Carbon Border Adjustment Mechanism (CBAM) Explorer

Abstract

In December 2022, the EU reached a provisional agreement on the world's first Carbon Border Adjustment Mechanism (CBAM), which aims to combat climate change and prevent carbon leakage (EP, 2022). The CBAM implementation will start by covering direct emissions from iron and steel, aluminum, cement, fertilizers, and electricity, with a further extension of commodity coverage and emissions' scope over time.

Governments of many EU trading partners have raised concerns about the possible implications of the CBAM for their economies, and several earlier studies have provided an assessment of various CBAM architectures in countries around the world (e.g., Chepeliev, 2021; Magacho et al., 2022; UNCTAD, 2021; Zhong and Pei, 2022). Overall, these earlier results suggest that at the macro level, implications of the CBAM for EU trading partners would be relatively modest, but selected producers of energy-intensive and trade-exposed goods in such countries, like Russia, China, India, Turkey, and Ukraine, might be impacted substantially.

While providing valuable insights into the topic, earlier studies have not adequately considered several essential points, including the uncertainty around CBAM implementation. First, the future architecture of the CBAM, as suggested by the earlier policy discussions and legislations, is flexible and is expected to change over time. The latter would include changing commodity and emissions' scope coverage. Second, the level of carbon prices in the EU that would be observed in the future is also uncertain and is subject to change depending on the stringency of the mitigation efforts. Third, as most studies utilize the standard Global Trade Analysis Project (GTAP) Data Base (Aguiar et al., 2019) for assessing the CBAM impacts, corresponding analyses suffer from aggregation bias. A number of commodities that are expected to be covered by the CBAM, such as cement, aluminum or fertilizers, are aggregated within broad GTAP sectors (non-metallic minerals, non-ferrous metals and chemicals, respectively). Finally, most of the earlier studies have a specific geographical focus with a limited set of individual countries included in the assessment.

In the current study, we aim to address some of the limitations of the earlier studies. Our assessment will start from the most recent Version 11 of the GTAP Data Base, which has the 2017 reference year (Aguiar et al., 2022). This version of the GTAP Data Base, apart from a more up-to-date base year, also includes a number of methodological improvements relevant to the assessment of the CBAM. The latter consists of a revised treatment of the fossil fuel combustion CO_2 emissions and a refined representation of the bilateral energy trade flows. Relying on the GTAP-Power version of this Data Base, we will implement selected sectoral splits for the CBAM-relevant commodities following an approach developed by Chepeliev et al. (2022). With this, we will split such commodities like steel (separating casting), cement, aluminum and plastic out of the aggregated GTAP sectors. In the next step, we will develop sectoral and regional aggregation retaining a high level of spatial resolution with a particular focus on developing regions keeping at least 60 individual countries in the aggregation. We will further update the database to the 2030 reference year via a one-step run of the GTAP-E-Power model using the macro assumptions from the most recent World Economic Outlook (IMF, 2022).

Using these refined data inputs to support the improved understanding of the potential impacts of CBAM-type measures, this study will provide an assessment of the wide range of CBAM options using the static

GTAP-E-Power modeling framework. Considering a wide range of uncertainties around the potential CBAM implementation framework, a conducted modeling exercise will run a set of scenarios that would include variation in carbon prices (from $50 to $250 per ton of CO2 with a step size of $25), emissions' scope coverage (Scopes 1, 2 and 3), commodity coverage (partial or full coverage of various sectors, as well as commodity-specific coverage, including cases of disaggregated goods) and varying geographical treatment (inclusion or exclusion of low-income countries from the CBAM coverage). A combination of these alternative options would result in 200+ scenarios covering a plausible range of the CBAM configurations at a highly disaggregated regional level with a detailed representation of individual developing countries.

The analysis and dissemination of results will be carried out via two channels. First, the results would be used to estimate a wide range of impact assessment indicators across considered CBAM architectures - macro impacts, implications for exports, imports, output, consumer prices, emissions, etc. These results would be used for future visualization and public sharing via an online platform so that an interested user can either bulk download all indicators or select a specific CBAM architecture and visualize the corresponding impacts via the developed platform. We refer to this platform as a "CBAM explorer". Second, the results would be used to estimate the CBAM exposure index (see Annex), which is aimed at identifying the most vulnerable countries and commodities under alternative CBAM architectures. The original CBAM exposure index developed by Fischer et al. (2022) is based on the static reflection of the trade flows and emission intensity of the CBAM-related products. In this study, we will use this concept and will be extended it with the model-based results, which take into account trade adjustment and substitution opportunities. This will allow us to identify countries and sectors/commodities that are expected to be the most vulnerable to CBAM under alternative architectures.

