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Measuring the Cost of the European Union's Carbon Border Adjustment Mechanism on Moroccan Exports

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Abstract: The 'Fit for 55' policy package was presented in the European Commission's Green Deal framework, comprising a set of proposals to improve existing energy and climate legislation. Among its main proposals was a revision of the European Union's Emission Trading System to expand its sectoral coverage. Anticipating the possible loss of competitiveness with carbon pricing within the EU—which may lead to 'carbon leakage'—a carbon border adjustment mechanism (CBAM) was included in the package. This scheme takes the form of an export tax levied by the European Union on some goods manufactured in non-carbon-taxing countries. In this paper, we provide a first-order estimate of the potential impact of CBAM on Morocco's exports using an input–output approach. Our main findings suggest that the scheme would yield a carbon bill ranging from USD 20 to 34 million annually to Moroccan exporters in its initial phase. Morocco can mitigate such economic losses by instituting a national Emission Trading System, a tax reform, or speeding up the decarbonization of its economy.

Keywords: European Green Deal; carbon leakage; carbon border adjustment mechanism; Morocco; input–output approach

JEL Classification: C64; D57; F18; F14; H23

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1. Introduction

In December 2019, the European Commission announced its "Green Deal", an overarching environmental strategy to achieve climate neutrality across the European Union by 2050. This ambitious plan includes a broad spectrum of policies and actions dedicated to addressing climate change, promoting sustainable development, and improving living standards for citizens within the EU. Following this initiative, in July 2021, the Commission launched "Fit for 55", a crucial subset of policy measures under the Green Deal's umbrella aimed at significantly reducing greenhouse gas emissions—targeting at least a 55% reduction from 1990 levels by the year 2030. This policy package includes a proposal to implement a carbon border adjustment mechanism [1]. The purpose behind CBAM is mainly to tackle carbon leakage's economic and environmental risks by applying charges on select imports into Europe. The scheme takes the form of a levy and ensures that goods imported are subjected to equivalent carbon constraints as those produced domestically under the EU's Emission Trading System (ETS)—thereby shielding EU industries against inequitable competition while motivating global emission reductions [1–3].

While CBAM is promoted as part of an ambitious climate policy to counteract carbon leakage, some authors view it as disguised protectionism that could sabotage climate policy endeavors and development prospects [4,5]: the CBAM is likely to impose higher export costs on the EU's trade partners that do not tax carbon emissions, disproportionately affecting developing countries [6,7]. Since the "Fit for 55" was released to the public, numerous researchers have been attempting to predict both its economic impact and environmental benefits. Proponents have highlighted its potential to reduce carbon emissions [8], while critics pointed out issues related to inconvenience for developing countries and conflicts with World Trade Organization rules [4,9], especially if CBAM coexists with free allowances [3]. At the time of writing this paper, the implementation phase for the CBAM had already begun. As a result, discussions about its compliance with WTO regulations have become less relevant.

Morocco and the European Union share solid economic ties; in addition to their geographic proximity, both parties signed an Association Agreement in 1996. In 2021, they started discussing modernizing trade investments and relations to deepen their cooperation [10]. The region is the primary trade partner and has accounted for more than half of Morocco's exports in the past decade [11]. The EU's purchases from Morocco consist mainly of mechanical, metallurgical, and electrical machinery, transport equipment, textiles, food, and miscellaneous manufactured products [12]. According to Berahab and Dadush [9], only 3% of Morocco's exports to the EU are covered by the initial phase of CBAM. Although Morocco would not be the most affected by the tax, the authors expect it to damage its export interests. Likewise, Eicke et al. [13] found the country to be at a relatively high risk of repercussions following the full implementation of CBAM.

To the best of our knowledge, the quantitative impacts of CBAM on Morocco have not yet been assessed. This study aims to provide a first-hand measure of the policy's potential repercussions on Morocco's exporting sectors.

This paper is structured as follows. Section 2 outlines the relevant features of the 'Fit for 55' policy package and provides a concise literature review on the rationale and implementation of carbon border adjustments. The section concludes with a summary of scientific research conducted on the EU's CBAM. Section 3 outlines the methodology employed to construct the model for Morocco and the data used to estimate the carbon bill the Moroccan exporters will be charged. Section 4 is dedicated to the presentation and discussion of our results. Section 5 explores policy issues and implications. We conclude in Section 6.

2. A Literature Review

2.1. On the European Union's Emission Trading System

The carbon border adjustment mechanism has a complementary relationship with the EU's carbon market. To understand why the European Commission has put the carbon border adjustment mechanism among its top policy priorities, we provide a brief background of the EU's ETS in the following.

The EU's ETS was launched in 2005 to regulate greenhouse gas emissions within the Union. It mainly targets highly polluting sectors such as power and heat generation along with other energy-intensive industries, including oil refineries, iron and steel, aluminum, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids, and bulk organic chemicals [14].

The system relies on a 'cap-and-trade' principle, where a limit (or cap) is set each year for the maximum level of allowable greenhouse gas emissions from designated industries. Tradable permits equivalent to one ton of carbon dioxide are created for each emission unit; these permits, also called allowances, can be received or purchased by regulated industries that must surrender enough to cover their emissions. If a regulated firm reduces its emissions, it can either keep the excess permits to cover its future needs or sell them to another firm that is short of permits. Equivalently, entities that do not have enough allowances must either reduce their emissions or buy allowances from other firms on the carbon market, depending on their cheapest alternative. To cut down overall greenhouse gas emissions within the union, the cap (and thus available permits in circulation) is lowered over time.

2.2. The "Green Deal" and the "Fit for 55" Policy Package

The European Union has a long history of being engaged in tackling climate change and global warming through the implementation of ambitious legislation and binding emission targets. The Green Deal provides a roadmap to transform the EU's climate aspirations into tangible outcomes and recognizes the importance of efficient policies in achieving climate neutrality by 2050. The 'Fit for 55' policy proposals have been developed to strengthen existing legislation in accordance with the European Union's new climate objectives. This comprehensive package includes some revisions to the EU's ETS, such as accelerating the pace of the annual cap reduction, cutting down free carbon allocations, and expanding the scheme to cover other sectors and scopes [15]. While these regulations have praiseworthy intentions, they may pose potential threats to the European Union on two different yet very related levels. From an economic perspective, a stricter ETS can induce higher production costs for EU-based manufacturers compared to their foreign counterparts. This loss of competitiveness can yield a relocation of heavy-emitting industries to other countries and brings up the environmental aspect of the threat: the EU's climate endeavors would be antagonized if these industries were to relocate to non-carbon-taxing countries [16–18].

