. The total volume of EU-28 exports of clinker products increased from 1.4 Mt in 2000 to 9.5 Mt in 2016 with new export markets emerging in West Africa. This is also reflected by the decreasing trend in the share of intra EU-28 exports in total exports over time. The allocation rules of the EU ETS (i.e., setting activity level thresholds to reduce the over allocation of allowances to low activity installations) may have actually

induced excess clinker production in the EU-28 during the third trading period. It has been argued that cement producers may have strategically adjusted their output in order to obtain more free allocation and that this has partly contributed to the distortion in trade patterns [25].

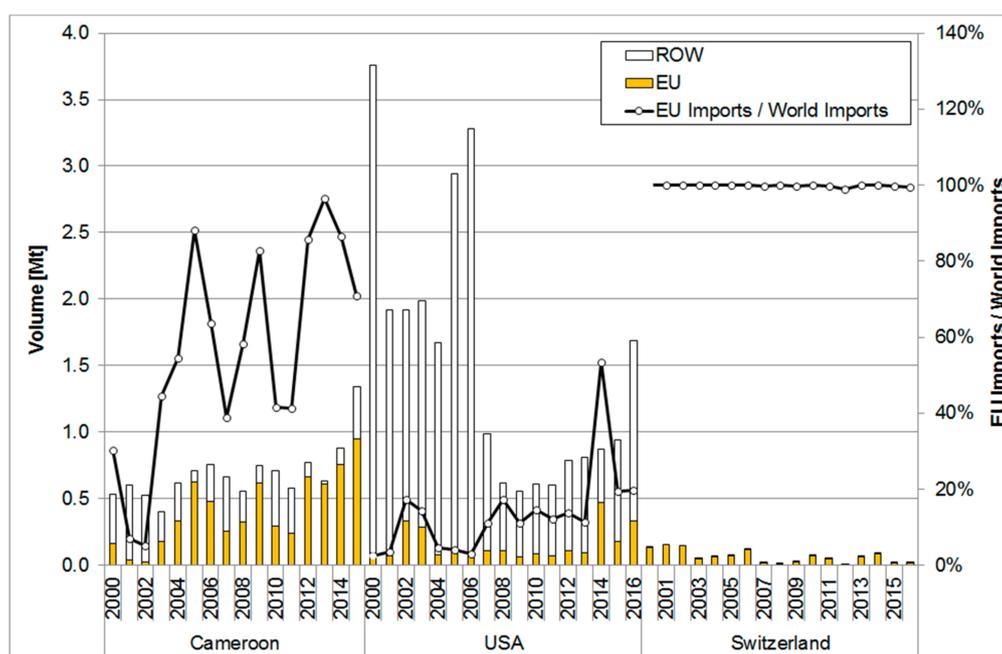


**Figure 10.** EU-28 extra export volumes (Mt) of cement clinker by trading partner. Note: CN code 25231000—Cement clinkers. Source: [24].



**Figure 11.** EU-28 extra and intra export volumes (Mt) of cement clinker. Note: CN code 25231000—Cement clinkers. Source: [24].

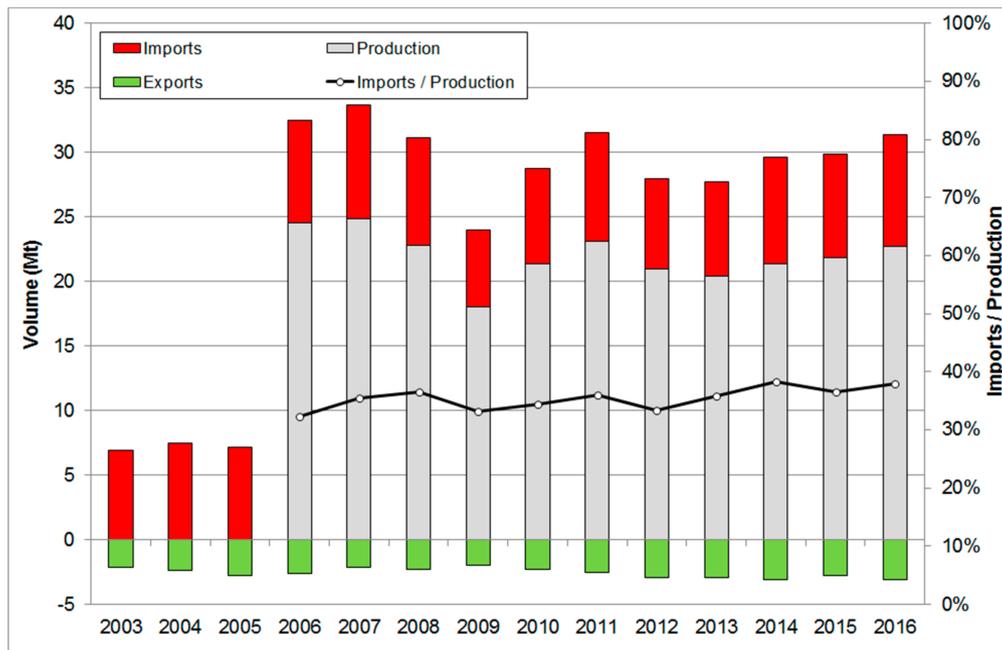
Figure 12 shows several of the EU's main export markets for clinker between 2000 and 2016. The EU has become the dominant player in the Cameroon market accounting for 71% of the country's total import of clinker in 2015. Despite rising levels of domestic production, a large proportion of clinker demand in West Africa is currently met through imports [26]. The operation of new grinding facilities in Cameroon (i.e., which only produce cement from clinker produced elsewhere) has provided a market for the over-supply of clinker produced in the EU. However, the EU share of this market may decline in the future as the domestic capacity of the region increases over time with the support of further inward investment. For example, the Dangote group strategy involves the scaling up of the production of clinker at integrated plants (i.e., which produce clinker and cement and requires continuous operation) located in countries with plentiful limestone resources (i.e., Nigeria and Senegal), exporting this to new grinding facilities in underserved markets (i.e., in Cameroon and Côte d'Ivoire), and then exporting surplus cement to landlocked countries [26].



