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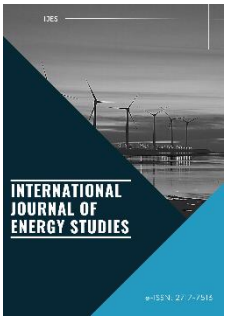

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Potential effects of the carbon border adjustment mechanism on trade between Germany and Türkiyeϕ

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Highlights

- The Carbon Border Adjustment Mechanism (CBAM) is an example of green trade policy and serves as a carbon taxation instrument.
- The CBAM covers the aluminum, cement, electricity, fertilizers, hydrogen as well as iron and steel sectors.
- The findings show that in Turkish export trade to Germany the iron and steel sector is set to be most affected by the CBAM application.
- Due to cost effects a loss of price competitiveness and a decline in trade volume from the perspective of Turkish exporters may occur.
- Product prices for German importers may rise and supply chain risks grow due to lower availability of competitive products and suppliers from Türkiye.

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ABSTRACT

Turkish-German economic relations have been continuously improving. Germany is one of Türkiye's leading export destinations and partners in trade. Recently implemented environmental trade policies, such as the CBAM, can affect their trade development mutually. The CBAM is a great example of green trade policy and serves as a carbon taxation instrument linking the emission footprint of goods imported to the European Union to an emission cost, potentially putting strain on trade ties. The CBAM encompasses the aluminum, cement, electricity, fertilizers, hydrogen as well as iron and steel sectors. This study focuses on the CBAM's potential economic effects on trade relations between both countries, in particular cost effects on Turkish exports to Germany in the iron and steel and aluminum sectors since these two sectors represent a significant economic value in bilateral trade among the CBAM-relevant sectors. The total additional cost on a four-digit Combined Nomenclature (CN) code basis is calculated for the iron and steel and aluminum sectors annually between 2019 and 2024. Furthermore, the relative shares of additional cost in relation to Turkish export trade volumes to Germany on a sectoral basis is examined. According to the findings, the sector to be most affected by the CBAM is the iron and steel sector. On the basis of two individual scenarios each regarding the CN code-based emission intensity data and the carbon pricing levels as well as export trade flows, the potential costs are calculated The cost effects can cause a loss of price competitiveness and a decline in trade volume from the perspective of Turkish exporters. German importers may face increased product prices as well as supply chain risks due to lower availability of competitive products and suppliers from Türkiye. These risks demand policy measures to protect and facilitate trade relations between the two countries.

Keywords: International trade, CBAM, Green trade, Carbon taxation, Emissions trading system

1. INTRODUCTION

The ties between the two countries are forged through the different dimensions of society, politics, and economy (Bedir et al., 2022). The relations historically started back in the 11th century (Konukman, 2023). It is estimated that about three million people with Turkish roots live in Germany (Federal Foreign Office, 2024; Republic of Türkiye Ministry of Foreign Affairs, 2023). The Customs Union forms the base for the connection between Türkiye and the European Union (EU) economically, in particular regarding the exchange of goods (Selçuki & Tulan, 2021). Over the past 30 years Turkish-German trade relations have been expanding. Germany is one of the most important trade partners of Türkiye. In 2024 according to Turkish export trade volumes Germany was the country's leading export destination with a volume of about 18,4 billion USD (TURKSTAT, 2025b). Germany's export trade with Türkiye made up for the third largest share in Türkiye's total import volume, along with an amount of 25,1 billion USD according to data from the general trade system .

In the context of climate action, the goal of the EU is to support the protection of climate by implementing the European Green Deal (Şahin et al., 2021). The European Green Deal aims to achieve net zero emissions in the EU by mid-century, to support the protection of the climate and to separate the expansion of the economy from the consumption of resources as well as to define the course for a sustainable transformation (European Council - Council of the European Union, 2024; Fetting, 2020; Şahin et al., 2021). Furthermore, the policy package aims to encourage the actions necessary to create a net zero emissions and more sustainable surroundings while endorsing fair and competitive conditions along with the climate neutrality goal by 2050 (Şahin et al., 2021). Beyond the transition internally in the EU the European Green Deal intends to lower the carbon footprint and hinder the migration of greenhouse gas emissions to third countries by moving their manufacturing facilities accordingly, the so-called "*carbon leakage*", in the global context (Long et al., 2023; European Commission - Directorate-General for Taxation and Customs Union, 2024).

A related tool from the policy package is the CBAM, a component of the so-called "*Fit-for-55*" bundle (Dröge, 2021). It connects the generated carbon footprint from manufacturing processes of EU import goods which are elevated emitters to a corresponding emissions cost (European Commission - Directorate-General for Taxation and Customs Union, 2024). Simultaneously, the CBAM is supposed to encourage the transformation of the manufacturing sector to become greener

in foreign countries. CO_2 taxation is substantially grounded on the conceptual framework established by Arthur Cecil Pigou (Kawecka-Wyrzykowska, 2024; Pigou, 1920).

In terms of the environment, sectors that produce the most carbon emissions have been prioritized and the CBAM encompasses first off, the following high-emitting industries: aluminum, cement, electricity, fertilizers, hydrogen as well as iron and steel (Council of the European Union, 2022; European Union, 2024; German Chamber of Commerce and Industry (DIHK), 2024; European Union EUR-Lex, 2023a). Scholar notes that the ties between Türkiye, European countries and the EU may be endangered in the context of this instrument and underlines the necessity of its assessment (Şahin et al., 2021). Furthermore, the CBAM's impact from an expense perspective may lead to implication regarding the total export trading activity from Türkiye to the European market (Long et al., 2023). Considering that more than 40 percent of Türkiye's exports are to European Union countries, it is clear that the effects of these new practices will be significant for the Turkish economy.

Both Germany and Türkiye have established climate policies and decarbonization strategies nationally. In Türkiye, the Paris Agreement was ratified and issued with the *Official Gazette 31621* on October 7th, 2021. Türkiye declared its objective for climate neutrality until 2053 in September 2021 commencing the local transformation process (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2021). The country's goal is to proceed along the course of sustainable economic growth by means of taking into account national strategic development pathways as well as progress abroad (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2023). Germany and the EU signed the Paris Agreement on April 22, 2016, and ratified it on October 5 the same year (*Paris Agreement, 2016, CHAPTER XXVII, 7.d.*). According to the climate protection legislation *Bundes-Klimaschutzgesetz* by the Federal German Government, Germany must achieve net zero by 2045 (Federal Government, 2022).

The research focuses on the potential economic effects against the backdrop of trade relations between Germany and Türkiye is conducted, in particular cost effects of the CBAM regulation on Turkish export trade to Germany for the iron and steel as well as aluminum sectors are assessed. The total additional cost on a four-digit CN code basis is calculated for the iron and steel as well as aluminum sectors annually for the period 2019 to 2024. Furthermore, the relative shares of the additional cost in relation to the overall Turkish export trade volume to Germany is examined. The research results are intended to enable the private and public sector to identify individual risks and develop as well as carry out corresponding risk management measures.

The findings clearly show that Turkish-German trade relations will be affected by the CBAM regulation. Critical in this context is the increase in costs for exported goods in the aluminum and iron and steel sectors. In particular, the iron and steel sector will relatively be most impacted in comparison to the aluminum sector. The cost effect may lead to a detriment of price competitiveness for Turkish exporters and a recede in exports volume. On the other hand, German importers may face increased product prices as well as supply chain risks due to lower availability of competitive products and suppliers from Türkiye. These potential risks need policy measures to protect and further facilitate trade relations between two countries that have had long-standing economic relations.

2. ENVIRONMENTAL POLICIES: GREEN TRADE, DECARBONIZATION AND THE CARBON BORDER ADJUSTMENT MECHANISM

2.1. The European Green Deal

The European Green Deal represents the expansion plan of the EU which was initiated in 2019 (European Council - Council of the European Union, 2025). It consists of a set of policy measures designed to guide the EU through the green transitioning process, with the underlying aim of accomplishing carbon neutrality by 2050. The European Green Deal aims to achieve net zero emissions in the EU by mid-century, to support the protection of the climate and to separate the expansion of the economy from the consumption of resources as well as to define the course for sustainable transformation (European Council - Council of the European Union, 2024; Fetting, 2020; Şahin et al., 2021). The Green Deal represents a comprehensive and multidimensional policy touching up the environmental, economic, as well as social dimensions (Hajdys, 2024). Several legislative measures under the Green Deal have been implemented, such as the Fit for 55 bundle, which encompasses several instructions and laws touching upon the energy transition and advancing toward net zero. Also, the CBAM is part of the so-called Fit for 55 bundle (European Parliament, 2022). The Green Deal is centered around the agenda that greenhouse gases should be lowered by at least 55 percent by 2030 as well as accomplishing the net-zero target in 2050 (Guzal-Dec, 2022).

Fetting (2020) stresses that the European Green Deal does not represent legislation instead it is a broad strategic plan sketching the aims and objectives across various domains. Furthermore, the policy package aims to encourage the actions necessary to create net zero emissions and more sustainable surrounding endorsing fair and competitive conditions alongside the climate neutrality

goal by 2050 (Şahin et al., 2021). As part of the Green Deal's execution current legislation and criteria is modified and updated framework conditions are established (Fetting, 2020). To ultimately reach net zero by 2050 the plan touches upon the following areas: Carbon reduction in the energy domain, assistance of the industrial sector to emerge as frontrunners as part of the sustainable transformation, improving building structures to increase energy efficiency and establishing more affordable, conscious, and sustainable modes for individual and community transportation (European Commission, 2019). The European Green Deal's initiatives form the groundwork to foster the transition leading to the reorganization of the continent's market (Kalaycı and Artekin, 2024).

2.2. The EU Emission Trading System

With the Directive 2003/87/EC the EU introduces a scheme for the exchange of "greenhouse gas emission allowance", the so-called EU Emissions Trading System (ETS) with the goal to facilitate the abatement of polluting emissions "in a cost-effective and economically efficient manner" (European Union EUR-Lex, 2003). Following its adoption in the year 2003, the EU ETS was introduced in the year 2005, functioning on separate market windows and currently experiencing stage four which spans from 2021 to 2030 (European Commission - Directorate-General for Climate Action, 2024c; 2024d). In accordance with the EU's environmental objectives the trading scheme for greenhouse gases has been subject to multiple amendments throughout time. The scheme's scope of validity covers the sum of EU member countries, states of the European Free Trade Association which encompass Lichtenstein, Norway as well as Ireland and, beyond that, in the context of power production the nation Northern Ireland (European Commission - Directorate-General for Climate Action, 2024b). The EU ETS was internationally the earliest one of its kind and remains in the midst of the biggest emissions trading schemes existing around the world today. Following the implementation of the EU ETS it quickly became popular with legislators and academics due to the fact that it was the first cross-border cap-and-trade system as well as the most comprehensive ETS, covering aviation, globally (Borghesi et al., 2016).

Through the EU ETS a total exceeding 175 billion EUR in earnings has been collected from 2013 on. Based on data of Sandbag (2024), the current price for a carbon permit, published on 5.02.2025, for one ton of emissions emitted measured in Carbon Dioxide Equivalent (CO_2eq) and traded in futures on the carbon market amounts to 82,08 EUR. According to the development of carbon prices one ton of greenhouse gas emissions between April 2008 and February 2025 its peak was reached in August 2022 at a value of 96,35 EUR per unit.

Together with the amendments to the *Directive 2003/87/EC* laid out in *Directive (EU) 2023/959* in 2023, the EU established an updated EU ETS, the so-called "ETS2" (Emissions Trading System 2), a structure apart from the present greenhouse gas emissions trading scheme (European Commission - Directorate-General for Climate Action, 2024a; European Union EUR-Lex, 2003, 2023b). The latest design is set to include as well as address emitted greenhouse gases in connection with engine burning inside of houses, as part of overland transportation as well as other areas which mostly encompass minor manufacturing businesses the EU ETS currently not considers. From a structural perspective also the ETS2 represents a "cap and trade" regime same as the current EU ETS, despite that it will encompass upstream greenhouse gases. According to the European Commission - Directorate-General for Climate Action (2024a) this means that tracking and disclosing levels of greenhouse gases will be mandatory for parties like the providers of petrol as opposed to the final user, e.g., homes or drivers of automobiles.