Anticipating the public's reaction to these new reforms, the European Commission has proposed a carbon border adjustment mechanism (CBAM). This scheme is designed to parallel the EU's ETS by applying similar carbon prices on imported goods [15].

2.3. Carbon Leakage and the Rationale for Carbon Border Adjustments

Unilateral policies to battle climate change are prone to be antagonized by free-riding and carbon leakage [19]. The reasoning behind this is very straightforward: in the case of carbon pricing, the induced cost increase may motivate targeted industries and firms to relocate their carbon-intensive activities to countries or areas with little to no emission constraints, also called 'pollution havens'. Meanwhile, domestic consumers increase their consumption of cheaper carbon-intensive products. As a result, the emission reduction achieved by the country implementing the climate policy would be counterbalanced by the increase in emissions in other countries with no restrictions in place [17,18,20–22].

While the authors have not agreed on the magnitude of the potential carbon leakage induced by a given environmental policy [16], border adjustment measures for competing imports seem the most popular and widely discussed way to address this concern in the relevant literature. According to Ismer and Neuhoff [23], carbon adjustments can mitigate carbon leakage and loss of competitiveness for domestic firms and act as leverage for foreign industries to implement emission reduction measures. Essentially, there are two principal motives behind carbon border adjustments: the economic rationale to mitigate the competitive advantages of non-taxed, carbon-intensive foreign products due to industrial relocation and the environmental motivation to suppress or diminish resulting emission increases [24]. Such measures can come in the form of import tariffs, export rebates, or the necessity for importers to surrender carbon permits to cover the greenhouse gases emitted during the production process of the imported goods.

Despite uncertainties surrounding the magnitude of carbon leakage and the effectiveness of carbon pricing under a carbon border adjustment mechanism in reducing global emissions [19], the CBAM has been proposed by the European Commission and is already underway at the time of writing this article. On one hand, in their report for UNCTAD [3], the authors found that an increase in carbon pricing could lead to an increase in carbon leakage, with higher prices resulting in higher leakage rates. However, this study presents the CBAM as a potential, although partial, mitigating approach. Clora et al. [25] further suggested that the magnitude of leakage is due to fragmented climate policies, as greenhouse emission reductions in each country can be partially offset by an increase in emissions in other countries. The authors call for a joint CBAM implementation involving China and the US, arguing that such a coalition could reduce leakage, improve energy-intensive sectors production, and increase welfare for the participating countries.

On the other hand, Korpar et al. [26] argued that CBAM has limited impacts on emissions and may contribute to an increase in emissions within the EU, making it harder to achieve its carbon neutrality goals. Similarly, Siy et al. [27] concluded CBAM's potential to counteract the EU's efforts to reach carbon neutrality.

Notwithstanding these uncertainties and contrasting views, the mere proposition by the European Commission has sparked protests from countries like China, Brazil, India, and South Africa [9]. In this study, we focus on assessing and discussing its potential effects on Morocco.

2.4. The Empirical Assessment of the EU's CBAM

In practice, the CBAM mirrors the ETS: European importers must purchase emission allowances to cover greenhouse gas emissions embedded in products imported from non-carbon-taxing countries. The European Commission foresaw a transitional period from 1 October 2023 to 31 December 2025 [28] before the full implementation of CBAM. This period is intended to allow the Union's trade partners to establish effective carbon auditing mechanisms for their supply chains and to adapt to the Union's trade laws.

In its initial phase, CBAM includes the power generation sector and energy-intensive industries, such as oil refineries, cement, iron, steel, aluminum, paper, glass, chemicals, and fertilizers [3], and applies to direct greenhouse emissions of the production process (scope 1). The extension of CBAM to other products and services, the inclusion of emissions from electricity used in production (scope 2), and the possible extension to emissions from other industries along the value chain (scope 3) are to be determined by the end of the transition period [10].

As a relatively recent policy proposal, research papers on the EU's CBAM are not abundant, particularly quantitative assessments of its effects. Reviewing the relevant literature reveals that aside from document analysis, speculative reasoning, and review articles, researchers have used few empirical methods to evaluate CBAM's effects on the EU and its trade partners.

The widely employed method to conduct an impact assessment of the scheme is the Global Trade Analysis Project with Energy Substitution (GTAP-E), a static multisectoral multiregional computable general equilibrium approach. Chepeliev [29] used this model to study the possible implications of CBAM on Ukraine and other trading partners. For a carbon price of USD 26/tCO_2, the authors found Ukraine to be the most impacted country, with a per capita income change of 0.4% and reductions in iron and steel production of 3.9%, but minimal impacts were found on most EU partners. In their application, Morocco was aggregated with the MENA region, for which the author found a change in per capita income of −0.03% and a reduction in exports of 0.9%.

Similarly, in a joint project conducted with Purdue's Center for Global Trade Analysis, Durant et al. [3] used the same approach and found that countries like the US, China, and Japan benefit in terms of real income. In contrast, Russia, Saudi Arabia, and North African countries experience losses and an increase in unemployment. The study further suggests that the average reduction in exports for developing countries ranges between 1.4% and 2.4%, depending on the carbon price. Therefore, they conclude that for most countries, the effects of CBAM are not substantial.

Lee and Jeongho [30] observed a decrease in Korean output and exports of chemicals, metal, and machinery industries. Sun et al. [7] found the policy to increase the EU's GDP at the expense of developing countries experiencing diminished welfare due to contractions in production and export volumes. Gu et al. [6] and Ramadhani and Koo [31] found similar results for BASIC countries (Brazil, South Africa, India, and China) and Indonesia, respectively. Siy et al.'s [27] results suggest that the adoption of CBAM in the EU would negatively affect US social welfare but positively affect China, Russia, the EU, and the world. Additionally, their findings point to emissions reduction in the rest of the world but an increase in the EU's emissions, thereby counteracting the group's effort to reach carbon neutrality.

It is important to note that while GTAP-E allows for a global overview and benchmarking of the policy's effects, it requires substantial computational resources, extensive trade flow data, and the complex handling and calibration of economic structures and production technologies for multiple countries or regions.