**Figure 12.** EU's share of selected export markets for cement clinker. Note: HS commodity code 2523. Source: [23].

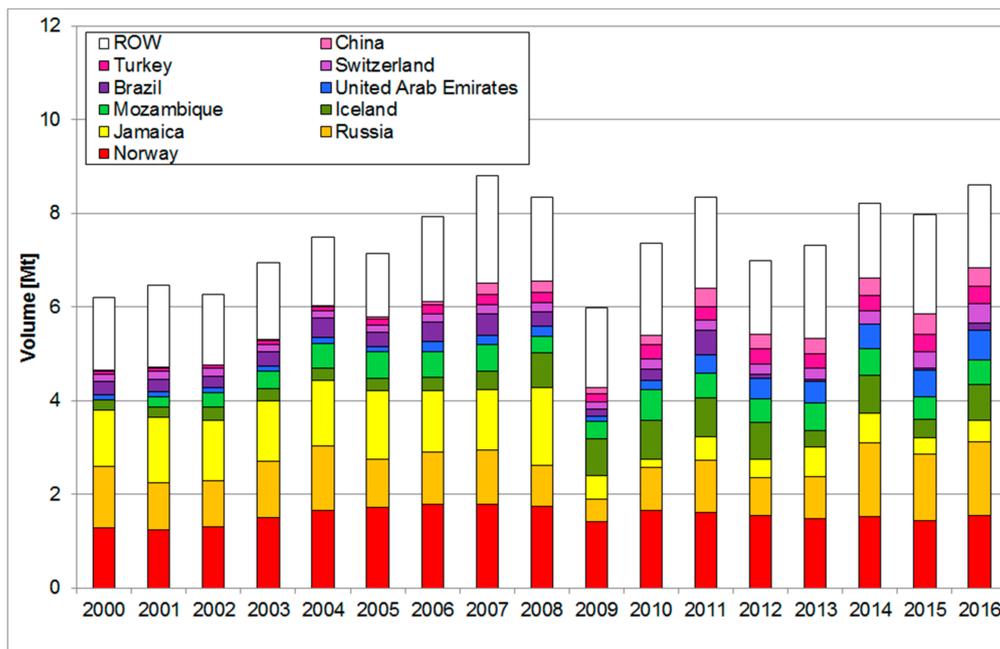
### 3.3. Aluminium

The analysis of the aluminium sector focuses on products classified under NACE code 2442, which includes the production of both primary and secondary aluminium (referred to as unwrought aluminium) as well as the downstream processing of aluminium into finished products (referred to as wrought aluminium). Figure 13 shows sold production, extra import and export volumes for EU-28 aluminium products between 2003 and 2016. Following the economic recession, the import volume of aluminium products declined sharply from 8.8 Mt in 2007 to 6.0 Mt in 2009. The import volume subsequently recovered and increased to 8.6 Mt in 2016. The EU-28 export volume of aluminium products for the time series under consideration was highest in 2016 reaching 3.1 Mt. The ratio between extra EU-28 imports and domestic production (sold) has also gradually increased since the economic recession from 33% in 2009 to around 38% in 2016. Based upon this indicator there may be evidence of carbon leakage for aluminium products at an aggregate level.

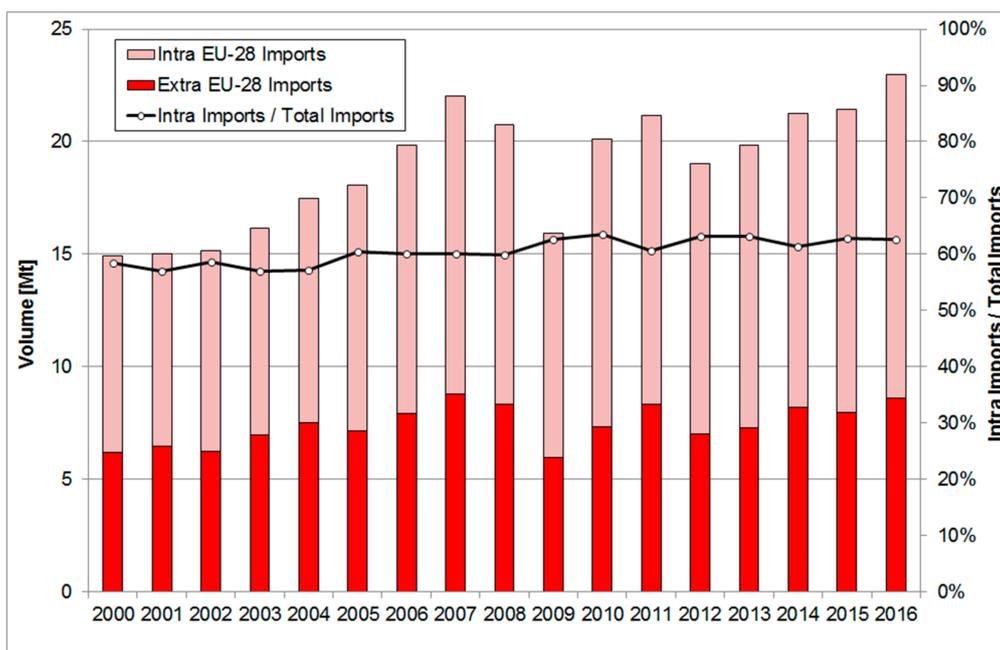


**Figure 13.** EU-28 production (sold), extra import and export volumes (Mt) for aluminium products. Note: Aggregate of PRODCOM codes 24421130, 24421153, 24421154, 24421155, 24421200, 24422100, 24422230, 24422250, 24422330, 24422350, 24422430, 24422450, 24422500, 24422630, 24422650, 24422670. No production data available for 2003, 2004 and 2005. Production volume may be under represented as it only refers to sold production. Source: [18].

