Consulting

Assessing the drivers and scale of potential resource shuffling under a CBAM

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1. Executive summary

Carbon pricing is a key policy measure to incentivise green technology adoption in the production, use and choice of materials in the industrial sectors (and more broadly). However, unilateral imposition of ETS in the EU could expose energy intensive trade-exposed sectors to competitive pressures. This is a critical economic issue – the steel industry alone generated value of over €60 billion (and directly employed 330,000 people) to the EU economy in 2019 (Oxford Economics, 2019). It also risks undermining environmental outcomes through carbon leakage. Hence free allowances have so far been granted to selected sectors to avoid carbon leakage risks. However, the result has been thatdue to the combination of free allowance allocation for carbon leakage protection and the international tradability of commodities like steel or cement, carbon costs are only partially reflected in material prices.

The EU is therefore discussing to no longer grant free allowance allocation as carbon leakage protection and instead make importers of basic materials liable to pay a levy or surrender CO2 allowances for the carbon emissions associated with the basic material production in the third country. The objective is to contribute to the realization of the 2050 climate neutrality objective by ensuring effective carbon price incentives for all mitigation options, while avoiding carbon leakage risks. While a variety of design options are being considered, many of these have one common feature. They apply a default value to determine the liability for importers and grantimporters the right to reduce this liability if they can demonstrate the material was sourced from a more carbon efficient production process. It is largely considered attractive to grant such an option to align the approach more closely with WTO principles and to create incentives for international material producers to improve their carbon performance.

However, due to this feature a carbon border adjustment mechanism (CBAM) also risks creating incentives for resource shuffling. Resource shuffling is the potential allocation or attribution of less carbon intensive materials production (or inputs to the production process, such as low-carbon electricity) outside of the EU towards exports to the EU, while the overall carbon intensity of production in the exporting country remains constant. As a result of such resource shuffling, EU production could be replaced by additional imports, which would lead to increased overall production and emissions outside of the EU to meet demand (carbon leakage). If the additional production is pursued by otherwise (partially) idle plants, then this marginal production is likely to be rather more carbon intensive. As a result, resource shuffling may result in an overall increase of global emissions. Even if this additional plant is equally or less carbon intensive than the European plant, then an induced increase of carbon emissions outside of the EU will imply a global increase in carbon emissions, as long as EU carbon emissions are strictly capped and on a pathway to climate neutrality and if this is not the case in the third country.

This policy brief assesses the resource shuffling potential in terms of reduction of the liability incurred by importers of steel. Due to the high carbon intensity of steel production, even relatively small amounts of resource shuffling can have major consequences on competitiveness and the risk of carbon leakage. At a carbon price of 50 Euro/t, efficient steel production incurs carbon costs of about 90 Euros per tonne of steel (for those emissions not covered by free allowances). Without resource shuffling, a European producer incurs these costs for acquiring CO2 allowances to comply with the ETS directive, and an importer an equally efficient foreign steel plant would face the same costs under a CBAM. If the importer can reduce the carbon emissions attributed to the imported steel by 10%, then this creates a cost advantage of 9 Euro/t steel, or roughly 8% of the gross value added (GVA) of steel making (assuming a steel price of 450 euros/t and a ratio of GVA to turnover of roughly one quarter). A 5% cost increase relative to value added is the trigger level that was used until

2020 to assess whether trade intensive activities may be at risk of carbon leakage.

A variety of different resource shuffling drivers exist and can be characterized as "Output Shuffling" (imports switching to low emissions suppliers) and "Input Shuffling" (reducing the duty base through designation of lower carbon inputs). We focus on the attribution of green electricity to the production of steel as an illustrative example of input shuffling, since this would be relatively easy to implement for importers.

The resource shuffling risks are expected to vary widely across sectors, with aluminium being an example of a value chain which is potentially relatively high exposed to input shuffling risks. This is because the large majority of emissions is linked to electricity inputs and can be avoided by allocating or attributing electricity production from existing hydro or nuclear power to the smelter process. However, the extent and channels for resource shuffling in aluminium markets warrant further validation and quantification. In the case of steel, the result is perhaps less obvious and hence the analysis quantifies the potential risk.

We differentiate between two main types of steel. Higher-value flat products are mostly produced via the blast furnace-basic oxygen furnace (BF-BOF) route. Long products have lower quality requirements and are typically produced by the re-use of scrap in electric arc furnaces (EAF). However, long products may also be produced via the BF-BOF route, particularly if there is insufficient availability of scrap. Our study uses data on the carbon intensities of physical installations for two major (anonymous) trading partners of the European Union.

With respect to output shuffling alone (ignoring potentials for input shuffling), our study finds significant potential to reduce the carbon intensity of imported steel, which would increase carbon leakage risks for European steelmaking:

- flat products by 0.1-0.3 t CO2/t steel, creating a cost differential in the order of 5-13% relative to GVA. The differential increases with the variation of technical efficiencies in the exporting country.
- long products by 0.7-1.3 t CO2/t steel, corresponding to 35%-58% of GVA.

These assessments are likely to form an upper bound for the particular channels and regions under analysis, based on the assumption that there are no barriers for exporting regions to shuffle production between different plants. In reality, certain steel trade flows will be sticky, due to quality constraints, service requirements or contract obligations. The ability to shuffle production may therefore also depend on whether existing suppliers own low carbon plants or whether they belong to competitors and would require additional trade transactions.

The motivation to pursue such adjustments will depend on how strategic the exports to the EU arefor each trading partner, considering:

- The quality of the steel products generated in the region.
- The size of the regional exports compared total regional production and the contribution to the respective GDP of a country.

However, resource shuffling potentials from adjusting overall trade flows were not considered and could further increase the resource shuffling potential (e.g. if countries with less carbon intensive steel production redirect their production to export to the EU). Resource shuffling might also result from additional use of less carbon intensive EAF steel for exports of flat products, which are normally produced via the BF-BOF route. However, company ownership and quality constraintsdue to technology and customer will limit the potential switch from BOF to EAF,as not all qualities of steel can currently be produced via the EAF route. It requires further quantification to assess the potential for incentives from a CBAM mechanism to trigger the replacement of BOF based with EAF based processes for imported flat products.

With respect to input shuffling, the most prominent opportunity relates to attribution of zero carbon power generation to steel making processes. In combination with the output-based shuffling, we find for the two selected regions a much higher overall potential to reduce the carbon intensity of imported steel also for long products:

- flat products by 0.4-0.7 t CO2/t steel, creating a cost differential in the order of 18-31% relative to GVA. The differential increases with the variation of technical efficiencies in a country.

- long products by 1-1.4 t CO2/t steel, corresponding to 45%-61% of GVA.

These incremental resource shuffling risks are once again likely to form an upper bound for the particular regions and channels under analysis, based on the assumption that there are no limits to the potential for firms to adjust their accounting for power related emissions. In practice, there may contractual, institutional or compliance related barriers to the ability of firms to adjust power procurement arrangements in order to avoid the duty.