2.3. The Carbon Border Adjustment Mechanism

A related tool from the European Green Deal is the CBAM, an essential component of the so-called "*Fit-for-55*" bundle (Dröge, 2021; European Union, 2024; European Parliament, 2022; European Union EUR-Lex, 2023a). In this context, the mechanism represents one of the central instruments by the EU to achieve net-zero-emissions until the year of 2050 aligned with the Paris Agreement (European Union EUR-Lex, 2023a). According to Eicke et al. (2021), the CBAM is at heart of the EU's approach to connect regulatory strategies in the areas of environmental protection and the exchange of goods as part of the EU Green Deal. Furthermore, Hancock and Wollersheim (2021) emphasize that the mechanism goes beyond representing a taxation instrument on exports to the EU but rather holds a purpose in the context of diplomacy. The CBAM with its corresponding requirements is set to be introduced step by step until 2026 in the wake of the gradual elimination of complimentary quotas under the EU ETS (Council of the European Union, 2022; European Commission - Directorate-General for Taxation and Customs Union, 2024; European Union, 2024; Simões, 2024). Moreover, the transition phase of the CBAM commenced on October 1, 2023, with an initial declaration interval until January 31, 2024, for importing parties and is set to continue until December 31, 2025.

In general, CO_2 taxation is substantially grounded on the conceptual framework established by Arthur Cecil Pigou (Kawecka-Wyrzykowska, 2024; Pigou, 1920). The scholar was the one initially introducing the notion which demonstrates that taxation, known as the Pigouvian tax, may

be applied to lower exterior adverse consequences due to actions of bodies. Moreover, the economist proposes applying levy to discourage polluting activities equivalent to the inclined harm (Aristei, 2021; Pigou, 1920). Here, the government body establishes a rate of tax through transferring the expenditure to firms which do not comply with the predefined prerequisites. Moreover, to become effective the levy needs to match the minimal outer expenditures for rectifying the adverse outward effects. Companies must incorporate the expenditure of polluting activities as part of their manufacturing. Hence, the good produced includes the complete manufacturing expenditures when this kind of taxation is applied. According to Kawecka-Wyrzykowska (2024), Grądalski (2002) and Prandecki (2007), the scholar presented the conceptual framework with an obvious differentiation among personal and common expenditure of commercial operations. The CBAM introduces a duty on imports created with the aim of counterbalancing the expenditure of buying carbon permits for manufacturers in the EU in the context of the EU ETS (European Union EUR-Lex, 2023a; Kawecka-Wyrzykowska, 2024).

The Pigouvian approach shows that fixing marketplace collapse concerns changing the volume or price as well as that replacement and the earnings impact play a significant role (Helm, 2005). Moreover, Nesheva-Kiosseva (2023) states that based on the polluting activities of a company measured in particular quantities the Pigouvian taxation is applied. Hereby, the differential harm inclined by the polluting activities linked to the manufacturing output is taken into consideration while the tax is imposed on the originator of adverse outer effects, also called "*negative externalities*". Negative externalities are described as *"the uncompensated impact of one's person or company action or company on the well-being*". These outward impacts as well as public expenses represent issues emerging due to business operations of an organization such as manufacturing or a person's commercial participation in the form of intake resulting in consequences for a third bystander which may be either harmful or advantageous (Cheung, 1978; Nesheva-Kiosseva, 2023). The expenses caused by operations and the level of advantageous outcome in combination decide the operational activities of an organization. These may vary from the public expenditure setting society's sought-after level of operational activity.

The mechanism connects the generated carbon footprint from manufacturing processes of EU import goods which are elevated emitters to a corresponding emissions cost by matching the cost of emissions among locally produced goods and imported ones (European Commission - Directorate-General for Taxation and Customs Union, 2024; European Union, 2024).

Simultaneously, the CBAM is supposed to promote the transformation of the manufacturing sector to become greener in foreign countries. The Council of the European Union (2022) and the European Union (2024) state that the CBAM is complementary to the EU ETS as it enforces comparable guidelines regarding importing activities addressed by the ruleset. The CBAM is set to substitute for components of the current scheme for mirroring the magnitude of EU ETS permits' distribution without charge.

The preliminary plan for the CBAM scheme was first presented by the European Commission during the month of July 2021 (Council of the European Union, 2022). The initiation of the instrument will be conducted bit by bit in a row with the dismissal of released quotas under the EU's ETS to additionally foster the low-carbon transformation of national manufacturing (Long et al., 2023; European Commission - Directorate-General for Taxation and Customs Union, 2024). According to the Council of the European Union (2022), the goals of the CBAM, to impede carbon leakage as well as importing of goods with high amounts of embedded emissions jeopardizing EU climate action regarding the lowering of harmful emissions, are to be achieved while being totally compliant within the framework of guidelines and principles of the multilateral trade systems. Over the course of time, a coefficient, the so-called "*CBAM factor*" will be implemented diminishing the amounts of free permits concerning the manufacturing of the products relevant under the CBAM (European Union EUR-Lex, 2003).

The CBAM encompasses first off throughout the first transition period, the following high-emitting industries: aluminum, cement, electricity, fertilizers, hydrogen as well as iron and steel, also incorporating certain subsequent items such as various kinds of fasteners (Long et al., 2023; European Commission - Directorate-General for Taxation and Customs Union, 2024; European Union, 2024; DIHK, 2024; European Union EUR-Lex, 2023a). Table 1 displays in more detail the wide array of goods covered by the *Regulation 2023/956 Annex I and Annex II* on the basis of their corresponding CN codes in the relevant sectors under the CBAM. Table 1 also includes classification information according to whether industries' emissions are direct or indirect.

Table 1. CN Codes for the Goods Affected by the CBAM

Industries/Goods affected by the CBAM	**CN codes**	**Direct/Indirect emissions are considered only**
Aluminum	7601	Direct
	7603-7608	Direct
	76090000	Direct
	7610	Direct
	76110000	Direct
	7612	Direct
	76130000	Direct
	7614	Direct
	7616	Direct
Iron and steel	26011200	Indirect/Direct
	7201	Direct
	720211-19	Direct
	7202 60	Direct
	7203	Direct
	7205-7229	Direct
	7301	Direct
	7302,	Direct
	7303 00	Direct
	7304-7308	Direct
	7309 00	Direct
	7310	Direct
	7311 00	Direct
	7318	Direct
	7326	Direct
Fertilizers	28080000	Indirect/Direct
	2814	Indirect/Direct
	28342100	Indirect/Direct
	3102	Indirect/Direct
	3105	Indirect/Direct

Electricity	27160000	Indirect/Direct
Cement	25070080	Indirect/Direct
	25231000	Indirect/Direct
	25232100	Indirect/Direct
	25232900	Indirect/Direct
	25233000	Indirect/Direct
	25239000	Indirect/Direct
Chemicals (Hydrogen)	28041000	Direct

Source: German Chamber of Commerce and Industry (DIHK), 2024; European Union EUR-Lex, 2023a (*Regulation 2023/956, Annex I and Annex II*).

As of the year 2026 and the full commencement of the CBAM, approved CBAM petitioners alone will be able to engage in importing activities around commodities covered by the regulation. In this context, importing parties and indirect customs agents are required to submit an application to the corresponding local body in their country or the so-called "*CBAM registry*" directly, to receive approval, by presenting underlying data regarding their business operations as well as tax and customs conformity in the prior five-year period, among others (European Union, 2024; European Union EUR-Lex, 2023a). As part of the CBAM, starting by 2026, providing so-called CBAM certificates will be mandatory for importing parties in the EU market, serving as a fiscal correction (Simões, 2024). Moreover, Lee (2022) states that although the importing party faces the cost of CBAM certificates for exports to the EU, in the end, the amount is shared by the manufacturing, importing and consuming parties. Through the lens of purchasers in the EU, rates for commodities affected by the CBAM may increase in price which would lead to diminishing earnings for consuming parties in the EU.

Scholars emphasize that the mechanism is an instrument to ensure that greenhouse gases of imports with high contents of those to the EU are addressed similar to the intranational EU ETS system already in place (Hancock & Wollersheim, 2021; Shi et al., 2024). The incorporated emissions, also referred to as "*embedded emissions*", reflect direct emission generation unleashed throughout the manufacturing process as well as indirect emissions off the used power while producing (European Union, 2024). It is emphasized that CBAM petitioners must submit the compulsory amount of CBAM certificates, as otherwise they may be subject to receiving a fine. The emissions costs already covered locally prior to exporting the goods to the EU as well as complimentary

quotas under the EU ETS are deducted from the amount which must be submitted (Long et al., 2023; Lee, 2022; Simões, 2024).

Shi et al. (2024) conclude that passionate discussions have been caused as a result of the possible repercussions in the context of the global exchange of goods as well as environmental action inclined by the CBAM. Koç and Kaynak (2023) claim that the CBAM will have a substantial impact on leading markets such as the US, China, India and Russia and on states with considerable commercial ties to the EU-27 like Türkiye. About 40 percent of Turkish export trade volume is linked to the EU and overall, the EU is the country's largest counterpart in trading (Alpay & Gökmen, 2023; Koç & Kaynak, 2023). Hence, tracking EU legislative plans is crucial. Gros (2009) examines the effects of a border tax considering carbon emissions on degrees of global prosperity. Manders and Veendaal (2008) explore a carbon border taxes' impacts considering the European perspective in terms of likely contributions to competitiveness as well as carbon leaks. The scholars completed that the impacts are too minor to use it to justify its corresponding implementation.

Holzer (2010) draws attention to the aspect that models concerning emission allowances tied to discounts in the area of export and import trade activities contest the guidelines of World Trade Organization (WTO). The opposition of developing markets towards the CBAM in front of the WTO should be nearly inevitable (Casarano and Villalta Puig, 2024). Furthermore, wrongfully the CBAM puts both emerging and developing markets at a disadvantage while breaking the underlying standards of the WTO around free exchange of goods and services. Furthermore, a number of scholars examined the possible effects of the CBAM on national markets and industries as well as imported goods to the EU originating from trading nations like China, Russia, Türkiye, Morocco and Ukraine (see, e.g., Acar et al., 2022; Assous et al., 2021; Aşıcı, 2021; Beder, 2024; Bromels, 2024; Chepeliev, 2021; Gültekin, 2022; Huang et al., 2022; Koç & Kaynak; 2023; Simola, 2021; Urazgaliev et al., 2021; Yan & Yuan, 2023; Zhu et al., 2024).

Scholars claim that there is a possibility that through CBAM the current competitive order between nations and geographical areas may change, especially impacting industries with a large carbon footprint as well as those ones highly involved in the exchange of goods (Shi et al., 2024; Zhong & Pei, 2022; 2023). Furthermore, the mechanism may affect the global exchange of goods significantly, in particular in industries with a high demand in power, which could have an effect

on nations lacking a carbon pricing instrument as well as pressure the ones adopting late to lowering their carbon footprint (Hancock & Wollersheim, 2021; Shi et al., 2024). Additional scientific assessments which are currently lacking must be conducted considering the point-of-view of nations involved in the trade of goods with a large carbon footprint as these will incur extra duties.

Furthermore, the enforcement of the mechanism may result in intergovernmental strain as well as triggers doubts regarding its capability in the context of environmental measures (Eicke et al., 2021; Shi et al., 2024). Eicke et al. (2021) further emphasized that the effects of the CBAM nationally may vary. For nations whose trade volumes rely on large shares of selling goods abroad to the EU and hence their commercial activity, the CBAM may pose a danger of an economic slow-down for specific industries. The assessments show that the CBAM inclined commercial dangers spread around the world in an asymmetrical manner (Beaufils et al., 2023; Sarangi, 2023). Zhong and Pei, (2022) conclude that based on the outcomes on an industry base, the CBAM may have a higher effect on developing markets like China, Türkiye, Russia, India and so forth. Beaufils et al. (2023) point out that a number of poor- as well as medium-income states reliant on their export trading activities to the EU market may be unevenly impacted through the CBAM due to the fact that a great percentage of national carbon emissions may prospectively be addressed through the EU cost for carbon.