Figure 14 shows the import volume of aluminium products by trading partner between 2000 and 2016, whilst Figure 15 puts this external trade into perspective by comparing the volume of extra EU-28 imports to the volume of intra EU-28 imports over the same time period. In 2016, intra EU-28 imports accounted for 63% of the total import volume and this share has remained relatively constant over the time period. The EU-28 primarily imports aluminium products further upstream, such as primary aluminium, which involves an energy intensive smelting process to produce. Norway represents the largest exporter of aluminium products into the EU-28 market between 2000 and 2016 with a trade volume of 1.5 Mt in 2016, of which unwrought alloyed aluminium accounted for 1.2 Mt [24]. Norway's main competitive advantage in the production of primary aluminium is its hydroelectric power, which provides inexpensive electricity to smelters [27]. Given that Norway also participates in the EU ETS, it does not however represent a carbon leakage risk.



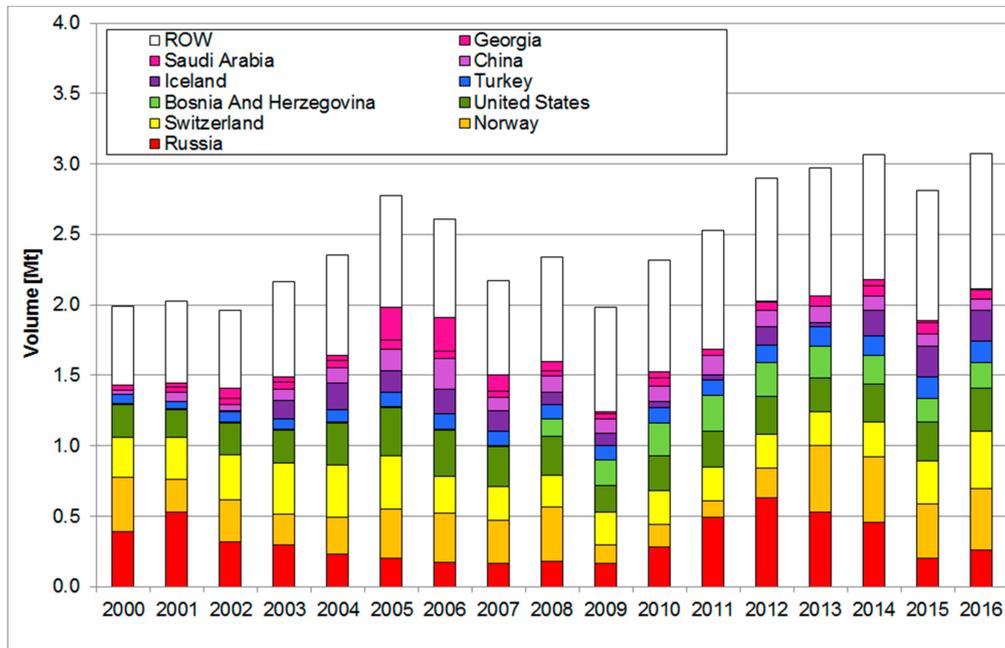
**Figure 14.** EU-28 extra import volumes (Mt) of aluminium products by trading partner. Note: CPA 2008 code: 2442. Source: [21].



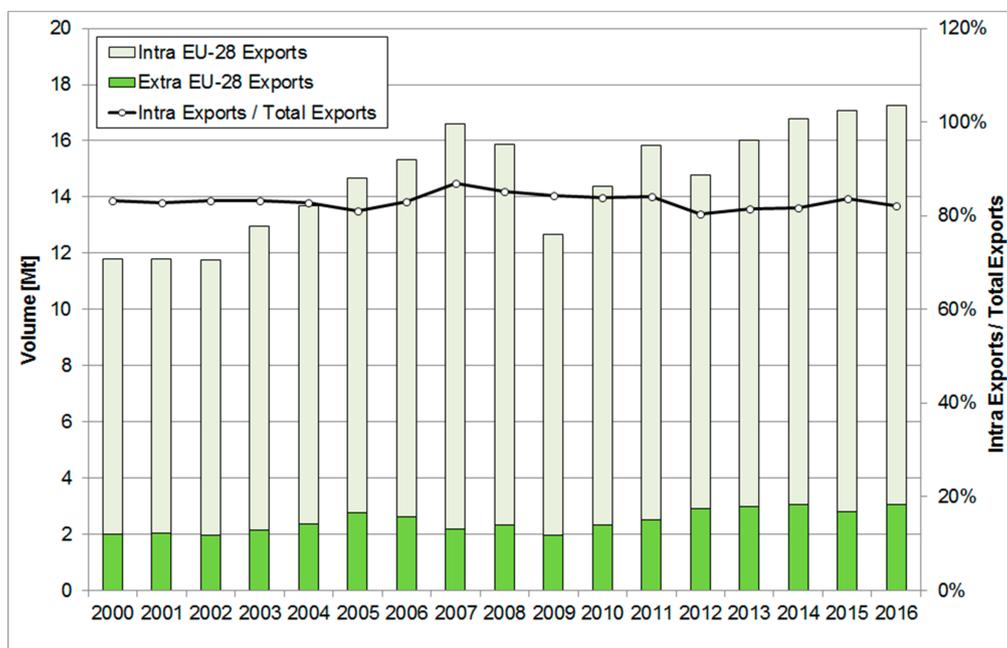
**Figure 15.** EU-28 extra and intra import volumes (Mt) of aluminium products. Note: CPA 2008 code: 2442. Source: [21].

