

The EU's CBAM and Its Implications for Greenhouse Gas Emission Intensity Trends in Turkish Industries

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Abstract

In December 2019, the European Commission introduced the European Green Deal (EGD), aiming for a climate-neutral Europe by 2050. As the EU targets net-zero emissions by 2050 and a 55% reduction by 2030, it encourages nations, especially those with strong EU ties, to align their climate policies. The EU's green leadership drives other countries to adopt similar measures to stay competitive, as green technologies become more mainstream. A key element of the EGD is the Carbon Border Adjustment Mechanism (CBAM), which will price greenhouse gas emissions from certain imported goods starting in 2026. To address CBAM risks, non-EU countries must reduce GHG emissions through green innovations and Best Available Techniques (BAT). This study contributes to the relevant literature in four areas by analyzing (1) the evolution of GHG emission intensities in 26 Turkish sectors from 2003 to 2019 in 2-digit NACE detail; (2) the competitiveness of countries in the EU27 market for six CBAM products; (3) the potential effects of export revenue loss on Turkish sectors in 4-digit NACE detail; and (4) the decoupling status of carbon-intensive Turkish sectors. Our findings show that while chemicals, basic metals, and electricity are showing weak decoupling, the non-metallic minerals, paper, and refinery sectors pose risks to competitiveness. Input-output analysis indicates that the impact of CBAM on Turkish gross value added, GHG emissions, and employment will be minimal, mainly due to lower emission intensities in iron, steel, and aluminum, and relatively low level of trade in cement, electricity, fertilizer and hydrogen with the EU.

JEL Codes: D57; C67; Q56

Keywords: European Green Deal; Carbon Border Adjustment Mechanism; Emission Intensity; Coupling; Decoupling; Input-Output Analysis

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In December 2019, the European Commission introduced the European Green Deal (EGD), aiming for a climate-neutral Europe by 2050. As the EU targets net-zero emissions by 2050 and a 55% reduction by 2030, it encourages nations, especially those with strong EU ties, to align their climate policies. The EU's green leadership drives other countries to adopt similar measures to stay competitive, as green technologies become more mainstream. A key element of the EGD is the Carbon Border Adjustment Mechanism (CBAM), which will price greenhouse gas emissions from certain imported goods starting in 2026. To address CBAM risks, non-EU countries must reduce GHG emissions through green innovations and Best Available Techniques (BAT). This study contributes to the relevant literature in four areas by analyzing (1) the evolution of GHG emission intensities in 26 Turkish sectors from 2003 to 2019 in 2-digit NACE detail; (2) the competitiveness of countries in the EU27 market for six CBAM products; (3) the potential effects of export revenue loss on Turkish sectors in 4-digit NACE detail; and (4) the decoupling status of carbon-intensive Turkish sectors. Our findings show that while sectors like chemicals, basic metals, and electricity are showing weak decoupling, the non-metallic minerals, paper, and refinery sectors pose risks to competitiveness. Input-output analysis indicates that the impact of CBAM on Turkish gross value added, GHG emissions, and employment will be minimal, mainly due to lower emission intensities in iron, steel, and aluminum, and relatively low level of trade in cement, electricity, fertilizer and hydrogen with the EU.

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1. Introduction

The European Green Deal (EGD), launched in December 2019, aims to make Europe the first climate-neutral continent by 2050. Spanning sectors like economy, labor, and agriculture, it emphasizes innovation, sustainability, and a just transition via mechanisms like the Just Transition Mechanism (European Commission, 2019). The EGD's influence extends globally, particularly affecting trade partners like Türkiye. By targeting net-zero emissions by 2050 and a 55% GHG reduction by 2030, the EU pressures other nations to align policies, leveraging tools like the Circular Economy Action Plan and the Carbon Border Adjustment Mechanism (CBAM) (Yeldan et al., 2022; European Commission, 2015). CBAM, which taxes embedded emissions in imports, necessitates decarbonization in trading partners to mitigate trade risks.

Türkiye responded to the EGD by forming a cross-ministerial working group in 2020 and adopting the European Green Deal Action Plan (EGDAP) in 2021, focusing on decarbonization, circular economy, and CBAM adaptation (Turkish Ministry of Trade, 2021). Further, Türkiye ratified the Paris Agreement in 2022, setting a 2053 carbon neutrality goal (Turkish Ministry of Environment, Urbanization and Climate Change, 2022). However, CBAM may raise production costs for high-emission sectors, potentially impacting employment and value added (Takeda and Arimura, 2024; Mörsdorf, 2022).

This study analyzes GHG emission intensities and decoupling status across 19 Turkish manufacturing sectors (2-digit NACE) and 7 other high-emission sectors (1-digit NACE). Existing research has limitations: it uses aggregated 1-digit NACE data, excludes non-CO₂ GHGs (e.g., methane), and overlooks Industrial Process and Product Use (IPPU) emissions. This paper addresses these gaps by providing detailed sectoral GHG intensity calculations and assessing CBAM's potential trade, employment, and GDP impacts via input-output analysis. Such granular analysis aids policymakers in designing sector-specific decarbonization strategies.

No prior studies have examined CBAM's implications for Türkiye's trade or GDP, limiting comparative analysis. The paper is structured as follows: Section 2 reviews literature, Section 3 outlines methodology, Section 4 presents results, and Section 5 concludes.

2. Literature Review

The greenhouse gas emissions of power plants and facilities located in the EU that produce energy- and carbon-intensive products—such as paper, cement, ceramics, iron, steel, refinery products, chemical products, and air transportation—have been regulated under the EU Emission Trading System (ETS) since 2005. Under this system, EU producers are required to purchase "emission rights" (European Union Allowances, EUA) at market prices to account for the emissions they generate. As emission reduction targets have increased, the number of allowances has decreased, resulting in higher costs for carbon- and energy-intensive industries that resist transformation.

While achieving climate neutrality by 2050 is theoretically possible through intra-EU emission reductions under the EU ETS, this approach can have negative consequences for global emissions, intra-EU production, and employment—a phenomenon known in the literature as carbon leakage (Branger and Quirion, 2014). To address this issue, the EU ETS has historically provided free allocations of EUAs (or up to a determined benchmark) to products deemed at risk of carbon leakage. This policy, known as free allocation, aims to mitigate the potential negative impacts on the competitiveness of the EU industries. However, free allocation policy contradicts the European Green Deal's objective of creating a climate-neutral continent by 2050. This is where the CBAM comes into play.

This study contributes to the relevant literature in four areas by analyzing (1) the evolution of GHG emission intensities in 26 Turkish sectors from 2003 to 2019 in 2-digit NACE detail; (2) the competitiveness of countries in the EU27 market for six CBAM products; (3) the potential effects of export revenue loss on Turkish sectors in 4-digit NACE detail; and (4) the decoupling status of carbon-intensive Turkish sectors.

2.1. Studies on the possible effects of the CBAM on EU-trading partners

The CBAM is designed to eliminate the risk of carbon leakage and help achieve global carbon reduction goals (European Commission, 2021; Keen and Kotsogiannis, 2014; Böhringer et al., 2022; Mörsdorf, G., 2022). It came into effect after being published in the Official Journal of the EU on 16 May 2023 (Official Journal, 2023). The key elements of the regulation are outlined below:

- The establishment of a new EU-wide central CBAM Authority to oversee the implementation process.
- A transitional phase from 1 October 2023 to 2025, during which importers are required to report embedded Scope 1 and Scope 2 emissions for cement and fertilizer, and Scope 1 emissions for iron-steel, aluminum, electricity, and hydrogen.
- Starting from 1 January 2026, importers must surrender CBAM Certificates for their imports.
- The price of the CBAM Certificate will be based on the average price of the EU Emission Trading System (EU ETS) during the relevant week.
- The continuation of free allocation under the EU ETS until 2034 (with a gradual phase-out from 2026) will also be applied to non-EU producers of relevant products identified as being at risk of carbon leakage under the EU ETS.
- To avoid double taxation, the carbon price paid in the country of origin will be deducted from the price paid at the EU border.
- The revenues generated from the sale of CBAM Certificates will be directed to the EU budget and will not be returned to the originating country, in contrast to the implementation of the EU ETS.

With CBAM, the EU ETS will expand beyond the EU, and similar to the EU, EU importers of listed products will begin paying a price for the greenhouse gases embedded in those products by 2026. By leveling the playing field for EU and non-EU manufacturers, CBAM is expected to alter the competitiveness of non-EU manufacturers (UNCTAD, 2021; Beaufils et al., 2023). Consequently, CBAM poses significant socio-economic challenges for developing and emerging economies. If not carefully designed to account for these economies' specific conditions, the policy could lead to adverse outcomes, including job losses, diminished tax revenues, and reduced export earnings. To mitigate these effects, targeted measures such as exemptions, technology transfers, and climate subsidies have been proposed (Amendola, 2025).

The literature on the effects of the CBAM on the EU and her trading partners' economies can be divided into two broad categories, namely, (i) those quantifying the direct impacts of the CBAM via computable general equilibrium (CGE) models, and (ii) those employing Input-Output (IO)

models. For a meta-analysis of CGE models see Branger and Quirion (2014), and Zhong and Pei (2022) for other studies employing the IO methodology.

The distributional effects of CBAM vary across the European Union's trading partners. Chepeliev (2021) projects that Ukraine could experience a substantial decline in domestic iron and steel production, while global chemical exports may also contract. The policy's impacts are highly uneven, with Russia, China, Turkey, and Ukraine being particularly vulnerable due to their high export volumes in CBAM-covered sectors (Magacho et al., 2023).

China's manufacturing sector is expected to face reduced price competitiveness in EU markets due to CBAM. A Computable General Equilibrium (CGE) model analysis by Chen (2023) indicates that carbon tariffs may marginally decrease China's real GDP while lowering the carbon intensity of certain industries. However, the overall effect on global carbon emissions remains negligible, suggesting that CBAM functions primarily as a protective measure for EU industries. The study underscores the necessity for China to adopt more stringent carbon taxation and export subsidies to sustain its competitive position.

In summary, CBAM is likely to reconfigure global competitiveness, disproportionately burdening non-EU economies such as China, Russia, Turkey, and India (Zhong & Pei, 2022). The mechanism risks exacerbating existing inequalities, particularly in developing and emerging economies that depend heavily on EU exports. These nations may encounter additional obstacles in transitioning to low-carbon technologies due to constrained institutional capacities and financial resources (Eicke et al., 2021).

