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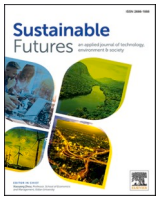

Readiness of the European trading countries toward carbon border adjustment mechanism: Evidence from Indonesia

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ABSTRACT

The serious consequences of greenhouse gas emissions destabilizing the world's climate have led the European Union (EU) to introduce the Carbon Border Adjustment Mechanism (CBAM) regulation. This regulation will be fully implemented by the EU in 2026 for its trading partner countries for six products, namely fertilizers, cement, iron and steel, aluminium, electricity, and hydrogen. This study, taking Indonesia as one of the EU's trading partners, aims: (1) to estimate the values of Indonesian export products to the EU affected by CBAM and their competitiveness, and the dynamic changes in the competitiveness level of the export product subject to the CBAM, and (2) to analyze the perceptions on the readiness of government and business actors to face the implementation of the CBAM. By applying the Revealed Comparative Advantage (RCA), Revealed Symmetric Comparative Advantage (RSCA) Indexes, and Export Product Dynamic (EPD) methods using the data published by the International Trade Centre (ITC) and Indonesia Iron and Steel Industry Association, the results indicate that the values and shares of Indonesia's export products to the European Union under CBAM are very low. Fertilizers and cement products are in the retreat position, which indicates a negative growth in a country's export share of a product, accompanied by a decrease in total exports, resulting in an uncompetitive and stagnant position. While aluminium and iron or steel products are in the lost opportunity position, indicating that the global export markets for iron-steel and aluminium products are very open, with opportunities for exports. Furthermore, the results of the PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) factor analysis based on interviews and focus group discussions with resource persons emphasize the importance of this country having policies in place to face CBAM including a policy to increase its carbon price, economic incentives, anticipating the social impact of CBAM on increasing unemployment, and fostering research and innovation in technologies with low carbon footprint.

1. Introduction

Rising greenhouse gas emissions are becoming an international concern because they are destabilizing the world's climate [1–5]. In part, this is because greenhouse gas emissions have caused all plant and animal species on the planet to be threatened with extinction. The planet's oceans, glaciers, forests, and other ecosystems are also suffering from an increase in greenhouse gas emissions [3,6,7]. If we fail to mitigate and adapt to climate change, natural disasters, biodiversity loss, and environmental degradation will occur in the next decade [8].

The serious consequences of greenhouse gas emissions have led the governments of developed and developing countries to establish various policies, strategies, and programs to reduce carbon emissions [9,10]. In particular, the European Commission established the Green Deal Program, which serves as a framework for environmental targets and instruments in 2019. The program includes some climate policies, such as

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the European Union Emissions Trading System (EU ETS) reform and the implementation of the Carbon Border Adjustment Mechanism (CBAM) regulation. However, the CBAM will not be fully implemented until 2026 [11–17].

Although the European Union has clarified that CBAM is not a form of tariff restriction [18], it is argued that CBAM will affect the export of products from trading partner countries to the EU [2,19]. The export products affected by the CBAM regulation are iron and steel, cement, aluminum, fertilizers, electricity, and hydrogen. The impact of CBAM is expected to be felt most in the EU's trading partner countries, especially in the Least-Developed Countries (LDCs) [20]. This is because a decline in exports from LDCs to the EU leads to a decline in welfare in these LDCs [21].

Since Indonesia is one of the trading partners of the EU, there is no doubt that this country will be affected by the CBAM regulation. Previous studies conducted by Sun et al. [16] and Korpar et al. [22], for example, show that CBAM will disrupt the economies of the EU's trading partners because it causes a decline in GDP. Chepeliev [23] and Korpar et al. [22] also show that CBAM will lead to a decrease in welfare and per capita income in almost all EU trading partners. This condition will increase the economic gap between developing and developed countries [24]. Korpar et al. [22] estimate that Indonesia will experience a decline in exports of up to 0.19 %. Rocchi et al. [25] highlighted the carbon border tax policy will affect Indonesia's trade due to the high intensity of carbon emissions during the production process.