For other methods, we found Beaufils et al.'s study [32], which used a throughflow-based accounting method to analyze the impact of CBAM on the EU's trade partners. They found that the most negatively impacted countries were the low- and middle-income countries with a proportion of exports to the EU. As for Mortha et al. [33], they used a gravity model to analyze the impact of CBAM on the Asian Pacific region. They found a limited welfare impact with the largest export reduction in the iron and steel industry (−1.5%). Dobranschi et al. [34] also used a gravity model to measure the impact of CBAM on Visegrad countries (Czechia, Hungary, Poland, and Slovakia) and found a small negative impact on growth and a small reduction in GHG emissions.

Given the available data and Moroccan exports' significant reliance on the European market, it is apparent that the new European trade law will inevitably impact the country. The studies conducted so far have lumped Morocco with neighboring countries to provide rough estimates. In the following section, we attempt to provide a quantitative analysis of the anticipated effects on the Moroccan economy.

3. The Model and Data Used

3.1. The Input–Output Framework

For a first-hand estimate of the effect of the EU's CBAM on Moroccan exports, we chose a single-region input–output analysis. This framework, while limited, allowed us to focus on domestic impacts rather than tracing global supply chains. It also accounts for data availability, ensuring transparency and ease of interpretation.

The input–output table is a collection of data characterizing the economic system for a specific geographic region. The basic form of the model consists of a system of linear equations, each of which describes how an industry's output is distributed throughout the economy. It can, however, be extended to incorporate "...additional details of economic activity, such as overtime or space, to accommodate limitations of available data or to connect input-output models to other kinds of economic analysis tools." [35]

The most used source of information to construct an input–output table is the national accounts. The popularity of these accounts is mainly due to two aspects. First, industrial design considers the industry's ability to produce multiple products. Second, since national accounts have been adopted by the UN as an international standard for data collection, they offer widespread availability and accessibility across various regions, facilitating in-depth economic studies.

The input–output approach is a well-established methodological framework pioneered by Wassily Leontief in the late 1930s. It is grounded in the general equilibrium theory, which emphasizes the interdependence of industries within an economy through the exchange of goods and services. Its core is the input–output table, a comprehensive data matrix that captures the flow of products across sectors, both as inputs to production processes and as final goods and services. By quantifying these inter-industry linkages, the input–output model enables researchers to identify the effects of changes in final demand, production levels, or investments within a particular sector on the wider economic system [35,36]. Several studies relied on an input–output approach for an impact assessment; Kim et al. [36] and Zhang et al. [37] employed this framework to analyze the mining industries in South Korea and China, respectively. Lee et al. [38] used it to inspect the coal extraction industry in Korea, while Yang et al. [39] leveraged it to estimate the embodied carbon in China's exports. Furthermore, Haddad et al. [40] used a regional input–output method to quantify the water content in Moroccan trade, and Acar et al. [41] to assess the impacts of CBAM on Turkish exports.

In its simplest form, the model takes the following general expression:

$$x = Ax + f \tag{1}$$

which can also be written as:

$$x = (I - A)^{-1} f = Lf \tag{2}$$

where x is the vector of gross output; f is the vector of final demand; and A is the input coefficients matrix (see Miller and Blair [42] for an in-depth explanation of the intuition behind basic input–output models and their use). Equation (2) illustrates the dependence of the gross output on the final demand.

3.2. Building the Moroccan Input–Output Matrix

The data used were obtained from the 2019 Supply and Use Table (SUT) for the Moroccan economy produced by the High Commission for Planning of Morocco, which comprises 20 sectors and 20 products. Although more recent data from 2020 are available [43], the period chosen is not trivial: Morocco announced its first lockdown in March 2020, after which the economy entered a recession. We preferred using 2019 as it represents an average year for the Moroccan economy, unaffected by the COVID-19 pandemic.

We followed the methodology Haddad et al. [44] proposed to build the 2013 Moroccan input–output matrix. The aim was to transform transactions initially evaluated at market prices into flows estimated at basic prices [45]. We provide an overview of the method relying on the author's procedure and Miller and Blair [46].

National accounts have a "commodity-industry" format, allowing for the fact that an industry may produce more than one commodity (product). Let x and q denote industry and commodity outputs, respectively.

i. Based on the SUT, the sales structure of the Use table's economic flows was deconstructed. The shares obtained were then used to estimate the allocation of margins and indirect taxes for all users of the economy as follows: intermediate consumption, household, public administration, and non-profit institution demands, gross fixed capital formation, and exports. The hypothesis obtained is that all users' margin coefficients and product tax rates are the same.
ii. Similarly, the allocation of imports for all users (except for the export component of the final demand) was also estimated.
iii. By simply deducting the indirect taxes, margins, and import allocations from the original Use table, a new Use table with flows evaluated at basic prices was obtained. The resulting matrix is denoted U. Each element of $U = [u_{ij}]$ is the value of purchases of commodity *i* by industry *j*. In junction with total industry output, x, those parallel to the classical technical coefficients ($A = [a_{ij}]$) are noted $B = [b_{ij}]$ and defined as:

$$B = U\hat{x}^{-1} \tag{3}$$

where column *j* represents the value of inputs of each commodity per the dollar worth of industry *j*'s output. The table obtained has a commodity-by-industry structure.
iv. The structure of the make table was used to transform it into a symmetrical matrix. The make table or matrix shows how industries make commodities, usually denoted as V. Each element of the matrix v_{ij} shows the value of the output of commodity *j* produced by industry *i*. The transformation of the Use table with a basic price to an input–output occurs as it relies on matrix D, which reallocates back the commodity inputs into the industries where they are made (for intermediate consumption and final demand). D has the following industry-by-commodity dimensions:

$$D = V\hat{q}^{-1} \tag{4}$$

Here, q is the total commodity output in the use table. Each element of D $[d_{ij}]$ is the fraction of the total commodity j output that was produced by industry i.
The key equation in an industry-by-commodity framework becomes the following:

$$x = DBx + De \tag{5}$$

DB is a matrix of technical coefficients more parallel to A in the classic input–output model. It shows inputs from industries per the dollar worth of industry production. And it has an industry-by-industry dimension.

The outcome of these steps is a ready-to-use symmetric input–output table with 20 sectors and the final demand for the 2019 Moroccan economy required for our analysis. More details on the definitions and calculations in such a framework can be found in Miller and Blair [46].

3.3. Sectoral Greenhouse Gas Emission Intensity

Greenhouse gas emission intensity coefficients are essential for calculating the emissions associated with commodities exchanged within an economy. These coefficients indicate the amount of pollution emitted by each industry to produce one unit of gross output.