We believe that this study would be of interest to the GTAP conference participants, as well as a broader community of modelers and policymakers. On the methodological side, the paper introduces additional commodity details to the standard GTAP Data Base, enabling a more granular assessment of the CBAM policies in future studies. On the policy side, the analysis will support the decision-making process by providing a publicly available set of alternative CBAM scenario metrics accompanied by user-friendly visualization tools.

References

Aguiar, A., Chepeliev, M., Corong, E., & van der Mensbrugghe, D. 2022. The Global Trade Analysis Project (GTAP) Data Base: Version 11. *Journal of Global Economic Analysis*, *7*(2). Retrieved from https://jgea.org/ojs/index.php/jgea/article/view/181

Aguiar, A., Chepeliev, M., Corong, E. L., McDougall, R., & van der Mensbrugghe, D. 2019. The GTAP Data Base: Version 10. Journal of Global Economic Analysis, 4(1), 1–27. https://doi.org/10.21642/jgea.040101af

Chepeliev, M. 2021. Possible Implications of the European Carbon Border Adjustment Mechanism for Ukraine and Other EU Trading Partners. Energy RESEARCH LETTERS, 2(1). https://doi.org/10.46557/001c.21527

Chepeliev, M., Aguiar, A., Farole, T., Liverani, A., & van der Mensbrugghe, D. 2022. EU Green Deal and Circular Economy Transition: Impacts and Interactions. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6607

European Parliament (EP). 2022. Deal reached on new carbon leakage instrument to raise global climate ambition. Press Release. 13-12-2022. https://www.europarl.europa.eu/news/en/press-room/20221212IPR64509/deal-reached-on-new-carbon-leakage-instrument-to-raise-global-climate-ambition

Fisher, C., Jung, E. and Maliszewska, M. 2023. CBAM Exposure Index. World Bank (forthcoming).

International Monetary Fund (IMF). World Economic Outlook (October 2022). https://www.imf.org/external/datamapper/datasets/WEO

Magacho, G., Espagne, É., & Godin, A. 2022. Impacts of CBAM on EU trade partners: consequences for developing countries. *AFD Research Papers*, (238), 1-20. https://www.afd.fr/en/ressources/impacts-cbam-eu-trade-partners-consequences-developing-countries

United Nations Conference on Trade and Development (UNCTAD). 2021. A European Union Carbon Border Adjustment Mechanism: Implications for Developing Countries. Accessed via: https://unctad.org/system/files/official-document/osginf2021d2_en.pdf

Zhong, J., & Pei, J. 2022. Beggar thy neighbor? On the competitiveness and welfare impacts of the EU's proposed carbon border adjustment mechanism. *Energy Policy*, *162*, 112802.

Annex CBAM Exposure Index[1]

The CBAM exposure index that aims to identify countries with a high degree of cost and trade exposure to CBAM. To measure the scale of potential costs, the CBAM exposure index reflects two aspects of trade and emission intensity: 1) The share of a country's exports of CBAM-related products that go to the EU indicates the degree of trade dependence with the EU and challenges in finding other markets. 2) The unit cost increase indicated by the emissions intensity of production at an emissions price of $100/ton CO2e reveals the change in the relative export competitiveness of countries.

When CBAM is launched, companies that import covered goods from outside the EU will need to report the amount of emissions generated in the production of those goods and ultimately purchase and surrender certificates corresponding to those emissions each year. The CBAM will initially be limited to carbon-intensive industrial products, most notably cement, electricity, fertilizers, aluminum, and iron and steel. We collect trade data of such products at Harmonized System 6 digit level in 2019 from the World Bank's World Integrated Trade Solutions (WITS). For emissions, we rely on Chepeliev and Corong (2022), who develop a very useful dataset that provides greenhouse gas emission intensity embodied in exports by sector and by scope.[2] Scope 1 indicates direct emissions from production, scope 2 is indirect emissions produced from electricity generation. Under the EU provisional agreement, CBAM will cover direct emissions and indirect emissions "in a well-circumscribed manner" of select carbon-intensive sectors: iron and steel, cement, fertilisers, aluminum, electricity, and hydrogen, as well as some precursors and a limited number of downstream products. In this index, we include scope 1 and 2 emissions and draw country-specific carbon emission intensity data from Chepeliev and Corong (2022) for non-ferrous metals (aluminum), non-metallic minerals (cement), iron and steel, electricity, and chemicals (fertilizer). Export data of aluminum are matched with non-ferrous metals (NFM); Cement with non-metallic minerals (NMM), Electricity with electricity (ELY); fertilizer with (CHM) and iron and steel with (I_S) in the GTAP Sector code. The caveat is that the GTAP dataset provides aggregate sectors with a different composition of commodities, as well as underlying emission intensities. For example, non-ferrous metals (NFM) include aluminum, zinc, copper, precious and semi-precious metals.[3] Combining the trade and emissions intensity datasets, the sample covers 120 countries.