Figure 16 shows the export volume of aluminium products by trading partner between 2000 and 2016 and Figure 17 puts this external trade into perspective by comparing the volume of extra EU-28 exports to the volume of intra EU-28 exports over the same time period. The EU-28 mainly exports aluminium products processed further downstream. The majority of the export volume of aluminium products consisted of intra EU-28 trade over the time period. Germany is the largest European producer of wrought aluminium (i.e., semi-finished products) with the majority exported to other European countries. Germany benefits from good access to domestic recycled metal and

furthermore, is one of the few countries ‘possessing the technical expertise and the technology to meet the exacting specifications of the aerospace industry for wrought aluminium’ [27]. The largest export markets for the EU-28 for aluminium products in 2016 included Russia, Norway, Switzerland and the United States with the largest exported aluminium products related to downstream processing.



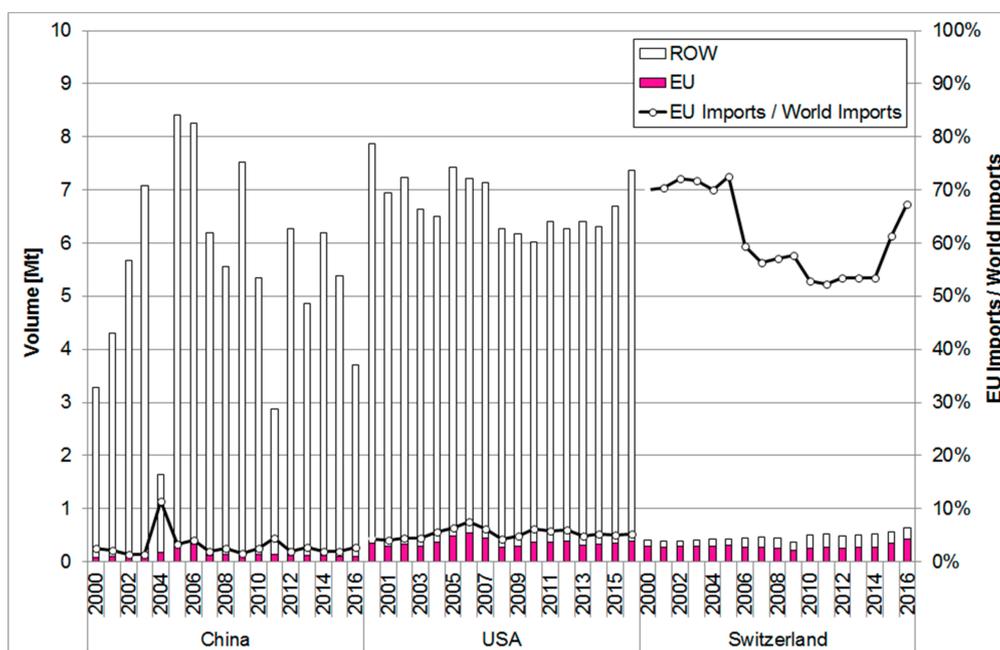
**Figure 16.** EU-28 extra export volumes (Mt) of aluminium products by trading partner. Note: CPA 2008 code: 2442. Source: [21].



**Figure 17.** EU-28 extra and intra export volumes (Mt) of aluminium products. Note: CPA 2008 code: 2442. Source: [21].

Figure 18 shows several of the EU’s main export markets for aluminium products. In 2016, the EU accounted for 5% of US imports of aluminium products. Unwrought aluminium (relating to HS

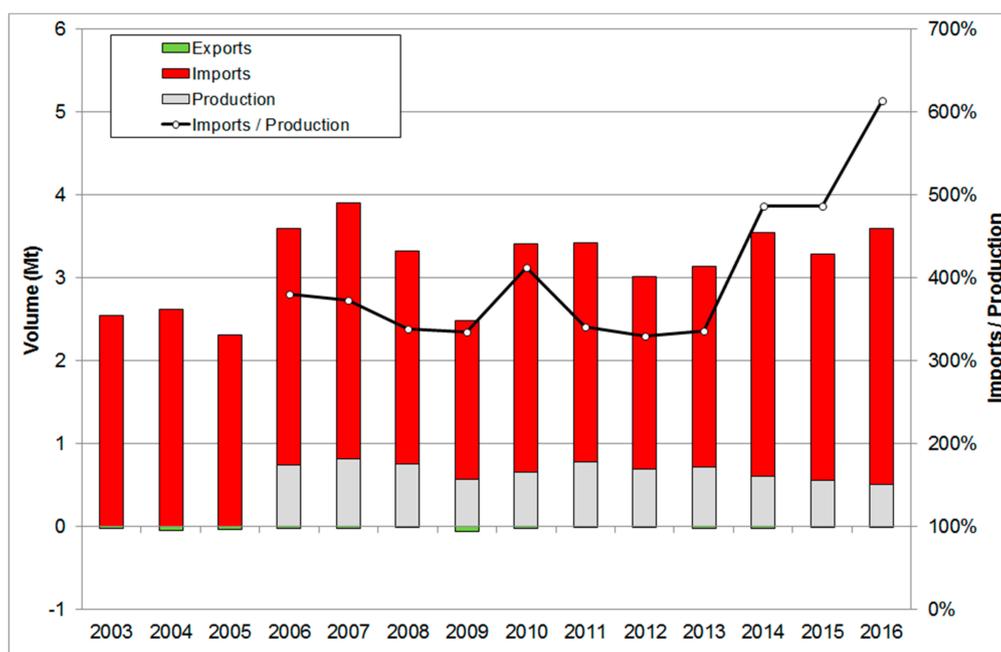
code 7601) represented the majority of US aluminium imports in 2016 (i.e., 4.3 Mt), with wrought aluminium imports (relating to HS codes 7604–7608) accounting for a smaller share (i.e., 1.7 Mt). Aluminium imports of aluminium oxide (i.e., input for production of primary aluminium) account for the remaining import volume of 1.4 Mt in 2016 [23]. Germany is currently the largest EU exporter of wrought aluminium products to the USA, which have remained relatively stable at around 0.1 Mt between 2011 and 2016 [27]. However, Chinese exports of unwrought aluminium products have collectively more than doubled between 2011 and 2016. This trend, in part, reflects the growth in China’s primary aluminium capacity that has led to an expansion of wrought aluminium production in the country [27]. In the Chinese market, 3.1 Mt of aluminium oxide was imported in 2016, which represented 83% of all aluminium imports [23]. Such demand reflects the fact that the majority of the country’s domestic consumption of unwrought aluminium is produced within China [27]. Overall, the EU accounted for 3% of the Chinese market, with exports in unwrought aluminium competing with products from Japan, the Republic of Korea and Taiwan.