2.2. Studies on the possible responses to the introduction of the CBAM

The announcement of the CBAM increases the climate ambition of EU trading partners (Sculecki et al., 2022). The number of countries implementing a carbon pricing instrument increase rapidly in recent years. According to the World Bank's Climate Dashboard website, as of 2025, there are 36 ETS, 39 Carbon Tax and 35 Governmental Crediting mechanisms are implemented globally.

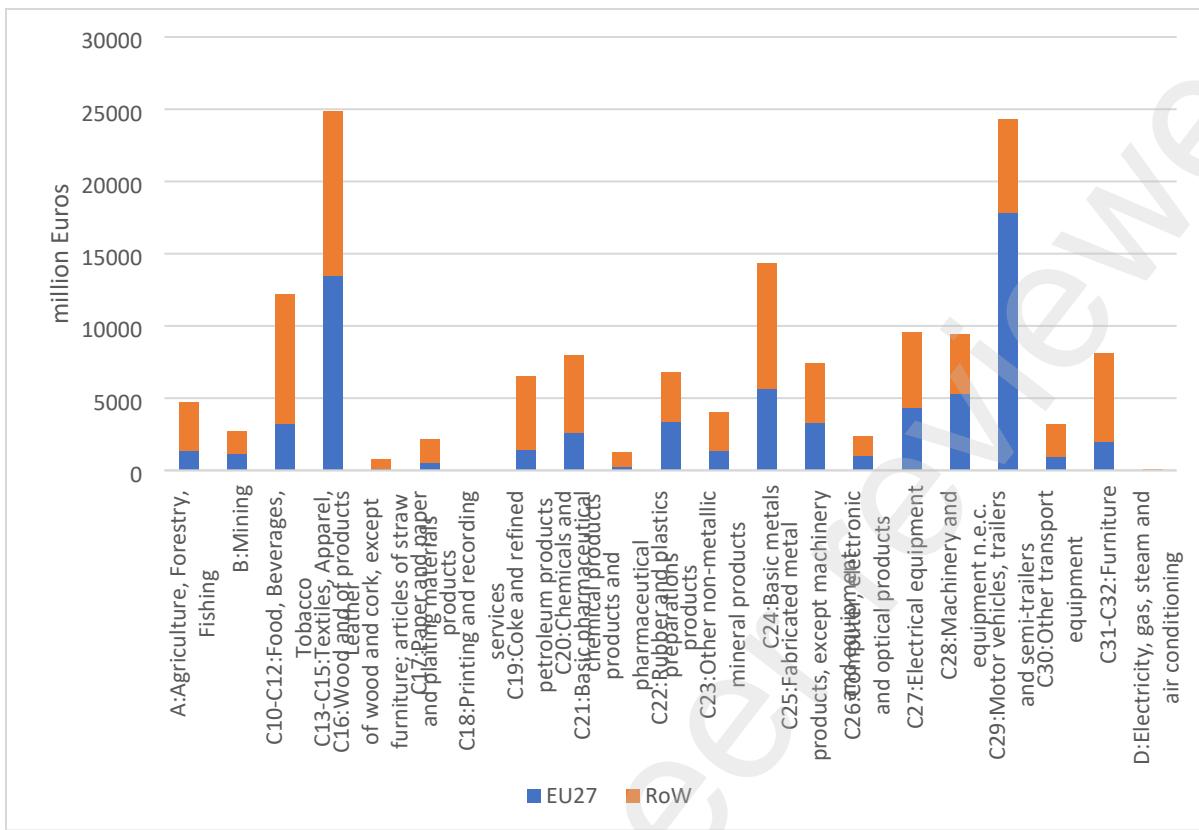
Pricing GHG emissions can be seen as a part of a broader green transition path which is a long and complex process. Ghorbani et al. (2024) introduced a comprehensive strategy aimed at fostering a globally inclusive green energy transition that goes beyond traditional decarbonization methods. The study first examined the role of CO₂ in this transition, emphasizing the importance of addressing other significant greenhouse gases. It also identified several challenges facing

current decarbonization efforts, including growing dependence on the mineral value chain, technological and infrastructure limitations, and socio-economic impacts, among others.

The increased ambition of adopting green technology innovation has become a key strategy for achieving net zero emissions by 2050 (Xu et al., 2023). Green technological innovation refers to the development of environmentally friendly products that utilize technological solutions to minimize the use of raw materials, reduce energy consumption, and decrease environmental pollution (Obobisa et al., 2022). Unlike traditional innovations, green technology innovation is rooted in principles of energy efficiency, environmental optimization, and sustainable development. Its outcomes are primarily seen in technological advancements that contribute to emissions reductions, improved energy efficiency, and resource conservation (Wang et al., 2021). Green technologies, such as renewable energy and energy efficiency, are expected to play a leading role in cutting emissions, achieving net zero emissions, and limiting global warming to 1.5°C, as outlined in the IEA (2021) scenario. As a result, many economies are working towards zero emissions by fostering green technology innovation and increasing investments in net zero technology initiatives.

2.3. Studies on the effects of the CBAM on the Turkish economy and Türkiye's response

The effect of EU's CBAM on the Turkish economy is expected to be substantial (Acar et al. 2022). As shown in Figure 1, the EU, accounting for almost 50% of total exports, continues to be Türkiye's main trading partner. As of 2019, the top exporting sectors included C13-C15: Textiles, Apparel, Leather; C29: Motor Vehicles; C24: Basic Metals; and C10-C12: Food, Beverages, and Tobacco.



Source: Eurostat Comext and TURKSTAT Foreign Trade datasets

Figure 1. The Geographic Distribution of Sectoral Exports (million Euros, 2019)

Acar et al. (2022) constructed a Computable General Equilibrium (CGE) model to assess the potential impacts of CBAM on the Turkish economy. The study finds that, compared to a no-CBAM Business-as-Usual (BaU) scenario, the introduction of CBAM could result in a decline in GDP by 2030. The magnitude of this decline is estimated to range between 2.7% and 3.6% for carbon prices of 30 and 50 euros per ton of greenhouse gases (GHGs), respectively. A later study commissioned by the Turkish Ministry of Environment, Urbanization and Climate Change (2023), reported that “considering the embedded Scope 1 and Scope 2 emissions in the targeted products that export to the EU, the potential annual CBAM costs to industry assuming a CBAM charge of EUR 75/tCO₂e amounts to EUR 138 million in 2027. However, if the CBAM charge increases to EUR 150/tCO₂e, these costs could escalate to EUR 2.5 billion annually by 2032. These rising costs through time are not only a function of a higher modelled CBAM charge, but also due to the phase out of free allowances in the EU ETS, which results in a growing CBAM charge burden to covered industries over time”.

The implementation of CBAM highlights the emissions embodied in basic commodities exported to the EU27 market. To minimize potential economic losses caused by CBAM, it is crucial to decouple GHG emissions from production processes. This involves finding ways to reduce emissions while maintaining or improving economic output. A closer cooperation with the EU, including engagement with decentralized EU agencies like the European Environment Agency and participation in EU industrial alliances such as the European Clean Hydrogen Alliance could provide a window of opportunity for Turkish businesses (Aşıcı and Acar, 2022; Kaeding and Krull, 2021).

Turkish climate policy ambition grew steadily following the Paris Agreement in 2015. According to the draft carbon market regulation announced in November 2023, the pilot phase of the Turkish Emissions Trading System (ETS) begins in 2025. The first step in establishing an ETS in Türkiye began with the establishment of a Monitoring-Reporting-Verification (MRV) system in 2015. According to the ETS regulation, installations in the electricity, refinery, non-metallic minerals, basic metals, paper, and the chemicals sectors emitting above a certain level of greenhouse gases (GHGs) ($> 500 \text{ ktCO}_2\text{e}$) will be covered under the new system. As of 2020, 476 installations under the Turkish MRV system emitted 251 MtCO₂e of GHG, which corresponds to 48.2% of total emissions (520 MtCO₂e) (Aşıcı, 2024).

2.4. Studies on the emission-economic growth nexus in the Turkish economy

The concept of decoupling, initially introduced by Zhang (2000), examines the relationship between CO₂ emissions and economic growth. In order to address limitations related to the sensitivity of base period selection and the lack of result stability, Juknys (2003) proposed three types of decoupling states: *decoupling*, *coupling*, and *negative decoupling*. Tapió (2005), when analyzing decoupling in the European transport sector, modified Juknys' idea and introduced the Tapió decoupling index. The Tapió decoupling index differentiates decoupling cases more effectively by categorizing the three decoupling states into eight logical possibilities: *strong decoupling*, *weak decoupling*, *expansive coupling*, *expansive negative decoupling*, *strong negative decoupling*, *weak negative decoupling*, *recessive coupling*, and *recessive decoupling*.

The majority of sectoral studies on the Turkish economy focus on the economic growth-emission nexus focuses on decomposition of sectoral CO₂ emissions from fuel combustion. Tunç et al. (2009), Akbostancı et al. (2011), Lise (2006), and Kumbaroğlu (2011) indicate that the scale effect

is the main factor behind emission increases in the manufacturing, electricity, agriculture, and transport sectors, while the composition effect accounts for emission decreases. By employing aggregated data, Karakaya et al. (2019) analyzes the Turkish economic growth for the period 1990–2016 and finds that there is either no decoupling or weak decoupling in most of the years considered. Ozdemir (2023) employs decomposition and decoupling analyses for Türkiye's CO₂ emissions from electricity generation using primary fossil fuels from 1990 to 2020 and found that weak decoupling was the most frequent decoupling state during the study period.

Existing studies on the Turkish economy have overlooked several crucial factors: (i) significant variations in emission intensities among sectors within the manufacturing industry, (ii) the presence of other emission sources, such as industrial processes and product use (IPPU), and (iii) the presence of other greenhouse gases (GHGs) like N₂O, CH₄, and HFCs, among others. This paper aims to fill the gap in the relevant literature on the above-mentioned fronts. To the best of our knowledge, no previous study has analyzed the decoupling or coupling relationship between GHG emissions and real gross value added at the 2-digit NACE sectoral level in Turkish manufacturing subsectors. Moreover, this study presents a more refined analysis by incorporating 4-digit detailed CBAM product exports to the EU27 market in the IO analysis, as opposed to the 2-digit detailed data employed in previous studies employing the IO methodology. Therefore, this study addresses this important gap by providing policymakers with a better understanding of the changes in GHG emission intensities within emission-intensive manufacturing sectors by considering all GHGs and other emission sources such as IPPU. It aims to assist them in implementing effective measures to transition toward a low-carbon economy.

The following section will outline the data and methodology employed in this study.

3. Data and Methodology

This paper employs the Tapio decoupling model to identify the decoupling relationship between real gross value added and GHG emissions in Türkiye's manufacturing industry at the 2-digit NACE level, as well as in other emission-intensive sectors such as agriculture, electricity, and transportation at the 1-digit NACE level.