We used emission coefficients from the EORA database to estimate carbon emissions associated with economic activities [47,48]. It is a multiregional input–output (MRIO) table that provides a time series of high-resolution input–output tables, together with matching environmental and social satellite accounts for 190 countries. The version used in this study is the EORA26 MRIO, which aggregates all countries into a common 26 industry classification. It converts the full EORA MRIO into symmetric product-by-product input–output tables using the industry technology assumption. The EORA26 MRIO's sector classification aligns with the procedures used to construct the input–output table for Morocco, facilitating a straightforward mapping of the Moroccan data from the 26 sectors in EORA26 to the 20 sectors in our input–output table [40].

Table 1 depicts sectoral greenhouse gas emissions in tons per unit of gross output, and the most carbon-intensive sectors are electricity and water (E00), followed by transport (I01), the mining industry (C00), and agriculture, forestry, hunting, and related services (A00). Aside from electricity and water, the industries targeted by CBAM have relatively moderate greenhouse gas emission intensities.

Table 1. Sectoral greenhouse gas emissions are expressed in metric tons of a CO_2 equivalent per unit of gross output.

Sectors		CO_2/GO (Tons Per Million USD)
A00	Agriculture, forestry, hunting, and related services	7.366
B05	Fishing, aquaculture	0.372
C00	Mining industry	5.757
D01	Food industry and tobacco	0.585
D02	Textile and leather industry	1.180
D03	Chemical and para-chemical industry	6.537
D04	The mechanical, metallurgical, and electrical industry	1.878
D05	Other manufacturing, excluding petroleum refining	1.644
D06	Oil refining and other energy products	6.537
E00	Electricity and water	47.678

Table 1. *Cont.*

Sectors		CO_2/GO (Tons Per Million USD)
F45	Construction	0.816
G00	Trade	0.999
H55	Hotels and restaurants	1.434
I01	Transport	17.892
I02	Post and telecommunications	1.096
J00	Financial activities and insurance	0.685
K00	Real estate, renting, and services to enterprises	0.685
L75	General public administration and social security	1.059
MNO	Education, health, and social action	7.089
OP0	Other non-financial services	0.257

Source: EORA and Morocco's input–output table

3.4. Morocco's Exports to the EU

The SUT provides Morocco's exports to all its trade partners taken together. Table 2 provides a profile of Moroccan sectoral exports to the rest of the world, converted into USD.

Table 2. Morocco's exports to the rest of the world per sector for the year 2019 (in millions USD).

		Exports to the Rest of the World (Million USD)
A00	Agriculture, forestry, hunting, and related services	2504.97
B05	Fishing, aquaculture	382.13
C00	Mining industry	1102.27
D01	Food industry and tobacco	2842.00
D02	Textile and leather industry	3565.98
D03	Chemical and para-chemical industry	4087.49
D04	The mechanical, metallurgical, and electrical industry	9699.62
D05	Other manufacturing, excluding petroleum refining	1149.46
D06	Oil refining and other energy products	32.10
E00	Electricity and water	68.32
F45	Construction	18.52
G00	Trade	936.48
H55	Hotels and restaurants	69.77
I01	Transport	4615.71
I02	Post and telecommunications	256.87
J00	Financial activities and insurance	165.80
K00	Real estate, renting, and services to enterprises	3903.24
L75	General public administration and social security	230.79
MNO	Education, health and social action	5.33
OP0	Other non-financial services	16.87

Source: Morocco's input–output table from the author's computations.

Since the CBAM is exclusively applied to the commodities destined for the EU, we need to dissociate the relevant information for our analysis from Morocco's exports to the rest of the world provided by Table 2. To this end, we used other sources of data to provide estimates.

The trade map is an online trade statistics database developed by the International Trade Centre, a joint agency of the United Nations and the World Trade Organization. This tool provides comprehensive international trade statistics reported by countries to the United Nations Statistics Division. With data coverage spanning over 220 countries and territories and 5300 product categories defined at the two-, four-, or six-digit level of the harmonized system level [49], the trade map offers a robust source for examining trade flows, market shares, and competitive indicators. Exports in services were estimated using OECD.Stat database. Morocco's exports to the EU are depicted in Table 3.

Table 3. Moroccan sectoral exports to the EU27 market for the year 2019 (millions of USD).

		Exports to EU27 (Million USD)
A00	Agriculture, forestry, hunting, and related services	2068.26
B05	Fishing, aquaculture	145.62
C00	Mining industry	342.68
D01	Food industry and tobacco	1905.97
D02	Textile and leather industry	3535.49
D03	Chemical and para-chemical industry	1244.57
D04	The mechanical, metallurgical, and electrical industry	8698.75
D05	Other manufacturing, excluding petroleum refining	1057.42
D06	Oil refining and other energy products	1.79
E00	Electricity and water	60.74
F45	Construction	12.36
G00	Trade	645.10
H55	Hotels and restaurants	46.57
I01	Transport	3081.00
I02	Post and telecommunications	171.46
J00	Financial activities and insurance	110.67
K00	Real estate, renting, and services to enterprises	2605.42
L75	General public administration and social security	154.05
MNO	Education, health, and social action	3.56
OP0	Other non-financial services	11.26

Source: International Trade Center [12], OECD stat [50], and authors' computations.

In the short term, immediately after the transition period, CBAM only applies to a few highly polluting sectors. Magacho et al. [51] identified cement (HS code 2523), electricity (HS code 2716), nitrogenous fertilizers (HS code 3102), iron and steel (HS code 27), and aluminum (HS code 76). Each product was linked, according to the HS system, to the corresponding production sector. The result of this process is depicted in Table 4.

Table 4. Sectors and products targeted by CBAM in the initial phase.

		Exports to EU27 (USD Million)
C00	Mining industry	12.03
D03	Chemical and para-chemical industry	5.50
D04	The mechanical, metallurgical, and electrical industry	11.00
D05	Other manufacturing, excluding petroleum refining	64.15
E00	Electricity and water	60.74

Source: International Trade Center [12] and author's computations.