**Figure 18.** EU’s share of selected export markets for aluminium products. Note: Aggregate of HS commodity codes 2818, 7601, 7603, 7604, 7605, 7607, 7608, 7609. Matching based upon the correspondence table between PRODCOM List 2016 (for 2442) and CN 2016. Source: [23].

### 3.4. Unwrought Non-Alloyed Aluminium

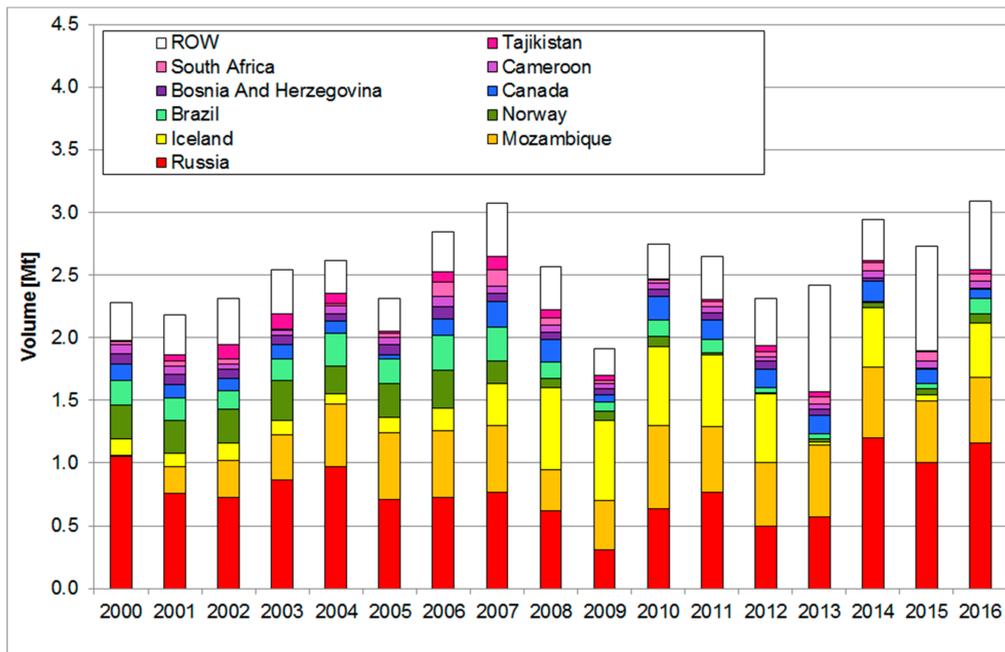
Within the sector specific guidance from the European Commission [15] that describes the product benchmarks, which determine free allocation in the third trading period of the EU ETS, the product entitled ‘unwrought non-alloyed aluminium’ is referred to as a relevant PRODCOM code for the primary aluminium product benchmark. It is therefore the focus of our analysis in order to see if the carbon leakage indicators differ at the product level of disaggregation. Figure 19 shows that EU-28 imports of unwrought non-alloyed aluminium were higher than the sold production with imports reaching 3.1 Mt by 2016 after the volatility of the economic recession. The extra EU-28 export volume of unwrought non-alloyed aluminium is very low in comparison to the volume of imports. In addition, the sharp increase in the imports to (sold) production ratio after 2012 suggests that the product may be at an increasing risk of carbon leakage.



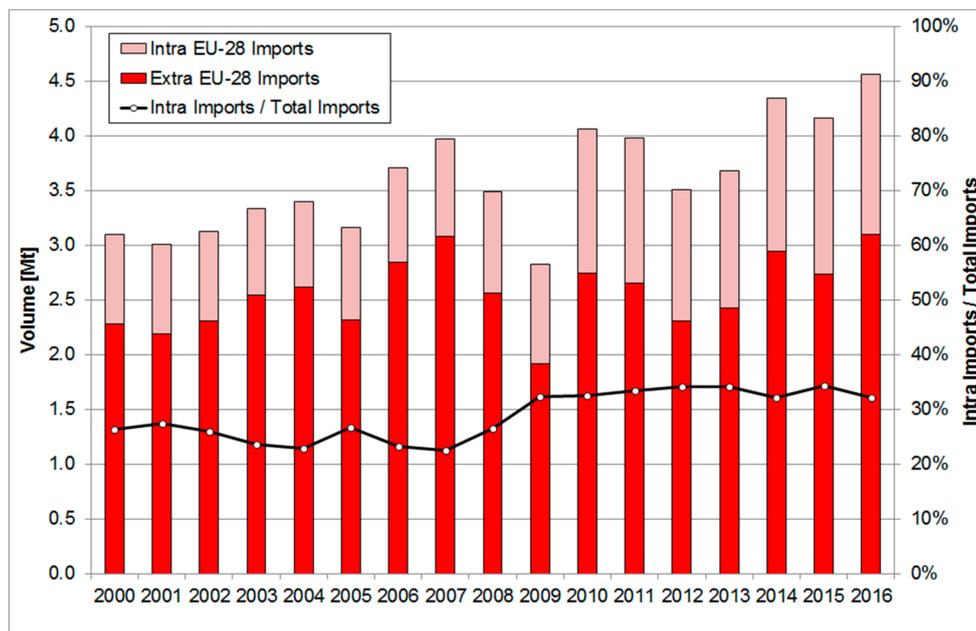
**Figure 19.** EU-28 production (sold), extra import and export volumes (Mt) for unwrought non-alloyed aluminium. Note: No production data available for 2003, 2004 and 2005. Production volume may be under represented as it only refers to sold production. Source: [18].