The Tapio decoupling indicator is expressed as Equation (1).

$$\gamma = \frac{\frac{\Delta C}{C}}{\frac{\Delta Y}{Y}} \quad (1)$$

where γ represents the decoupling indicator between real gross value added and GHGs emissions; C represents the sectoral GHGs emissions; Y represents the sectoral gross real value-added; and ΔC and ΔY represent the incremental indicators of GHGs emissions and real value-added, respectively. The classification of decoupling states is presented in Table 1.

Table 1. Decoupling states and their classification

Decoupling state	$\Delta Y/Y$	$\Delta C/C$	γ
Strong decoupling	> 0	< 0	(-∞, 0)
Weak decoupling	> 0	> 0	[0, 0.8]
Recessive decoupling	< 0	< 0	(1.2, +∞)
Strong negative decoupling	< 0	> 0	(-∞, 0)
Weak negative decoupling	< 0	< 0	[0, 0.8]
Expansive negative decoupling	> 0	> 0	(1.2, +∞)
Recessive coupling	< 0	< 0	[0.8, 1.2]
Expansive coupling	> 0	> 0	[0.8, 1.2]

The Eurostat air emissions accounts dataset provides information on sectoral greenhouse gas (GHG) emissions at the 2-digit level for the manufacturing sector. However, data on Turkish real gross value-added is only available at the 1-digit NACE level in Eurostat's national accounts dataset for Türkiye. To overcome this limitation, as shown in Table 2, weights derived from TurkStat's 2-digit detailed gross value-added values (measured in current Turkish Lira) are used to allocate real gross value-added values of Eurostat data (measured in 2005 Euros) to Türkiye's manufacturing sectors.

Table 2. Extending TURKSTAT's Gross Value-Added series over Eurostat Data (2018)

NACE Codes	Sectors	TURKSTAT GVA (in millions TL)	TURKSTAT GVA Shares (%)	Corresponding Eurostat GVA values (in millions euros)
C	Manufacturing	4,63187E+11	100	138898,4
C10-C12	Manufacture of food products; beverages and tobacco products	49543383768	10,7	14856,9
C13-C15	Manufacture of textiles, wearing apparel, leather and related products	75496029694	16,3	22639,4

C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	6338887734	1,4	1900,9
C17	Manufacture of paper and paper products	13419680277	2,9	4024,2
C18	Printing and reproduction of recorded media	3229368894	0,7	968,4
C19	Manufacture of coke and refined petroleum products	10752176542	2,3	3224,3
C20	Manufacture of chemicals and chemical products	28386232982	6,1	8512,3
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	8664620833	1,9	2598,3
C22	Manufacture of rubber and plastic products	26731375708	5,8	8016,1
C23	Manufacture of other non-metallic mineral products	27093617360	5,8	8124,7
C24	Manufacture of basic metals	48360033228	10,4	14502
C25	Manufacture of fabricated metal products, except machinery and equipment	32267169268	7,0	9676,1
C26	Manufacture of computer, electronic and optical products	11449427963	2,5	3433,4
C27	Manufacture of electrical equipment	24293643630	5,2	7285,1
C28	Manufacture of machinery and equipment n.e.c.	28343943745	6,1	8499,7
C29	Manufacture of motor vehicles, trailers and semi-trailers	36100985542	7,8	10825,8
C30	Manufacture of other transport equipment	9758192542	2,1	2926,2
C31_C3_2	Manufacture of furniture; other manufacturing	13528271197	2,9	4056,8
C33	Repair and installation of machinery and equipment	9429494093	2,0	2827,7

Source: Author's calculations from the TURKSTAT and the Eurostat's Gross Value-Added datasets

Data on exports to the EU27 market at the 4-digit level are obtained from Eurostat's Comext database. In section 4.3 where 6 CBAM products in EU27 market are analysed in detail, we employ OECDStat's definition of emission intensity, "*TeCO2: CO2 emissions embodied in trade*," which measures intensity as "tons of CO2 embodied per million USD of exports" (OECD, 2021), due to the lack of data for most competitor countries in Eurostat.

Table 3 presents sectoral GHG emissions for the years 1998 and 2020 (the latest available year), with the sectors ordered based on their respective shares of total emissions related to economic activity for the year 2020.

Table 3. Sectoral GHGs Emissions (million tons of CO2e)

NACE Code	Sector	1998	2020	% Change (1998-2020)	2020 Share in Total GHG Emissions (%)
D	Electricity, gas, steam and air conditioning supply	62.7	136.1	117.1	30.2
A	Agriculture, forestry and fishing	52.7	84.7	60.7	18.8
C23	Other non-metallic mineral products	28.9	77.7	168.9	17.2
H	Transportation and storage	12.5	29.1	132.9	6.5
C24	Basic metals	14.3	17.0	18.5	3.8
E	Water supply; sewerage, waste management and remediation activities	13.5	16.2	20.4	3.6
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	0.5	15.4	2781.8	3.4
C20	Chemicals and chemical products	5.6	10.2	82.0	2.3
C19	Coke and refined petroleum products	4.0	8.9	122.9	2.0
C10-C12	Food products; beverages and tobacco products	6.8	7.9	16.2	1.8
C28	Machinery and equipment n.e.c.	1.5	6.7	358.6	1.5
B	Mining and quarrying	4.7	6.1	30.3	1.4
F	Construction	7.6	5.7	-25.0	1.3
C13-C15	Textiles, wearing apparel, leather and related products	7.6	3.1	-58.6	0.7
C25	Fabricated metal products, except machinery and equipment	2.5	1.5	-40.7	0.3
C17	Paper and paper products	0.4	1.5	243.4	0.3
C22	Rubber and plastic products	1.6	0.8	-48.3	0.2
C27	Electrical equipment	1.1	0.7	-42.4	0.1
C29	Motor vehicles, trailers and semi-trailers	1.4	0.6	-57.8	0.1
C31_C32	Furniture; other manufacturing	0.7	0.4	-40.2	0.1
C16	Wood and of products of wood and cork	0.7	0.4	-40.8	0.1
C18	Printing and reproduction of recorded media	0.6	0.3	-52.2	0.1
C21	Basic pharmaceutical products and pharmaceutical preparations	0.4	0.3	-33.5	0.1
C33	Repair and installation of machinery and equipment	0.0	0.3	1050.8	0.1
C30	Other transport equipment	0.4	0.2	-61.4	0.0
C26	Computer, electronic and optical products	0.3	0.1	-59.8	0.0
C	Manufacturing	79.0	132.6	67.8	29.4
<i>TOTAL</i>	<i>Total - all NACE activities</i>	<i>234.6</i>	<i>450.5</i>	<i>92.1</i>	<i>100.0</i>

Source: Eurostat air emissions accounts dataset

As indicated in Table 3, Türkiye's economic activity-related greenhouse gas (GHG) emissions increased significantly by 92.1%, rising from 235 million tons of CO₂e in 1998 to 451 million tons of CO₂e in 2020. While certain major exporting sectors, such as textiles and motor vehicles,

experienced a decline in emissions, there was a notable surge in emissions within energy-intensive sectors, including transport and storage, non-metallic minerals, refinery products, and basic metals.

Despite Türkiye's commendable efforts in renewable energy investments, the electricity sector saw a substantial increase in emissions of 117.2%. This poses a significant risk to the Scope 2 emissions of exporting sectors, highlighting the urgent need to address emissions in this sector to mitigate its environmental impact.

3.1. Input-Output Analysis

The greenhouse gas (GHG) emissions embedded in, as well as the gross value-added and employment created by exports to the EU27 market, can ideally be calculated using Input-Output analysis. Note that the most recent Turkish IO table released by Turkstat is from 2012. To better capture changing economic structure, we updated this table with year 2018 data. In the first step, 65 sectors from the original 2012 IO table were aggregated into 24 model sectors (see Appendix Table A.1 for model sectors). In the second step, using the final demand components of national income accounting from Turkstat, the 2012 intermediate flows were updated to 2018 values using the RAS technique. This consistent data set is then used to calibrate the micro/sectoral and macroeconomic balances of the analytical model to the existing data.

The IO model, at the defined sectoral level, begins with the definition of sectoral gross output production. Therefore, for each of the n sectors, one has:

$$X = AX + Y \quad (2)$$

where X is the vector of total outputs, Y is the vector of final demands, and A is the $(n \times n)$ matrix of production coefficients whose typical element $a_{i,j} = \frac{X_{i,j}}{X_j}$.

Rearranging Equation (2) yields the fundamental equation for I-O analysis:

$$X = (I - A)^{-1}Y \quad (3)$$

where $(I - A)^{-1}$ represents the Leontief inverse matrix.

Final Demand for each sector $Y = C + I + G + EX$, consists of household consumption expenditures, C ; gross fixed investment expenditures, I ; public expenditures, G ; and foreign demand (exports) EX .

The total output generated by exports to the EU27 market can be found as follows:

$$X = (I - A)^{-1}EX_{EU27} \quad (4)$$

Pre-multiplying the RHS of Equation (4) by a GHG-intensity matrix, K_{GHG} , hosting elements $\frac{GHG_j}{X_j}$ on the diagonal of the $(n \times n)$ K_{GHG} matrix, yields:

$$GHG_{EX_EU27} = K_{GHG}(I - A)^{-1}EX_{EU27} \quad (5)$$

where GHG_{EX_EU27} is the $(n \times n)$ matrix of GHGs embedded in the exports made to the EU27 market.

Similarly, one can calculate the sectoral gross value-added (GVA) and employment (EMP) generated by EU27 exports, by pre-multiplying Equation (4) with $K_{GVA} = \frac{GVA_j}{X_j}$, and $K_{EMP} = \frac{EMP_j}{X_j}$ to get

$$GVA_{EX_EU27} = K_{GVA}(I - A)^{-1}EX_{EU27} \quad (6)$$

$$EMP_{EX_EU27} = K_{EMP}(I - A)^{-1}EX_{EU27} \quad (7)$$

The row-sum of any sector j of GHG_{EX_EU27} (GVA_{EX_EU27} and EMP_{EX_EU27}) then, illustrates the total GHGs embedded in (gross value-added and employment created by) the exports of sector j made to the EU27 market.

It is possible to decompose the total GHGs embedded in exports over different emission scopes. The diagonal element of GHG_{EX_EU27} shows the Scope 1 emissions of sector j ; the cell belonging

to the D: Electricity row shows the Scope 2 emissions; while the sum of the rest of column j shows the Scope 3 emissions generated at the rest of the economy.