Additional input shuffling can result from increasing the scrap use in primary steel making, which for cooling purposes is typically in the order of 10-20%. A global supply-demand balance for steel implies that the reduction of primary production in the specific plant would need to be replaced by additional primary steel production in other plants, unless scrap generation is increased.If plants in regions with scrap scarcity currently operate with 10% scrap input, then these would face strongfinancial incentives to increase the scrap share, e.g. to 20% or 30%. Such input shuffling would represent an additional resource shuffling potential in the order of 0.3 t Co2/ t steel, corresponding to 13% of GVA.

There are further input shuffling potentials. Our analysis assumes that steel plant operating conditions are static. However, steel producers may choose to redirect the 'greenest' raw materials to a plant supplying the EU market, e.g. by concentrating the use of high-quality raw materials or biofuels at certain plants.[4] The extent of carbon savings through this input shuffling effect will vary from plant to plant. For example, the use of biofuels alone couldresult in CO2 reductions of 0.1-0.3 t CO2/t steel, or cost savings corresponding to 5% to 13% of GVA.

Furthermore, there are traceability and consistency issues when it comes to the verification of generating abatement. For example, there are currently several different methods of carbon accounting in the steel sector, particularly with regards to credits for by-productssuch as slag. A standardised methodology needs to be established to ensure a comparisonon a like-for-like basis.

Overall, we find for our two example countries, that at an EU ETS carbon price of 50 Euro, output shuffling in combination with input shuffling of electricity could potentially allow importers of long products to avoid a large share of the liability, creating cost savings from steel imports by as much as 45-61% of GVA.

For flat products, we find corresponding potential savings from output shuffling in combination with input shuffling by as much as 18-31% of GVA, largely caused by attributing zero-carbon electricity to steel production. Moreover, we approximate additional resource shuffling potentials from increased scrap use in BF-BOF processes (additional cost savings of 13% of GVA) and operation adjustments and biomass use (cost reductions of 5-13% of GVA). Finally, we argue that inconsistencies in MRV systems can create additional opportunities to reduce import liabilities.

The analysis thus suggests that resource shuffling could potentially have a major impact on the overall effectiveness of a carbon border adjustment mechanism to address carbon leakage risks in the somewhat stylised case in which there are no practical barriers to firms shuffling production between different plants or adjusting their accounting of power related emissions. The benefits for importers are at a multiple of the 5% threshold level of cost increase relative to GVA traditionally used to assess whether carbon costs could trigger a relocation of the production of trade intensive commodities. However, if the costs for adjustments to realize these savings are very high particularly in the event of persistent contractual, institutional or compliance related barriers to such behavioural responses or if carbon prices are significantly lower, the scale of realized resource shuffling incentives and potentials may be lower.

As such, further analysis is required to better understand the practical hurdles for producers in diverting volumes across processing routes, as well as other potential factors shaping implementation risks such as: industrial structure and transnational ownership, firm specific factors (including organisational strategy and behaviour, product mix, customer relationships), as well as broader channels for shuffling (e.g. on raw materials) and the associated traceability/ enforcement issues. **Critically, given the widely differing magnitude of resource shuffling effects across the regions studied in this paper, a fuller assessment of the potential impacts - considering a broader and more representative sample of the EU's trading partners - is warranted to better inform policy makers regarding the scale and locus of these risks.**

Figure 1: Theoretical maximum potential emission cost differential as a percentage of GVA under a 50 Euro/ tonne CO2 CBAM, by resource shuffling channel and steel product

2. Introduction

The European Union is discussing different CBAM options, designed to allow for effective carbon pricing to support the achievement of the EU climate neutrality objective by 2050, while mitigating risks from carbon leakage, particularly in energy intensive-trade exposed sectors, such as Steel, Cement or Aluminium. In many proposed design options, importers are liable for a charge based on the carbon intensity of the imported basic materials to broadly replicate the costs and emission reduction incentives on imports that apply to domestic industries which are regulated under the EU Emission Trading System.

However, a CBAM risks creating incentives for resource shuffling: the potential allocation or attribution of less carbon intensive materials production towards EU exports. These risks arise from the fact that, while all domestic production is covered by the EU ETS, only the fraction of foreign production that is exported to the EU is covered by CBAM. This is a material policy concern given the potential of resource shuffling to: create wind-fall profits forexisting less carbon intensive producers abroad at the expense of EU consumers, thus encouraging an increase of emissions from production abroad substituting potentially more efficient domestic production (carbon leakage). It would also reduce revenues from CBAM required for climate action and support for a just transition domestically and abroad.

While the basic idea of resource shuffling is generally accepted, the potential mechanisms and potential scale of resource shuffling is not yet well established. This policy brief outlines the nature of resource shuffling drivers and risks, and provides indicative guidance, where readily calculable, on their potential scale in the case of selected segments of the steel industry. It subsequently discusses potential issues shaping the existence, magnitude and specific locus of risks in other industrial chains potentially subject to a future CBAM, including aluminium.

This paper makes a material contribution to our collective understanding of these issues. However, the authors would generally counsel against drawing too firm policy conclusions from this largely heuristic approach. In this context, it is important to recognise the papers' limitations particularly related to: i) assumptions regarding the absence of practical or regulatory constraints on output or input shuffling, ii) the narrow range of resource shuffling effects (for example, changes in scrap utilisation and other non-power related feedstocks were ignored, and, iii) the limited and unrepresentative nature of the regional sample (these were explicitly selected to draw inference on the potential scale and drivers of resource shuffling but cannot be directly aggregated to the industry level).

3. CBAM design description / scenario outline

As a basis for framing the magnitude of potential resource shuffling under different technical implementation options for CBAM, CRU evaluate two potential scenarios against a **"Reference Case"** comprising CRU's current view of the 2019 regional market and trade conditions and considering average carbon intensity of selected exporting regions. To examine the potential and drivers of resource shuffling, we compared two stylised scenarios against the Reference Case, specifically:

1. **"Output Shuffling"**: considers emissions reduction potential if imports are supplied by producers with lowest emissions intensity (i.e. on the left hand side of the carbon curve) under the Reference Case.

2. **"Input Shuffling"**: considers emissions reduction potential if imports are supplied by producers with lowest emissions intensity (i.e. on the left hand side of the carbon curve) while scope 1 and 2 electricity-related emissions are removed i.e. zeroed (scope 1 related emissions are emissions used for onsite of offsite power generation).[1]

Both output and input shuffling scenarios yield a decrease in embedded emission associated with exports. We use the Reference Case as a benchmark for comparison in this analysis.

These scenarios are evaluated under different CBAM designs, we chose to focus on

- **"EU average CBAM"**: Weighted average carbon intensity of primary steelmaking European installations. In this case, the CBAM default value is assumed to be around 1.97 tCO2/t.

- **"Top 10% CBAM"**: Average of Top 10% best-in class carbon intensity by process route: BF/BOF and EAF. Current ETS rules differentiate by steel process route by giving default values for different production steps (coke, hot metal and sinter for BF-BOF steelmaking; EAF carbon steel has its own benchmark). In this case, the following CBAM default values are assumed: 1.44 tCO2/t and 0.29 tCO2/t applied respectively on BF-BOF-based and EAF-based exports volumes.