This exercise intends to measure how much cost a border adjustment with a $100 carbon price would impose per dollar of exports to the EU. The tax equivalent of the CBAM will depend on both the carbon intensity and the price of CBAM certificates, which will in practice be calculated to reflect the average weekly price of ETS auctions. For scale in our exercise, we set a notional carbon price τ = $100 per ton CO2e, which is in the range of recent EUA futures trading. The value of carbon emission intensity of

[1] The note has been prepared by Carolyn Fisher, Euijin Jung and Maryla Maliszewska.
[2] Maksym Chepeliev and Erwin Corong (2022), "Revisiting the environmental bias of trade policies based on an environmentally extended GTAP MRIO Data Base." Center for Global Trade Analysis, Purdue University.
[3] In this regard, gold exports from some African countries would not be facing CBAM at all as an example.

exports by country is measured as a product of the carbon price ($100 per CO2 eq ton) and carbon emission intensity of exports (KG/USD), divided by 1000 to convert to tons. To take the exports to the EU into account, we create a variable for product exports to the EU as share of product exports to the world. The cost of CBAM is calculated as a product of the value of emission intensity of exports and the share of sectoral exports to the EU. Then, countries are determined as highly exposed to the CBAM if country's cost of CBAM is larger than a threshold of 3% of their global export value. In this step, we exclude the EU and EFTA countries (which are part of the ETS) and countries with minimal export values (below $0.5 million for a given sector) from the sample.

The tax equivalent of CBAM may be compared with two potential benchmarks: the value of average EU emissions intensity and the intensity of the average of the worst three EU countries. The former indicates the average burden on EU producers, which are subject to the ETS, paying comparable emissions prices, and will be losing free allocations of emission allowances. A cost increase due to the CBAM only creates a relative loss in competitiveness if it is higher than the EU cost increase and that of most competitors that export to the EU. The latter average of the dirtier EU producers represents a potential default benchmark for embodied emissions where data are not available.[4] To the extent that non-EU producers are more carbon intensive than this default, the full cost burden may not be imposed in practice. However, EU plans for setting embodied emissions defaults have yet to be detailed.

Iron and steel

In the iron and steel sector, Zimbabwe is the most vulnerable among 12 countries with a high degree of CBAM exposure. Figure 1 displays the unit cost increase for exports to the EU with the EU average (orange line) and the average of the worst 3 EU countries (grey line) as benchmarks. The tax equivalent of CBAM of all 12 countries exceeds the EU average, with India being the most emissions intensive, and only Venezuela is below the average of worst 3 EU countries. On the trade exposure dimension, Zimbabwe sees 92% of its steel exports to the world gone to the EU, which is 3% of its total merchandise exports to world in 2019 (figure 1). Given a large EU share in its iron and steel exports, the country can experience challenges of redirecting its exports or diversifying its export markets. On the other hand, Venezuela and Tunisia also export a significant share of their products to the EU, but they are better positioned to potentially expand their exports to the EU under the CBAM, since they see relatively smaller tax equivalent than other exporters. However, if the CBAM benchmark is the average of the worst 3 EU countries, India, Ukraine[5], and Zimbabwe would face much more limited cost impacts, while Venezuela, Turkey and Tunisia would lose their ability to differentiate their products from these more carbon-intensive producers.

Commented [EJ1]: @Carolyn Fischer @Maryla Maliszewska Venezuela's unit cost increase is below the grey line. Doesn't it gain the advantage relatively?

[4] Both the Commission proposal and the Council approach suggest using the 10% worst EU performers, while the Parliament position suggests using the dirtiest performers in the exporting country.

[5] The war in Ukraine has significantly impacted exports from Ukraine to the EU so the current exposure is lower.

Figure 1-1. Unit cost increase for steel and iron exports to the EU

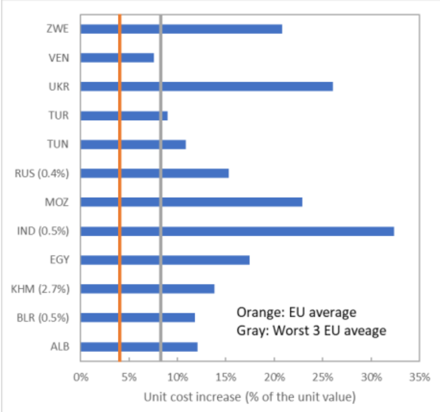
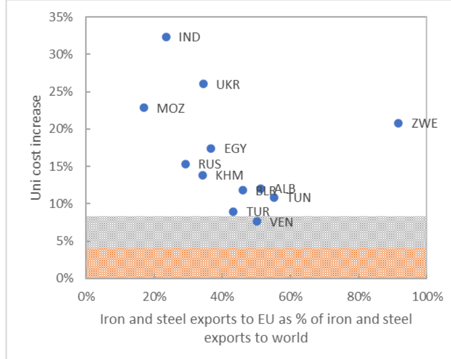