The same applies to GVA_{EX_EU27} and EMP_{EX_EU27} matrices which shows the gross value-added (employment) at sector j created by the EU27 exports of sector j , and the sum of the rest of column j shows the gross value-added (employment) in the rest of the economy. The results are presented in section 4.2.

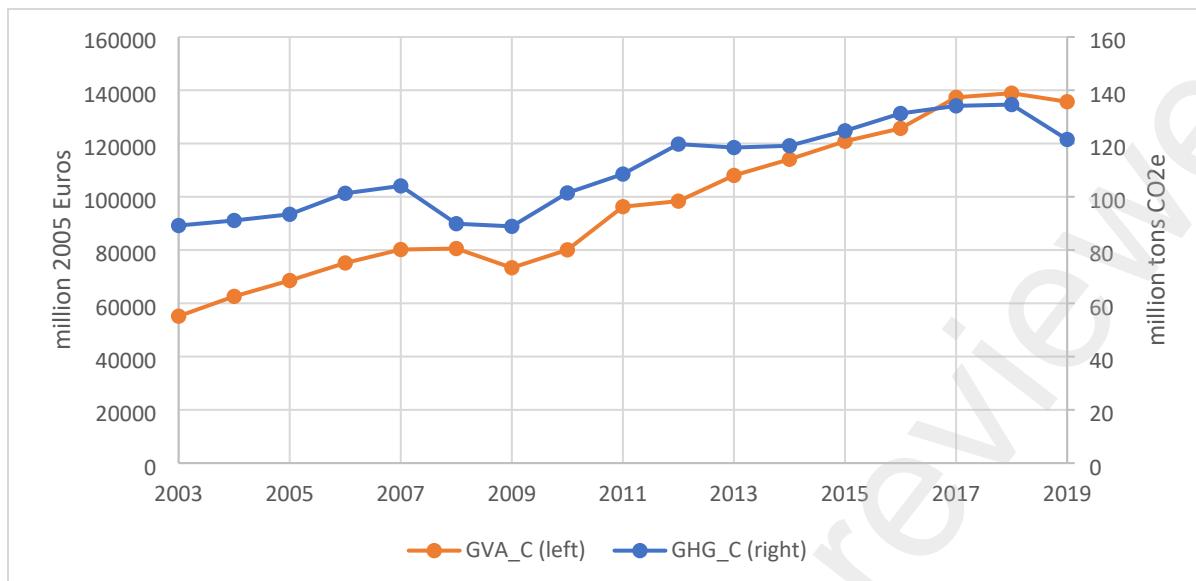
4. Results

This section presents the decoupling states of Turkish emission-intensive sectors between 2003 and 2019; evaluates the relative competitiveness of Turkish CBAM-product exports to the EU27 market; and finally analyzes the sectoral GHGs, gross value-added, and employment induced by exports to the EU27 market in 2018 using the I-O analysis presented in Section 3.

4.1. The Decoupling States of Turkish Emission-Intensive Sectors

To minimize CBAM-related risks, sectors should reduce the GHG emission intensity of their products, in other words, decouple the value-added process from emissions.

As depicted in Figure 2, the Turkish manufacturing sector experienced weak decoupling between 2003 and 2019. The real gross value-added of the manufacturing sector increased from €55.2 billion to €135.7 billion (in 2005 prices), indicating an annual average growth rate of 8.6%, while GHG emissions increased from 89.2 to 121.5 million tons of CO₂e, reflecting an annual average growth rate of 2.1%.



Source: Eurostat air emissions accounts and gross value-added datasets

Figure 2. GHGs Emissions and Real Gross Value Added of Manufacturing (C)

Table 4 illustrates the decoupling status of various sectors, their respective shares in total emissions in 2020, and provides a comparison with the EU27 averages.

Table 4. The GHGs Scoreboard of Sectors

	%Δgva	%Δghg	decoup_elas	status	2020 GHGs Share (%)	GHGs Intensity (tCO2e per million GVA)	Türkiye	EU27
Strong Decouplers								
C10-C12: Food products; beverages and tobacco products	1.10	-0.07	-0.06	strong decoupling	1.8	435.3	309.2	
C13-C15: Textiles, wearing apparel, leather and related products	0.73	-0.64	-0.87	strong decoupling	0.7	147.7	122.1	
C16: Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	2.29	-0.50	-0.22	strong decoupling	0.1	274.7	150.4	
C18: Printing and reproduction of recorded media	0.40	-0.59	-1.48	strong decoupling	0.1	318.6	81.5	
C21: Basic pharmaceutical products and pharmaceutical preparations	0.71	-0.44	-0.62	strong decoupling	0.1	78.4	65.6	
C22: Rubber and plastic products	2.21	-0.56	-0.25	strong decoupling	0.2	106.9	104.0	
C25: Fabricated metal products, except machinery and equipment	3.68	-0.50	-0.14	strong decoupling	0.3	161.3	75.3	
C26: Computer, electronic and optical products	1.92	-0.65	-0.34	strong decoupling	0.0	38.8	25.9	

C27: Electrical equipment	2.11	-0.51	-0.24	strong decoupling	0.1	96.5	47.2
C29: Motor vehicles, trailers and semi-trailers	1.30	-0.73	-0.56	strong decoupling	0.1	60.8	41.3
C30: Other transport equipment	6.00	-0.66	-0.11	strong decoupling	0.0	48.2	40.3
C31_C32: Furniture; other manufacturing	1.51	-0.48	-0.32	strong decoupling	0.1	103.9	48.8
F: Construction	2.16	-0.37	-0.17	strong decoupling	1.3	117.7	117.2
				Sub-total	4.6		
Weak decouplers							
B: Mining and quarrying	0.70	0.43	0.61	weak decoupling	1.4	1188.2	1622.2
C17: Paper and paper products	3.52	1.33	0.38	weak decoupling	0.3	30202.2	704.3
C20: Chemicals and chemical products	1.52	0.60	0.40	weak decoupling	2.3	316.6	704.3
C24: Basic metals	1.21	0.11	0.09	weak decoupling	3.8	1073.7	1446.1
D: Electricity, gas, steam and air conditioning supply	1.59	0.98	0.62	weak decoupling	30.2	1807.6	2476.2
E: Water supply; sewerage, waste management and remediation activities	1.66	0.02	0.01	weak decoupling	3.6	13767.1	4995.3
				Sub-total	41.6		
Recessive couplers							
A: Agriculture, forestry and fishing	0.61	0.58	0.95	recessive coupling	18.8	1487.7	2548.1
C23: Other non-metallic mineral products	1.24	0.99	0.80	recessive coupling	17.2	8398.5	2881.6
C33: Repair and installation of machinery and equipment	11.53	9.19	0.80	recessive coupling	0.1	92.3	41.7
C28: Machinery and equipment n.e.c.	2.79	2.82	1.01	recessive coupling	1.5	820.4	55.4
				Sub-total	37.6		
Expansive negative decouplers							
C19: Coke and refined petroleum products	0.09	0.85	9.52	expansive negative decoupling	2.0	6187.2	4456.5
G: Wholesale and retail trade; repair of motor vehicles and motorcycles	1.54	24.03	15.61	expansive negative decoupling	3.4	156.4	68.6
H: Transportation and storage	0.97	1.26	1.30	expansive negative decoupling	6.5	472.8	960.8
				Sub-total	11.9		
<i>Notes</i>							
C: Manufacturing	1.46	0.36	0.25	weak decoupling	29.4	895.6	427.3
<i>TOTAL: Total - all NACE activities</i>	1.26	0.72	0.57	weak decoupling	100.0	661.5	298.3

Based on the results presented in Table 4, the following observations can be made:

- All sectors listed above experienced positive gross value-added growth rates ($\%gva > 0$).
- A 126% growth in gross value-added, accompanied by a 72% growth in emissions, indicates that the Turkish economy experienced relative decoupling overall. This is also true for the manufacturing (C) industry as a whole.
- Although there are 13 sectors with strong decoupling, their share of total emissions in 2020 amounts to only 4.6%.
- The combined emissions from the 6 sectors exhibiting weak decoupling account for 41.6% of total emissions. While decoupling progress in the CBAM-covered sectors of Electricity (D), Basic Metals (C24), and Chemicals and Chemical Products (C20) has been relatively sluggish (see Table A.2 in the appendix for the evolution of intensities during the study period), it is noteworthy that Türkiye's emission intensities in these sectors are lower compared to the average emission intensities of the EU27.
- Regressive coupling is observed in 4 sectors, which contributed to 37.6% of the emissions in 2020. Increasing emission intensity in the C23: Non-Metallic Mineral sector, where the CBAM product cement is produced, could deteriorate the sector's competitiveness in the EU27 market. Note also that while the EU27 emitted 2,881.6 tons of CO₂e per one million euros worth of gross value added, it emitted 8,398.5 tons of CO₂e in the C23 sector in Türkiye.
- Expansive negative decoupling is observed in 3 sectors—C19: Coke and Refined Petroleum Products, G: Wholesale and Retail Trade, and H: Transportation and Storage—which contributed to 11.9% of total emissions in 2020.

4.2. Input-Output Analysis

The implementation of CBAM will have wide-ranging effects, impacting not only a country's export sectors but also the overall economy through various input-output linkages. The potential rise in CBAM costs may lead to a decline in exports, resulting in reduced economic growth and increased unemployment both within the affected sectors and across the entire economy.

Examining Table 5, we observe that Türkiye exported €4.8 billion worth of CBAM products to the EU27 market in 2018, with iron, steel, and aluminum comprising the majority of these exports. However, when considering the total export value of €192.5 billion, these CBAM products accounted for only 2.5% of total exports in 2018.

Table 5. The Effects of EU27 Exports (2018)

	Fertilizer	Cement	Iron-Steel&Aluminium	Electricity	2018 Total
Exports (bn Euros)	0.1	0.07	4.5	0.06	192.5
Gross Value-Added (m TL)					3724388
<i>GVA_{EX_EU27}</i>					
At the sector	91.9	131.3	2817.4	225.8	
At the rest of the economy	121.3	179.3	14311.9	91.0	
Total	213.2	310.6	17129.3	316.8	
<i>% of 2018 Gross Value-Added</i>	0.006	0.008	0.460	0.009	
Employment					28737561
<i>EMP_{EX_EU27}</i>					
At the sector	635	1038	13767	160	
At the rest of the economy	663	596	80506	136	
Total	1298	1634	94273	296	
<i>% of 2018 Employment</i>	0.005	0.006	0.328	0.001	
GHGs Emissions (m ton CO₂e)					464
<i>GHG_{EX_EU27}</i>					
Scope 1	0.017	0.273	1.464	0.202	
Scope 2	0.009	0.016	1.070	0.000	
Scope 3	0.010	0.008	0.798	0.002	
Total	0.037	0.297	3.332	0.204	
<i>% of 2018 GHGs Emissions</i>	0.008	0.064	0.718	0.044	

Source: Author's calculations.