Figure 20 shows the import volume of unwrought non-alloyed aluminium by trading partner between 2000 and 2016, whilst Figure 21 puts this external trade into perspective by comparing the volume of extra EU-28 imports to the volume of intra EU-28 imports over the same time period. Intra EU-28 imports accounted for only 32% of the total import volume in 2016, which is a slightly higher share than at the start of the time period. Russia represents the largest exporter of unwrought non-alloyed aluminium into the EU-28 market with a trade volume of 1.2 Mt in 2016. The majority of Russian exports to the EU-28 in 2016 were in the form of unwrought non-alloyed aluminium. This reflects the fact that Russia is one of the world's lower cost producers of primary aluminium as it has access to cheap electricity and raw materials that offsets the country's relatively high cost of transportation amongst aluminium producers [27]. Mozambique and Iceland represent the second and third largest exporters of unwrought non-alloyed aluminium into the EU-28 market in 2016, both of which also benefit from access to cheap electricity via hydro-power.

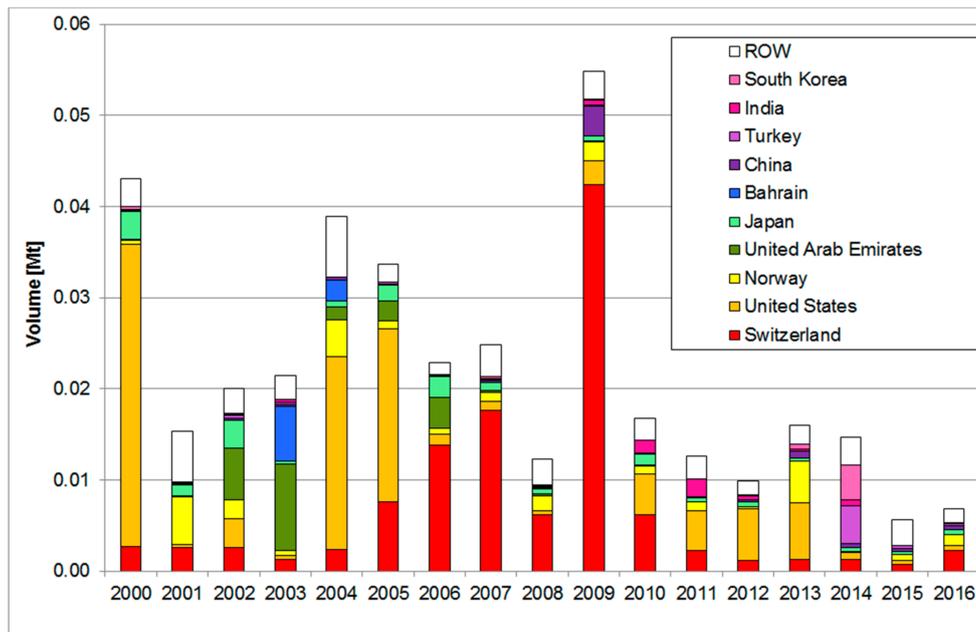
Figure 22 shows the export volume of unwrought non-alloyed aluminium by trading partner between 2000 and 2016 and Figure 23 puts this external trade into perspective by comparing the volume of extra EU-28 exports to the volume of intra EU-28 exports over the same time period. Intra EU-28 exports accounted for over 99% of the total export volume in 2016. Given the energy intensive process of unwrought non-alloyed aluminium production, differentials in electricity prices play an important role in the development of this trade pattern. According to [28] the electricity prices in the EU-28 are considerably higher than international competitors with the exception of China. These differences are due to regional factors ranging from the availability of significant hydro-electric power that are often owned or operated by the producers of primary aluminium, which enables producers to acquire electricity at production cost. Alternatively, an abundance of fossil fuels in other regions (i.e., US and the Middle East) also drive down electricity prices [28].



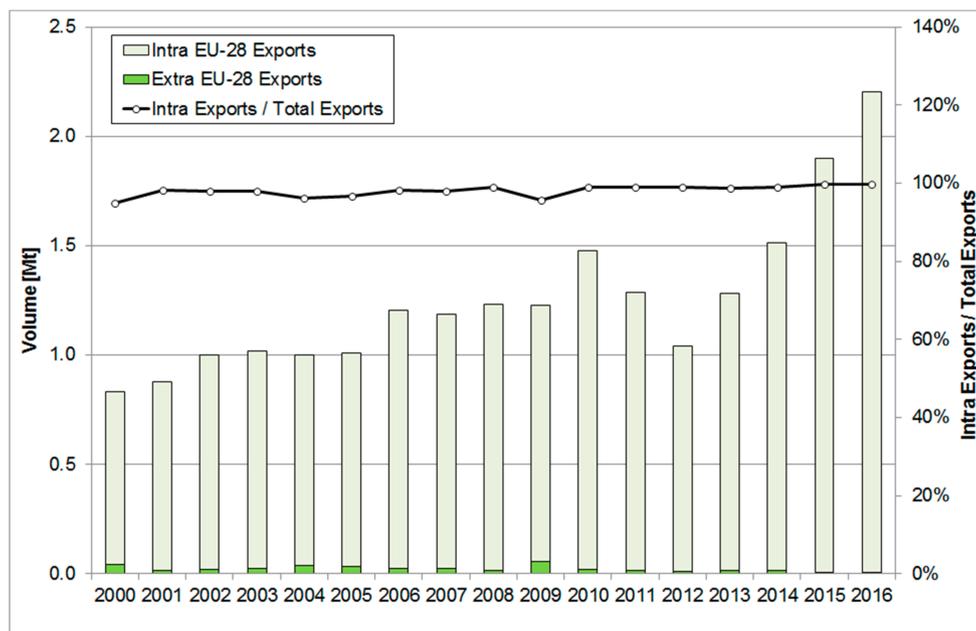
**Figure 20.** EU-28 extra import volumes (Mt) of unwrought non-alloyed aluminium by trading partner. Note: CN code 76011000—aluminium, not alloyed, unwrought. Source: [24].