Figure 1-2. Steel and iron exports to the EU and unit cost increase



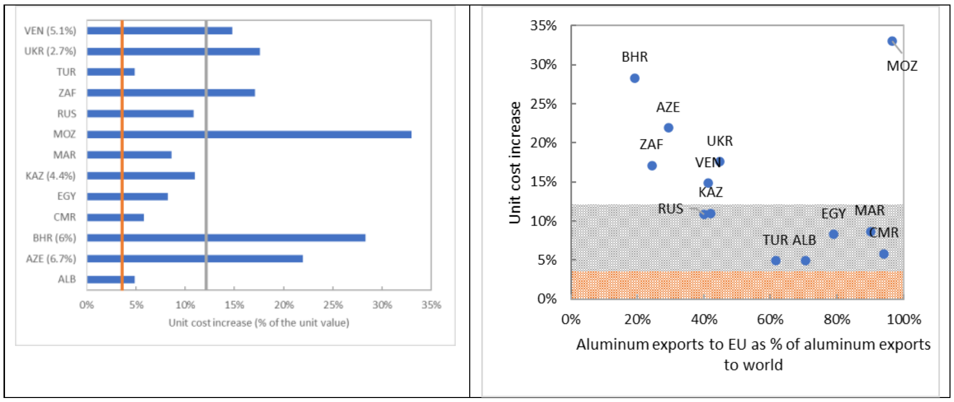
Note: the worst 3 EU countries include Poland, Romania, and the Slovak.

Source: WITS mirror and Chepeliev and Corong (2022).

Aluminum

In aluminum sector, Mozambique is found as most vulnerable to the CBAM among 13 countries with a high exposure to the CBAM. All six countries record a higher tax equivalent of CBAM for exports to the EU than the worst 3 EU countries (figure 2-1). If the benchmark is the average of worst 3 EU countries, those six countries can't be differentiated from one another. So, the CBAM would have limited impact on their export competitiveness. Aluminum imports from Mozambique, Bahrain and Azerbaijan could face large cost increases related to CBAM. Mozambique could be impacted the most as 97% of the country's aluminum exports go to the EU (figure 2-2). Given a dominant EU share in its aluminum exports, Mozambique could face challenges in redirecting its exports to other markets in a short term. Despite duty free access, aluminum from Mozambique is likely to be less competitive in the EU market as a result of CBAM, however the import costs of aluminum from Bahrain and Azerbaijan comes on top of the 6% EU tariffs.

Figure 2-1. Unit cost increase for aluminum exports	Figure 2-2. Aluminum exports to the EU and unit cost increase



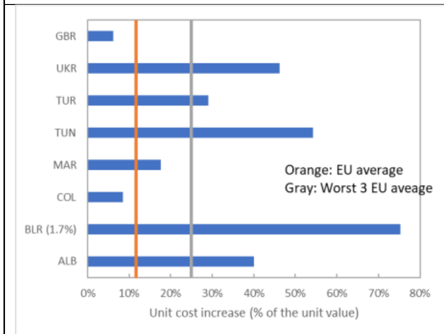
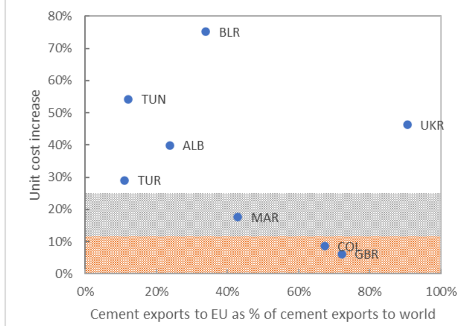
Note: the number on country label indicates the EU tariff on the imports from countries.

Note 2: the worst 3 EU countries include the Slovak, Ireland and Greece.

Source: WITS mirror and Chepeliev and Corong (2022).

Cement

In cement sector, Ukraine is identified as most vulnerable among eight exporting countries with a high degree of CBAM exposure (figure 3-1). Belarus, Tunisia and Ukraine could face large tax equivalent of CBAM for exports when carbon emissions are taxed. While Belarus records the highest increase in tax equivalent, its exports to the EU account for 34% of its cement exports to the world (figure 3-2). The exposure of Ukraine to the CBAM and potential loss of competitiveness on the EU market is higher as its export to the EU represent 91% of its cement exports to the world. Also, a large EU share can hinder Ukraine to divert its exports to non-EU market in the short term. The exposure of Morocco to CBAM is still above the EU average, but smaller than for Belarus and Tunisia. However, if the average of worst 3 EU countries is the benchmark, Morocco loses its carbon competitiveness to carbon intensive exporters.