Furthermore, in 2018, the Turkish economy demonstrated considerable strength, generating a gross value-added of 3.7 trillion Turkish Lira (TL) and creating 28.7 million jobs. However, this economic activity also contributed to environmental concerns, leading to the emission of 464 million tons of CO₂e.

Table 5 provides insights into the macroeconomic and environmental implications of exporting six CBAM products to the EU27 market in 2018. Through input-output analysis, it is determined that the impact of CBAM on both the sectors and the broader economy will be minimal. However, the

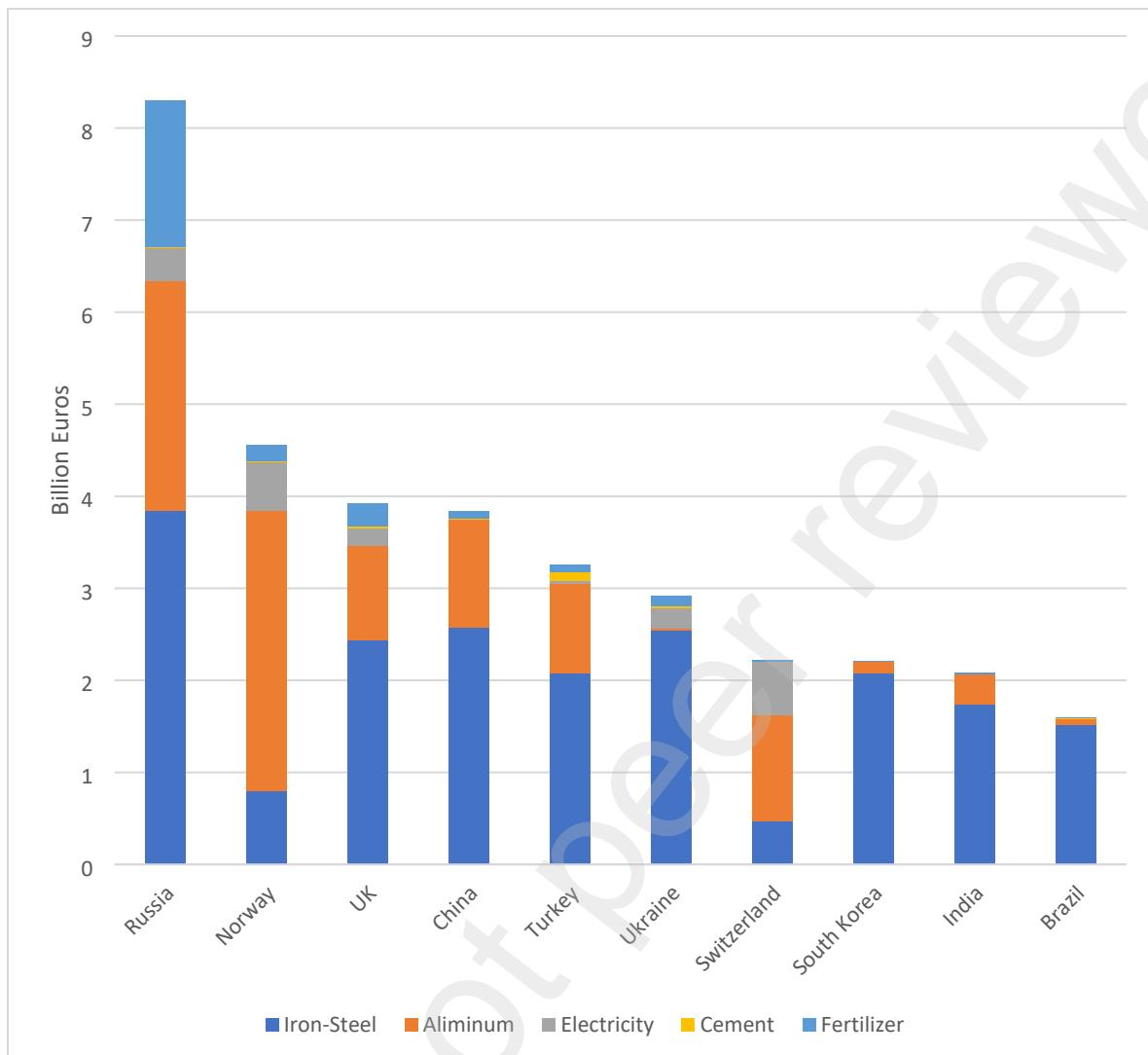
sector most susceptible to the effects of CBAM, based on its significant share in CBAM-product exports, is C24: Basic Metals.

Specifically, the export of €4.5 billion worth of basic metal products to the EU27 market in 2018 generated 94.3 thousand jobs throughout the economy, accounting for 0.33% of total employment. Simultaneously, this level of basic metal exports resulted in the emission of 3.33 million tons of CO₂e across the economy, representing 0.72% of total emissions in 2018.

4.3. How CBAM Will Affect Competitiveness in the EU27 Market

The impact of CBAM extends beyond Turkish products and affects the products of other countries engaged in trade with the EU27. Figure 3 shows that Türkiye ranks as the fifth-largest exporter of the six CBAM products, following Russia, Norway, the UK, and China.

From 2015 to 2020, the average export volume of these six products to the EU27 market amounted to €34.9 billion. Among these exports, iron and steel (€20 billion) and aluminum (€10.4 billion) are the primary products. Of all the exporting nations, Russia appears to be the most vulnerable to the effects of CBAM, as it exports over €8 billion worth of the six CBAM products to the EU27 market.



Source: Eurostat (2022b)

Figure 3. Top 10 Exporters of 6 CBAM products in the EU27 Market (Billion Euros, 2015-2020 Averages)

Figure 3 highlights that the impact of CBAM will primarily affect Türkiye's iron and steel exports, valued at €2.1 billion, and aluminum exports, valued at €1 billion.

Once CBAM is implemented, countries' shares in the EU27 market will shift depending on their relative emission intensities. Due to the lack of data for most competitor countries in Eurostat, this section employs OECDStat's definition of emission intensity, "TeCO₂: CO₂ emissions embodied in trade," which measures intensity as "tons of CO₂ embodied per million USD of exports"

(OECD, 2021). While export data is available at the 4-digit NACE level, emission intensities are only available at the 2-digit NACE level.

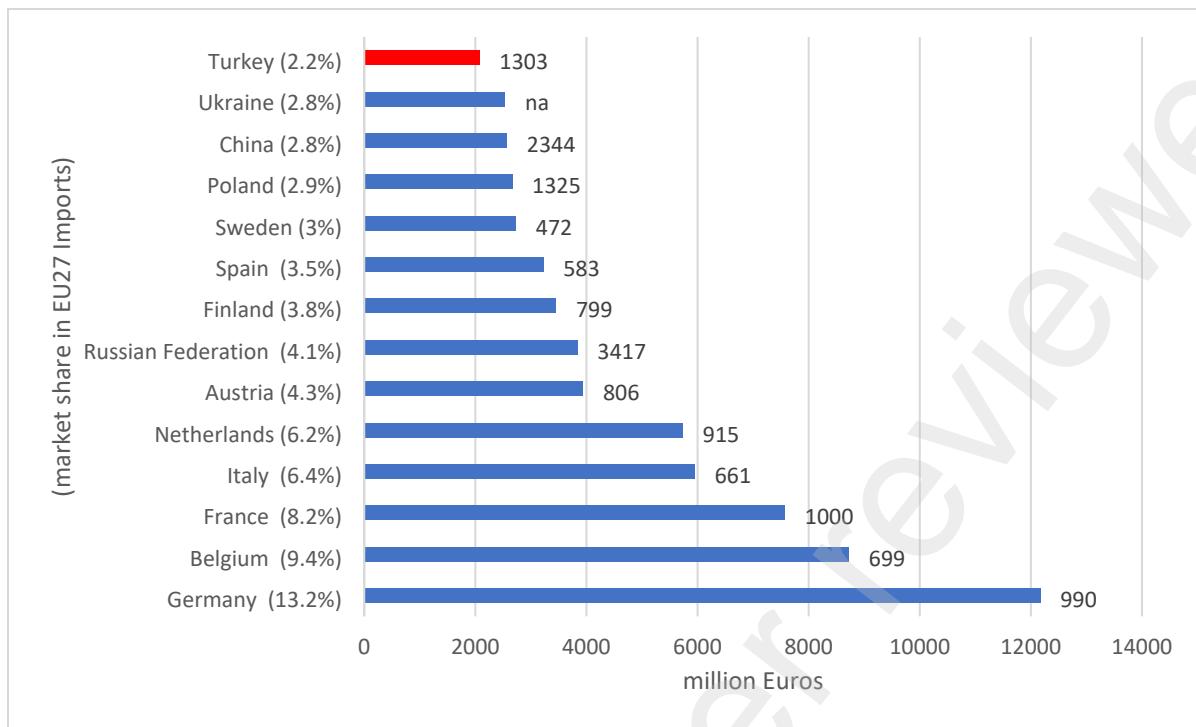
Figures 4-9 depict the average export volumes of countries between 2015 and 2020, shown on the horizontal axis in million euros, along with their share of total imports in the EU27 market (indicated in parentheses as EU27 market share). The values next to the bars represent the emission intensities, which are also available only at the 2-digit NACE level.

Iron and Steel (C24.10)

During the period from 2015 to 2020, the EU27 imported iron and steel valued at €92.4 billion annually. Of these imports, 72% originated from intra-EU27 trade, while the remaining 28% was sourced from non-EU27 countries (extra-EU27). Figure 6 shows that Türkiye, on average, exported iron and steel worth €2.1 billion to the EU27 market, securing a 2.2% market share. This places Türkiye behind Russia (4.1%), China (2.8%), and Ukraine (2.8%) in terms of market share. However, with the implementation of CBAM, market shares are expected to shift based on the relative sectoral emission intensities of countries.

Compared to non-EU competitors like China and Russia, Turkish basic metal products in the C24 category demonstrate lower emission intensity, with 1,030 tons of CO₂ per million USD of exports, compared to China's 2,344 tons. This disparity in emission intensities can be attributed to factors such as product mix at the 2-digit NACE level, fuel types, and production technologies (such as electric arc furnace [EAF] carbon steel versus basic oxygen furnace [BOF] steel). The lower emission intensity of Türkiye's basic metal sector is due to the prevalence of less carbon-intensive EAF processing, whereas Russia, Ukraine, and China primarily rely on high-emission-intensive integrated facilities (He and Wang, 2017).