The United Nations Conference on Trade and Development (UNCTAD) (2021) provides a ranking of the 20 most vulnerable nations with regard to their total export sum in billion USD in 2019 considering the CBAM-relevant sectors in the context of export volumes to the EU. According to the ranking, Russia, China as well as Türkiye represent the nations set to be most affected by the CBAM. Türkiye's high ranking is particularly driven by its high shares of exports in the iron and steel industry and followed by the aluminum sector.

3. CLIMATE POLICY AND DECARBONIZATION STRATEGIES IN GERMANY AND TÜRKİYE

On December 12, 2015, the country approved the Paris Agreement which was then sealed on April 22 of 2016 while giving importance to Türkiye's status as an emerging economy (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2021; 2023). The Paris Agreement was later ratified and issued with the *Official Gazette 31621* on October 7th, 2021.

Türkiye declared its objective for climate neutrality until 2053 in September 2021 commencing the local transformation process (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2021). As a result of the declaration of both the local carbon neutrality goal until 2053 as well as the ratification of the Paris Agreement require extensive modifications and transition across each industry. In this context, the Directorate of Climate Change (as part of the Republic of Türkiye Ministry of Environment, Urbanization and Climate Change) was given the responsibility to conduct the process of developing plans, measures and tactics in the local and global context, to lead corresponding talks as well as to guarantee an inclusive environment for other stakeholders, all in the context of climate action and accommodating the results of climate change. The introduction of the Directorate of Climate Change as part of the Republic of Türkiye Ministry of Environment, Urbanization and Climate Change in October 2021, was for the purpose of implementing the corresponding operations and procedures in cooperation with a number of Turkish organizations. The Directorate is responsible for local and universal political approaches, plans and measures in the context of the country reacting and adjusting to global warming, while leading discussions as well as guaranteeing organized stakeholder cooperation.

The Republic of Türkiye Ministry of Environment, Urbanization and Climate Change (2023) states that the country's goal is to proceed along the course of sustainable economic growth by means of taking into account national strategic development pathways as well as progress abroad. At the same time, Türkiye thrives to tackle challenging matters in the context of the society, economy as well as environment adhering to a symmetrical approach. Furthermore, the country works persistently to follow its climate action objectives by means of various efforts such as danger and exposure analyses, data schemes as well as regulatory and legislative tools. Some of these documents already exist and have been enforced whereas other leading measures are in the preparatory phase and to set to be concluded as early as possible to strengthen the country's efforts against climate change.

The introduction of the Climate Law to the Grand National Assembly of Türkiye and the corresponding vote was expected for the near future as announced by Turkish President Recep Tayyip Erdoğan and Minister of Environment, Urbanization and Climate Change Murat Kurum in recent years (Presidency of the Republic of Türkiye, 2023; Levi et al. 2024; Sonkaya & Açıkgöz, 2024). Furthermore, the first blueprint of the Climate Law was disclosed in August 2023 (Levi et

al., 2024). Moreover, in November 2023 the blueprint for a legislation in the context of a local ETS was shared.

The blueprint of the Climate Law stresses the suggested domestic ETS, although scholars note the potential for more comprehensive rules regarding environmental legislation outside of a pricing mechanism for emissions (Levi et al., 2024). Furthermore, through the Climate Law Türkiye demonstrates its efforts to tackle the change of the climate, outlining particular approaches to reduce corresponding consequences. The plans encompass the reinforcement of regional authority positions, the integration of environmental concerns within infrastructural works as well as the advancement of energy from renewable resources and energy conservation.

On July 2, 2025, the Turkish Parliament passed the country's Climate Law encompassing 20 articles, two provisional ones as well as revisions to three distinct laws (Daily Sabah & Daştan, 2025; Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025). The Law represents a comprehensive regulatory structure to respond to climate change, setting out framework and protocols for emission mitigation and climate resilience measures as well as related instruments. Furthermore, it encompasses the implementation of a local ETS, the strengthening of responsibilities of the Climate Change Directorate to apply environmental policies while covering aspects such as just transition, a national CBAM and Green Taxonomy. The Law targets the creation of a stronger Turkish economy against the negative effects of climate change (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025). Moreover, it is set to support more environmentally friendly and resource-efficient manufacturing to boost the global competitive capabilities of industries in Türkiye. The Law also aims to safeguard urban development, farming, livestock breeding, and natural spaces.

Under its authority the Climate Change Directorate is responsible for inter-organizational alignment, initiatives and guidelines while tracking advancements in emission mitigation and climate resilience efforts (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025). Carbon pricing is set to be overseen by the Directorate through operations of market-oriented instruments. The Directorate will implement the local ETS, and related allowances will be issued under this framework. The Turkish Energy Market Regulatory Authority will be responsible for supervising ETS-linked operations in the energy sector (Daily Sabah & Daştan, 2025). The legislation includes an initial preliminary stage in the context of the ETS, set to be supervised by the Carbon Market Board prior to full implementation.

The Carbon Market Board is set to authorize the local disbursement scheme, determine the issuance of complimentary allowances in the ETS context, establish the quantities of allowances to be sold as part of the primary market, set the proportions of offset operations permitted under the ETS framework (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025). Furthermore, the Board will formulate the guiding scheme regarding regulations and initiatives in the context of the ETS while defining the industries and areas bound by the global carbon market and specifying applicable restrictions as well as core legislative guidelines regarding import and export trade.

The Law also prioritizes the capacity building, advancement and broad deployment of environmentally friendly technologies (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025). The Directorate of Climate Change is set to collaborate with concerned bodies to track the latest technological innovations to enhance climate mitigation efforts, e.g., tech solutions in the area of hydrogen and carbon capture and storage as well as the evolvment of initiatives in these domains. Furthermore, the Directorate can initiate and collaboarte with bodies to conduct related R&D activities. Required R&D bodies can be created as under joint effort with associated organizations.

The aim is also to launch a Turkish Green Taxonomy system and climate-related incentive-based instruments aimed at directing funding flows to be conducted by the Climate Change Directorate. (Daily Sabah & Daştan, 2025; Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025). Furthermore, a local CBAM will be implemented to tackle carbon emissions in the context of imports (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025).

Locally, so-called Provincial Climate Change Coordination Boards are implemented in all provinces connected to the governor’s office, including local delegates (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025). Furthermore, Climate Change Action Plans are set to be developed by December 31, 2027 with a possible deadline postponement by at most another year to be determined by the Ministry of Environment, Urbanization and Climate Change (Daily Sabah & Daştan, 2025; Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2025). Overall, the preparatory and adaptation conditions in the context of the regulations and organizational device set out by the Law must be met by the

related bodies until December 31, 2027. The target date may be pushed by one year by the Presidency of the Republic of Türkiye.

According to Reimer (2023) on November 7, 1990, the German government at the time introduced the first CO_2 emission mitigation target of 25 percent for 2005 using the base year 1987. In consequence, Germany became the first country globally to define a domestic climate objective. In 1995, at the first Coference of the Parties (COP) held in Berlin then German Chancellor Helmut Kohl announced an adapted objective of 25 percent until 2005, but applying the base year 1990 as well as enlarging its scope of application to all of Germany, following the reunification of West and East Germany. Following 2007, a number of programs and schemes in the context of climate action were established by the different governments up to the introduction of the climate protection legislation referred to as Federal Climate Protection Act (*Bundes-Klimaschutzgesetz (KSG)* [German]) and its corresponding mitigation goals (Federal Ministry for Economic Affairs and Climate Action, 2021; Reimer, 2023). Furthermore, the CO_2 emission reduction objective for 2020 was met, also benefiting from the slowdown in activity due to the Corona pandemic, e.g. in the transportation sector (Ell, 2024; Reimer, 2023).

Germany ratified the Paris Agreement on September 22, 2016, following its signing on December 12, 2015, and hereby committing itself to the goal of ensuring that global warming remains less than two degrees Celsius (German Bundestag, 2016). Regarding the domestic Nationally Determined Contributions (NDCs), Germany as an EU member state adheres to the points determined on an EU level which were last submitted on October 16, 2023, by Spain and the European Commission (European Commission, 2023; United Nations Climate Change, 2025).
The so-called Climate Protection Program (*Klimaschutzprogramm* in German) represents the general agenda for political climate action strategies by the German government (Federal Government, 2023). Furthermore, the program packages the government's activities concerning climate objectives both on a domestic and EU level (Federal Ministry for Economic Affairs and Climate Action, 2023). The Federal Ministry of Economic Affairs and Climate Protection aims to facilitate creating an environment driving innovation for the protection of the climate in industrial sectors (Federal Ministry for Economic Affairs and Climate Action, n.d.). In this context, the ministerial side claims that it is substantial to set up structures for the industrial sector to benefit from as part of approaching periods of reinvestment during this ten-year period to apply for the green transformation of their manufacturing processes.

The targeted net zero levels until 2045 refer to the symmetry of emitted carbon emissions as well as their compensation (Federal Government, 2022). Starting in 2050 the aim is to even reach greenhouse gas levels less than zero. Several landmarks have been set in the process to achieving net zero compensation. In 2024, the government was set to determine the yearly targets for reduction for the timeframe 2031 until 2040 on an individual industry basis. For the period 2023 until 2030 the sectoral targets had previously been raised in 2021, together with aligning on the annual overall targets of reduction for the period 2031 until 2040 compensation. At the latest in 2032 the government will then determine overall yearly targets of reduction for the timeframe 2041-2045. Following in 2034 again sectoral targets will be determined for the previously mentioned period until 2045, the point in time when reaching net zero compensation.

4. THE POTENTIAL EFFECTS OF THE CARBON BORDER ADJUSTMENT MECHANISM ON TRADE BETWEEN GERMANY AND TÜRKİYE

Having long term relationship and millions with Turkish roots living in Germany provide a crucial position in the context of the countries' economic ties. These ties between the two countries are forged through the different dimensions of society, politics, and economy (Bedir et al., 2022). Paul and Schmidt (2017) point out this relationship as follow; "*Germany and Turkey have had close relations since the Ottoman times, being intertwined by multiple historical, economic, cultural, and societal ties.*". The two countries have been upholding well-established connections with one another in various manners, e.g., in regard to politics, society, defense as well as trade (Republic of Türkiye Ministry of Foreign Affairs, 2023).

The relations between Türkiye and Germany historically started back in the 11th century (Konukman, 2023). Önsoy (2016) contradicts this statement, noting that the bilateral ties found their beginning at the closing of the 16th century, but over time evolved at low pace. The scholar states that the German side did not start to truly make advances toward the Ottomans prior to the early 19th century. In 1898, while traveling through the Ottoman Empire, Emperor Wilhelm II affirmed himself to be an ally and friend of the Islamic religion and the Turkish people (Baş, 2021; Reyhan, 2005; Schaper, 2019). In times of World War I, the Ottoman Empire and the German Empire became allies (Götting, 2014; Konukman, 2023; Kreiser, 2013; Republic of Türkiye Ministry of Foreign Affairs, 2023). The alliance treaty was signed by the two parties on August 2, 1914 (Alkan, 2014; Götting, 2014; Kreiser, 2013; Reyhan, 2005).

On March 1995, the enforcement of the Customs Union was concluded and went into effect at the beginning of 1996, in accordance with the with the Decision 1/95 by the European Council-Türkiye Association Council (Republic of Türkiye Ministry of Foreign Affairs - Directorate of EU Affairs, 2024). The Customs Union forms the base for the strong ties between Türkiye and the EU economically, in particular regarding the exchange of goods (Selçuki & Tulan, 2021). In recent times, a number of scholars and key stakeholders have been advocating for the modernization of the Customs Union's framework for reasons of shortcomings and challenges in the context of changed external framework conditions and demands (Federation of German Industries (BDI), 2017; Dawar et al., 2018; Karataş, 2016; Özekan, 2023; Özer, 2020; Özgöker & Bedirhan, 2016; Slevogt & Seyfert, 2022; Ülgen et al., 2022).

Germany and Türkiye have established a Joint Economic and Trade Commission in 2018 to increase their trade relations as well as the German-Turkish Energy Forum, like an exchange forum for governmental representatives and the private sector from both sides (Federal Foreign Office, 2024). Turkish-German trade relations have been expanding in both dimensions import and export. Figure 1 plainly depicts the increase in trade volume between the two countries between 1990-2024.