Figure 3-1. Unit cost increase for cement exports	Figure 3-2. Cement exports to the EU and unit cost increase
	

Note: the number on country label indicates the EU tariff on the imports from countries.

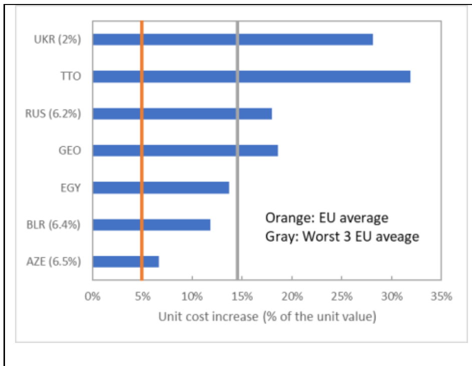
Note 2: the worst 3 EU countries include Croatia, Bulgaria and Greece.

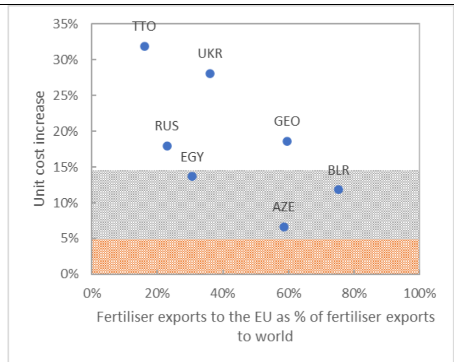
Source: WITS mirror and Chepeliev and Corong (2022).

Fertilizer

In fertilizer sector, Georgia is most vulnerable to the CBAM among seven countries that are highly exposed to the CBAM (Figure 4.1). The largest tax equivalent of CBAM is found in Trinidad and Tobago while the smallest in Azerbaijan. Although Trinidad and Tobago could see the largest tax equivalent among the 4 most impacted countries, about 16% of its fertilizer exports to the world goes to the EU market, which can be diverted to other markets. But, Georgia, facing a larger tax equivalent of CBAM than the average of worst 3 EU countries, registers 59% of its total fertilizer exports directing to the EU (figure 4-2). On the other hand, in Azerbaijan and Belarus more than 50% of cement exports head to the EU, and face lower tax equivalent than other competing countries. Azerbaijan and Belarus would likely be willing to pay the extra cost related to CBAM as their production is relatively greener than that of its competitors.

Figure 4-1. Unit cost increase for fertilizer exports	Figure 4-2. Fertilizer exports to the EU and unit cost increase





Note: the number on country label indicates the EU tariff on the imports from countries.

Note 2: the worst 3 EU countries include Croatia, Bulgaria and Romania.

Source: WITS mirror and Chepeliev and Corong (2022).

Electricity

In electricity sector, five countries face a high level of exposure to CBAM. All five's tax equivalent of CBAM for exports to the EU is above the EU average but below the average of worst 3 EU countries (figure 5-1). Russia sees the largest cost increase while the United Kingdom relatively face the lowest cost increase. All but Russia shows 100% of total electricity exports going to the EU (figure 5-2). The UK is in a position to gain market share as a relatively less carbon-intensive exporter.

Figure 5-1. Unit cost increase for electricity exports

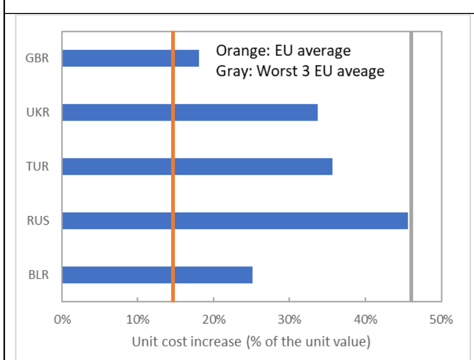
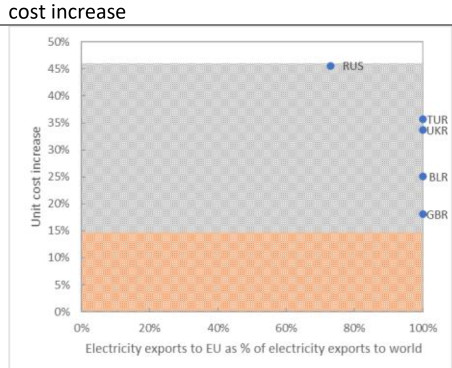