**Figure 21.** EU-28 extra and intra import volumes (Mt) of unwrought non-alloyed aluminium. Note: CN code 76011000—aluminium, not alloyed, unwrought. Source: [24].



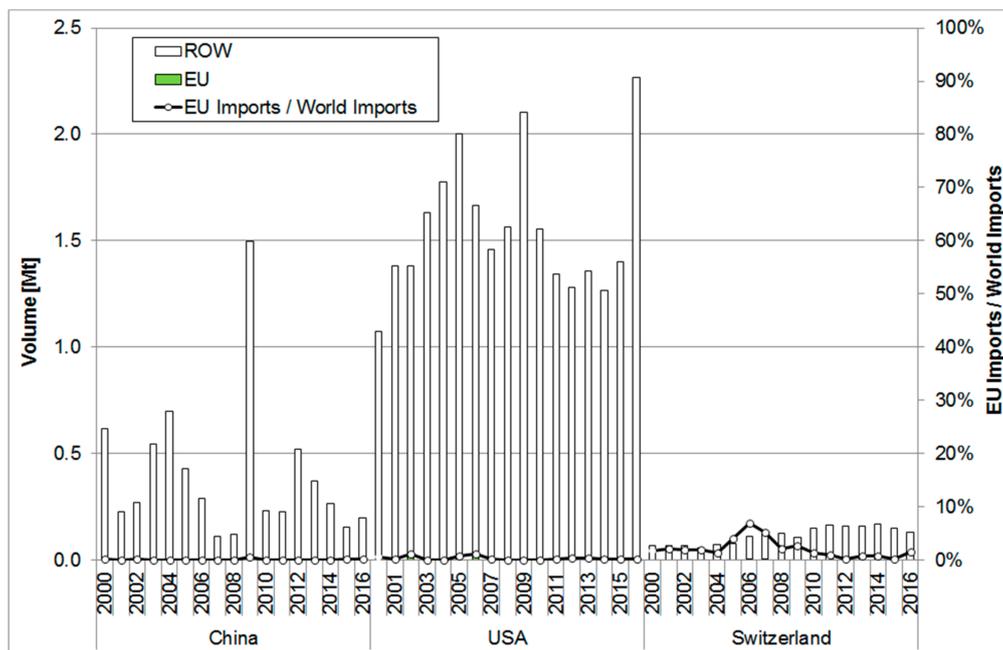
**Figure 22.** EU-28 extra export volumes (Mt) of unwrought non-alloyed aluminium by trading partner. Note: CN code 76011000—aluminium, not alloyed, unwrought. Source: [24].



**Figure 23.** EU-28 extra and intra export volumes (Mt) of unwrought non-alloyed aluminium. Note: CN code 76011000—aluminium, not alloyed, unwrought. Source: [24].

Figure 24 shows competitors in several of the EU’s main export markets for unwrought non-alloyed aluminium. The EU plays a minor role in these export markets compared to other countries primarily due to the differential in energy pricing. For example, Canada benefits from low cost electricity due to low cost hydro-electric power and improved efficiency of output following recent investments in the country’s smelter technology [27]. As a consequence, Canada has a high share of the US import market for unwrought non-alloy aluminium accounting for around 59% in 2016. In the Chinese market, Russia and Australia are the main exporters of unwrought non-alloyed aluminium into the market with the EU only accountable for a very low share of total imports. Although EU

exports of unwrought non alloyed aluminium are small, tax exemptions from energy/electricity taxes for energy-intensive industries are also implemented in Europe [29].



**Figure 24.** EU's share of selected export markets for unwrought non-alloyed aluminium. Note: HS commodity code 760110—aluminum unwrought, (not alloyed). Source: [23].

#### 4. Discussion

The purpose of the study was to identify whether or not reforms to the EU ETS at the start of the third trading period have led to changes in trading patterns in the cement and aluminium sectors.

Evidence of carbon leakage in the cement sector is rather limited with the key indicators developed in the analysis illustrating that (1) the share of extra EU-28 imports compared to domestic production has declined, (2) intra EU-28 imports have increased relative to total EU-28 imports and (3) that the share of EU imports in several key export markets have increased over the time period (refer to Table 1).

There has been a reversal in the trade pattern of the EU-28 in cement clinker (i.e., changing from a net-importer to a net-exporter) following the economic recession, which undoubtedly contributed to this trend with the lower domestic demand necessitating the expansion of export markets for a product that continued to be produced to ensure the financial viability of cement plants in the long run. Cement clinker continued to be produced at times of low demand due to a range of considerations (i.e., including maintenance, employment and eligibility for free allowances) and the resulting over-capacity in Europe has led to both a slight increase in the clinker cement ratio (reversing a previously declining trend) and an increase in EU-28 exports of clinker products.

Evidence of carbon leakage in the aluminum sector is more likely but mixed and warrants further research with the key indicators developed in the analysis illustrating that (1) the share of extra EU-28 imports compared to domestic production has increased, (2) intra EU-28 imports have increased only marginally relative to total EU-28 imports and (3) that the share of EU imports in key export markets has decreased in some or remained constant over the time period (refer to Table 1).