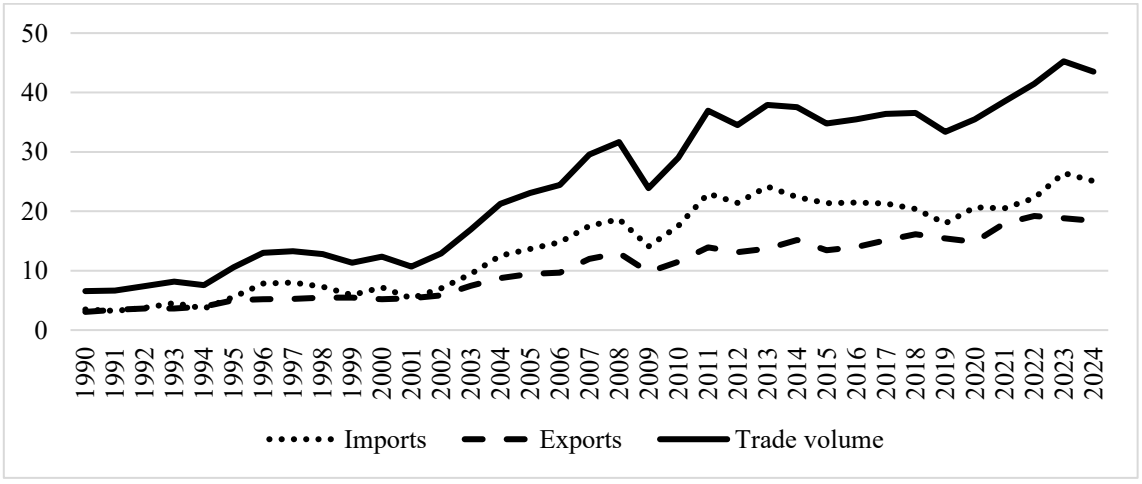

Figure 1. Development of Trade Between Türkiye and Germany (Billion USD, 1990-2024)
Source: TURKSTAT, 2025b.

Over the past two decades bilateral trade between Türkiye and Germany has been developing in a positive manner (see Figure 1). Between 2004 and 2024 the total turnover in trade grew by 104,6

percent (TURKSTAT, 2025b). With the emergence of the global financial crisis emerging between 2007 and 2008, bilateral trade dropped by 24,5 percent according to the overall turnover in 2009 versus 2008. During this period especially imports from Germany to Türkiye dropped. Following the global crisis years bilateral trade quickly recovered, exceeding pre-crisis results as early as 2011 mainly driven by the increase of German exports to Türkiye. The period between 2011 and 2019 represents continuous fluctuation but with an overall stagnation of bilateral trade between the two countries. Moreover, Covid-19 pandemic in 2020 affects the trade volume negatively between Türkiye and Germany as did it in the world but not as much as in 2009. The bilateral trade result as part of the special trade system slightly decreases in 2024, reaching 18,4 billion USD in Turkish exports and 25,1 billion USD in Turkish imports which amounts to a total of about 43,5 billion USD.

When considering the trade balance's development over the past two decades imports from Germany have been mostly exceeding exports from Türkiye, causing a trade deficit from a Turkish perspective (TURKSTAT, 2025b). On average between 1990 and 2024, the Turkish trade deficit with Germany amounted to about -3,9 billion USD, reaching its all-time high in 2013 at about -10,5 billion USD and an amount of about -7,6 billion USD in 2023 and -6,7 billion USD in 2024. In 1994, the period's highest ever Turkish trade surplus was reached at 288,7 million USD.

In 2024, according to Turkish export trade volumes Germany was the country's leading export destination (TURKSTAT, 2025b). Furthermore, Germany's export trade with Türkiye made up for the third largest share in Türkiye's total import volume. Germany is Türkiye's overall third most important trade partner country, following Russia and China in first and second place respectively in 2024. As for the export, Germany has long been the largest destination among the countries to which Türkiye exports to. In 2024, following Germany, the United Kingdom and the US take their places on the list of countries of most exports, respectively. In 2024, considering German trade statistics, overall Turkish exports rank 14th in the international comparison and Türkiye's import volumes to Germany value the country as 16th largest the same year (Destatis, 2025). Measured by turnover referring to Turkish-German total exports plus imports, Türkiye is Germany's 14th largest partner in trade in global comparison. Moreover, measured by the individual foreign bilateral trade balance which means calculating exports minus imports, Türkiye reaches 21st places with a positive result amongst the international ranking in 2024.

4.1. Trade Relationship in Related Sectors Within the Context of the Carbon Border Adjustment Mechanism

The framework of the EU's CBAM covers aluminum, cement, electricity, fertilizers, hydrogen as well as iron and steel also incorporating certain subsequent items such as kinds of fasteners (Council of the European Union, 2022; European Commission - Directorate-General for Taxation and Customs Union, 2024; European Union, 2024). Since there is currently no significant trade related to the electricity and hydrogen sectors between Türkiye and Germany, these sectors have not been considered as part of study.

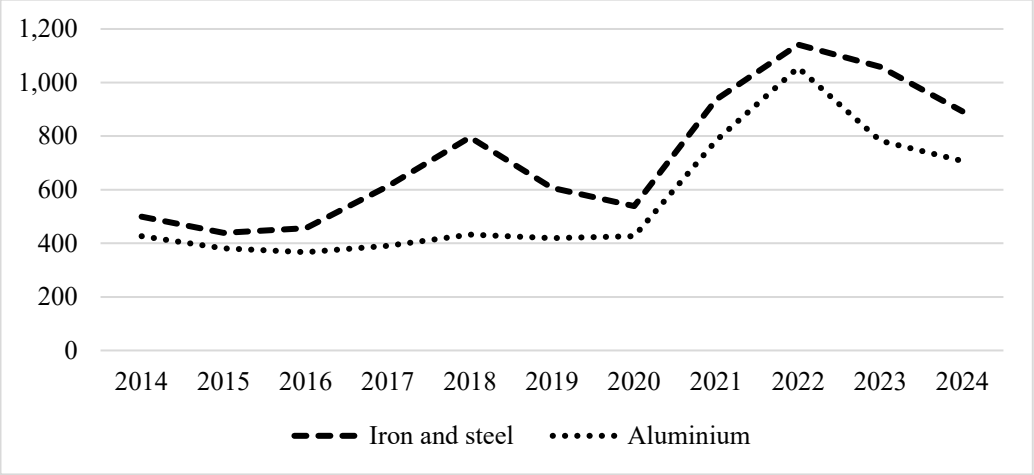

Figure 2. Türkiye's Iron and Steel and Aluminum Exports' Value to Germany (2014-2024, million USD)

Source: TURKSTAT, 2025c.

Figure 2 and Figure 3 as well as Table 2 describe the development of exports to Germany in the scope of the Combined Nomenclature (CN) codes for the iron and steel, aluminum, fertilizer and cement as defined under the CBAM between 2014 and 2024 in million USD (TURKSTAT, 2025c). The iron and steel, aluminum, fertilizer and cement industries may be most affected by the CBAM according to the amount of selected CN codes and the annual Turkish export volumes in the context of German-Turkish bilateral trade. Overall, based on the trade volumes, the iron and steel industry is most impacted, followed by the aluminum sector. The fertilizer and cement industries follow subsequently but only account for overall small export volumes in comparison to the iron and steel as well as aluminum sector as displayed in Figure 2 and Figure 3 as well as Table 2.

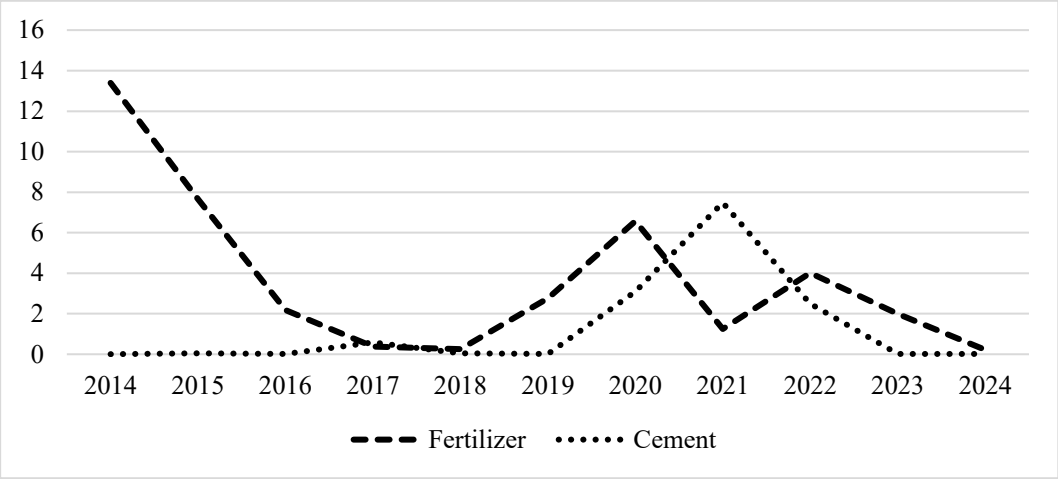

Figure 3. Türkiye's Fertilizer and Cement Exports' Value to Germany (2014-2024, million USD)

Source: TURKSTAT, 2025c.

Table 2. Türkiye's Iron and Steel, Aluminum, Fertilizer and Cement Exports' Value to Germany (2014-2024, million USD)

Year	Iron and steel	Aluminum	Fertilizer	Cement
2014	499,2	426,2	13,4	0,004
2015	439,1	380,6	7,7	0,1
2016	456,8	366,9	2,2	0,02
2017	612,4	390,7	0,4	0,6
2018	796,1	433	0,3	0,04
2019	607,3	419	2,8	0,02
2020	538,4	426,3	6,6	3,1
2021	936,8	783,4	1,3	7,5
2022	1.141,7	1.055,7	4,	2,5
2023	1.058,2	782,2	2	0,01
2024	892,8	707,2	0,2	0,02

Source: TURKSTAT, 2025c.

Considering the export trade results in the CBAM-relevant sectors between 2014 and 2024, the outcome shows that the iron and steel and aluminum sectors account for substantial trade volumes in Turkish export trade (TURKSTAT, 2025c). On the other hand, the cement and fertilizer sectors represent significantly lower shares in connection to trade outcomes. Hence, the potential economic impact on an overall bilateral trade basis remains comparably small for these sectors. Furthermore, the United Nations Conference on Trade and Development (2021) regarding the

impact on the CBAM-relevant sectors in the context of export volumes to the EU by the 20 most vulnerable nations emphasizes that, in the context of Türkiye, the iron and steel and aluminum sectors will be most affected by the CBAM (see Figure 4). As part of the detailed assessment regarding the potential effects of the CBAM on Turkish exports to Germany, this study focuses solely on the iron and steel as well as aluminum sectors.

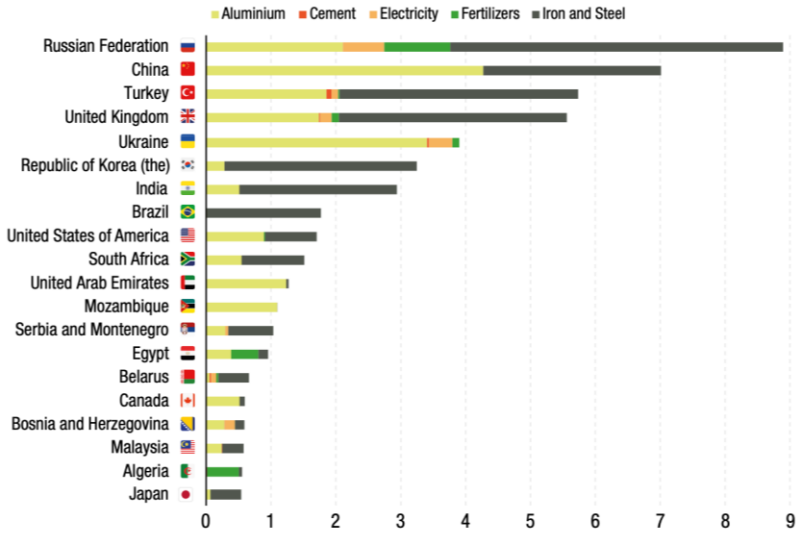

Figure 4. Türkiye's Iron and Steel, Aluminum, Fertilizer and Cement Exports' Value to Germany (2014-2024, million USD)

Source: United Nations Conference on Trade and Development, 2021.