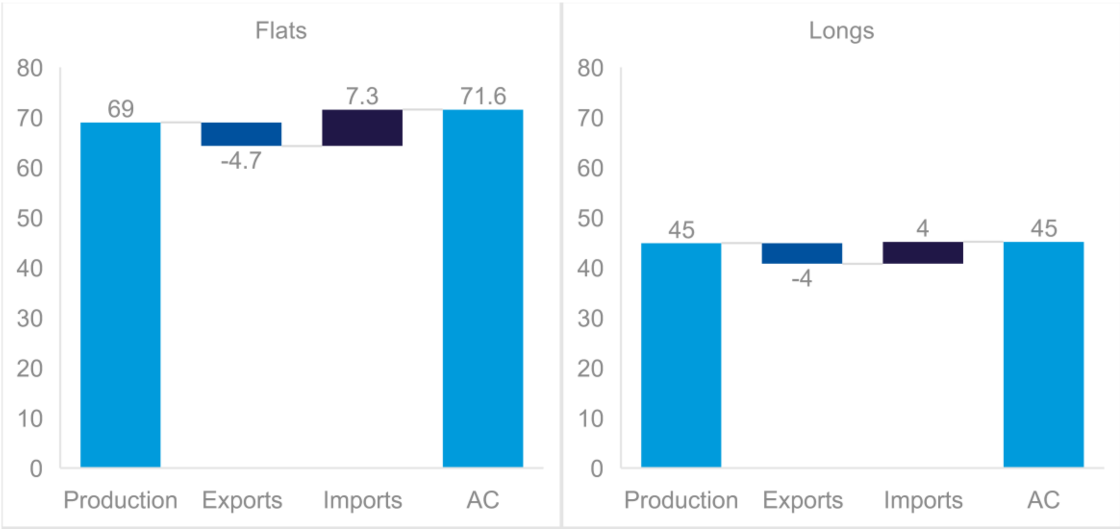
4. EU steel market overview

EU steel demand amounted to ~150 Mt in 2019, equivalent to around 8% of the global market. The sector is broadly segmented into two product classes: (i) flat products such as steel sheets and plate (used for a range of consumer durable and industrial applications in auto manufacture and construction), accounting for 60% of the EU production in 2019; and, (i) long products such as bars, rods and beams (used principally for construction and other industrial applications), accounting for 40% of the market in 2019 (see Figure 2).[2]

In aggregate, the EU has sufficient steelmaking capacity to satisfy domestic steel demand. However, the global steel market is highly competitive and interregional trade is widely observed in the EU for flat and long products market in 2019, accounting for 7 Mt and 4 Mt respectively.[i] The key trade partners are Turkey, Russia, Ukraine, and APAC (Australia, Taiwan, and South Korea) (see Figure 3). Turkey and Russia comprise over 50% of import market for each product. China is a key source of imports in Longs, while India is an important player in flats imports to Europe.[3]

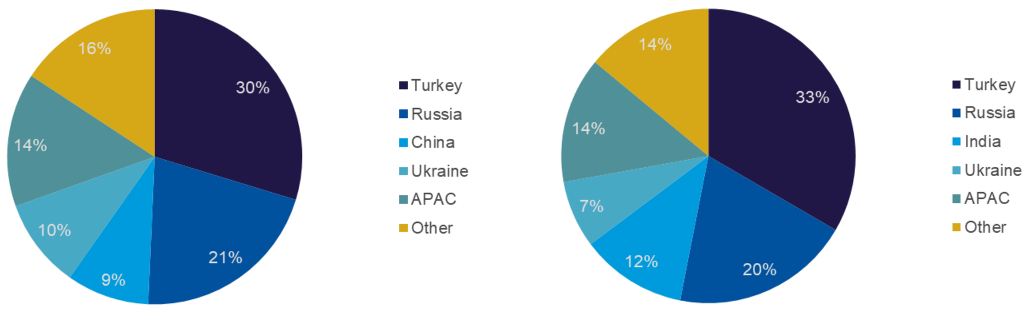
[1] In principle, input shuffling could also happen through other mechanisms than the attribution of renewable electricity generation, such as the attribution of carbon emissions of the steel production process to co-products (e.g. slag). However, this report focuses on electricity-related emissions reductions only.
[2] For the purposes of our analysis, we have focused on the major categories of carbon steel flat and long products: flat products are defined as hot-rolled coil (HRC) plus 50% coil products (plates are excluded); long products represent rebar, merchant bar and wire rod (sections, rail and seamless pipe are excluded), which together account for 80% of theEU longs market.

Figure 2: EU flats (LHS) and long (RHS) production, apparent consumption (AC) and trade flows, 2019, Mt



Source: CRU. Note: Flats refers to gross hot-rolled coil (HRC) + 50% coil; longs refer to the light longs market (excluding sections, rail and seamless pipe).

Figure 3: Longs imports to Europe, 2019, % Flats imports to Europe, 2019, %



Source: CRU

5. Steel emissions by region / technology

The choice of process route has critical implications for the carbon intensity of steel manufacture. The vast majority of EU flat products (which require a high level of cleanliness) are produced using integrated blast furnace-basic oxygen furnaces (BF-BOF), with iron ore and coal as the primary raw materials. By contrast, the lower quality requirements of the long products means that the majority of EU production is produced via the mini-mill EAF process, using scrap as the major feedstock. This is due to the fact that higher residuals (such as copper) in scrap have a less significant bearing on the mechanical properties of long products, due to their dimensions.

[3] We have focused on the major consistent trade partners with the EU. Minor countries such as Bosnia, Serbia are grouped in 'other'.

EAF technologies generally have lower Scope 1 emissions compared to an average BF-BOF plant but trade off with higher electricity consumption. Overall, EAF based production in Europe around 60% less carbon intensive than BF-BOF based manufacture. As such flat products are typically more carbon intensive than longs, reflecting their manufacture via BF-BOF process. On average, for example, one tonne of flats produced in the EU generates ~1.6 tonnes of CO2, compared to around 0.7 tonnes CO2 per tonne of longs.

Figure 4 compares regional average CO2 intensity between the EU and its major trading partners. In both product segments, EU steelmakers have lower emissions intensity than most trading partners. For example, flats manufactured in key importing regions generate ~1.7 - 2.3 tonnes of CO2 per tonne of steel. However, the carbon intensity of longs imports varies more widely spread, being on average ~8 fold higher per tonne in Russia compared to the EU. This is because at a global scale insufficient scrap is available to serve the demand for long products and hence steelmakers in regions such China, India and Russia with cheap local supplies of iron ore and coal and more limited access to scrap also produce long products via the BF-BOF route.