**Table 1.** Summary of results of the carbon leakage indicators. Note: Aluminium \* refers to Aluminium Products and Unwrought \*\* to Unwrought non-alloyed aluminium.

|   | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Change |
|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--------|
| <b>PRODCOM (Extra EU-28 Imports/Production)</b>                           |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |        |
| Cement  |      |      |      |      |      | 6%   | 6%   | 7%   | 4%   | 4%   | 3%   | 2%   | 2%   | 2%   | 2%   | 2%   |      | −4.6%  |
| Clinker   |      |      |      |      |      | 6%   | 7%   | 8%   | 5%   | 3%   | 2%   | 1%   | 1%   | 1%   | 1%   |      |      | −4.9%  |
| Aluminium *   |      |      |      |      |      |      | 32%  | 35%  | 37%  | 33%  | 34%  | 36%  | 33%  | 36%  | 38%  | 36%  | 38%  | 5.6%   |
| Unwrought **  |      |      |      |      |      |      | 380% | 373% | 339% | 335% | 413% | 341% | 330% | 336% | 487% | 487% | 613% | 232.8% |
| <b>COMEXT (Intra EU-28 Imports/Total EU-28 Imports)</b>                   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |        |
| Cement  | 67%  | 64%  | 59%  | 58%  | 59%  | 58%  | 59%  | 56%  | 68%  | 69%  | 76%  | 82%  | 86%  | 88%  | 89%  | 88%  | 88%  | 21.1%  |
| Clinker   | 43%  | 42%  | 36%  | 38%  | 36%  | 30%  | 28%  | 23%  | 33%  | 37%  | 52%  | 61%  | 71%  | 73%  | 81%  | 76%  | 78%  | 35.2%  |
| Aluminium *   | 58%  | 57%  | 59%  | 57%  | 57%  | 60%  | 60%  | 60%  | 60%  | 63%  | 63%  | 61%  | 63%  | 63%  | 61%  | 63%  | 63%  | 4.1%   |
| Unwrought **  | 26%  | 27%  | 26%  | 24%  | 23%  | 27%  | 23%  | 23%  | 26%  | 32%  | 32%  | 33%  | 34%  | 34%  | 32%  | 34%  | 32%  | 5.9%   |
| <b>UN COMTRADE (EU share of import volume of its main export markets)</b> |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |        |
| <i>Cement Products</i>  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |        |
| Algeria   | 52%  | 46%  | 42%  | 39%  | 23%  | 20%  | 27%  | 33%  | 32%  | 32%  | 52%  | 64%  | 89%  | 87%  | 77%  | 73%  | 69%  | 17.0%  |
| USA   | 18%  | 17%  | 17%  | 13%  | 16%  | 15%  | 11%  | 7%   | 6%   | 7%   | 8%   | 6%   | 16%  | 17%  |      | 25%  | 30%  | 11.5%  |
| Switzerland   | 99%  | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 99%  | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 0.7%   |
| <i>Cement Clinker</i>   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |        |
| Cameroon  | 30%  | 7%   | 5%   | 44%  | 54%  | 88%  | 64%  | 39%  | 58%  | 83%  | 42%  | 41%  | 86%  | 97%  | 87%  | 71%  |      | 40.8%  |
| USA   | 3%   | 4%   | 17%  | 14%  | 5%   | 4%   | 3%   | 11%  | 17%  | 11%  | 15%  | 12%  | 14%  | 11%  | 54%  | 19%  | 20%  | 17.3%  |
| Switzerland   | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 99%  | 100% | 100% | 100% | 99%  | −0.6%  |
| <i>Aluminium Products</i>   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |        |
| China   | 3%   | 2%   | 1%   | 1%   | 11%  | 3%   | 4%   | 2%   | 3%   | 2%   | 3%   | 4%   | 2%   | 3%   | 2%   | 2%   | 3%   | 0.1%   |
| USA   | 4%   | 4%   | 5%   | 5%   | 6%   | 6%   | 7%   | 6%   | 4%   | 5%   | 6%   | 6%   | 6%   | 5%   | 5%   | 5%   | 5%   | 0.9%   |
| Switzerland   | 70%  | 70%  | 72%  | 72%  | 70%  | 73%  | 59%  | 56%  | 57%  | 58%  | 53%  | 52%  | 53%  | 54%  | 54%  | 61%  | 67%  | −2.5%  |
| <i>Unwrought Non-Alloyed Aluminium</i>                                    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |        |
| China   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 1%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0.0%   |
| USA   | 1%   | 0%   | 1%   | 0%   | 0%   | 1%   | 1%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | −0.4%  |
| Switzerland   | 2%   | 2%   | 2%   | 2%   | 1%   | 4%   | 7%   | 5%   | 2%   | 3%   | 1%   | 1%   | 0%   | 1%   | 1%   | 0%   | 2%   | −0.2%  |

The EU-28 has been a net importer throughout the 2006 to 2016 time period. Given the electricity intensive processes associated with primary aluminium smelting, the high imports of unwrought non-alloyed aluminium by the EU-28 from countries such as the Russian Federation and Mozambique imply that the cost of electricity may be a more significant explanatory factor (than changes to the allocation of allowances) in this trend. However, the indirect effects of the EU ETS on trading patterns in the aluminium sector (i.e., electricity costs) certainly warrants further investigation to determine impacts on international competitiveness for European producers.

The use of key indicators that consider different aspects of trade (i.e., trade's relationship to domestic production, internal and external trade and developments in key export markets) enables us to better assess the risk of sectors and sub-sectors to carbon leakage. However, such an approach needs to be extended regularly in order to account for changes in the economy and technological and political developments. An important limitation to this analysis is that the changes in trade patterns identified do not necessarily provide robust evidence of carbon leakage as these changes in trade may have occurred for a variety of reasons. Further research is required on an ongoing basis to attribute the key drivers behind the changes in trading patterns that have been identified (using both quantitative and qualitative methods). Further research should also take into account the differentiation in trading patterns that occur at the Member State level, especially in order to consider border effects on trade.

Developing robust approaches to distinguish between the effects on trading patterns that are caused by external factors (i.e., economic growth, currency fluctuations and energy prices) as opposed to the EU ETS will be of paramount importance going forward.

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