4.1.1. Iron and steel sector

The iron and steel industry is most affected by the CBAM on the basis of the amount of selected CN codes. On the basis of the CN codes for the iron and steel sector and the export trade levels between 2014 and 2024, the goods' classification groups *7326*, *7318* and *7308* represent the most significant product categories according to export volumes measured in USD (TURKSTAT, 2025c). Moreover, the product categories *7326* and *7318* overall clearly dominate export trade among the listed CN codes throughout the mentioned time period. Figure 5 shows the Top-3 exports categories relevant under the CBAM for the iron and steel sector between 2014 and 2024.

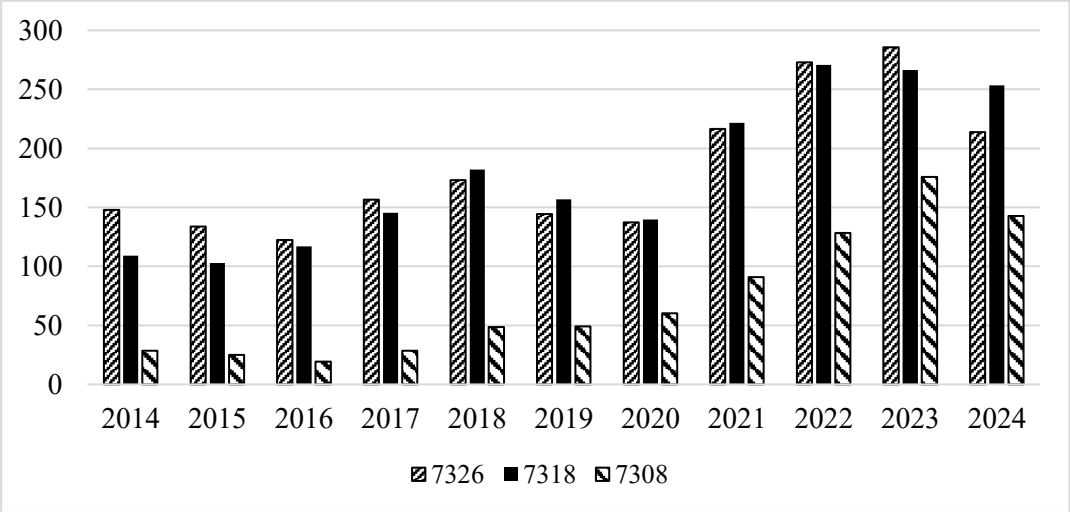

Figure 5. Top-3 Export Categories Relevant Under the CBAM for the Iron and Steel Sector (2014-2024, million USD)

Source: TURKSTAT, 2025c.

The CN code *7326* represents for "*articles of iron or steel, n.e.s. (excl. cast articles)*", which between 2014 and 2024 amounted to a total export volume of two billion USD, making it the most significant product group. Furthermore, the product category "*screws, bolts, nuts, coach screws, screw hooks, rivets, cotters, cotter pins, washers, incl. spring washers, and similar*", symbolized by the code *7318*, ranks in second place with a result of about two billion USD throughout 2014-2024. Ranking third, the CN code *7308* represents "*structures and parts of structures e.g., bridges and bridge-sections, lock-gates, towers, lattice masts, roofs, roofing*" and accounts for an export trade volume of 797,6 million USD during the same time period.

The product category *7308* started substantially increasing following 2020 while during previous times its levels were fairly small, achieving its peak at 175,8 million in 2023 and its lowest in 2016 at 19,4 million USD. The average value for this product category between 2014 and 2024 amounts to only 72,5 million USD. On the other hand, the product category *7326* achieved its highest results between 2021 and 2024. The two product categories regularly alternate in the ranking for first and second place, increasing at similar rates over time. Considering the decrease of overall levels in 2024, in particular the category *7326* declined from 285,5 million to 213,7 million USD in export volumes.

In 2024, considering the product categories *7326, 7318* and *7308* amounted to 609,8 million USD accounting for 68,3 percent of the total amount of 892,8 million USD representing all export trade across the relevant CN codes of the iron and steel sector under the CBAM. For the year 2024, the Top-3 product categories *7326*, *7318* and *7308* amounting to 609,8 million USD account for a proportion of 3,3 percent in relation to the 18,4 billion USD Turkish export trade with Germany (TURKSTAT, 2025c; 2025d).

4.1.2. Aluminum sector

The aluminum sector is the second most affected sector by the CBAM on the basis of the amount of selected CN codes. Figure 6 depicts the development of the Top-3 export categories relevant in the context of the CBAM for the aluminum sector from 2014 to 2024 (TURKSTAT, 2025c). Based on the CN codes for the aluminum industry and the export trade results, the products' classification groups *7604*, *7606* and *7616* represent the most significant categories of goods according to export trade volumes presented in USD. Moreover, in total, the product category *7604* distinctly comes to the fore in the ranking on overall amounts of export trade among the listed CN codes from the sector throughout the above-mentioned period.

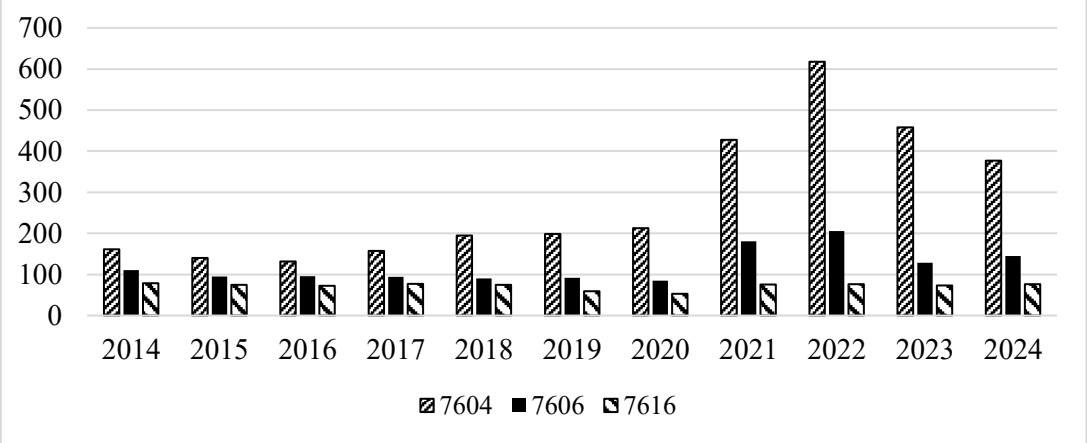

Figure 6. Top-3 Export Categories Relevant Under the CBAM for the Aluminum Sector (2014-2024, million USD)

Source: TURKSTAT, 2025c.

The CN code *7604* represents "*bars, rods and profiles, of aluminum, n.e.s.*", which between 2014 and 2024 accounted for an overall export volume of 3,1 billion USD, making it the most important product group. Moreover, the CN code *7606* depicting "*plates, sheets and strip, of aluminum, of a thickness of > 0,2 mm (excl. expanded plates, sheets and strip)*", comes in second place with a

total result of about 1,3 billion USD in between 2014 and 2024. Ranking third, the CN code *7616* represents "articles of aluminum, n.e.s.", amounting to an export trade volume of 790,6 million USD.

While up to the year 2020 only exhibiting low growth rates on average, the product category *7604* experiences substantially increasing result in 2021 and 2022, peaking the same year at 617,5 million USD compared to the mean value of 279,7 million USD between 2014 and 2024. However, compared with the product category *7604,* the product category *7606* shows on average fairly low performance. In 2021 and 2022 the category *7606* demonstrates substantial growth rates reaching its height at 206 million USD in 2022, followed by a decline to 128,5 million USD in 2023 and, again, a slight increase in 2024 to 144,5 million USD. The average value for this good between 2014 and 2024 amounts to only 120,3 million USD.

In 2024, the export levels for the product categories *7604, 7606* and *7616* represented an amount of 597,7 million USD, representing a proportion of 84,5 percent of the total amount of 707,2 billion USD originating from the compiled export trade across the corresponding CN codes of the aluminum sector under the CBAM. Considering the overall Turkish export trade results in Turkish-German bilateral exchange of 18,4 billion USD in 2024 and the aforementioned Turkish export levels in the Top-3 product categories *7604*, *7606* and *7616* in the aluminum sector of 597,7 billion USD, they exemplify a proportion of approximately 3,3 percent.

4.2. Potential Effects of the Carbon Border Adjustment Mechanism on Turkish Exports

To assess the potential effect of the CBAM on German-Turkish trade activities, in particular Turkish exports, the corresponding target of the study is to analyze the prospective cost effects of Turkish export trade with Germany in in selected industries relevant under the framework of the CBAM in accordance with the predetermined CN codes (see Table 1). Hereby, the aim is to calculate the potential additional cost added to a product's price exported from Türkiye to Germany through the required consideration of the added cost of carbon permits for importers in the EU. As the iron and steel as well as aluminum sectors stand for the majority of Turkish export trade activity with Germany among the industries relevant under the CBAM, the assessment will focus on the aforementioned sectors only.

For the calculation of additional yearly costs on a product basis, the amount of goods in tons, the carbon intensity, and the price for CBAM certificates are employed. The following calculation formula has been proposed by Assous et al., (2021) and Simola (2021):

$$\boldsymbol{EXP_{Türkiye} * CI_{Good} * P_{CBAMC}} \quad (1)$$

where $EXP_{Türkiye}$ stands for the Turkish export trade with Germany measured in tons on product basis considering the corresponding CN codes. The Turkish export trade results in 2024 for the CBAM-related CN codes in the iron and steel as well as aluminum sectors form the basis for the assessment. *CI* represents the carbon intensity of a good given in ton CO_2e/ton goods (tCO_2e/t). Furthermore, P_{CBAMC} indicates the pricing of CBAM permits/EU ETS carbon permits in USD per ton. These values are then multiplied by one another to establish the corresponding inclined costs in USD.

The European Commission has published predefined values in tCO_2e/t (CBAM default coefficients) to be used during the transition phase of the CBAM leading up to December 31, 2025 (European Commission - Directorate-General for Taxation and Customs Union, 2023). The given predefined values are valid with no relation to the place of origin of any product. Starting by 2026, a different collection of default rates is set to be enforced and established by a corresponding implementing act up for approval in 2025. These rates are intended to reflect the mean carbon intensity levels of individual export nations and further raised through proportionally drafted surcharge. In addition, through an assessment by the Joint Research Centre of the European Commission in form of a technical report emission' intensity levels for the iron and steel, fertilizer, aluminum and cement sectors in the context of the EU's primary counterparts in the exchange of goods have been determined on a country-basis (regional rate coefficients) (Vidovic et al., 2023). The emission' intensity levels provided are given on the basis of the CN Codes relevant under the CBAM and for the countries affected in tCO_2e/t. The rates are presented in the form of indirect and direct emissions as well as in sum. Both the determined country-based values and the default values are considered as part of this research.

Table 3. Dataset example for CN code 7326 (December 2024)

Weight in tons	Export Volume	$P_{CBAM\ C}$ 80	$P_{CBAM\ C}$ 100	CBAM Default Coefficient	Regional Rate Coefficient	CBAM Cost CBAM Default/80	CBAM Cost CBAM Default/100	CBAM Cost Regional rates/80	CBAM Cost Regional rates/100
2.964 t	12.718.032 USD	80	100	2,25	2,4	533.487,06 EUR	666.858,83 EUR	569.052,86 EUR	711.316,08 EUR

Source: European Commission - Directorate-General for Taxation and Customs Union, 2023; TURKSTAT, 2025a; Vidovic et al., 2023.

Locally, the cost of carbon already settled before exporting a product to the EU market and complimentary quotas under the scope of the EU ETS are subtracted from the amount required to be submitted to the EU (Long et al., 2023; Lee, 2022; Simões, 2024). Although, as the distribution of free permits is set to be gradually discontinued under the scope of the EU ETS between 2026 to 2034, amounts of potential free emission permits are not considered in this assessment. The price for CBAM certificates will be connected to the price of permits under the EU ETS. In regard of the CBAM, over time, the introduction of the CBAM factor, a coefficient, is expected to be conducted, continuously reducing the levels of free permits available in connection with the manufacturing of products associated with the CBAM (European Union EUR-Lex, 2003; 2023b; European Commission - Directorate-General for Taxation and Customs Union, 2024; Simola, 2021).