Apart from the above potential economic implications, the CBAM will certainly reduce the competitiveness of Indonesian products exported to the EU. This is partly because Indonesia's energy consumption is still dominated by coal and fossil fuels with high carbon emissions [26], so the implementation of policies such as the carbon tax has a significant impact on reducing the competitiveness of Indonesian products [27]. Conversely, the competitiveness of domestic EU products will increase in the face of competition with products from countries with weak emission regulations [10].

Indonesia's export products in the EU market that were uncompetitive and inferior to products from China are iron and steel products [28]. Anam and Solikin [29] showed that Indonesian aluminium-zinc-coated steel products are also uncompetitive in the world. Even in the ASEAN and Chinese markets, Indonesian steel products are still unable to compete with products from China, Malaysia, Thailand, and Vietnam [30]. This is because Indonesia's comparative advantage is still dominated by the primary product group [31]. Therefore, the various potential impacts of the CBAM regulation need to be anticipated by the EU's trading partner countries.

However, little is known about studies that examine the readiness of the EU's trading partners to deal with various potential economic and trade impacts of the implementation of CBAM as outlined above. While it is true that the CBAM will be fully implemented in 2026, a study on this issue is not very timely. This study is not only urgent to fill the research gap, but also for the EU's trading partner countries, including Indonesia, to start preparing for the CBAM implementation.

Also, it is because the impact of the implementation of the CBAM will be different in each EU trading partner country, depending on their ability to adapt through implementing decarbonization or changing trade destinations [32]. More importantly, the implementation of CBAM will also have implications for business actors on how to respond to the existence of CBAM as they have to reduce carbon emissions in their production processes [33,34] on one hand, and the implementation of a large carbon tax by the government will encourage business actors to innovate and utilize new technology, thereby having a big impact on the economy in the long term on the other hand [20]. Therefore, this research has novelty not only to bridge the research gap related to the CBAM issues but more importantly to boost the EU trading partner countries to take urgent action, especially to combat climate change and its impacts as highlighted in the Sustainable Development Goals (SDGs) [35].

The organizational structure of this paper is as follows. The following Section 2 details the source of data and methods of data analysis to estimate the values of export products from Indonesia to the EU affected by the CBAM and its competitiveness, the dynamic changes in the competitiveness level of the export product subject to CBAM as the background of analysis before analyzing the readiness of government and business actors' reactions to face the implementation of the CBAM policy. This is then followed by results and a discussion in Section 3. Finally, the conclusions are drawn in Section 4.

2. Research methods

As mentioned at the outset, two research objectives were examined in this study. The first is to estimate the values of Indonesian export products to the EU affected by the CBAM and its competitiveness, and the dynamic changes in the competitiveness level of the export product subject to the CBAM. The second is to analyze the perceptions on the readiness of government and business actors to face the implementation of the CBAM.

The source of data to examine the first objective was obtained from the International Trade Centre (ITC)-Trade Map for the 2017–2021 period [36] and from the Indonesia Iron and Steel Industry Association-IISIA [37]. These data were then analyzed to estimate (a) Indonesia's export share of products affected by the CBAM, (b) Revealed Comparative Advantage (RCA) and Revealed Symmetric Comparative Advantage (RSCA), and (c) Export Product Dynamic (EPD).