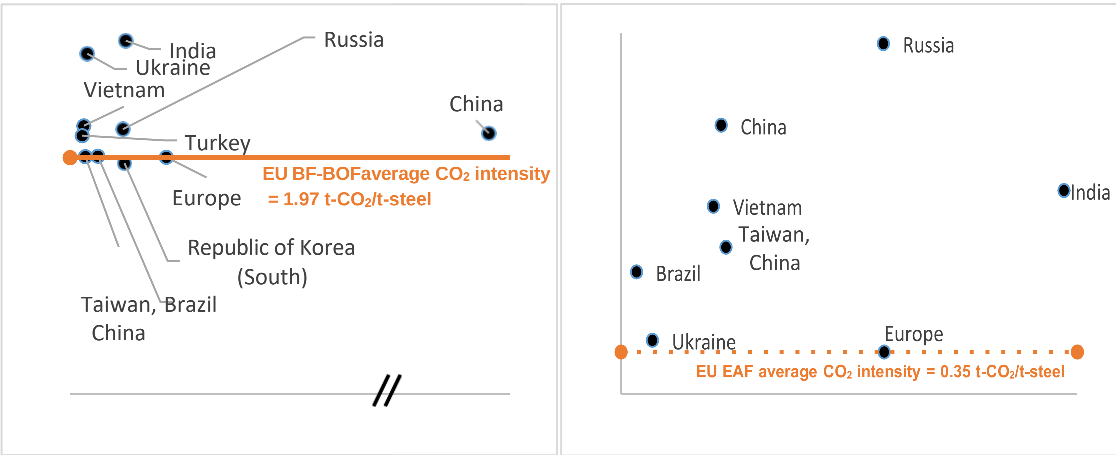
Figure 4: Steel CO_2 intensity segmented by product of key countries

y-axis: CO2 intensity of BF-BOF steel, tCO2/t steel

x-axis: BF-BOF steel production, 2019, Mt

y-axis: CO2 intensity of EAF steel, tCO2/t steel

x-axis: EAF steel production, 2019, Mt



Note: // is an axis break

Source: CRU

6. Resource shuffling

6.1. Overview of channels and drivers

There are a wide range of practical issues and constraints bearing on the efficient implementation of a CBAM. This includes partial capacity to monitor and verify the carbon basis of complex international trade flows. This creates two significant implementation risks: i) the resorting of trade flows so that lower carbon products are exported to Europe ("Output Shuffling"), and, ii) the reduction of emissions on existing physical goods trade through reported reductions in the carbon intensity of key factors of production ("Input Shuffling").

These risks have the potential to undermine the fiscal base and carbon reduction incentives arising from a CBAM. Their scale and nature are likely to depend on factors including: i) the design of the CBAM (particularly with regards to the default values), ii) the mix of plant technologies in any given region (i.e. the shape of the carbon curve), and, iii) the importance of EU exports to overall regional production.

This is illustrated through a comparative analysis of two representative exporting regions A and B in both steel flat and longs product markets.

In addition, if financial gains are sufficiently attractive, then resource shuffling can incentivise changes in regional trade flows to allow producers to access further sources of less carbon intensive inputs and production processes. This potential is not considered in the current analysis.

It is important to reiterate that, in the case of both output and input shuffling, we make a critical simplifying assumption that that there are no practical limits to the potential for firms to adjust their export patterns of their accounting for power related emissions. Given the likelihood of costs (including through potential CBAM compliance protocols) and other real world barriers to such supply chain and input accounting adjustments, the following assessments should be considered as an upper bound for the particular channels and regions under analysis. Moreover, conclusions regarding the aggregate nature of these effects cannot readily be drawn, in particular given the limited and unrepresentative nature of the regional sample.

6.2. A comparative illustration for 2 selected regions

At the outset it is critical to understand the structure of the domestic market and the role international trade in each region. In particular, regions A and B differ according to technology utilisation and dependency on international trade for overall sales revenues: specifically, the steel industries in region B utilise a broader range of technologies (and thus carbon intensities) and are significantly more reliant on exports compared to region A (see Table 12 for details). Region A has a number of characteristics that are similar to the Chinese market in terms of scale and the degree of trade exposure with Europe. These characteristics are found to have a decisive bearing on the risks of resource shuffling.

Table 1: Summary of two regional steel markets

Region	Technology		Trade	
	Flats	Longs	Flats	Longs
A	Entirely BF-BOF	Mix of scrap-based EAFs, BF-BOF	Exports ~2% of output	Exports <1% of output
B	Mostly BF-BOF, one EAF mill	Mix of scrap-based EAFs, BF-BOF *(Note: one EAF plant has higher CO2 intensity as it produces electricity from coal onsite)*	Exports >40% of output	Exports ~24% of output

To see this let us consider first the case of *output shuffling,* displayed in Figure 5. Initially, under an EU average CBAM in each region:

- In flats production in region A, the available volumes of lower carbon steel exceed the volumes exported to the EU, therefore 100% of exports can be reallocated to the cleanest BF-BOF plants. In addition, in region B, the presence of the EAF producer also creates the potential to shuffle exports towards this cleaner production technology.

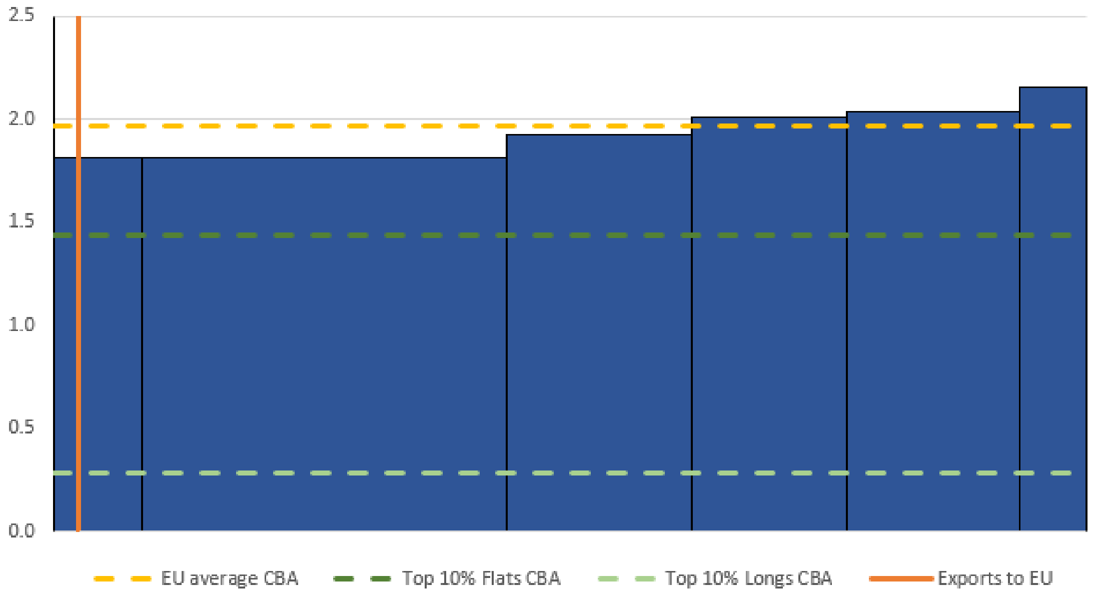
- In longs production, for the same reason as for flats, 100% of exports can be reallocated to cleaner plants, which are the EAF plants located are the bottom half of the curves in both regions.