3.5. Emissions Embedded in Morocco's Exports to the EU

To assess the potential effect of CBAM, we computed the sectoral emissions embedded in the commodities of interest exported to the EU27. The analysis was conducted exploiting the equation Acar et al. [41] used in a similar setting for the Turkish economy:

$$GHG = K_{GHG}(I - A)^{-1}EX_{27} \tag{6}$$

where

- GHG is the 20 × 20 matrix of greenhouse gases expressed in tons of CO_2 equivalents embedded in exports to the EU27 (see Figure 1 below).
- K_{GHG} is the 20 × 20 diagonalized greenhouse emission intensity vector depicted in Table 1.
- $(I - A)^{-1}$ is the Leontief inverse.
- EX_{27} is the 20 × 20 diagonalized vector of exports to EU27.

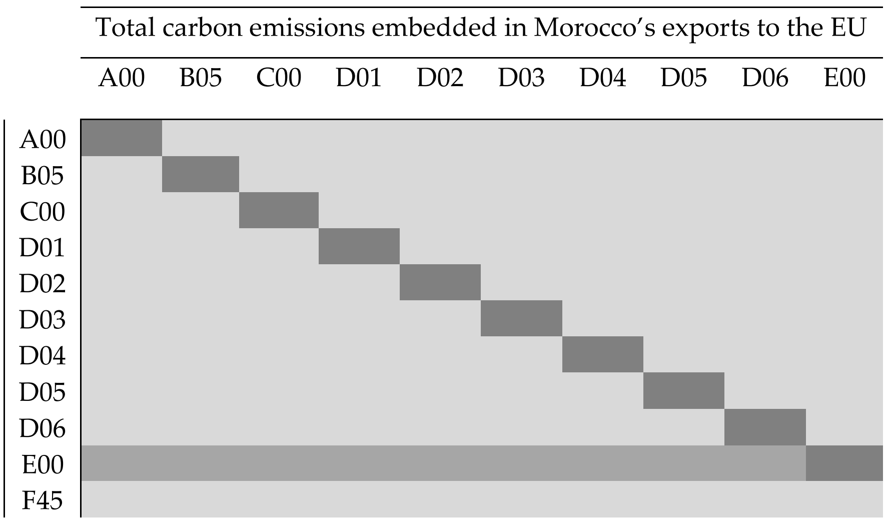

Figure 1. Decomposition of emissions into scope 1, scope 2, and scope 3 emissions (darker to lighter grey, respectively).

The reasoning behind the equation is straightforward; it is a slight modification of Equation (2) in Section 3.1. By multiplying export demand with the Leontief inverse, we calculate the total output needed to satisfy that demand. Then, by pre-multiplying these results with greenhouse emission intensity coefficients, we transform this output into an equivalent quantity of CO_2 emitted.

3.6. Scenarios Investigated

As detailed in Section 2, there are still some doubts about how the CBAM is implemented. Considering that the scheme was designed to mirror the EU's ETS, electricity energy-intensive industrial sectors, such as cement, iron and steel, aluminum, oil refinery, paper, glass, chemicals, and fertilizers, are included [3]. Taking the available information into account, we chose to conduct our analysis within the scenarios described below. The scenarios investigated are summarized in Table 5.

Table 5. Summary of the scenarios investigated.

		Description
Scenario 1	Scen1sim1b	Only the direct emissions of sectors targeted by CBAM in phase 1 are considered (scope 1).
	Scen1sim2b	Electricity consumption is considered in addition to direct emissions for the aforementioned sectors (scope 1 and scope 2).
Scenario 2	Scen2sim1b	For all the sectors of the economy, only scope 1 emissions are considered.
	Scen2sim2b	For all the sectors of the economy, electricity consumption is considered in addition to direct emissions.

3.7. Carbon Pricing

Since the launch of ETS, the carbon price reached its historical peak in February 2022 when it hit EUR 104. The International Monetary Fund recommended a global average price of USD 75 by the end of the decade to reach carbon neutrality by 2050, and the median view of 30 climate economists polled by Reuters argues that this figure should be at least USD 100 [52]. In addition, Trading Economics [53] forecasts for 2024 A range of carbon prices between EUR 60 and EUR 120.

Considering the information available about carbon pricing, we deemed it reasonable to retain USD 60 as a minimum and USD 100 as a maximum carbon price to conduct our analysis.

4. Results and Discussion

The sectoral structure of the input–output matrix and the analysis we conducted to allow for decomposing greenhouse gas emissions into the three emission scopes. In an input–output setting, the sectors depicted in columns buy inputs from the sectors in the rows to produce their output: each column shows an industry's need for inputs from the other sectors (including itself), and each row details how an industry's output is distributed to other sectors to produce their output (including itself).

The same reasoning can be applied to other variables studied in the input–output framework (greenhouse gas emissions in our case). With that said, the decomposition of the emission into the emission scopes becomes straightforward as follows (see Figure 1 for a graphical representation):

- The diagonal elements of the GHG matrix (the intra-industry flows of greenhouse gas emissions) represent each sector's scope 1 emissions.
- The elements of the electricity row (i.e., what the electricity sector sells to other industries to use as input) are represented by the buying sector's scope 2 emissions.
- The rest of the elements of a column represent scope 3 emissions. Thus, it covers emissions embedded in inputs purchased from other sectors.

4.1. Calculating the CBAM-Induced Carbon Costs

To compute the CBAM-induced carbon costs, we multiplied the emissions embedded in exports, expressed in tons of equivalent CO_2, by the carbon prices of USD 60 and USD 100.

Scenario 1 analysis:

In this phase, only the sectors targeted by CBAM are considered. Table 6 summarizes the results of our calculations.

Table 6. Greenhouse gas emissions embedded in exports to the EU targeted by CBAM in phase 1.

		Emissions in tCO_2e		**Total**	**Share**
		Scope 1	**Scope 2**		
C00	Mining industry	6904.97	1270.90	8175.87	2.5%
D03	Chemical and para-chemical industry	3756.83	401.57	4158.40	1.3%
D04	The mechanical, metallurgical, and electrical industry	2194.74	677.51	2872.24	0.9%
D05	Other manufacturing, excluding petroleum refining	11,411.53	9370.21	20,781.74	6.3%
E00	Electricity and water	295,268.42	-	295,268.42	89.1%
	Total	319,536.49	11,720.18	331,256.67	
	Share	95.5%	3.5%		

Source: from authors' calculations.

The table highlights the exports to the EU27 market from the targeted sectors contributed to a minimum of 331,256.67 metric tons of CO_2-equivalent emissions, encompassing both direct sources and electricity generation. The *Electricity sector (E00)* stands as the primary contributor, succeeded by *other types of manufacturing, excluding petroleum refining (D05)* and the *mining industry (C00)*.