We applied the RCA method here as this method is one of the common approaches used to assess a country's competitive export capabilities [38,39]. This approach originates from Ricardo's trade theory, which states that variations in productivity influence trade patterns between countries [38]. The RCA method itself was developed by Béla Balassa in 1965 with the basic concept of measuring a country's comparative advantage in a specific product based on actual trade performance [39]. Mathematically, RCA calculates the ratio of a product in a country's total exports and compares it to the ratio of the same product in global exports [40]. The use of actual data in its approach allows RCA to provide a practical and accurate assessment of comparative advantage, that differs from other predictions based solely on economic theory [41]. The formula to estimate RCA was as follows [42].

$$RCAAi = (XAi / XAj)/(Xwi / Xwj) \quad (1)$$

Where:

XAi is the export of product i from country A;

Xwi is the world export of products I;

XAj is the total export of product j (all products) from country A

Xwj is the total export of product j (all products) worldwide.

If the value of RCA is greater than 1 (RCA $>$ 1), then the country has a comparative advantage above the world average [43].

However, the measurement results using the RCA method can yield extremely high values, even up to infinity. This can lead to confusion when observing a country's export value that increases significantly within a brief period, resulting in a non-constant trend [44,45]. Mohamad and Ab-Rahim [44] and Dalum et al. [45] among others, suggest that the symmetric range of -1 to 1 is considered to reflect competitiveness more accurately, making it easier to determine a country's competitiveness. We, therefore, applied the Revealed Symmetric Comparative Advantage (RSCA) method [45]. The formula to calculate RSCA is as follows [46,47]:

$$RSCA_j^A = \left(RCA_j^A - 1\right) \Big/ \left(RCA_j^A + 1\right) \quad (2)$$

Where:

$RSCA_j^A$ is the Revealed Symmetric Comparative Advantage of country A for commodity j.

Apart from RCA and RSCA, we also estimated the dynamic changes

in the level of competitiveness of the export product from Indonesia to the EU subject to CBAM. We applied the Export Product Dynamic (EPD) method as it is a popular analytical tool used to measure competitive advantage [48,49]. The EPD calculation results were mapped into the EPD matrix, where market attractiveness (measured based on demand growth) serves as the horizontal axis or X-axis, and business strength (measured based on market acquisition or market share growth) serves as the vertical axis or Y-axis, as shown in Eqs. (3) and (4) [50,51].

$$AxisX = \frac{\sum_{t=1}^{t}\left(\frac{X_{ca}}{W_{ca}}\right)t - \sum_{t=1}^{t}\left(\frac{X_{ca}}{W_{ca}}\right)t - 1x100\%}{T} \quad (3)$$

$$AxisY = \frac{\sum_{t=1}^{t}\left(\frac{X_{ta}}{W_{ta}}\right)t - \sum_{t=1}^{t}\left(\frac{X_{ta}}{W_{ta}}\right)t - 1x100\%}{T} \quad (4)$$

Where:

X_{ca} is the export value of product c to the country a;

W_{ca} is the world export value of product c;

X_{ta} is the total export value of all products from Indonesia to the country a;

W_{ta} is the total export value of all commodities worldwide to the country a;

T is the number of years; a is the export destination country.

After calculating the X and Y axes, four position categories were obtained, namely, rising star, falling star, lost opportunity, and retreat as can be seen in Table 1.

As shown in Table 1, "Rising star" signifies that the country is gaining additional export market share with fast-growing products; “Falling Star” indicates positive growth in the country’s total export market share, but a decline in the export market share of a specific product; “Lost Opportunity” refers to the country’s total export market share decreasing with positive growth in the market share of a product; and “Retreat” points to negative growth in the country’s export share and total exports, resulting in an uncompetitive and stagnant position [51, 52].

To measure the competitiveness, we have calculated the export cost or price (FOB) of the Indonesian export products to the EU subject to CBAM. The calculation takes into account the conditions both before and after the implementation of the CBAM provisions. Note that the export products from Indonesia under CBAM that were estimated using the EPD approach are iron and steel, aluminuim, fertilizer, and cement. Hydrogen and electricity, however, are not included in this analysis due to zero export values.