Figure 5-2. Electricity exports to the EU and unit cost increase

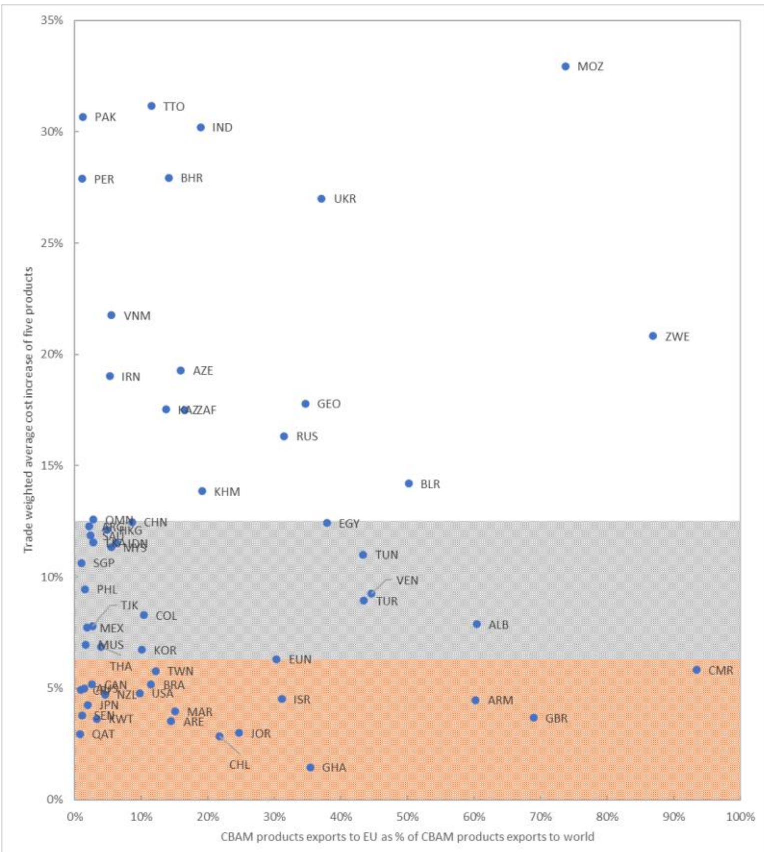


Note: the worst 3 EU countries include Spain, Greece and Poland.

Source: WITS mirror and Chepeliev and Corong (2022).

Overall, developing countries are highly exposed to the CBAM, at the same time, can find an export opportunity to the EU. Several developing countries could become relatively less competitive on the EU market due to CBAM. Figure 6 demonstrates the position of countries in terms of their exports and CBAM cost. X axis shows how much the EU accounts for the total five CBAM products exports to world. Y axis displays a tax equivalent of CBAM for exports to the EU, reflecting five CBAM products exports. This represents the total value of exports at risk and the degree to which cost pressure might put them at risk. Red and grey areas indicate the EU average and the average of worst 3 EU countries in the tax equivalent of CBAM for exports to the EU, respectively. Mozambique and Zimbabwe are identified by a high degree of CBAM exposure. Mozambique has a comparative advantage in aluminum while Zimbabwe in iron and steel. Both register a high EU share in the CBAM product exports to the world and a large trade weighted tax equivalent of CBAM. They are likely to see themselves less competitive in the EU market in two aspects. The cost increase for importers to purchase certificates for Zimbabwe's steel and iron would be larger than steel and iron from other countries (e.g. Venezuela and Turkey). Also, Mozambique and Zimbabwe would find difficulties to diversify their export markets in a short term due to the EU dominance in their CBAM products exports. On the other hand, Cameroon, as a medium sized aluminum exporter, is well positioned to seek an opportunity to expand its exports to the EU market. The country has a high EU share in total CBAM products exports with the tax equivalent below the EU average. Armenia and the United Kingdom can benefit from CBAM as relatively cleaner producers as in Cameroon.

Figure 6. A snapshot of CBAM exposure by country



Note: countries with less than $1 million of CBAM exports to the EU are excluded; the worst 3 EU countries include Bulgaria, Greece and Spain.

Source: WITS and Chepeliev and Corong (2022).

Summary statistics of CBAM exposure dataset

Figure 1. Exports of each product as share of region's total merchandise exports in 2019, by region

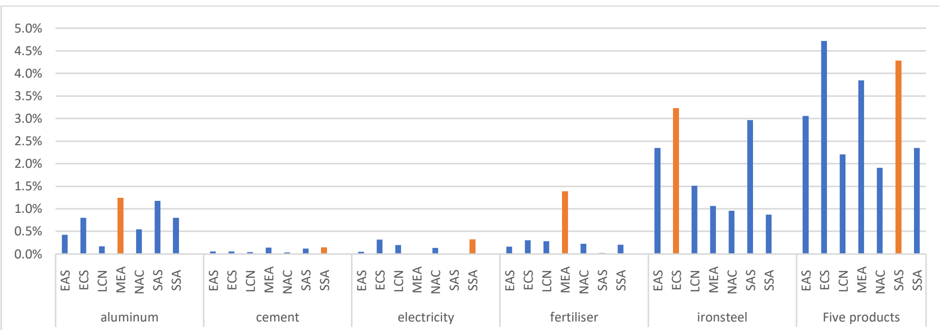
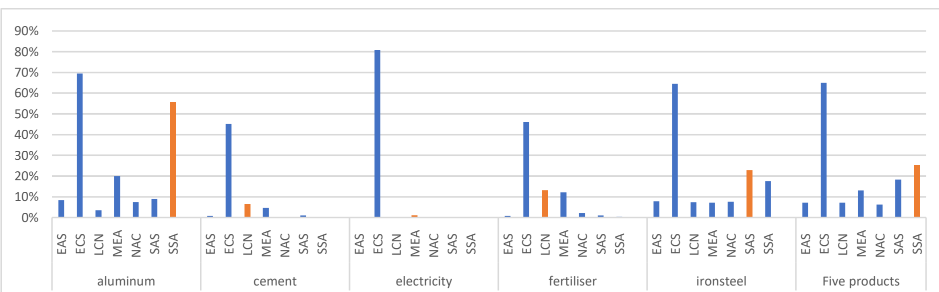