In Table 7, we multiplied these figures by USD 60 and USD 100 to obtain the carbon costs that these sectors would face in each variant of Scenario 1:

Table 7. CBAM-induced bill for scenario 1 in USD.

		Scen1sim1b (Scope 1)		**Scen1sim2b (Scopes 1 and 2)**	
		60 USD	**100 USD**	**60 USD**	**100 USD**
C00	Mining industry	414,298	690,497	490,552	817,587
D03	Chemical and para-chemical industry	225,410	375,683	249,504	415,840
D04	The mechanical, metallurgical, and electrical industry	131,684	219,474	172,335	287,224
D05	Other manufacturing, excluding petroleum refining	684,692	1,141,153	1,246,904	1,078,174
E00	Electricity and water	17,716,105	29,526,842	17,716,105	29,526,842
Total carbon bill in USD		19,172,189	31,953,649	19,875,400	33,125,667

Source: from authors' calculations.

Our calculations indicated that the bill would vary from USD 20 million to USD 32 million when considering only direct emissions and between USD 20 million and USD 34 million when electricity consumption is factored into the bill. These results are consistent with the predominance of direct emissions (96.5% of total greenhouse gas emissions embedded in exports to the EU).

Although it is interesting to estimate the carbon bill induced by the CBAM, it does not reasonably assess its impact on the sectors covered. One way to approximate this effect is to compute tax rates. We divided sectoral carbon costs by the European Union market export revenues.

Figure 2 shows that in terms of tax rates, the *electricity and Water sector (E00)* is the most affected by CBAM, followed by *the chemical and para-chemical industry (D03)* and the *mining industry (C00)*. The effects are more significant for these sectors if carbon prices reach or exceed USD 100/tCO_2e. More specifically, the electricity operators will have to pay between USD 29 and USD 49 for every USD 100 they earn in the UE27 market. Similarly, the *chemical and para-chemical industry* will be subjected to a tax rate ranging from 4% to 8%, and the *mining industry* will have to pay between 3 USD and 7 USD for each 100 USD. Other targeted sectors will have to pay less than 3 USD for each 100 USD earned. Although the tax rate for the electricity sector may seem alarming, it should be put into perspective at the macro level since it represents less than 5% of exports to the European Union.

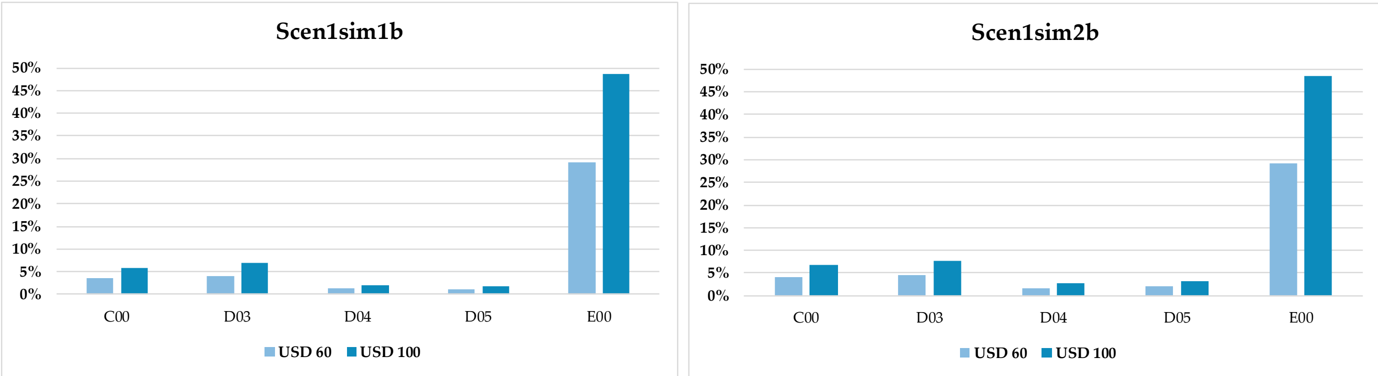

Figure 2. Tax rates on exports in scenario 1. Source: from authors' calculations.

Scenario 2 analysis

In this part of the analysis, all sectors are targeted by the scheme.

When considering all sectors, Moroccan exports to the EU account for a minimum of 12 million metric tons of CO_2 equivalent emissions (Table 8). Leading the emissions contribution is the *transport sector (I01)*, which is responsible for about 44% of the total emissions, followed by the *mechanical, metallurgical, and electrical industry (D04)* and *agriculture, forestry, hunting, and related services (A00)* with 18% and 14%, respectively.

Table 8. Greenhouse gas emissions are embedded in all exports to the European Union.

		Emissions in tCO_2e		**Total**	**Share**
		Scope 1	**Scope 2**		
A00	Agriculture, forestry, hunting, and related services	1,739,454.14	110,676.92	1,850,131.06	14.1%
B05	Fishing, aquaculture	5861.89	2191.64	8053.53	0.1%
C00	Mining industry	196,722.19	36,207.83	232,930.02	1.8%
D01	Food industry and tobacco	124,941.91	115,538.71	240,480.62	1.8%
D02	Textile and leather industry	486,774.25	219,643.56	706,417.81	5.4%
D03	Chemical and para-chemical industry	849,496.17	90,802.30	940,298.48	7.1%
D04	The mechanical, metallurgical, and electrical industry	1,736,059.76	535,916.15	2,271,975.91	17.3%
D05	Other manufacturing, excluding petroleum refining	188,091.43	154,445.11	342,536.54	2.6%
D06	Oil refining and other energy products	1162.23	129.33	1291.55	0.0%
E00	Electricity and water	295,268.42	-	295,268.42	2.2%
F45	Construction	1001.73	593.69	1595.42	0.0%
G00	Trade	63,171.40	47,431.45	110,602.85	0.8%
H55	Hotels and restaurants	6663.76	4618.52	11,282.28	0.1%
I01	Transport	5,642,488.05	188,065.32	5,830,553.38	44.3%
I02	Post and telecommunications	18,967.15	26,539.24	45,506.40	0.3%
J00	Financial activities and insurance	8660.85	4962.98	13,623.84	0.1%

Table 8. *Cont.*

		Emissions in tCO_2e		Total	Share
		Scope 1	**Scope 2**		
K00	Real estate, renting, and services to enterprises	183,694.71	34,751.76	218,446.47	1.7%
L75	General public administration and social security	16,259.37	20,394.44	36,653.81	0.3%
MNO	Education, health, and social action	2517.43	195.28	2712.71	0.0%
OP0	Other non-financial services	292.07	916.65	1208.71	0.0%
Total	11,567,548.91	1,594,020.90	13,161,569.81		

Source: from authors' calculations.