Further, to analyze the perceptions of the readiness of government and business actors to face the implementation of the CBAM as the second objective of the study, we collected data from a fieldwork survey in DKI Jakarta, West Java, Central Java, and East Java provinces. The instruments used to obtain these data were conducted by employing in-depth interviews and Focus Group Discussions (FGD). The resource persons for the in-depth interviews and FGDs included the central government (e.g. the Ministry of Trade, the Ministry of Industry, and the Ministry of Environment and Forestry), regional governments (e.g. Provincial Office of Energy and Mineral Resources in Central Java, Provincial Office of Energy and Mineral Resources in West Java, and Provincial Office of Energy and Mineral Resources in East Java), business actors (PT Semen Gresik, PT Petro Kimia Gresik, and PT. Tri Sinar Purnama), business associations (the Indonesian Iron and Steel Industry Association-IISIA, and the Association of Indonesian Fertilizer Producers-APPI), and academicians (the University of Diponegoro and the University of Brawijaya).

Note that, the in-depth interviews were conducted by visiting the above resource persons, while the FGD was done via Zoom media and direct visits to the research field locations in the provinces of West Java, Central Java, and East Java. Also, the materials used for the interviews with the resource persons and the focus group discussion were approved by the Ethics Commission for Social Humanities, National Research and Innovation Agency (BRIN) based on Decree No 358/KE.01/SK/06/2023.

The interview and the group discussion with the resource persons were intended to obtain their perceptions or views on the readiness and reactions to the planned implementation of the CBAM policy in Indonesia related to political, economic, social, technological, environmental, and legal aspects. This method is called PESTEL, which stands for Political, Economic, Social, Technological, Environmental, and Legal. PESTEL was employed here as it is a powerful analytical tool that is widely used to assess strategic risks related to the external macro-environment for businesses [53–58].

Table 1
Export product dynamic classification.

		Share of country’s export in world trade	
		Falling (Non-Competitive)	Rising (Competitive)
Share of Product in World Trade	Rising (Dynamic)	Lost opportunity	Rising stars
	Falling (Stagnant)	Retreat	Falling stars

Source: Wardani et al. [49] and Destiningsih et al. [51].

3. Results and discussion

3.1. Indonesian export values and their competitiveness affected by CBAM

Using data obtained from the International Trade Centre (ITC)-Trade map for 2017–2021, the study found that the export products from Indonesia to the EU that are subject to the CBAM only cover the product groups of iron and steel, aluminium, fertilizer, and cement. The average market share of each of these export products was far less than one percent from 2017 to 2021. Whereas the export value, particularly for cement decreased to zero during those years, as shown in Table 2.

The low export shares and export values of these products are because these products are predominantly exported to Asian countries such as China, Vietnam, India, Japan, Thailand, Australia, and the United States. This suggests that the imposition of CBAM on these export products will have a relatively minor impact on Indonesia’s trade with the EU. This condition, however, does not imply Indonesia does not need to respond to the CBAM regulation for its export products to the EU. This is partly because in the future more countries other than the EU may have CBAM-type measures. Also, it is because Indonesia is one of the world’s countries most vulnerable to climate change so that this country must reduce carbon emissions of their products, and increase the development and use of new energy friendly technologies to sustain its economic growth [26,35].

Table 2
Export values of Indonesian products to the European Union for the years 2017–2021.

Product	Exportvalue(‘000’US$)andShare(%)				
	2017	2018	2019	2020	2021
Aluminium (US$)	12.769	22.135	15.187	11.094	63.710
(%)	0.03	0.04	0.03	0.0	0.10
Iron and Steel (US$)	134.713	309.254	478.091	308.989	1.058.534
Share (%)	0.07	0.14	0.25	0.19	0.41
Fertilizer (US$)	150	105	176	305	113
(%)	0.00040	0.00066	0.00045	0.00004	0.0000
Cement (US$)	7	13	9	1	0
(%)	0.0022	0.0015	0.0024	0.0046	0.0011

Source: Estimated from the International Trade Centre data [36].