For the assessment under this study, emission cost scenarios of 80 USD and 100 USD are applied for the corresponding CBAM certificates determining the additional cost to be covered by the EU importing party. For the calculations conducted as part of this research on a sector-based level the monthly export volumes from Türkiye to Germany on a four-digit CN code base are considered taken from the special trade system (TURKSTAT, 2025a). Table 3 depicts a dataset example for the CN code 7326 for December 2024 used as the calculation basis.

Regarding potential limitations of the data used as part of the assessment different aspects may be underlined. The emission coefficients applied are in both scenarios average values. Hence, on a company-based level actual emission rates may vary from the average rates. In addition, different measurement approaches, reporting techniques as well as technical limitations may cause

discrepancies between data sets collected internationally and as part of different studies, making it challenging to be fully contingent on reliably.

In the context of the trade data, especially more recent trade results may be subject to frequent change which ultimately also affects the results of this assessment. Furthermore, due to different data collection and measurement methodology trade data from an individual country perspective may vary. The results of the study are based on the status-quo of trade relations between the two countries. Prospectively, trade flows may change e.g., due to unforeseen economic shifts or international crises as seen during the COVID-19 pandemic. Furthermore, two carbon pricing scenarios are used for the assessment which may differ from the actual pricing scenarios as a result of the carbon pricing developments both in the EU and Türkiye. These developments short-, mid- and long-term may display volatility. The topical nature of the applied trade data in combination with the assumed pricing scenarios have a significant impact on the cost effect of the CBAM on Turkish exports and hence also their limitations.

Future studies may consider these limitations and focus on further assessments on a company-level including the corresponding trade and emission intensity data sets as well as apply additional modelling approaches.

4.3. Findings Regarding Potential Effects and Conclusion

As demonstrated by the recent trade data Turkish-German trade relations play an economically important role from the perspective of both countries. Hence, the implementation of the CBAM will affect the course of bilateral trade ties and requires that measures are taken to prevent negative implementations. Due to the comparably negligible export trade amounts from Türkiye to Germany in the cement and fertilizer sectors between 2014 and 2024, the assessment focuses only on the potential cost effects in the aluminum and iron and steel sectors (TURKSTAT, 2025c). In the context of the iron and steel sector the assessment shows a significant cost increase for the corresponding exports from Türkiye to Germany between 2019 and 2024 (TURKSTAT, 2025a). In comparison to the aluminum sector, the iron and steel industry is relatively more affected by the additional costs inclined by the CBAM regulation.

Regarding the iron and steel sector, considering only the year 2024, using the 100 USD price scenario for CBAM certificates to be purchased by the importer the highest result is achieved in the context of the regional emission intensity levels amounting to an additional cost of 81,5 million

USD (see Table 4). This result represents a share of 8,6 percent in relation to the total trade volume of 941,7 million USD across the relevant CN codes in the iron and steel sector in 2024. In the context of the total Turkish export volume of 237,5 billion USD the same year, the costs stand for a small share of 0,03 percent (TURKSTAT, 2025d). In the context of the 80 USD price scenario for CBAM certificates the primary outcome is achieved for the provided regional rates equaling to 65,2 million. USD in 2024. This result portrays a proportion of 6,9 percent in respect to the total trade volume of 941,7 million USD among the CBAM-relevant CN codes and a 0,03 percent share in the context of the overall export volume of Türkiye with the world in 2024. Overall, the results show no substantial difference between the outcomes in the context of the provided default rates and regional values, indicating that the values are in close proximity to one another.

Table 4. Sum of additional CBAM cost in the iron and steel sector (2024, USD)

Regional rates/100 USD	**Default rates/100 USD**	**Regional rates/80 USD**	**Default rates/80 USD**
81.449.990,67	81.098.906,29	65.159.992,53	64.879.125,03

Source: TURKSTAT, 2025a.

In the context of the aluminum sector the assessment shows a smaller cost raise for the corresponding exports from Türkiye to Germany in relation to the overall trade volumes than in comparison to the iron and steel sector. When using the 100 USD price scenario the highest outcome is demonstrated in the context of the default emission intensity levels amounting to 43 million USD across the relevant CN codes in the aluminum sector in 2024. This result represents a percentage share of 5,8 percent relative to the total trade volume of 738,8 million USD across the relevant CN codes for the same year. In the context of the total Turkish export volume of 237,5 billion USD the same year, the costs stand for a minor share of 0,02 percent (TURKSTAT, 2025d). Regarding the 80 USD price scenario the top result is depicted in the default rates amounting to 34,4 million USD in 2024. This result portrays a proportion of 4,7 percent in respect to the total trade volume of 738,8 million USD among the affected CN codes and a small share of 0,01 percent in relation to the overall Turkish export trade volume of 237,5 billion USD in 2024 (TURKSTAT, 2025d).

Applying the regional emission rates in connection with the 100 USD cost scenario represents the highest outcomes on average with a peak in 2022 at 107,3 million USD (see Table 5). Overall, the

CBAM costs rise with the increase in Turkish exports to Germany explaining the growth in value in 2021 and 2022 among the other years.

Table 5. CBAM cost in the iron and steel sector (2019-2024, USD)

Year	CBAM Cost Regional rates/100	CBAM Cost CBAM Default/100	CBAM Cost Regional rates/80	CBAM Cost CBAM Default/80
2019	78.935.975,36	78.306.997,91	63.148.780,28	62.645.598,33
2020	64.837.212,53	64.326.505,45	51.869.770,02	51.461.204,36
2021	98.968.432,89	98.118.173,55	79.174.746,31	78.494.538,84
2022	107.306.754,15	106.253.007,24	85.845.403,32	85.002.405,79
2023	85.545.024,33	84.502.536,67	68.436.019,46	67.602.029,33
2024	81.449.990,67	81.098.906,29	65.159.992,53	64.879.125,03
Total	**517.043.389,91**	**512.606.127,10**	**413.634.711,93**	**410.084.901,68**

Source: TURKSTAT, 2025a.

In the context of the aluminum sector, the scenario using the default emission values in connection with the 100 USD cost scenario leads to on average the highest results with a peak at 54,2 million USD in 2022 (see Table 6). This outcome is followed by the result applying the same cost scenario in combination with the regional emission rates amounting to a peak at 45,8 million USD in 2022 as well. The ranking remains the same also when applying the 80 USD cost scenario in connection with the default emission values and regional emission rates, reaching its height at 43,3 million and 36,6 million USD respectively in 2022. The results for the regional rates are mentioned here as they are closer to the local conditions in connection with emission levels in production facilities.

Table 6. CBAM cost in the aluminum sector (2019-2024, USD)

Year	CBAM Cost CBAM Default/80	CBAM Cost CBAM Default/100	CBAM Cost Regional rates/80	CBAM Cost Regional rates/100
2019	26.004.009,25	32.505.011,57	21.948.623,60	27.435.779,51
2020	26.963.415,25	33.704.269,06	22.773.435,58	28.466.794,48
2021	41.425.089,62	51.781.362,02	34.971.463,32	43.714.329,15
2022	43.320.183,58	54.150.229,47	36.616.027,46	45.770.034,32

2023	35.656.423,15	44.570.528,94	30.179.728,10	37.724.660,13
2024	34.423.309,07	43.029.136,34	29.070.055,01	36.337.568,77
Total	**207.792.429,92**	**259.740.537,41**	**175.559.333,08**	**219.449.166,35**

Source: TURKSTAT, 2025a.

On a sectoral basis for the iron and steel sector, considering the average rates for the additional CBAM cost in relation to the total trade volume between 2019 and 2024, the highest shares among all the different scenarios are achieved in 2019, followed by the year 2020 (see Table 7).

To assess the inclined CBAM cost its results may be compared with the overall annual export trade volumes on a scenario basis, calculating the share of the scenario-based CBAM costs in relation to total exports annually. Considered here are the results to the CBAM-relevant CN codes of that sector. When evaluating the iron and steel sector's shares of CBAM costs in relation to total exports the highest results are achieved in connection with the regional rates applied as the underlying emission coefficient using the 100 USD scenario (see Table 7). In 2019, the peak is achieved for the regional rates in relation to the 100 USD scenario amounting to 12,5 percent. Throughout the years with growing CBAM costs the export trade with a comparatively increased share of carbon-intensive goods rose. Hence, higher emission levels caused, when multiplied with the different expense scenarios for CBAM certificates, overall growing costs.

Table 7. Annual CBAM cost share relative to overall yearly trade volumes on a scenario basis in the iron and steel sector (2019-2024, in percent)

Year	**CBAM Cost Share Regional rates/100**	**CBAM Cost Share CBAM Default/100**	**CBAM Cost Share Regional rates/80**	**CBAM Cost Share CBAM Default/80**
2019	12,5	12,4	10	9,9
2020	11,4	11,3	9,1	9
2021	10,4	10,3	8,3	8,2
2022	9,4	9,3	7,5	7,4
2023	7,9	7,8	6,4	6,3
2024	8,6	8,6	6,9	6,9

Source: TURKSTAT, 2025a.

In the context of the aluminum sector the yearly CBAM cost share in relation to the total annual export trade volume from Türkiye to Germany between 2019 and 2024 are evaluated as well and the greatest outcomes occur in connection with the default rates in combination with the 100 USD cost scenario (see Table 8). The results peak in 2020 in connection with the default rates and the 100 USD cost scenario accounting for a result of 7,5 percent whereas the same pricing scenario combined with the regional rates only amounts to 6,3 percent.

Table 8. Annual CBAM cost share relative to overall yearly trade volumes on a scenario basis in the aluminum sector (2019-2024, in percent)

Year	CBAM Cost Share CBAM Default/80	CBAM Cost Share CBAM Default/100	CBAM Cost Share Regional rates/80	CBAM Cost Share CBAM Regional rates/100
2019	5,9	7,3	5	6,2
2020	6	7,5	5,1	6,3
2021	5	6,3	4,2	5,3
2022	4,3	4,9	3,3	4,2
2023	4,3	5,3	3,6	4,5
2024	4,7	5,8	3,9	4,9

Source: TURKSTAT, 2025a.

Overall, from a sectoral perspective the iron and steel industry and the corresponding CN codes are on average more affected by the additional costs inclined through the CBAM in context of Turkish exports to Germany. As the default values are derived from the global average on a product basis, corresponding higher results in connection with the default values in comparison to the regional rates imply that in a global comparison the added costs would be greater internationally than locally.

Considering only the scenario of regional rates results in connection with a CBAM certificate pricing of 100 USD, the additional cost amount to 517 million USD between 2019 and 2024. Compared to that the added costs for the aluminum sector regarding the identical scenario representing 219,4 million USD. In the context of the scenario applying default values in connection with a CBAM certificate pricing of 100 USD the corresponding outcome amounts to 512,6 million USD for the iron and steel sector and to 259,7 million USD in the context of the

aluminum sector during the timeframe 2019 to 2024. The results provide an indication regarding the positioning of the aluminum and iron and steel sectors from an added cost perspective on a global scale as results can be compared. In respect to the iron and steel sector, Türkiye is at a disadvantage as the result in connection with the default values is lower than the outcome derived from the regional rates. On the other hand, the added costs concerning the Turkish aluminum sector remain on average lower than the international results and hence imply a corresponding cost advantage.

For both sectors annual CBAM cost results vary due to the facts that relative proportions of the individual product categories as part of export trade to Germany change. Therefore, when the relative share of products with a comparably higher emission coefficient grows, the overall added costs also increase. In the context of the percentage proportions of the additional costs relative to the overall export volume, regarding the scenario regional rates in combination with a 100 USD pricing for CBAM certificates, the shares account for on average ten percent for the timeframe 2019 to 2024. For the aluminum sector the corresponding outcome only amounts to an average of five percent between 2019 and 2024.