We used the results to compute the induced carbon bill as shown in the table below (Table 9).

Table 9. CBAM-induced bill for scenario 2.

		Scen2sim1b (Scope 1)		**Scen2sim2b (Scopes 1 and 2)**	
		60 USD	**100 USD**	**60 USD**	**100 USD**
A00	Agriculture, forestry, hunting, and related services	104,367,248	173,945,414	111,007,864	185,013,106
B05	Fishing, aquaculture	351,714	586,189	483,212	805,353
C00	Mining industry	11,803,331	19,672,219	13,975,801	23,293,002
D01	Food industry and tobacco	7,496,514	12,494,191	14,428,837	24,048,062
D02	Textile and leather industry	29,206,455	48,677,425	42,385,069	70,641,781
D03	Chemical and para-chemical industry	50,969,770	84,949,617	56,417,909	94,029,848
D04	The mechanical, metallurgical, and electrical industry	104,163,586	173,605,976	136,318,555	227,197,591
D05	Other manufacturing, excluding petroleum refining	11,285,486	18,809,143	20,552,192	34,253,654
D06	Oil refining and other energy products	69,734	116,223	77,493	129,155
E00	Electricity and water	17,716,105	29,526,842	17,716,105	29,526,842
F45	Construction	60,104	100,173	95,725	159,542
G00	Trade	3,790,284	6,317,140	6,636,171	11,060,285
H55	Hotels and restaurants	399,825	666,376	676,937	1,128,228
I01	Transport	338,549,283	564,248,805	349,833,203	583,055,338
I02	Post and telecommunications	1,138,029	1,896,715	2,730,384	4,550,640
J00	Financial activities and insurance	519,651	866,085	817,430	1,362,384
K00	Real estate, renting, and services to enterprises	11,021,683	18,369,471	13,106,788	21,844,647
L75	General public administration and social security	975,562	1,625,937	2,199,229	3,665,381
MNO	Education, health, and social action	151,046	251,743	162,763	271,271
OP0	Other non-financial services	17,524	29,207	72,523	120,871
	Total Carbon bill in USD	694,052,935	1,156,754,891	789.694,189	1,316,156,981

Source: from authors' calculations.

The sectors facing higher costs vary, with the transport sector expected to incur expenses ranging from USD 260 million to USD 446 million, followed by the agricultural sector, with costs ranging from USD 160 million to USD 280 million. Subsequently, the textile and leather industry, real estate, services to enterprises, and the mechanical, metallurgical, and electrical industries also face significant costs. However, when examining tax rates (see Figure 3), the sectors bearing the heaviest tax burden were consistent with the sectoral carbon intensity and our previous findings: electricity and water lead with tax rates ranging from 28% to 47%, followed by the transport sector (13% to 23%), and mining and agriculture (8.5% to 15%). Other sectors also experienced impacts, albeit to a lesser degree.

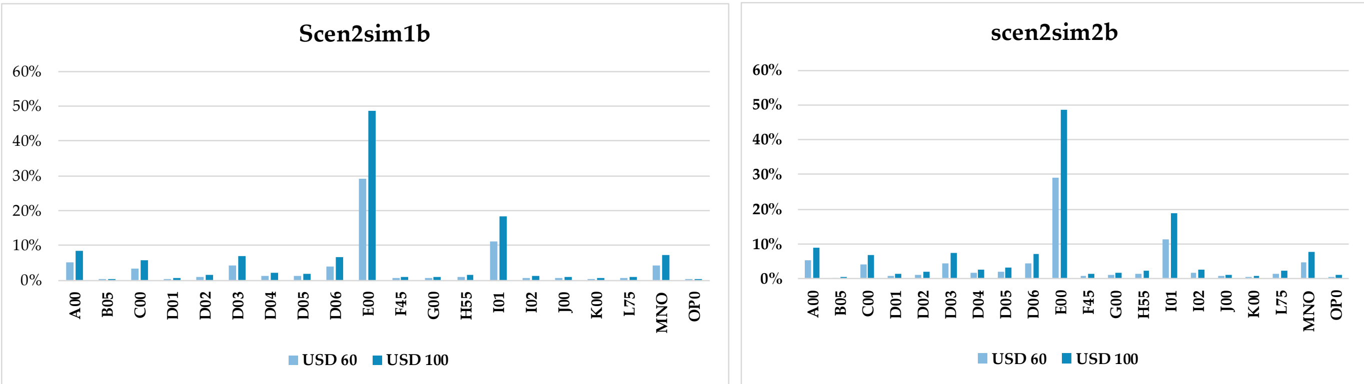

Figure 3. Tax rates on exports in scenario 2. Source: from authors' calculations.

To conclude this section, we highlight that we, like most others using I-O for impact analysis, used the most recent SUT available (with sectoral carbon data). As no major carbon pricing initiatives are being planned in this country [54], we do not expect important changes either (a) in the production structure or (b) in the carbon intensity of products. For a, we analyzed the evolution of the share of sectors between 2015 and 2019, and the only sector that exhibited a noticeable increase was the automobile sector, with its share increasing from 3.4% to 4.7%, and for b, Ben Azzeddine et al. [54] estimated a stable and long-term relationship between GDP and GHG (0.83).

4.2. The Effects of CBAM on Morocco

Although our calculations show that CBAM's effects are not as high as some authors like Berahab and Dadush [9] expected for Moroccan exporters, they maintained a considerable loss of revenue. Moreover, long after the implementation of CBAM, EU27-based manufacturers are likely to continue to receive allowances. Although CBAM was presented as a scheme to gradually phase out free emission permits [3,32], some authors like Evans et al. [55] argue that both policies are not redundant: they reason that CBAM could level the competitive field in the EU markets, though it cannot address competition in external markets. Furthermore, the findings of this study are a first-hand estimate of the CBAM's effects on Moroccan exports as a mere component of a more complex and dynamic system. Indeed, the CBAM—which in our case took the form of an export tax—represents an external shock on final demand, and its effects are expected to have a larger scope given the sectors' interdependencies within the Moroccan economy. The rationale behind this reasoning is grounded in the possibility that exporters could explore several alternatives to maintain market shares when confronted with increased export costs: shift to input suppliers with a lower carbon intensity, producers within the EU, or another country with a similar carbon pricing mechanism; absorb the additional cost or pass them through along their value chain. Thus, in all cases, other sectors are affected either by decreased demand or increased production costs. Consequently, North African countries like Morocco are likely to experience income and employment losses, as projected by Durant et al. [3].