Since all EU27 countries generally exhibit lower emission intensities, the implementation of CBAM is anticipated to boost intra-EU27 iron and steel trade.



Source: Eurostat (2022b) and OECDStat (2021)

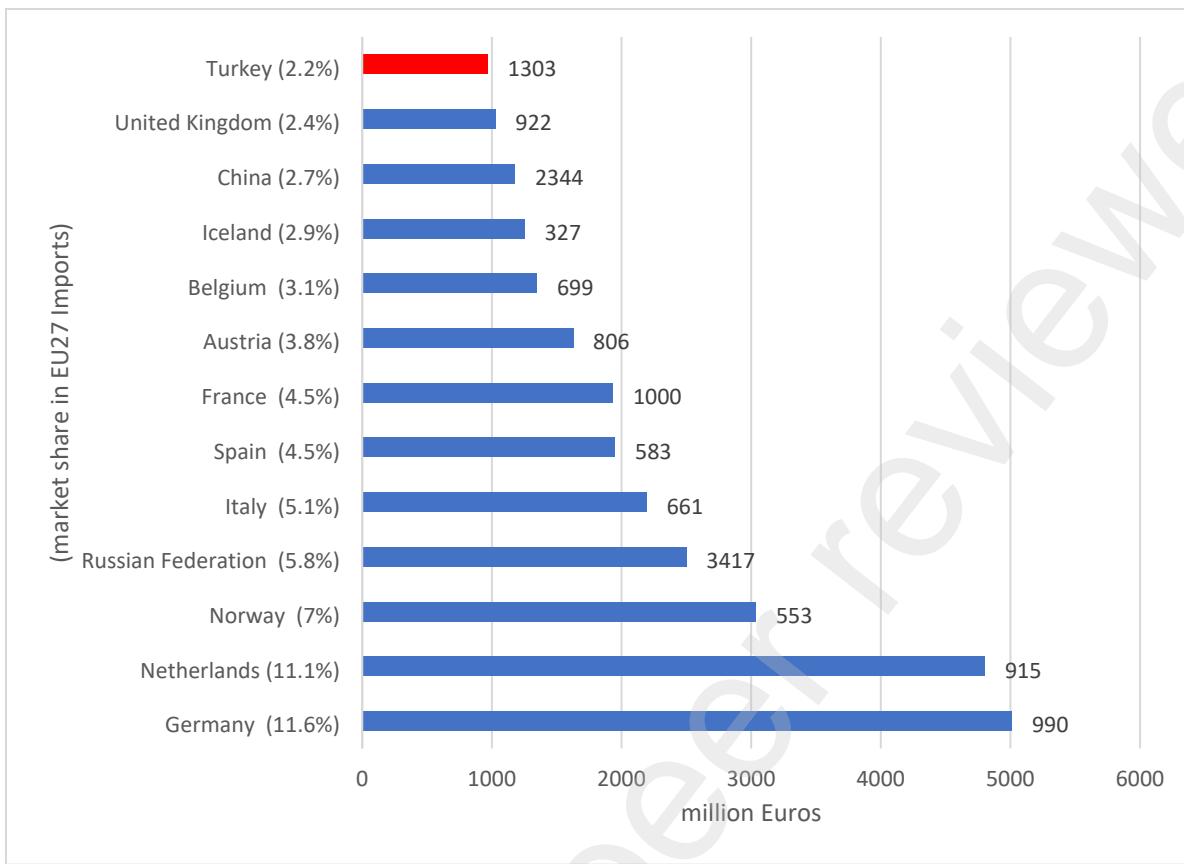
Figure 4. Iron-Steel Trade in the EU27 Market and CO2 intensity of C24: Basic Metal products

Aluminum (C24.42)

From 2015 to 2020, the EU27 imported an average of €43.3 billion worth of aluminum annually, with 61% coming from intra-EU27 trade and 39% from non-EU27 countries (extra-EU27). Figure 5 shows that Türkiye, on average, exported €1 billion worth of aluminum to the EU27 market, representing a 2.2% market share. This places Türkiye behind Russia (5.8%), China (2.7%), and the United Kingdom (2.4%) in terms of market share.

Compared to non-EU competitors such as China and Russia, Turkish aluminum products exhibit lower emission intensities, measured at 1,303 tons of CO2 per million USD of exports, compared to Russia's 3,417 tons of CO2 per million USD of exports.

Since all EU27 countries, as well as Norway and Iceland, which are part of the EU Emissions Trading System (ETS), have relatively lower emission intensities, the implementation of CBAM is expected to promote increased trade within the EU-EFTA (European Free Trade Association) region.



Source: Eurostat (2022b) and OECDStat (2021)

Figure 5. Aluminum Trade in the EU27 Market and CO2 intensity of C24: Basic Metal products

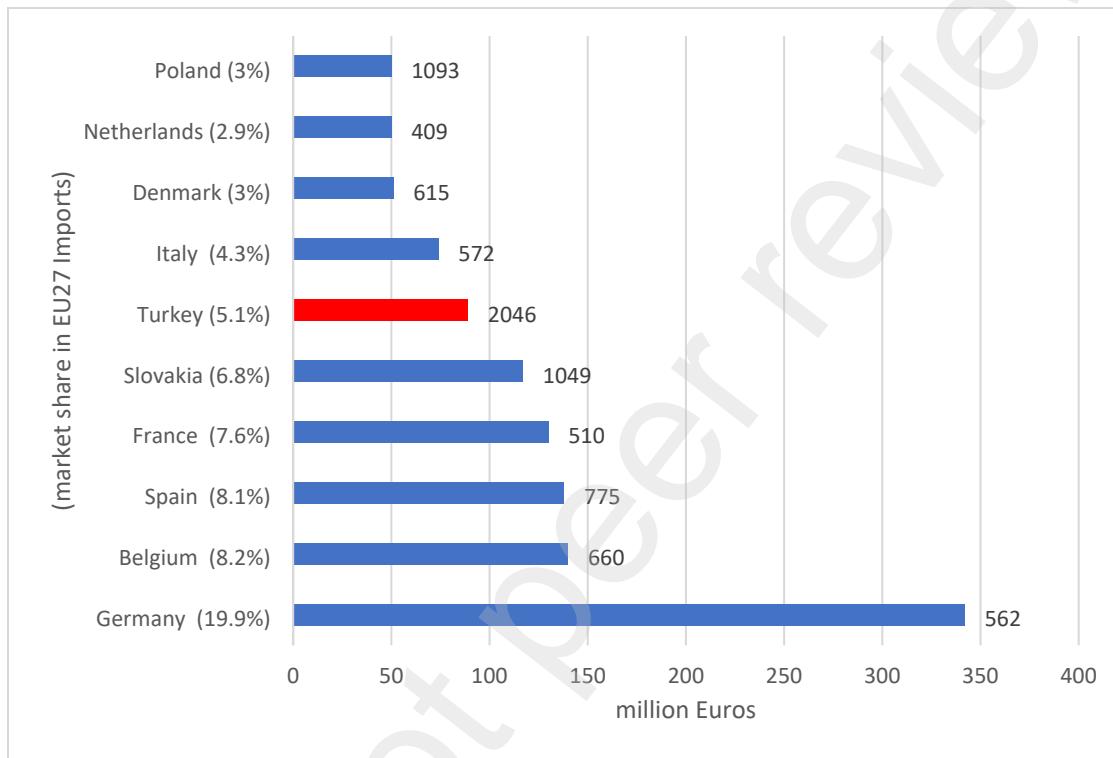
Cement (C23.51)

Between 2015 and 2020, the EU27 imported an average of €1.7 billion worth of cement annually, with 85% of these imports coming from intra-EU27 trade and 15% from non-EU27 countries (extra-EU27). Figure 6 shows that Türkiye, on average, exported €90 million worth of cement to the EU27 market, capturing a 5.1% market share. This places Türkiye behind Germany (19.9%), Belgium (8.2%), Spain (8.1%), France (7.6%), and Slovakia (6.8%) in terms of market share.

Compared to EU27 competitors, Turkish C23: Non-metallic mineral products, specifically cement, exhibit significantly higher emission intensity. For example, Turkish cement has an emission intensity of 2,046 tons of CO2 per million USD of exports, whereas Slovakia's emission intensity is 1,049 tons of CO2 per million USD of exports. These variations in emission intensity can be attributed to several factors, including the product mix at the 2-digit NACE level (which includes

cement, glass, and ceramics, each with different emission intensities) and the types of fuel used in production. Notably, all EU27 countries have relatively lower emission intensities.

As a result, the implementation of CBAM is expected to encourage increased intra-EU27 cement trade, given the relatively lower emission intensities of all EU27 countries.



Source: Eurostat (2022b) and OECDStat (2021)

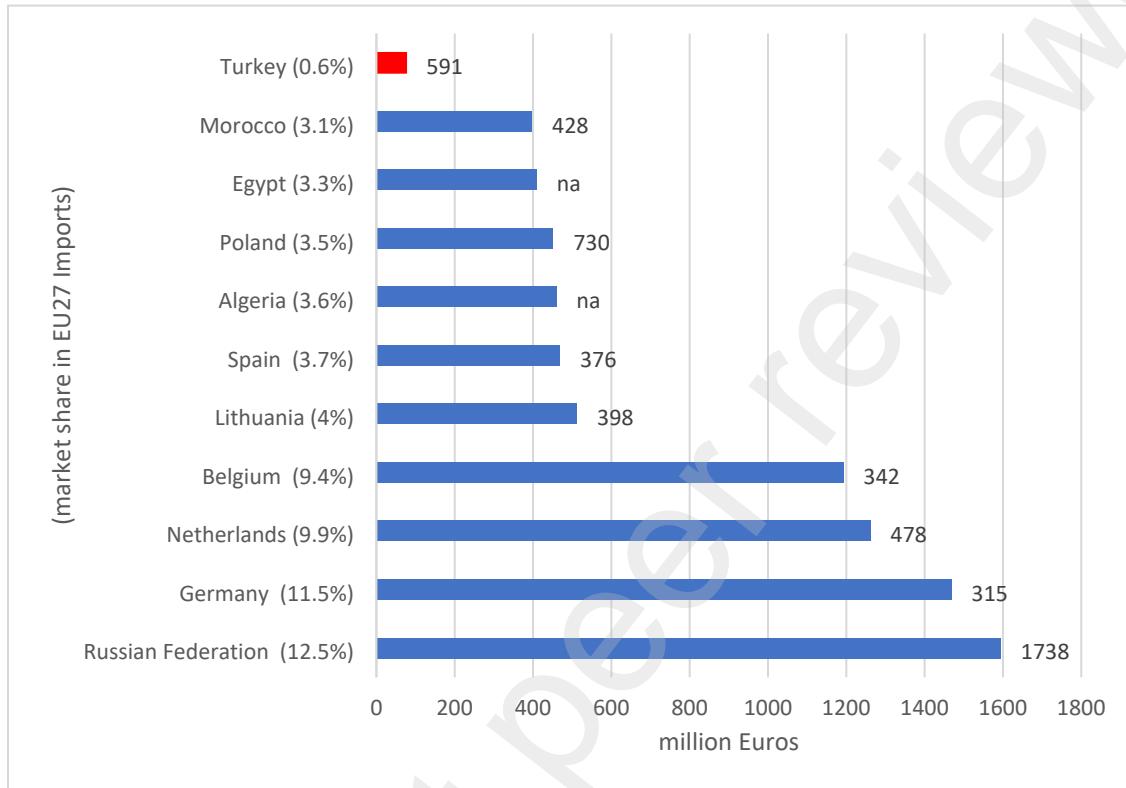
Figure 6. Cement Trade in the EU27 Market and CO₂ intensity of C23: Non-metallic Mineral products

Fertilizer (C20.15)

Between 2015 and 2020, the EU27 imported an average of €12.8 billion worth of fertilizer annually, with 59% of these imports coming from intra-EU27 trade and 41% from non-EU27 countries (extra-EU27). Figure 7 shows that Türkiye, on average, exported €77 million worth of fertilizer to the EU27 market, representing a modest market share of 0.6%.