The low average market share and the export values of iron and steel, aluminium, fertilizers, and cement on the EU market were also confirmed by estimating the average RCAs of these products. As can be seen in Table 3, the average of the RCAs of these four products is <1. The RCAs that are greater than 1 were only for iron and steel products. This was particularly true for the years 2019 and 2021. While the RCAs of other export products of aluminium, cement, and fertilizers were <1.0.

The above results of the RCA estimations were also supported by the RSCA calculations (Table 4). As shown in Table 4 only iron and steel products have comparative advantages. These comparative advantages are only observed in specific years, namely 2019 with a value of 0.0245, and 2021 with a value of 0.2001. Aluminium, fertilizers, and cement, however, have no comparative advantages as their RSCA values were negative throughout the analysis period. Maliszewska et al. [59] and Hanafi et al. [60] suggest to improve the RCA and the RSCA Indonesia is necessary to implement policies that incorporate the use of export duty benefits, the enforcement of exploration commitments, and the establishment of special tax incentives for mineral products to enhance industry competitiveness.

Judging from the data published by the Indonesian Iron and Steel Industry Association [37], the explanation for the better export values and the positive RSCA of iron and steel compared to other export products (aluminium, fertilizer, and cement) was because of the progress of the consumption, production, export, and import values of Indonesia's iron and steel products for the period 2017–2021 as shown in Fig. 1.

However, the export of iron and steel products from Indonesia are dominated by Asian countries such as China, Taiwan, Malaysia, the Republic of Korea, and India. In line with exports, the imports of iron and steel products are also dominated by Asian countries such as China, Japan, India, and the Republic of Korea, as well as the African country of South Africa. The distribution of exports and imports of iron and steel products from Indonesia during the latest analysis period (2021) is given in Figs. 2 and 3.

The Indonesian Iron & Steel Industry Association [61] highlights that the low volume and value of steel product exports to the European Union (EU) are strategically important since the EU is the third-largest export destination in terms of volume and the fifth largest in terms of value in 2022. As the CBAM will be fully implemented in 2026, there are at least three trade implications for the iron and steel exported from Indonesia to the EU. First, there will be additional costs for steel producers from Indonesia in the form of purchasing carbon emission certificates. Second, the implementation of the CBAM policy could affect steel product exports from Indonesia to China and Taiwan as these two countries are the main export markets destinations. Third, the implementation of CBAM will potentially be followed by similar regulations in other export destination countries, which could have a significant impact on steel product exports from Indonesia to the EU in the future.

3.2. Estimation of the export product dynamic affected by CBAM

The above-estimated results of Indonesian export values and their competitiveness affected by CBAM were also confirmed by the export product dynamic (EPD) calculation using data published by the International Trade Centre 2017–2021 [36].

Table 3
RCA results of Indonesian export products to the European Union.

Product	Year					Average
	2017	2018	2019	2020	2021	
Aluminium	0.089	0.145	0.129	0.102	0.364	0.166
Iron and Steel	0.251	0.525	1.05	0.761	1.5	0.817
Fertilizer	0.008	0.005	0.01	0.018	0.004	0.009
Cement	0.001	0.002	0.002	0	0	0.001

Source: Estimated from the International Trade Centre data [36].

As can be seen in Table 5, the EPD for each product under CBAM shows varied performance. Fertilizers and cement products are in the retreat quadrant position. The "Retreat" position indicates the presence of negative growth in a country's export share of a product, accompanied by a decrease in total overall exports, resulting in an uncompetitive and stagnant position. Some factors influencing the lack of interest in using these products include higher prices compared to those of competing countries, product quality not meeting market specifications, bureaucracy, and limited domestic production [62].

Meanwhile, aluminium and iron or steel products were found in the lost opportunity quadrant. The "lost opportunity" position indicates that the global export markets for iron and steel as well as aluminium products are highly open, with opportunities for exports. However, Indonesia has not been able to respond to these global market demands and is still primarily focused on meeting domestic demand.