Figure 5: Emissions curve under reference case / output shuffling for regions A andB, EU average CBAM (yellow) and Top 10% CBAM (green), 2019

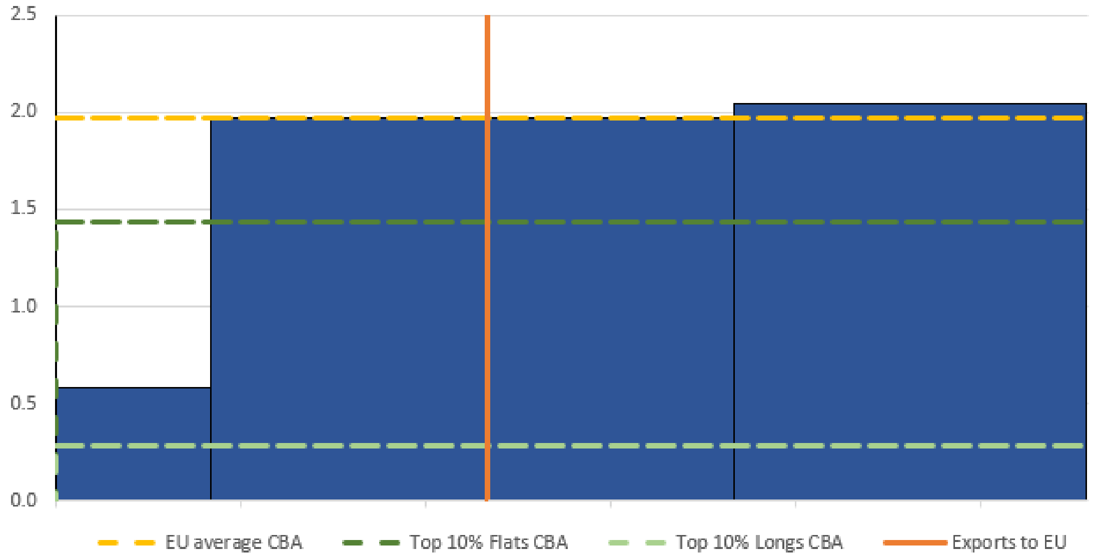
x-axis: annual Flats or Longs production by plant, Mt

y-axis: Scope 1 and 2 CO_2 emissions, tCO_2/t

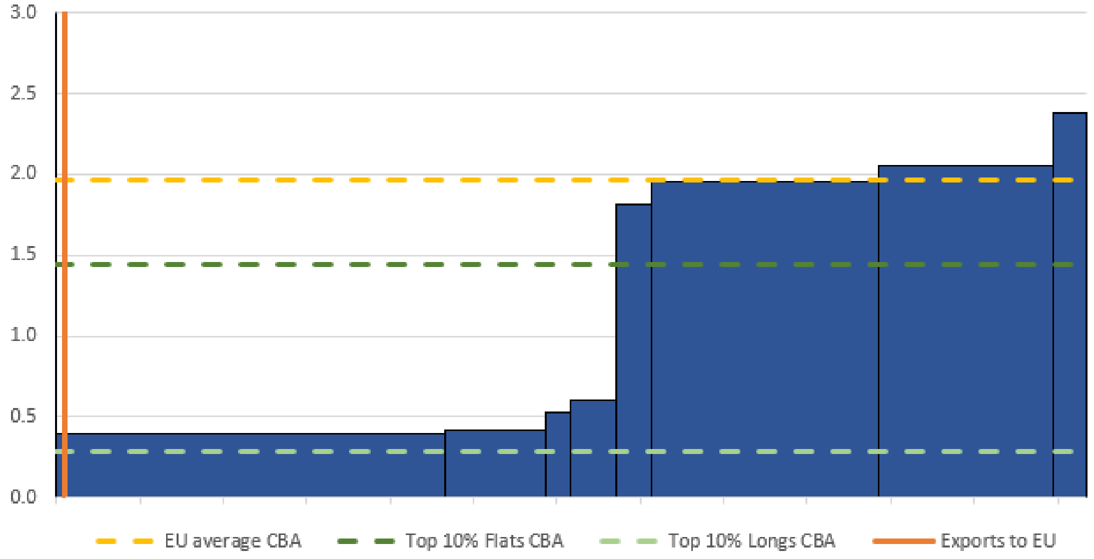
a) Flats – Region A



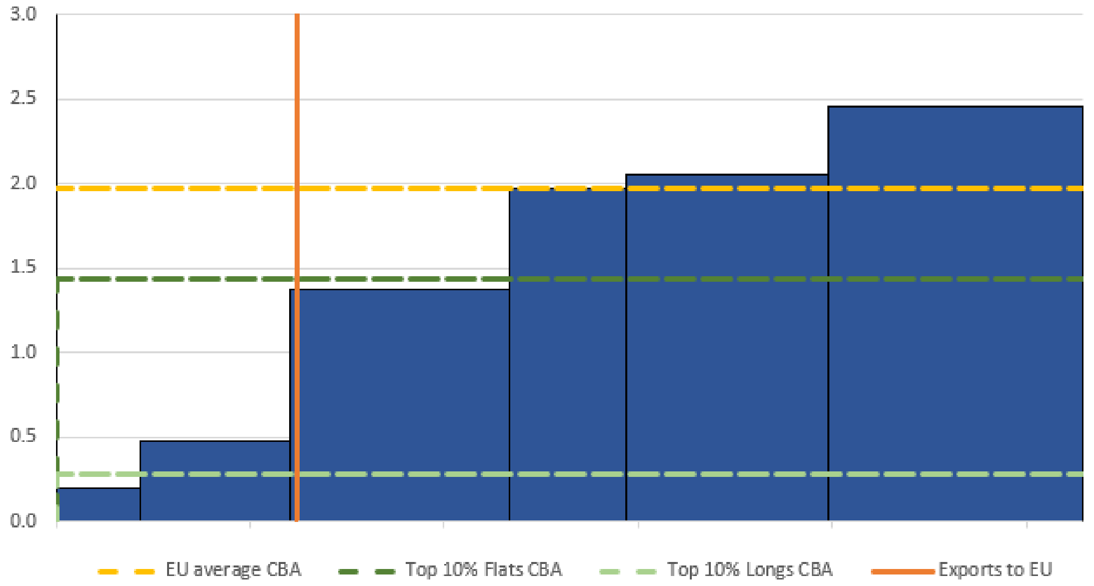
b) Flats – Region B



c) Longs – Region A



a) Longs– Region B



Source: CRU

We now consider the case of *input shuffling*, displayed in Figure 6. Initially, under an EU average CBAM in each region:

- In flats production, input shuffling reduces the overall emissions intensity levels in both regions. In regions A and B, all produced volumes moved under the CBAM default value, creating an incentive to implement this abatement channel.
- In longs production, in both regions, all but the marginal plant on the curves is under the CBAM default value, leaving enough low-carbon volumes to be reallocated towards the export volumes.