Compared to non-EU competitors such as Russia, Turkish C20: Chemical Products have a lower emission intensity. Specifically, Turkish fertilizer has an emission intensity of 591 tons of CO₂ per million USD of exports, whereas Russia's emission intensity is significantly higher, at 1,738 tons of CO₂ per million USD of exports.

Given that all EU27 countries exhibit relatively lower emission intensities, the implementation of CBAM is expected to promote an increase in intra-EU trade.



Source: Eurostat (2022b) and OECDStat (2021)

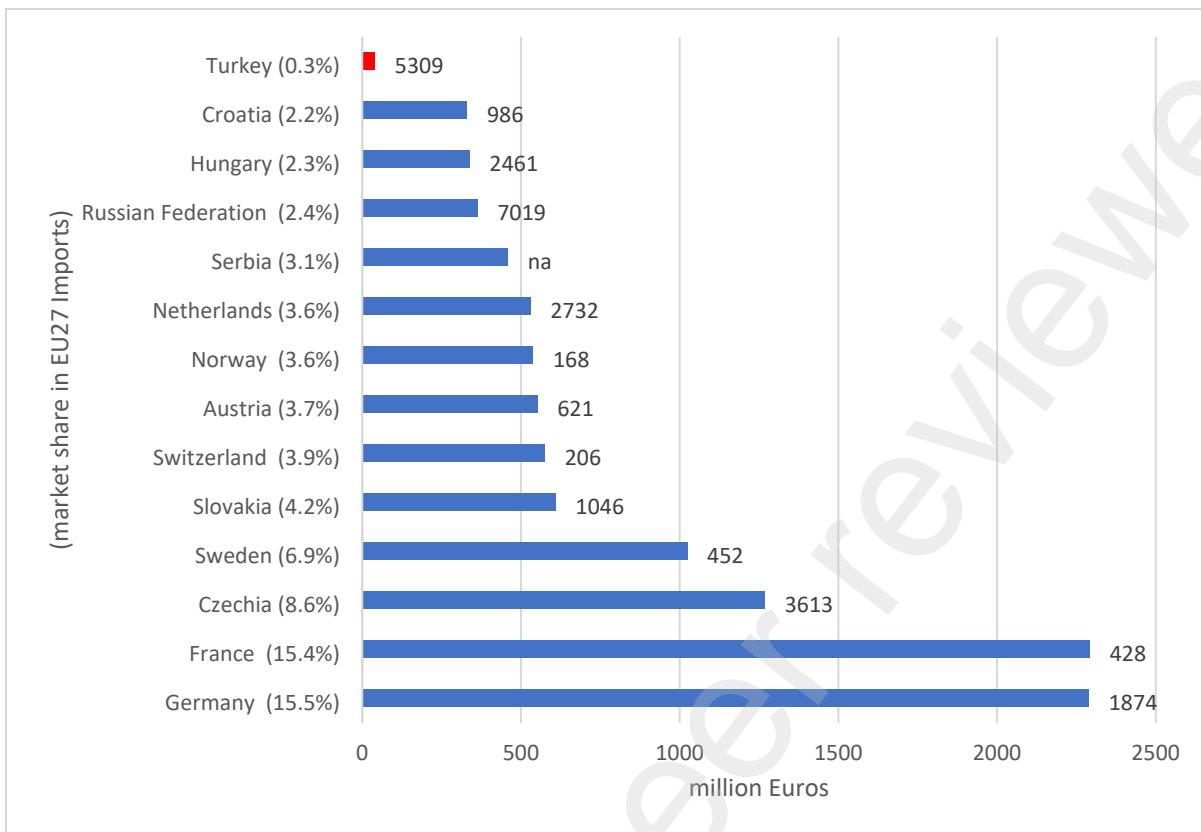
Figure 7. Fertilizer Trade in the EU27 Market and CO2 intensity of C20: Chemical Products

Electricity (D35.11)

Between 2015 and 2020, the EU27 imported an average of €14.8 billion worth of electricity annually, with 81% sourced from intra-EU27 trade and 19% from non-EU27 countries (extra-EU27). Figure 8 indicates that Türkiye, on average, exported €40 million worth of electricity to the EU27 market, representing a modest market share of 0.3%.

Compared to non-EU competitors like Russia, Turkish D35: Electricity, Gas, and Steam products have a lower emission intensity. Specifically, Turkish electricity shows an emission intensity of 5,309 tons of CO2 per million USD of exports, while Russia's emission intensity is higher at 7,019 tons of CO2 per million USD of exports.

Given that all EU27 countries display relatively lower emission intensities, the implementation of CBAM is expected to encourage increased intra-EU trade.

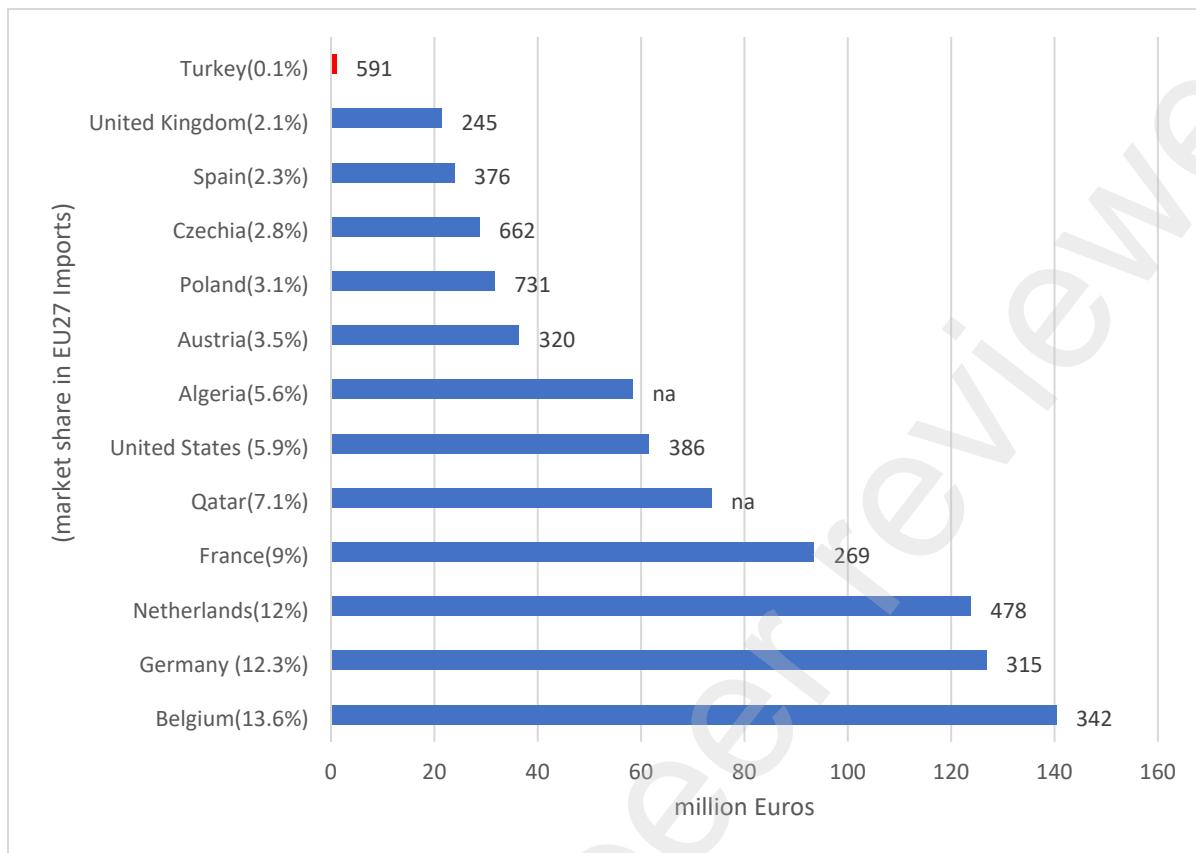


Source: Eurostat (2022b) and OECDStat (2021)

Figure 8. Electricity Trade in the EU27 Market and CO2 intensity of D35: Electricity, Gas, Steam

Hydrogen (C20.11)

Between 2015 and 2020, the EU27 imported an average of 1.03 billion euros' worth of industrial gases, including hydrogen, annually. Of this total, 68% originated from intra-EU27 trade, while the remaining 32% came from non-EU27 countries (extra-EU27). Figure 9 indicates that Türkiye, on average, exported only 1 million euros' worth of industrial gases to the EU27 market, representing an almost negligible market share.



Source: Eurostat (2022b) and OECDStat (2021)

Figure 9. Hydrogen Trade in the EU27 Market and CO2 intensity of C20: Chemical Products

When compared to non-EU competitors like United States, Turkish C20: Chemical products have a higher emission intensity, i.e. 591 vs. USA's 386 ton CO2 per million USD exports.

As all EU27 countries (except Poland and Czechia) have relatively lower emission intensities, CBAM can be expected to increase intra-EU trade.