The scenario using default values in connection with the 100 USD pricing scenario generates an average result of 9,9 percent for the iron and steel sector and of 6,2 percent in terms of the aluminum sector. These outcomes emphasize the Turkish iron and steel sector's cost disadvantage. Furthermore, from the perspective of the aluminum sector they show a cost advantage in a global comparison. In general, the percentage shares underline the comparably greater effect in the context of the Turkish iron and steel sector. Moreover, the additional costs may potentially harm the price competitiveness of the iron and steel sector as importers would have to pay on average a relatively higher price when procuring products from Türkiye. From an international benchmark perspective Turkish iron and steel exports to Germany are positioned above the global average due to more emission intensive manufacturing and the absence of a national carbon pricing mechanism. Furthermore, it must be noted that the percentage range on an annual product basis shows clear outliers in the context of the iron and steel sector. Although their individual contribution to the overall export volume to Germany is comparably less significant than that of the sector's Top-3 export categories some CN codes demonstrate cost shares exceeding 20 percent in the relation to the overall yearly export trade. On the other hand, the results of the aluminum sector show a more consistent image with only a few small outliers.

The Top-3 export categories are assessed on a sectoral basis as well. The best-selling product categories in Turkish exports to Germany include CN codes *7318*, *7326* and *7308* in the steel and iron sector and CN codes *7604*, *7606* and *7616* in the aluminum sector (TURKSTAT, 2025a; 2025c). For the iron and steel industry the CN code *7318*, in the context of regional rates and the 100 USD CBAM certificate pricing scenario, accounts for 63,7 million USD (TURKSTAT, 2025a). On the contrary, applying the default values together with the same pricing scenario the result is 65,4 million USD. Regarding the CN code *7326* the regional rates in combination with the 100 USD pricing scenario cause an outcome of 95 million USD whereas the default values account for a result of 89,1 million USD. The CN code *7308* in combination with the regional rates and the 100 USD pricing scenario amounts to 69,9 million USD and connected to the default values to 69,3 million USD. Besides the outcomes for CN code *7318*, the other results confirm the overall findings in the context of the iron and steel sector that on average production in Türkiye is more emission intensive compared to the global average. The fact that the results connected to the default values fall below those linked to the regional rates verifies that emission coefficients in Türkiye for the corresponding CN codes are on average higher.

In the context of the CN code *7604*, applying the regional rates in combination with the 100 USD CBAM certificate pricing scenario, the result accounts for 114,1 million USD. On the other hand, against the backdrop of the default values in connection with the same CBAM certificate pricing the value amounts to 134,1 million USD. For the CN code *7606* the outcome applying the 100 USD pricing scenario in connection with the default values results in 70,3 million USD and with the regional rates in 59,2 million USD. Furthermore, in the context of the CN code *7616* when applying the same pricing scenario in combination with the default values the outcome amounts to 17,3 million USD and linked to the regional rates results in 14,5 million USD. The results for the aluminum sector confirm that in global comparison emission levels in Türkiye are lower than those on an international average. The same result was found when considering the sectors total added cost outcomes as well. Here, Turkish producer's may benefit from improved price competitiveness compared to their average competitor on an international stage.

As part of the assessment the Top-3 export product categories from Türkiye to Germany among the CBAM related CN codes for the iron and steel sector the CBAM costs are calculated accordingly. From a total cost perspective, the average value of CBAM cost amounts to 13,8

million USD for the CN code *7326*, making it the category with the highest overall CBAM costs among the Top-3 export product categories (see Table 9). Regarding the CN code *7308*, the overall cost across all scenarios amounts to 10,4 million USD, placing it in second place among the Top-3 export categories between 2019 and 2024. In the context of the CN code *7318* the average value of CBAM cost accounts for 9,7 million USD across all scenarios, making it the category with the lowest overall CBAM costs among the Top-3 export product categories during the period 2019 to 2024.

Table 9. CBAM cost for the CN code 7326 (2019-2024, USD)

Year	**CBAM Cost Regional rates/100**	**CBAM Cost CBAM Default/100**	**CBAM Cost Regional rates/80**	**CBAM Cost CBAM Default/80**
2019	12.949.488,00	12.140.145,00	10.359.590,40	9.712.116,00
2020	11.838.390,48	11.098.491,08	9.470.712,38	8.878.792,86
2021	15.923.962,08	14.928.714,45	12.739.169,66	11.942.971,56
2022	20.123.858,88	18.866.117,70	16.099.087,10	15.092.894,16
2023	19.383.916,56	18.172.421,78	15.507.133,25	14.537.937,42
2024	14.816.439,12	13.890.411,68	11.853.151,30	11.112.329,34
Total	**95.036.055,12**	**89.096.301,68**	**76.028.844,10**	**71.277.041,34**

Source: TURKSTAT, 2025a.

Considering the Top-3 export product categories from Türkiye to Germany among the CBAM related CN codes for the aluminum sector, depending on export and emission levels also here the inclined costs differ. For the CN code *7604* the average value of CBAM cost amounts to 18,6 million USD across all scenarios, making it the category with the highest overall CBAM costs among the Top-3 export product categories between 2019 and 2024 (see Table 10). In the context of the CN code *7606* the average value of CBAM cost accounts for 9,7 million USD across all scenarios, ranking it in second place. In the context of CN code *7616* the average value of CBAM cost amounts to about 2,4 million USD across all scenarios, making it the category with the lowest overall CBAM costs

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Table 10. CBAM cost for the CN code 7604 (2019-2024, USD)

Year	**CBAM Cost CBAM Default/80**	**CBAM Cost CBAM Default/100**	**CBAM Cost Regional rates/80**	**CBAM Cost Regional rates/100**
2019	11.804.625,70	14.755.782,12	10.044.529,28	12.555.661,60
2020	12.976.797,68	16.220.997,10	11.041.927,77	13.802.409,71
2021	21.617.292,71	27.021.615,89	18.394.105,43	22.992.631,78
2022	23.786.413,08	29.733.016,35	20.239.805,04	25.299.756,30
2023	19.595.143,62	24.493.929,52	16.673.463,34	20.841.829,18
2024	17.538.412,44	21.923.015,55	14.923.395,44	18.654.244,30
Total	**107.318.685,23**	**134.148.356,53**	**91.317.226,31**	**114.146.532,88**

Source: TURKSTAT, 2025a.

Considering the percentage shares for the CN code *7308* it represents the highest among the Top-3 export categories and accounts for an overall mean value of 9,3 percent (see Table 11). In comparison the CN code *7326* represents the second lowest values with an overall average of 6,2 percent. Regarding the CN code *7318* outcomes account for an average value of 4,3 percent representing the lowest proportional results among the Top-3 export product categories. Furthermore, except for the product category *7308* the CN codes remain far below the sectoral average share of nine percent. For the CN code *7308* this indicates a relatively increased proportion of carbon emissions being released during the production process for this CN code positioning it above the sectoral average of nine during the period 2019 to 2024.

Table 11. CBAM cost in relation to the total trade volume for the CN code *7308* (2019-2024, in percent)

Year	**CBAM Cost Regional rates/100**	**CBAM Cost CBAM Default/100**	**CBAM Cost Regional rates/80**	**CBAM Cost CBAM Default/80**
2019	11,2%	11,1%	8,9%	8,9%
2020	9,2%	9,1%	7,3%	7,3%
2021	10,8%	10,7%	8,6%	8,6%
2022	10,3%	10,3%	8,3%	8,2%

2023	9,7%	9,7%	7,8%	7,7%
2024	11,1%	11%	8,8%	8,8%

Source: TURKSTAT, 2025a.

In the context of the aluminum sector percentage shares across the different product categories vary as well. The average value of shares for the CN code *7606* across all scenarios accounts for 7,4 percent during the timeframe 2019 to 2024 (see Table 12). In the context of the Top-3 export categories this CN code stands for the highest results concerning the percentage shares achieved during the 2019 to 2024 period. Regarding the CN code *7604* the average across all scenarios amounts to about five percent. This product category ranks in second place among the other two Top-3 CN codes. For the CN code *7616* average value of shares throughout all scenarios amounts to only 2,7 percent for the period 2019 to 2024. Among the Top-3 export product categories this represents the lowest relative percentage share for the timeframe from 2019 to 2024. The sectoral average equals 5,2 percent for the period 2019 to 2024. Both the CN codes *7604* and *7616* are positioned below the sectoral average whereas the CN code *7604* accounts for a higher average percentage share.

Table 12. CBAM cost in relation to the total trade volume for the CN code *7606* (2019-2024, in percent)

Year	**CBAM Cost Regional rates/100**	**CBAM Cost CBAM Default/100**	**CBAM Cost Regional rates/80**	**CBAM Cost CBAM Default/80**
2019	9,1%	10,8%	7,2%	8,6%
2020	9,6%	11,4%	7,7%	9,1%
2021	6,8%	8,1%	5,5%	6,5%
2022	5,3%	6,3%	4,2%	5%
2023	7%	8,3%	5,6%	6,7%
2024	7,1%	8,5%	5,7%	6,8%

Source: TURKSTAT, 2025a.

The different expenditure outcomes in the context of the regional rates and default values providing the emission coefficient emphasize the impact of emission levels on the total sum of costs inclined by the CBAM. This disparity underlines the variation in the applied emission

coefficients emphasizing that the actual emission load must be lower locally compared to the global average. Consequently, providing a competitive advantage to the local industry in Türkiye in an international comparison. Moreover, it underlines that the expenses to be covered for the purchasing of CBAM certificates can substantially decrease or increase the total additional costs from the importing parties' perspective. Furthermore, the varying levels of cost in connection with the default and regional rates also imply that the assumptions regarding the level of emissions locally and internationally differ significantly. The lower cost level in conjunction with the regional values implies that products e.g., corresponding to CN code *7604* and *7606* are produced with lower emissions in Türkiye than in an international comparison. The effect of the pricing of CBAM certificates on the overall incurring additional CBAM costs also emphasizes the importance of a local carbon pricing mechanism as it directly impacts the competitiveness of product pricing levels from the perspective of the EU importer.

The results in both the aluminum and iron and steel sectors show that the cost effects on a product basis may strongly differ, making it challenging to draw a general conclusion on a sectoral basis as not every item and every producer is affected equally.

As already mentioned, generally the assumption that CBAM costs grow with the increase in Turkish exports to Germany holds true. Although, at the same time, the relative share of products with higher emission levels as part of the total export volume must always be considered as they act as the cost driver. In some cases, e.g., in the aluminum sector when comparing the CBAM costs of the year 2021 to the year 2023. In 2023, CBAM costs are relatively lower although the export volume is higher in comparison to 2021. This example emphasizes the importance of considering the relative share of CBAM costs to the overall annual export volume. Here, the calculated average using the default values in combination with the 100 USD scenario amounts to 5,3 percent in 2023 versus 6,3 percent in 2021. Nonetheless, in addition, the change in price per ton of a good needs to be considered as well. The higher the price per ton of product the lower the relative share of carbon tax despite the fact that emission levels are comparably higher and hence their overall incurred cost.

For the assessment in accordance with the regulation only Scope 1 emissions are considered. Furthermore, for a number of CN codes both in the context of the regional rates and default values a category average is applied. This means that on a four-digit CN code level an emission coefficient is not provided and hence, the calculated averages out of the given values in connection with the

longer CN codes out of this product category are used. As mentioned above, due to the substantial role the emission coefficients play in calculating the CBAM costs, their correct determination is crucial. Regarding the calculated costs as part of this study more importance should be given to the outcomes in connection with the regional rates as the corresponding emission coefficient. As they are based on a national assessment, they may be truer to the actual production conditions found locally. In the context of the CBAM, manufactures must assess the emission levels that occur during the production process on the basis of the three emission scopes given. Furthermore, this also implies that the emission coefficients applied during the assessment only allow for a general picture in terms of the results regarding the potential costs as emission levels on a production facility basis may differ locally.

Regarding the applied pricing for the CBAM certificates, as carbon costs are set to rise in the EU an assumption in form of two scenarios, 80 USD and 100 USD, was implemented, considering the current costs for EU ETS allowances and the potential deductible due to a local ETS to be introduced in Türkiye. Due to the fact that the values for the emission coefficient and the cost of CBAM certificates are assumed in the context of the calculations, the actual occurring expenses for CBAM certificates to be purchased by an EU importer in connection with exports from Türkiye in the corresponding sectors may differ in the future. Nonetheless, the results offer a reliable indication in terms of what potential cost in connection with the CBAM regulation from the perspective of the Turkish iron and steel as well as aluminum sector could amount to. In particular for the iron and steel sector where additional costs reach double-digit percentage shares in relation to the overall trade volume in USD, the findings provide a cost estimation.