As the Indonesian export products of fertilizer, cement, aluminium, and iron or steel are not competitive and not dynamic in the EU market, Gupta et al. [63], for instance, suggest that factors related to the entire production process of a CBAM export need to be improved. These factors encompass the emission intensity of production across different jurisdictions, the level of trade reliance on the EU, existing carbon pricing policies, technical capabilities, and the precision of embedded emissions data. Moreover, the capacity and ability of exporting countries to improve their competitiveness is contingent on their ability to rapidly decarbonize their production processes.

3.3. Indonesia's readiness to face CBAM

By using primary data obtained from in-depth interviews and Focus Group Discussions with the stakeholders in three provinces of DKI Jakarta, West Java, Central Java, and East Java, and by employing the Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) analysis, we found the following views.

Concerning a political perception, for instance, the resource persons interviewed and the participants of FGD from the central and the regional governments generally agreed that the implementation of CBAM provides Indonesia with opportunities for domestic production efficiency, accelerating decarbonization, increasing competitiveness, improving domestic regulations, and adopting environmentally friendly technologies.

However, no special government policy and strategy have been issued yet to face specifically the CBAM regulation introduced by the EU. The present government policy only regulates the mix of use of New and Renewable Energy (EBT) to reduce emissions in sectors that contribute to the main carbon emissions, namely the electricity, transport, and industrial sectors. This regulation was issued under the Presidential Regulation No 22/2017 concerning the Energy Law and the General National Energy Plan -RUEN [64].

In terms of the economic perception, the government resource persons interviewed argued that the implementation of CBAM will not affect Indonesia's trade relations with the European Union. This is because the main export markets for Indonesian products under CBAM are China, the United States, and Japan. Moreover, the value of Indonesia's exports to the European Union in the sectors affected by CBAM regulations is still very small so the impact will not be significant to the economy [22,28].

The business actors interviewed, however, stated that they were quite surprised by the issuance of the CBAM regulation. They further addressed that the implementation of the CBAM will lead to an additional cost that increases trading costs and has the potential to trigger other trade distortions as also highlighted by Lim et al. [18]. The increase in costs is certainly a challenge for business actors to maintain the competitiveness of their products in the European Union and the global markets. The business actors interviewed suggest not only the importance of regulation for them, but more importantly the incentives given to them to sustain their business under the CBAM regulation. If not, they

Table 4
RSCA results of Indonesian export products to the EU.

Product	Year					Average
	2017	2018	2019	2020	2021	
Aluminium	−0.8374	−0.7472	−0.7714	−0.8155	−0.4668	−0.7277
Iron and Steel	−0.5993	−0.3117	0.0245	−0.1356	0.2001	−0.1644
Fertilizer	−0.9850	−0.9894	−0.9801	−0.9646	−0.9917	−0.9822
Cement	−0.9972	−0.9952	−0.9962	−0.9997	−1	−0.9977

Source: Estimated from the International Trade Centre data [36].

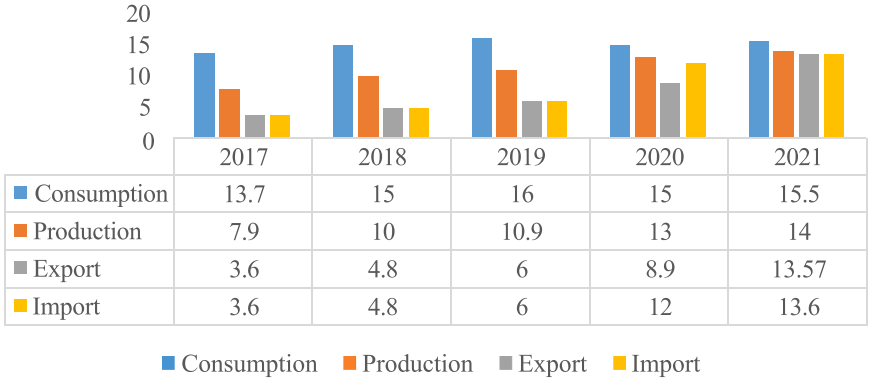

Fig. 1. Production, export, and import of iron and steel products in Indonesia (million tons).
Source: Estimated from Indonesia Iron and Steel Industry Association data [37].