5. Concluding Remarks

The European Green Deal (EGD) represents the European Union's comprehensive strategy to transition toward a sustainable, climate-neutral economy by 2050, with an interim target of reducing greenhouse gas (GHG) emissions by 55% by 2030 compared to 1990 levels. This transformation is driven by green innovation, including renewable energy adoption, energy-efficient technologies, and circular economy practices. As the EU decarbonizes key sectors such as energy, transport, and industry, the EGD is expected to spur significant investments in research

and innovation, positioning green technologies as essential tools in combating climate change while promoting sustainable economic growth.

The EGD's influence extends beyond the EU, encouraging other nations—particularly major trade partners—to align their climate policies with its ambitious standards. By setting a global benchmark through policies like carbon pricing and renewable energy adoption, the EU exerts pressure on both developed and developing nations to enhance their climate commitments. However, the transition poses challenges for fossil fuel-dependent economies, which may face trade disruptions unless they accelerate their own green transitions. The EU's climate diplomacy, particularly through frameworks like the Paris Agreement, further amplifies this global ripple effect, fostering international collaboration while ensuring competitive parity in green markets.

A cornerstone of the EGD is the Carbon Border Adjustment Mechanism (CBAM), designed to prevent carbon leakage by ensuring that imports into the EU face equivalent carbon costs as domestic production. Starting in October 2023, importers must report embedded emissions (Scope 1 and 2) for covered sectors such as cement and fertilizers, with financial obligations beginning in 2026. For countries like Türkiye, which export CBAM-covered goods to the EU, this necessitates urgent action to decouple economic growth from emissions and align with EU decarbonization benchmarks to maintain market access.

This study conducts a detailed analysis of emission intensities across Türkiye's manufacturing and other high-emission sectors, evaluating CBAM's potential impacts on trade, GDP, and employment. The findings reveal that while some sectors—such as paper, basic metals, and chemicals—perform favorably compared to the EU average, others, like electricity and mining, exhibit weak decoupling and higher emission intensities, increasing their vulnerability to CBAM. Notably, 12 manufacturing and construction sectors demonstrate strong decoupling but contribute minimally to national emissions, whereas weakly decoupled sectors account for over 40% of Türkiye's GHG emissions. The electricity sector's high emission intensity further exacerbates risks for downstream industries reliant on its output.

The economic implications of CBAM for Türkiye are nuanced. While the EU27 is a critical export market for CBAM-covered goods, these products represent a small fraction of Türkiye's total exports, suggesting limited short-term GDP and employment impacts. However, as CBAM expands to include additional sectors and phases out free allowances, the risks could escalate.

Proactive measures, such as adopting low-carbon technologies and accelerating renewable energy deployment, will be essential to mitigate these challenges.

Policy recommendations emphasize the need for Türkiye to implement robust carbon pricing mechanisms, including its planned Emissions Trading System (ETS), while ensuring alignment with international standards like the EU ETS. A hybrid carbon pricing approach—combining ETS with carbon taxes—could provide flexibility, with revenues reinvested in green subsidies and workforce retraining. Strengthening the European Green Deal Action Plan (EGDAP) with clear fossil fuel phase-out timelines and equitable transition measures is equally critical.

In conclusion, the EGD and CBAM underscore the imperative for Türkiye to balance industrial competitiveness with decarbonization. By leveraging green innovation, enhancing policy frameworks, and fostering international cooperation, Türkiye can navigate the challenges posed by CBAM while securing its position in a rapidly evolving global low-carbon economy. The study highlights the urgency of action, as delays risk exacerbating trade vulnerabilities and missing opportunities for sustainable growth in alignment with the EU's climate ambitions.

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Appendix

Table A.1 Input-Output Model Sectors

Sectors	NACE Codes
AG: Agriculture	A01 - A03
MI: Mining	B05, B06 - B09
FO: Food	C10 - C12
TE: Textiles	C13 - C15
OE: Other Economy	C16, C30 -C33, E36 - E39, G45, G46, N80 - N82, O84
PA: Paper	C17, C18
PE: Petroleum Prod.	C19
CH: Chemicals	C20 - C22
CE: Cement	C23
IS: Iron-Steel-Aluminum	C24
MW: Machinery	C25 - C28
AU: Automotive	C29
EL: Electricity	D35
CN: Construction	F41 - F43
RT: Retail trade	G47
TR: Transportation	H49, H50
AT: Air Transport	H51, H52
PS: Postal and Courier Serv.	H53
AF: Accommodation and Food	I55, I56
PR: Professional Serv.	J58 - J63, M71 - M75, N77 - N78, S94 - S96
FS: Financial and Real Estate Serv.	K64 - K66, L68, M69-M70
TS: Tourism	N79, R90 - R93,
ES: Education Serv.	P85
HE: Health Serv.	Q86 - Q88

Table A.2. The Evolution of the GHGs Intensities of the Turkish Sectors (tons of CO2e per million 2005 Euros gross value added)

	20 03	20 04	20 05	20 06	20 07	20 08	20 09	20 10	20 11	20 12	20 13	20 14	20 15	20 16	20 17	20 18	20 19
TOTAL:Total - all NACE activities	86 8	80 8	79 8	80 1	83 4	81 9	86 0	81 8	78 7	78 1	71 4	71 3	73 4	74 9	71 8	69 7	66 2
A:Agriculture, forestry and fishing	15 16	14 96	14 19	14 55	15 68	15 21	14 72	14 17	14 83	12 74	13 00	13 17	13 34	14 25	14 54	14 69	14 88
B:Mining and quarrying	14 14	13 05	13 01	13 85	17 10	15 56	17 14	16 58	15 68	16 19	14 33	17 18	17 6	77 53	81 7	96 2	11 88

C:Manufacturing	16 17	14 55	13 62	13 48	12 98	11 16	12 12	12 67	11 27	12 18	10 97	10 44	10 33	10 45	97 7	96 9	89 6	
C10-C12: Food, beverages, tobacco	98 0	82 4	68 4	77 9	71 0	43 9	34 1	37 6	48 0	48 9	45 5	38 7	43 3	44 2	43 9	49 2	43 5	
C13-C15: Textiles, apparel, leather	71 1	57 8	56 4	67 5	78 3	43 9	49 5	42 4	24 8	29 4	20 8	17 8	16 1	15 7	15 2	15 3	14 8	
C16: Wood and of products of wood and cork	17 94	12 80	75 4	10 64	83 2	55 6	60 4	48 9	31 6	31 6	24 6	25 5	25 1	24 0	24 7	24 9	27 5	
C17:Paper and paper products	61 3	43 8	33 8	36 5	39 4	25 1	22 0	19 7	47 7	45 2	44 3	40 1	41 1	46 6	34 1	30 7	31 7	
C18:Printing and reproduction of recorded media	10 80	89 2	52 8	84 5	89 2	45 3	46 9	42 9	30 1	34 1	28 5	25 8	25 0	27 5	27 6	32 3	31 9	
C19:Coke and refined petroleum products	36 51	31 96	14 99	28 07	21 27	24 51	30 98	28 47	23 41	31 55	34 72	47 22	24 80	32 20	23 59	21 53	61 87	
C20:Chemicals and chemical products	16 88	23 15	22 25	18 60	10 23	61 6	11 31	11 88	11 56	15 17	12 42	11 61	15 42	13 11	98 9	12 28	10 74	
C21:Basic pharmaceutical products and pharmaceutical preparations	23 9	22 3	26 5	29 7	28 3	15 8	15 2	13 6	13 9	15 3	15 7	11 9	11 7	10 9	96 96	11 0	78 78	
C22:Rubber and plastic products	77 4	56 1	50 4	53 9	61 1	29 1	30 5	28 2	16 8	19 5	16 1	13 7	12 1	11 3	10 7	11 0	10 7	
C23: Non-metallic mineral products	94 72	80 67	69 13	59 75	57 14	77 28	84 19	85 95	85 57	87 88	78 74	76 08	74 57	81 21	87 20	92 37	83 98	
C24:Basic metals	35 96	25 49	32 30	20 24	21 83	13 57	27 66	23 18	16 89	24 84	18 97	18 88	19 06	17 22	13 40	12 48	18 08	
C25:Fabricated metal products, except machinery and equipment	15 01	10 01	71 9	82 0	85 2	44 4	46 5	40 4	24 8	27 5	20 9	18 8	17 7	17 1	16 7	16 7	16 1	
C26:Computer, electronic and optical products	32 5	26 2	23 5	25 5	41 2	16 6	16 1	16 2	99 99	11 2	87 87	70 70	58 55	55 54	41 41	39 39		
C27:Electrical equipment	61 4	40 6	33 2	33 7	36 1	17 8	20 1	21 0	13 0	16 2	11 8	10 9	10 0	98 98	97 97	99 97		
C28:Machinery and equipment n.e.c.	81 5	59 7	46 0	50 3	50 7	28 6	31 6	26 3	15 5	18 2	16 9	13 3	11 9	12 1	11 1	11 4	82 0	
C29:Motor vehicles, trailers and semi-trailers	51 4	39 0	41 1	49 8	52 1	43 2	60 2	68 9	57 4	72 5	69 4	69 9	63 6	63 5	55 2	53 1	61 61	
C30:Other transport equipment	99 9	68 6	52 2	65 9	58 6	19 6	24 8	25 1	15 4	18 6	14 8	10 4	90 90	79 79	73 73	62 62	48 48	
C31_C32:Furniture; other manufacturing	50 3	47 3	46 9	47 5	42 4	11 0	10 7		10 99	12 92	10 2	10 4	10 3	10 2	10 7	11 4	10 7	
C33:Repair and installation of machinery and equipment	11 3	12 6				12 0			10 87	12 90	10 79	12 3	10 9	10 8	91 91	99 99	6 6	94 92
D:Electricity, gas, steam and air conditioning supply	18 00	17 62	19 17	19 32	21 95	22 61	25 05	19 63	22 37	20 20	17 89	17 78	17 79	17 01	16 58	16 58	13 76	
E:Water supply; sewerage, waste management and remediation activities	70 43	64 28	60 71	58 13	58 93	55 97	58 34	54 09	46 69	39 07	33 75	31 89	32 14	31 24	27 93	28 82	27 10	
F:Construction	59 1	40 8	34 5	34 4	35 7	22 5	28 4	23 3	14 4	17 1	15 7	12 5	11 6	11 7	11 1	11 0	11 8	
G:Wholesale and retail trade; repair of motor vehicles and motorcycles						12 8	14 3	12 5	11 3	14 8	17 2	15 5	18 8	19 2	17 6	16 1	15 6	
H:Transportation and storage	41 2	45 7	40 8	41 5	45 6	48 8	55 0	48 6	48 7	52 0	40 1	53 3	52 6	56 1	52 6	48 5	47 3	