In terms of the implementation of a local ETS, national carbon price levels will have a substantial effect on prices for goods exported from Türkiye to Germany. Although, the underlying assumption is that a carbon market will facilitate as well as incentivize the green transformation of industry and climate action, these national processes require time, know-how and investments. From the perspective of the exporter, the local additional costs to be covered due to a carbon price may be passed on to the importer on the customer side. This may also hold true in terms of the cost of decarbonization investments to be passed on to the customer by the producer. On the other hand, the lower the carbon price to be paid locally is in comparison to the cost of CBAM certificates, the more the German importer will have to pay as only little can be deducted. Furthermore, the level of Turkish carbon pricing also affects the national industries overall,

including companies that sell to the national market rather than export. This may also lead to price effects on Turkish products in the national market.

In this context, the policy framework and pricing of carbon emissions must consider both the perspective of non-exporting and exporting industry to prevent micro- and macro-economic implications. On the other hand, in the context of exports to Germany it must be emphasized that cost competitiveness from a global perspective must be considered. This includes both the scenario that exporters pass on the carbon price to German customers abroad via higher product prices and that the German importer has to pay higher costs for CBAM certificates if the local carbon price in Türkiye is low. This risk must be considered by both the private sector and the public sector in the course of bilateral trade relations. On the Turkish side, the main concern here is to maintain its own competitiveness both in the course of climate action and in terms of the price competitiveness of products. From a German perspective, this is about the security, diversification and resilience of supply chains as well as avoiding price increases that would have an impact on the domestic market and the exporter's own further business activities. A potential risk may be that supplying industries in countries abroad can no longer compete due to slow progress regarding decarbonization of production processes or asymmetry in carbon pricing locally.

In terms of recommendations for further research to be conducted similar assessments could be conducted in the context with the EU in general as well as other individual countries. Furthermore, these assessments could cover the other sectors relevant under the CBAM which were not considered as part of this analysis in detail such as the fertilizer or cement industries. Once confirmed emission level data sets are available on production facility basis further research regarding the actual cost on a sector basis could be executed across the CBAM-affected industries in Türkiye. In addition, with the full introduction of the CBAM following the end of the transitional phase in 2026, the cost assumptions can be tested and verified against actual trade data available in this regard. Furthermore, studies regarding local carbon pricing levels in the context of price competitiveness and micro- and macro-economic impact may provide orientation and a perspective on potential risks and opportunities. From a European and German perspective an assessment of potential risks regarding supply chain resilience, diversification and security as well as price effects should be conducted.

5. POLICY RECOMMENDATIONS

From the perspective of both countries the CBAM exerts additional cost pressures that affect the exporting and importing party as well as possibly the countries' economic development on a micro and macro level. In addition, the CBAM poses a risk from a supply chain security, resilience and diversification standpoint for both Germany and Türkiye. From a Turkish risk perspective, the buyer's side is more relevant here, whereas from a German point of view, the supplier side harbors a risk. On the other hand, the CBAM is a tool to ultimately facilitate the reduction of greenhouse gas emissions and foster the green transformation of industry as well as decarbonization of sectors in third countries.

Overall, to lower potential risks and economic effects cooperation between the two trade partners across the different policy areas is required. Due to the high importance of Germany as an export market for Turkish goods measures must be taken to prevent negative effects. Simultaneously, exports targeting other EU markets and beyond will also benefit from corresponding policy measures. Furthermore, Türkiye may regard this adaptation as an opportunity to position itself as a green sourcing country on a global scale. At the same time, it also provides the opportunity for German-Turkish economic ties to further evolve and grow as a result of the adaption process towards a greener supply country. Furthermore, to ensure and support a smooth transition and implementation process a joint council on a Türkiye-EU level may be implemented where aspects such as incentive and funding schemes, standards and norms, capacity building and challenges as well as risks can be adressed on a continous basis, among others.

From the Turkish perspective it is crucial to provide a comprehensive legislative framework, in form of a master plan such as the climate law which was passed in Türkiye on July 2, 2025, in the context of climate protection and corresponding measures, climate action, green transformation measures, emissions trading as well as clear targets covering the micro- and macro-economic level, in particular with the CBAM on the horizon.

This regulatory scheme should be in line with international norms and standards and must reflect and consider internationally concluded frameworks and agreements such as the Paris Agreement. Moreover, on a micro-economic level it may also include specific measures and actions for exporters in the context of the CBAM and the corresponding affected sectors. Furthermore, the responsibility of formulation, coordination, tracking and following-up on a macro level of the different aspects of the framework, such as target attainment should be done through a central

governmental body. The formulation, implementation of measures and action plans, tracking, follow-ups and coordination on a micro level, on the other hand, should be conducted by the for the specific area responsible public authority such as the corresponding ministries. If required beyond the framework of the Climate Law but complementary to it ministries may formulate additional legislation on a micro level.

This legislative framework should provide clear emission and pollution reduction targets linked to specific action plans on an overall economic and sectoral basis. The overall targets should concern the macro-economy and country as a whole whereas the sectoral targets should reflect the goals on a micro level. Simultaneously, orientation for the affected stakeholders such as companies and society should be provided through comprehensive action plans and roadmaps. In addition, awareness-building in the context of these targets should be widely conducted. Furthermore, public authorities may render corresponding guidance and contact points. In particular, small- and medium-sized enterprises (SMEs) as well as civil society must be supported throughout the transitional process.

As part of the execution of action plans and targets concerning climate protection and the green transformation process measures and sectors must be prioritized under a climate law. As the transition process is time- and cost-intensive, prioritizing specific measures and especially emission-intensive sectors provides for a more coordinated and more sustainable path towards goal achievement.

The transition process and decarbonization efforts require financial resources. Therefore, public authorities must develop a comprehensive plan encompassing various financial support mechanisms and tools as well as incentives. More vulnerable stakeholder groups such as SMEs or women should be considered against the backdrop of a just transition. In terms of the CBAM exporters should receive additional financial support to facilitate the transformation of production processes and create sufficient internal capabilities to adapt and manage the requirements. This area also offers opportunity for international cooperation and funding.
Nonetheless, designing funding and incentive programs, the approach of liberal market policy and market development should be considered. In the course of the green transformation, technological openness should be practiced. When choosing technologies decarbonization and competitive advantage benefits should be considered. Depending on the context, funding instruments and

subsidies should be used to promote the natural emergence of green lead markets rather than financing their existence such as the tool contracts for difference. This is crucial to sustainably create new and competitive markets and make the transitional process feasible.

Generally, funding in the form of subsidies or incentives can be used to reduce the entry barrier and financial burden, e.g. when using alternative, green energy sources or new technologies. Moreover, specifically in the context of global markets, in certain cases funding may be crucial to protect or increase levels of competitiveness during the transitional process although the aspects of market distortion and fairness must always be considered. A distinction is made here between support for investment and operating costs. Based on certain standardized criteria to be developed such as the stakeholder group, type of technology to be used, cost and project scope, importance of the projects for society or the economy, corresponding appropriate funding concepts should be developed and the funding of investment and/or operating costs determined.

The development of local capabilities and expert know-how in the area of climate protection and green transformation is crucial. The availability of local capabilities is crucial in terms of preparing, carrying out and coordinating the transition as well as in the context of prevention. In addition, CBAM affected groups, in particular those most vulnerable due to limited resources such as small- and medium-sized, should be supported in this regard. Furthermore, public authorities should develop corresponding programs and offer funding for corresponding efforts to be conducted by third parties. In this context, close cooperation with institutions and firms from the EU in the corresponding areas may benefit such measures. In particular in the context of cross-border SME cooperation.

The awareness building is particularly important in the context of prevention work, to create interest in climate action and green transformation measures as well as motivate stakeholders to participate in these processes. Awareness building activities should start at a young age and at the lowest educational level. The development of a skilled workforce is key to plan, prepare and conduct the transition and corresponding actions as well as achieve the set targets in the various areas. This skilled workforce encompasses both white- and blue-collar workers as well as scientists and educators, among others. Retraining opportunities are important. In addition, an increased demand for experts and Research and Development (R&D) activities will occur due to the innovative nature of certain areas of climate action and the green transformation process. This also

applies in the context of the CBAM for exporting companies where new services may be required, and internal capabilities may have to be extended through hiring additional expert staff. Public authorities should develop corresponding programs and offer funding for corresponding efforts to be conducted by third parties.

Public authorities should also actively support the development, facilitation and funding of national R&D capacities, e.g., for the development of required decarbonization technologies and their application in close cooperation with the private sector or the in-depth analyses of sectoral demands and risks. Forming their own capabilities in these areas can support local value creation, contribute to the development of new sales markets, lower the dependency in terms of know-how and availability of technology to third parties and accelerate the transition process. The national funding program portfolio may be further complemented by targeted incentive and funding schemes from provided by Germany or the EU.

Furthermore, public authorities should continuously evaluate and track the possible price effects and outlooks as well as potential effects on the supply chain with a particular focus on the most important sales markets for Turkish exporters in the EU due to the CBAM. Moreover, scenarios must be identified to lower corresponding risks on a sectoral basis in case demand from the European market declines in the context of the CBAM. Scenario analyses should also include continuous impact assessments of national economic development. Overall, based on the results of the above-mentioned suggested research measures on a micro and macro level should be formulated and implemented.

For incentivizing emission reduction efforts and funding the green transition a national ETS with a comprehensive sectoral coverage must be implemented. Against the backdrop of the CBAM such an ETS would lower the risk of diminishing price competitiveness for Turkish exporters. The locally paid carbon price can be deducted from the cost of CBAM certificates to be purchased by the German importers. When establishing the price for carbon emissions in the Turkish market a benchmark considering potential CBAM certificate prices, carbon costs in third countries and limiting price factors locally, e.g., possibly exerted high-cost pressure on non-exporting firms, must be assessed. International and EU standards as well as regulations must be considered to ensure compatibility with the systems.

From a German standpoint the CBAM's central benefit is that it protects the local manufacturing industry from a loss of competitiveness due to carbon leakage. Nonetheless, possibly rising prices for imported goods due to added emission costs as well as an increased risk regarding supply chain diversification, security and resilience call for precautious measures to be taken from a policy perspective.

As an EU member state Germany must support third countries and trade partners locally as part of their adaption process to the CBAM regulation. Furthermore, the lack of readiness in the context of the CBAM regulation of exporting third countries to Germany poses a supply chain risk to German importers. Here, a collaborative dialogue, technology and know-how transfer, close cooperation as well as provision of financial resources through specific funding programs may form the foundation of corresponding support measures. Specific action plans, programs and cooperation formats must be formulated and implemented in a continuously collaborative manner and on a demand-basis together with the partner and relevant stakeholders. Overall, this area also provides the opportunity to further grow and multiply relations in the Turkish-German context.

Based on assessments and analyses German public authorities should consistently estimate and follow up on the price risks and forecasts as well as potential impacts on the supply chain on a supplier country basis. Furthermore, possible alternative sourcing scenarios must be developed to minimize corresponding risks on a sectoral basis. Moreover, the impact of price increases on imported products from a sectoral perspective and its effects on national economic development and local inflation must be assessed. These measures apply both in the context of Turkish-German ties but also hold true in relation to other countries.

NOMENCLATURE

CBAM	Carbon Border Adjustment Mechanism
CN	Combined Nomenclature
COP	Coference of the Parties
CO_2	Carbon Dioxide
CO_2eq	Carbon Dioxide Equivalent
Destatis	Federal Statistical Office
DIHK	German Chamber of Commerce and Industry
ETS	Emission Trading System

EU	European Union
R&D	Research and Development
SME	Small and medium-sized enterprises
USD	United States Dollar
KSG	Bundes-Klimaschutzgesetz
tCO_2e/t	Tonne CO_2e/tonne Goods
TURKSTAT	Turkish Statistical Institute
UNCTAD	United Nations Conference on Trade and Development
WTO	World Trade Organization

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DECLARATION OF ETHICAL STANDARDS

The authors of the paper submitted declare that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Pauline Sophie Seyfert: Responsible for conceptualization, applied methodology, data collection and formal analysis as well as writing of the study.

Yunus Özcan: Performed supervision, supported in applied methodology and formal analysis as well as conducted review and editing.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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