The application of the Top 10% CBAMs on these resource shuffling incentives has varyingimpacts:

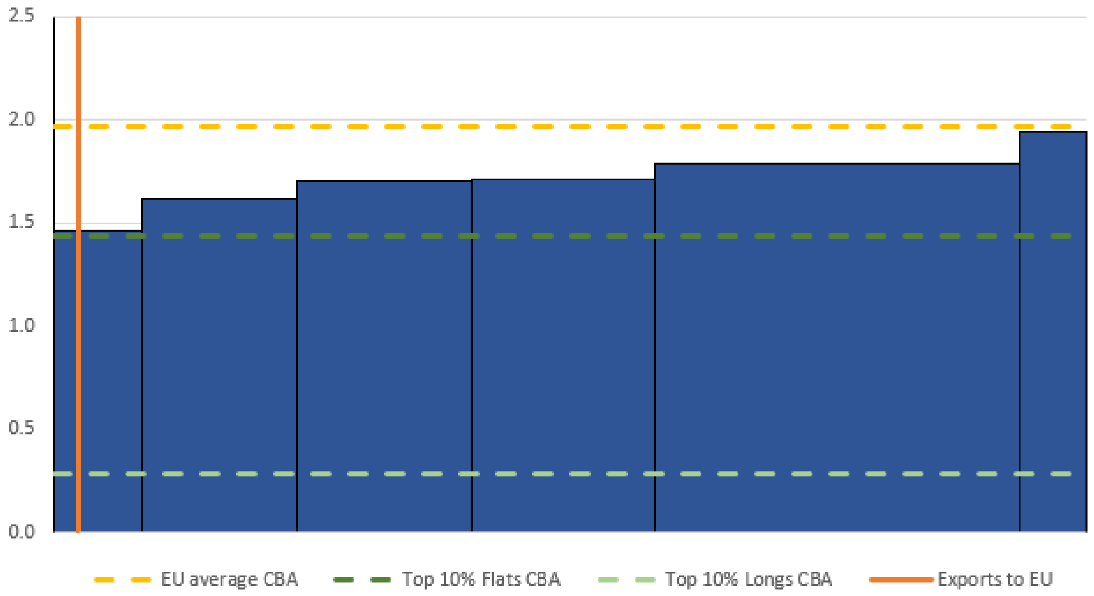
- All of region A's production (100% BF-BOF-based) is above the Top 10% BF-BOF default value. As such, there is no incentive to shuffling under either circumstance in region A under both Output Shuffling and Input Shuffling scenarios (although this does not necessarily preclude options other than electricity-related resource shuffling options). This is compounded by the fact that under this scenario, all EAF volumes are below the EAF CBAM default value, creating an incentive to shuffle emissions to EAF producers which benefit from a lower CBAM cost.
- In region B, Input Shuffling is effective in moving the intensities under the corresponding default value only for EAF volumes. It may be attractive for EAF producers to switch between process routes, but not necessarily for BF-BOF producers. However, the discount on CBAM received by EAF-based exported volumes may push a switch from BF-BOF to EAF to reduce the cost impact of CBAM.
- Unlike in region A, some BF-BOF volumes in region B do benefit from the removal of indirect emissions to move under the BF-BOF CBAM default value, providing some incentive to shuffle emissions.
- Under the Input Shuffling scenario, more scrap based EAF volumes move below the top 10% CBAM value compared to the Reference Case. But there are not enough scrap based EAF volumes below the CBAM to meet the exports level, indicating that there is an incentive to reduce the carbon footprint of the higher carbon intensity producer filling the gap.

Figure 6: Emissions curve for flats under input shuffling for regions A and B, average CBAM(yellow) and Top 10% CBAM (green), 2019

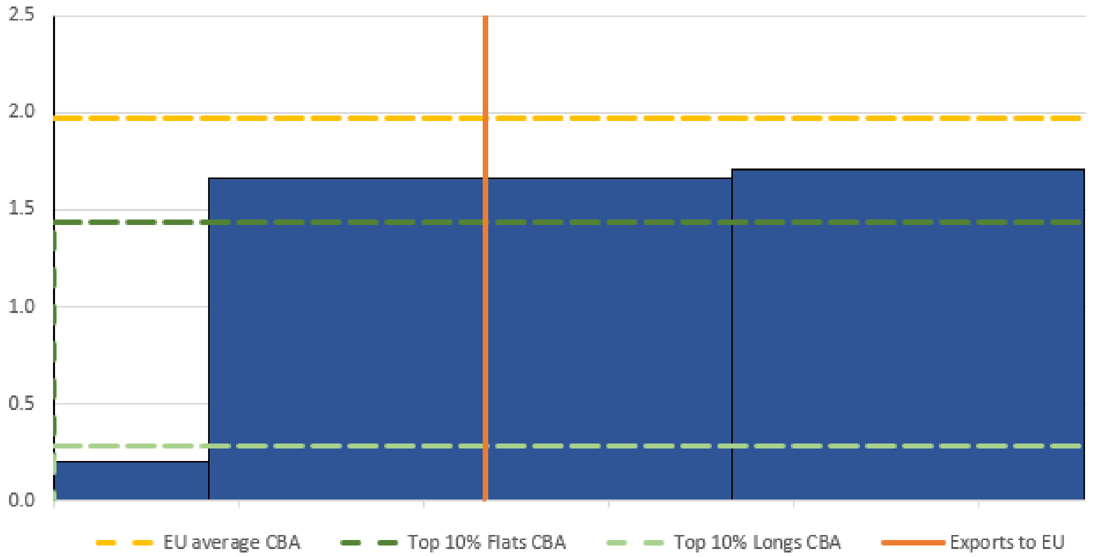
x-axis: annual Flats or Longs production by plant, Mt