Figure 2. Exports of each product to the EU as share of region's total product exports in 2019, by region



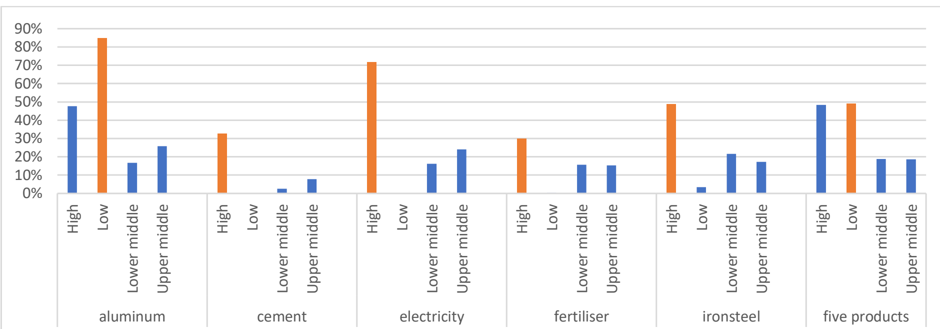
Note: EAS=East Asia – Pacific; ECS=Europe - Central Asia; LCN=Latin America – Caribbean; MEA=Middle East and North Africa; NAC=North America; OTR=Other Regions; SAS=South Asia; SSA=Sub-Saharan Africa.

Source: WITS mirror.

- Aluminum exports from Sub-Sahara Africa accounts for 1.2% of the region's total merchandise exports, but 44% of it headed to the EU market.
- Cement represents 0.14% of Middle East and North's total merchandise exports, and 4.7% of it is shipped to the EU market.
- Electricity exports by Sub-Sahara Africa and Latin America and Caribbean records 0.3% and 0.2% of total merchandise exports, respectively, which goes to non-EU market.

- Fertilizer exports by Middle East and North Africa registers 1.4% of total merchandise exports, and 12.1% of this export are sent to the EU market.
- Iron and steel exports from South Asia accounts for 3% of the region's total merchandise exports, and 22.8% of the region's iron and steel exports heads the EU countries.
- Total exports of all five product groups accounts for 4.3% of South Asia's merchandise exports, and 18.3% of this export goes to the EU market. This is mainly driven by South Asia's iron and steel exports to the EU that is larger than Sub-Sahara Africa's aluminum exports to the EU and Middle East and North Africa's fertilizer exports to the EU. By product group, aluminum exports by Sub-Sahara Africa, cement and fertilizer exports by Middle East and North Africa, and iron and steel exports by South Asia are mainly exposed to the EU's CBAM.

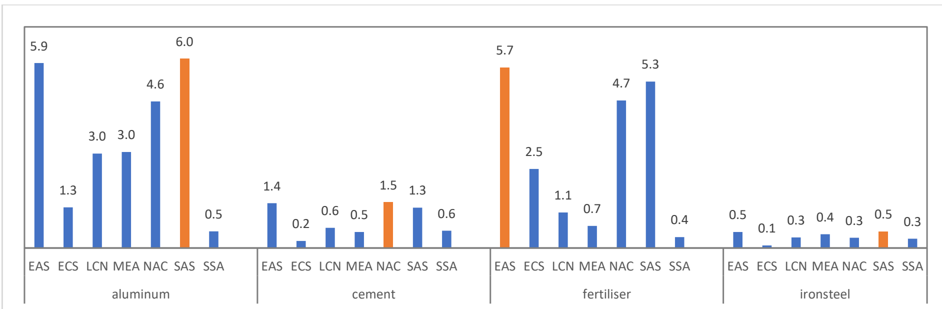
Figure 3. Product exports to the EU as share of total product exports in 2019, by income group



Source: WITS mirror.