Considering these aforementioned points, we abstain from making strong statements about the extent to which CBAM affects the Moroccan economy. Instead, we can assert that apart from the electricity sector—where there is a risk that export taxes could reach half of their value on the EU27 market—the impact on Morocco's exports is modest in comparison to our original expectations drawn from earlier studies. We can add that by applying a national carbon tax to targeted products in CBAM, the cost to the economy would be much higher since with CBAM, the only part subject to implicit tax is the exported projects to the

EU market, and the part exported to the rest of the world and sold on the national market is exempted.

5. Policy Issues and Implications

The European Commission has determined that the only way for a country to be exempt from the CBAM is to implement its national ETS and connect it to the EU's carbon market. This course of action has been suggested for Morocco by Berahab et al. [56] and Eicke et al. [13].

Although a national ETS may seem straightforward around CBAM, it may not be appropriate in the Moroccan case [57]. In theory, an ETS achieves its objectives when the emission market is competitive, in the presence of several polluters with different measures to control their emissions and different abatement costs. In Morocco, there are few large industrial emitters, and the energy market has a concentrated structure mainly dominated by the National Office for Electricity and Drinking Water (ONEE). Therefore, an ETS may not deliver its cost-saving potential (p. 19).

Another way around the EU's CBAM for Morocco to consider is to accelerate its economy's decarbonization. Initially, the CBAM is anticipated to target only direct (scope1) emissions, making export-oriented industries a primary focus in the short term [13]. Subsequently, to minimize indirect emissions and prepare for the CBAM's expected expansion, decarbonization efforts would eventually have to cover non-exporting sectors and their associated supply chains. The decarbonization option aligns with the country's low-carbon strategy, which aims to increase the share of renewables, particularly through the expansion of solar power in its energy mix.

While it presents an opportunity for Morocco to align with its climate goals, the decarbonization path simultaneously raises a financing issue. It is expected to be costly for the Moroccan government and threatens to widen its budget deficit. Carbon taxes stand out as attractive options for Ministries of Finance due to their simplicity and automatic revenue consolidation into the state budget. In Morocco, stakeholders exploring carbon tax options lean towards adjusting existing tax rates and coverage as a more pragmatic and efficient approach to environmental fiscal reform [57]. Berahab et al. [56] proposed ways for Morocco to decarbonize its economy and discussed the complications and risks that may cripple the successful implementation of these measures, such as the loss of competitiveness and—if the additional costs yielded by fiscal reforms were to be passed on to consumers—the creation of social cleavages.

Whether Morocco chooses to implement a national ETS, fiscal measures, or simply not take any measures to deal with the EU's CBAM, a good starting point would be to encourage Moroccan specialized institutions to advance in investigations that would allow them to produce an inventory of Moroccan emissions regularly. A performance emission monitoring system would help researchers conduct more thorough environmental studies and would allow decision makers to follow the evolution of emissions closely, assess progress, and set new decarbonization goals.

6. Conclusions

Designed to complement the EU's Emission Trading System, the newly proposed CBAM is the EU's way of including the union's trade partners in its endeavors toward carbon neutrality. To define its operating system more simply, the scheme is meant to pressure non-EU trade partners to buy enough carbon permits to cover all the emissions embedded in the products they wish to sell on the EU's market. Initially, CBAM will cover direct emissions embedded in energy and carbon-intensive sectors, but many (including the European Commission) expect that it will likely expand to indirect emissions and more sectors in time.

Since its proposal, several authors have rushed to discuss the potential effects of such a trade policy on the targeted countries, either with arguments based on trade law or empirical methods. Moreover, perhaps the most common finding is the throwbacks of

CBAM on developing economies in terms of income and employment due to the higher and disadvantageous production costs this new policy would yield.

Morocco's strong economic ties with the European Union justify the urgency to analyze the extent of CBAM's effects on Moroccan exporters' competitiveness. Using an input–output approach, this paper provides a first-hand computation of the costs these exporters would face when the policy is fully implemented in 2026. Our results indicate that during its initial phase, the carbon border adjustment mechanism (CBAM) could impose an annual carbon bill on Moroccan exporters ranging from USD 20 to 34 million, contingent upon carbon prices ranging from USD 60/tCO2e to USD 100/tCO_2e. Among the sectors involved, the electricity and water sector is projected to encounter the most substantial costs, facing a bill ranging from USD 17 to 29 million annually. Following other manufacturing industries closely, excluding petroleum and refining industries, expenses may be incurred ranging from USD 680 thousand to 2 million, while the chemical and para-chemical industry could confront costs of up to USD 287 thousand. However, concerning the tax burden, the electricity sector is expected to endure the highest tax rates, trailed by the chemical and para-chemical and mining industries, while other sectors targeted in the CBAM's initial phase face comparatively lower tax rates. Analyzing our results considering the environmental/sustainable objective of the CBAM, we can conclude that it is not likely to have an important impact on carbon emission reductions or provide a strong incentive for the Moroccan government to implement carbon pricing initiatives. Other factors need to be used to achieve this goal. Moreover, the economic cost for Morocco will lead to a loss in employment, which will have negative consequences for sustainable development in the country.

Our findings regarding the major exporting sectors do not present the anticipated dramatic outcomes. Nonetheless, even if these implicit taxes are relatively modest, they pose an additional cost for Moroccan manufacturers, potentially eroding their competitiveness compared to their European counterparts. Intuitively, an export tax would trigger price effects that necessitate adjustments throughout the value chain. These adaptations could manifest as shifts in sectoral demands for inputs, an increase in the supply of goods in the domestic market—particularly if domestic sales prove more profitable than exports—or a combination of both. With that said, further investigations are needed to assess the general equilibrium of price effects that CBAM might have on other critical components of the economy, like household welfare, employment, current account balance, and GDP. This comprehensive approach can aid policymakers in identifying and prioritizing interventions to mitigate negative impacts and sustain the decarbonization efforts of the Moroccan economy. In this regard, while a Leontief price model is a viable option, computable general equilibrium (CGE) models are likely more well-suited for such analyses.

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