y-axis: Scope 1 and 2 CO_2 emissions, tCO_2/t

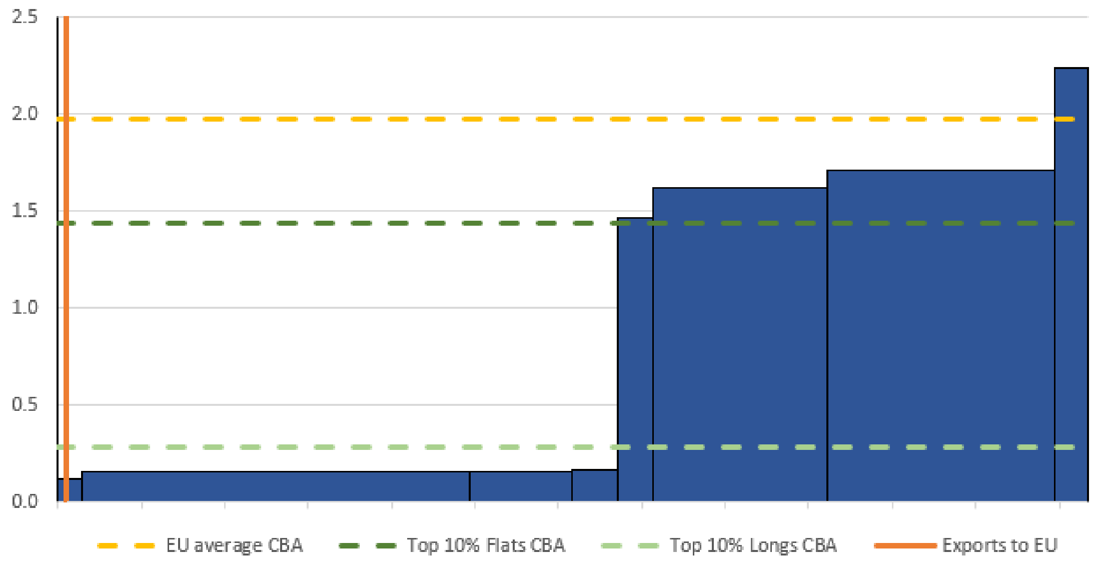
a) Flats – Region A



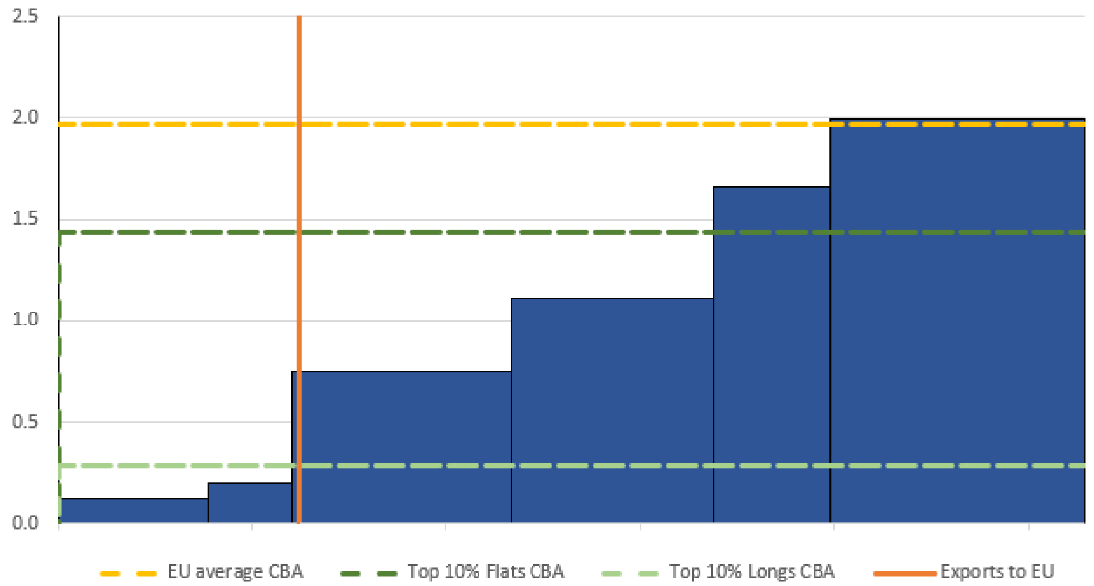
b) Flats – Region B



c) Longs – Region A



d) Longs – Region B



Source: CRU

6.3. Quantifying resource shuffling effects

Flats producers in regions A and B can reduce, from the Reference Case, the emissions intensity of their exports to the EU by:

- 6% (0.2Mt CO2) and 18% (0.8 MtCO2) respectively under the Output Shuffling scenario
- 24% (0.4Mt CO2) and 36% (1.5 MtCO2) respectively under the Input Shuffling scenario

Longs producers in regions A and B can reduce, from the Reference Case, the emissions intensity of their exports to the EU by:

- 66% (0.08Mt CO2) and 80% (1.6 MtCO2) respectively under the Output Shuffling scenario
- 89% (0.11Mt CO2) and 90% (1.8 MtCO2) respectively under the Input Shuffling scenario

These results are summarised in Table 2a below. Table 2b is an overview by CBAM and shuffling scenario for each studied region of whether there is an incentive to reshuffling volumes towards cleaner volumes located below CBAM default values.

Table 2: a) Summary of results for intensity of exports to the EU under shuffling scenarios (assumes weighted average intensity on left-hand side of exports line); b) Summary describing the potential to shuffle by region and product for different CBAM designs and shuffling scenarios

a)

Region / Product	Shuffling scenario	Intensity (tCO2/tcs)	Exports to EU (Mt)	Emissions (MtCO2)	% change vs RC
Region A / Flats	Reference case (RC)	1.9	1.0	1.9	0%
	Output Shuffling	1.8	1.0	1.7	-6%
	Input Shuffling	1.5	1.0	1.4	-24%
Region A / Longs	Reference case (RC)	1.1	0.1	0.12	0%
	Output Shuffling	0.4	0.1	0.04	-66%
	Input Shuffling	0.1	0.1	0.01	-89%
Region B / Flats	Reference case (RC)	1.8	2.3	4.2	0%
	Output Shuffling	1.5	2.3	3.4	-18%
	Input Shuffling	1.1	2.3	2.7	-36%
Region B / Longs	Reference case (RC)	1.6	1.2	2.0	0%
	Output Shuffling	0.3	1.2	0.4	-80%
	Input Shuffling	0.2	1.2	0.2	-90%

Numbers make not aligned due to rounding.

b)

Region / Product	Shuffling scenario	Potential to reshuffle:		
		Average CBAM	Top 10% BF-BOF CBAM	Top 10% EAF CBAM
Region A / Flats	Output Shuffling	Yes	No	No
	Input Shuffling	Yes	No	No
Region A / Longs	Output Shuffling	Yes	Yes	No
	Input Shuffling	Yes	Yes	Yes
Region B / Flats	Output Shuffling	Yes	Yes	No
	Input Shuffling	Yes	Yes	Yes
Region B / Longs	Output Shuffling	Yes	Yes	Yes
	Input Shuffling	Yes	Yes	Yes

7. Discussion of results

Our study suggests there is considerable potential for resource shuffling among trading partners exporting to the EU. However, the magnitude of these risks varies significantly across tradingregions and product segments. These effects are generally greatest for those regions with domestic steel markets which are large in relation to EU exports, where technical efficiencies vary widely, and among imports of long products (due to the greater proportion of EAF-based production and the higher share of indirect emissions generated via this process route).

However, these risks may not fully materialise given the likelihood of costs (including through potential CBAM compliance protocols) and other real world barriers to such supply chain and input accounting adjustments. As such, the assessments presented are likely to form an upper bound for the particular regions and channels under analysis (although recognising that not all potential shuffling channels are quantitatively assessed) Moreover, conclusions regarding the aggregate nature of these effects cannot readily be drawn given the limited and unrepresentative nature of the regional sample.

A fuller understanding of resource shuffling potentials would need to consider the implications of the following simplifications, inherent in our analysis, and implementation risks:

- Additional use of EAF steel for flat products: Company ownership and quality constraints due to technology and customer base will impact the potential switch from BOF to EAF, as not all qualities of steel can currently be produced via the scrap based EAF route. This will limit the ability of high-quality steel export volumes, e.g. certain automotive steel grades, to be shuffled to an EAF plant. In some cases, it may be feasible for steel plants to use higher quality scrap or scrap supplements (merchant pig iron ore direct reduction iron) to produce some of the more advanced steel grades, but often additional, significant capex is required to upgrade downstream processing capabilities to achieve the surface quality and dimensions required in high quality end uses. This is currently not incentivised in the markets where even some of long products are BOF based due to the scarcity of scrap at the global level. It requires further quantification to assess the potential for incentives from a CBAM mechanism to trigger the replacement of BOF based with EAF based processes for imported flat products.