- The EU represented 49% of low-income group's exports of five product groups to world, which is the highest among income groups. This can be explained by aluminum exports by low-income group. The EU accounted for more than 80% of low-income group's total aluminum exports to world. Compared to other income groups, the low-income group is more exposed to the EU's CBAM.

Figure 4. average applied EU tariffs in 2019 (%)



Note: EAS=East Asia – Pacific; ECS=Europe - Central Asia; LCN=Latin America – Caribbean; MEA=Middle East and North Africa; NAC=North America; OTR=Other Regions; SAS=South Asia; SSA=Sub-Saharan Africa.

Source: WITS.

- Sub-Sahara Africa faces the lowest tariff rate across product groups, excluding the Europe and Central Asia region. This is because most African countries enjoy their unilateral preferential treatment in the EU market, which allows imports from this region are duty free and quota free at the EU customs. The "Everything But Arms" (EBA) arrangement is part of the EU's Generalised Scheme of Preferences (GSP). The GSP allows vulnerable developing countries to benefit from lower duties or duty-free exports to the EU, and hence stimulate their economic growth.[6]
- On the other hand, South Asia and East Asia and Pacific face higher tariffs in aluminum and fertilizer, compared to other regions.
- This implies that South Asia's export competitiveness in iron and steel can be adversely affected in the EU market once the CBAM is launched. At the same time, many Sub-Sahara African countries can still enjoy duty free and quota free in the EU market if the CBAM also include the provision of special treatment for least developed countries.

Figure 4. Greenhouse gas emission intensity of exports, by GHG type and region (kg/USD)

[6] A list of Least Developed Countries defined by the United Nations is found available at https://unctad.org/topic/least-developed-countries/list

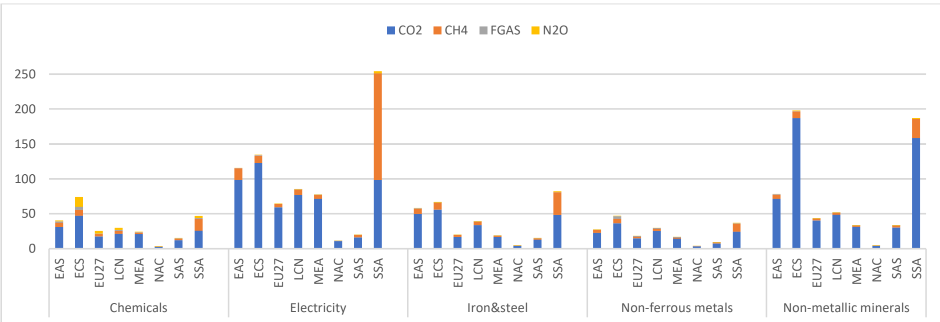
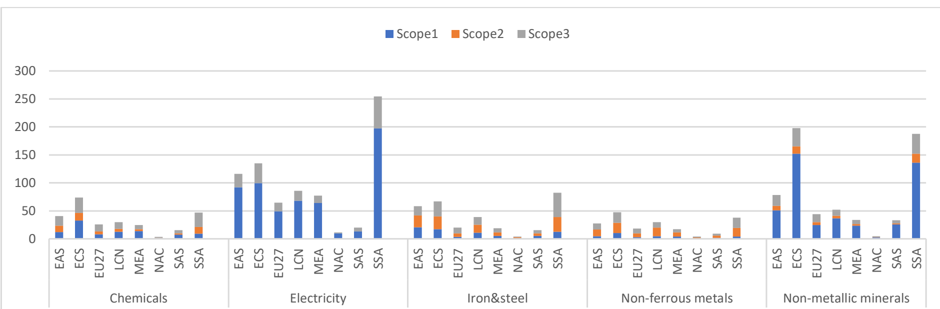


Figure 5. Greenhouse gas emission intensity of exports, by scope and region (kg/USD)



Source: Chepeliev et al (2022).

- Greenhouse gas emission intensity of exports in CBAM products are largely driven by CO2 in all regions.
- Sub-Sahara Africa is found most GHG intensive in all product groups if Europe and Central Asia excludes the EU27.
- In electricity sector Sub-Sahara Africa is most GHG intensive, interestingly it's mainly driven by methane. Particularly, Togo, Benin, and Ethiopia rank top 3 methane intensive countries in the region, recording 64 KG/USD, 27 KG/USD, and 24 KG/USD, respectively.
- Sub-Sahara Africa is also carbon intensive in cement (non-metallic minerals), driven by Madagascar (44KG/USD), Nigeria (19KG/USD), Benin (18KG/USD), and Ghana (13KG/USD) in carbon emissions.
- Greenhouse gas emission intensity of exports in electricity and cement (non-metallic minerals) are mainly from direct emissions (scope 1). Meanwhile, chemicals, iron&steel and aluminum (non-ferrous metals) find larger contributions of indirect emissions such as energy generation and inputs from supply chains to total emission intensity of exports.