- Our analysis assumes there are no barriers for exporting regions to shuffle production between different plants. In reality, certain steel trade flows will be sticky, due to quality constraints, service requirements or contract obligations. Therefore, the ability to shuffle production may depend on whether existing suppliers own low carbon plants or whether they belong to competitors and would require additional trade transactions.

- Increased scrap use in primary steel making: The BF-BOF process requires the addition of small shares (typically 10-20%) of scrap to the BOF for cooling purposes. This provides an additional method for primary steelmakers to reduce the carbon intensity of their steel, by increasing the quantity of scrap used in the BOF process. Measured at the primary ironmaking stage, carbon intensity may be 2.0 t CO_2/t output, but at the BOF, accounting for the scrap shares, the carbon intensity of the output may only be in the range of 1.6 t CO_2/t steel. As CBAM liability would most likely be based on the produced tonne of steel, rather than its primary iron component, it would create incentives to increase the scrap use in primary steelmaking. A global supply-demand balance for steel implies that the reduction of primary production in the specific plant would need to be replaced by additional primary steel production in other plants, unless scrap generation is increased. If plants in regions with scrap scarcity currently operate with 10% scrap input face strong financial incentives to increase the scrap share, e.g. to 20% of 30%, then this could represent an additional resource shuffling potential in the order of 15%.

- Further input shuffling potentials: Our analysis assumes that steel plant operating conditions are static. However, steel producers may choose to redirect the 'greenest' raw materials to a plant supplying the EU market, e.g. by concentrating the use of high quality raw materials or biofuels at certain plants.[4] The extent of carbon savings through this input shuffling effect will vary from plant to plant but for example the use of biofuels couldresult in CO2 reductions of ~5-15%.

- Changing trade flows: The intraregional and interregional competitivity of producers will determine which producers are best placed to fulfil the lowest carbon exports to the EU. For example, a CBAM could incentivise new trading partners with good access to lower carbon inputs such scrap and renewable energy, or lower carbon production methods such as Direct Reduced Iron-EAF to export to the EU, displacing existing higher carbon export volumes.In this context it also needs to be considered, to what extent resource shuffling reduces the costs for imports into the EU and hence may trigger increased import volumes replacing domestic production and emissions at the expense of increased international production and emissions.

- A broader and more representative sample of exporting regions: The analysis is undertaken on 2 regions which have been selected in order to derive insights regarding the potential scale and drivers of resource shuffling effects arising from differences in their structural characteristics (but not for the purposes of drawing inference on the industry wide implications). This raises the importance of undertaking a fuller assessment of the potential impacts - considering a broader and more representative sample of the EUs trading partners - to better inform policy makers regarding the scale and locus of these risks.

- There are traceability and consistency issues when it comes to the verification of generating abatement. For example, there are currently several different methods of carbon accounting in the steel sector, particularly with regards to credits for by-products such as slag. A standardised methodology needs to be established to ensure comparison on a like-for-like basis.

- Our analysis assumes there are no barriers for exporting regions to shuffle production between different plants. In reality, certain steel trade flows will be sticky, due to quality constraints, service requirements or contract obligations. Therefore, the ability to shuffle production may depend on whether existing suppliers own low carbon plants or whether they belong to competitors and would require additional trade transactions.

- The motivation to pursue such adjustments will depend on how strategic the exports are to the EU for each trading partner, considering:
  - The quality of the steel products generated in the region.
  - The size of the regional exports compared total regional production and the contribution to the respective GDP of a country.
  - The EU ETS carbon price determining the profits that can be obtained through resources shuffling. At a carbon price of 50 Euro/t, a reduction of 36% of carbon intensity creates additional revenue of about 20 Euro/t. This corresponds to more than half the operational margin of steel plants, probably sufficient to mobilise efforts. At significantly lower carbon prices or savings from resource shuffling efforts and therefore the scale of realized resource shuffling potentials may be lower.

Finally, this study has exclusively focussed on quantifying the scale of potential resource shuffling in the steel industry. However, it is important to recognise that these issues could also manifest in other industrial value chains. The magnitude and nature of these effects is likely to be shaped by the specificities of the value chains, trade flows, market structure and technologies deployed in any given sector. As such, no broad heavy industry wide conclusions can or should be drawn from this work. In the case of the aluminium sector, for example, there are a number of factors which, on the face of it, might suggest an equal or potentially even greater level of risk, specifically:

- Combined scope 1 and 2 emissions are extremely wide ranging from ~2-3 tCO2 per tonne of metal for hydro based smelters to around 20 tCO2 per tonne of metal for the least energy efficient coal-based producers. This raises the sensitivity of any conclusions to any given choice of benchmark.

- Low-carbon supply from Iceland & Norway, for example, is more than sufficient to cover all demand until 2025. Moreover, smelters employing different technologies co-exist within some major exporting regions. This generally increases the potential for output shuffling all other things being equal.

- This material chain is generally more commodities relative to steel. In addition, there is a greater role played by supply chain intermediaries. These factors generally increase the potential for output shuffling and the administrative challenges associated with product verification (since there are more links to certify in assuring the emissions associated with imported metal).

However, these points notwithstanding, there may also be a number of countervailing considerations. In particular, the capital stock in the aluminium is fundamentally more flexible compared to the steel industry. As such, there may be lower barriers to sector clean up, including, for example, through physical redeployment of smelting capacity to regions with low carbon power supply. Although not a major exporter of primary products to Europe, per se, recent large scale migration of aluminium smelting capacity within China to regions with abundant hydro power are evidence of this heightened potential. As such, while resource shuffling may, on the face of it, be easier in aluminium compared to steel, to the extent that decarbonisation in the power grid is gathering momentum, and that the capital required to rebuild a smelter is lower per tonne of capacity, the dynamic incentives to abate rather than shuffle may even plausibly be stronger. Regardless, these are questions that merit deeper enquiry.

8. Glossary of abbreviations

AC – apparent consumption

BF-BOF – blast furnace-basic oxygen furnace

CBAM – Carbon Border Adjustment Mechanism

EAF – electric arc furnaces

GVA – Gross Value Add

HRC – hot rolled coil

[4] The use of biofuels in steelmaking is currently restricted due to the high cost and limited supply of raw materials and process constraints. Current studies suggest biofuels and renewable carbon (such as waste plastics) may substitute up to 10-15% of total carbon inputs for a typical BF-BOF. Small sized BF-BOFs do not require the strength of fossil fuel-based coke and may substitute higher amounts biofuel. This practice is observed in Brazil, where small blast furnace operators utilise up to 100% charcoal as the carbon feedstock due to the abundant domestic availability of low cost, eucalyptus-based charcoal