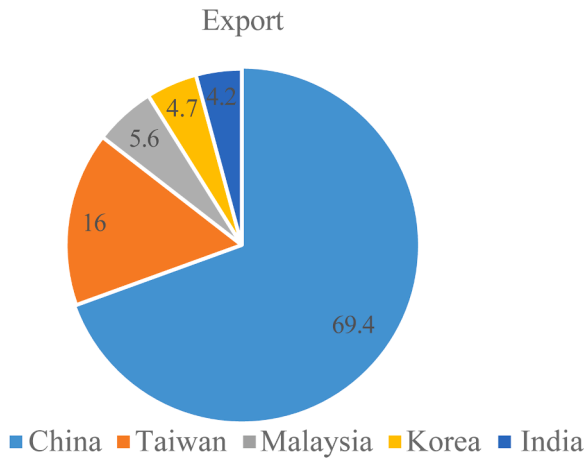

Fig. 2. Export of iron and steel products to main destination countries (%).
Source: Estimated from Indonesia Iron and Steel Industry Association data [37].

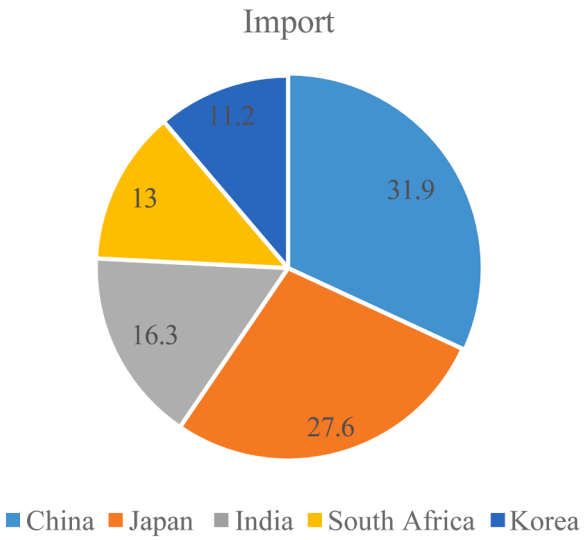

Fig. 3. Import of iron and steel products to main destination countries (%).
Source: Estimated from Indonesia iron and steel industry association data [37].

will seek other markets outside the EU.

In the context of social perception, the business actors interviewed stated that the implementation of the CBAM will have a potential impact on the incidence of unemployment in the sectors subjected to the CBAM. The incidence of unemployment was due to the increase in production, trade costs, and prices in the sectors affected by the CBAM. This view has been confirmed by previous empirical studies [22,65,66]. Magacho et al. [66], for example, pointed out that price changes that occur as a result of CBAM will not only have an impact on the sectors affected by CBAM but will also affect workers in other sectors in the production value chain. While Korpar et al. [22], estimated that implementing CBAM can reduce Indonesia's welfare by up to 0.0136 %. Thus, the business actors interviewed suggest that these social impacts must be anticipated by the Indonesian government before the CBAM is implemented.

Concerning the technological perception, the business actors viewed that the implementation of CBAM will certainly affect the production processes of producers in sectors affected by CBAM. They highlighted

Table 5
EPD results of Indonesian export products to the European union for the period 2017–2021.

Product	X axis	Y axis	EPD
Aluminium	−3.6383	0.0558	Lost Opportunity
Iron and Steel	−0.1644	0.0683	Lost Opportunity
Fertilizer	−0.9822	−0.0005	Retreat
Cement	0.0000	−0.0012	Retreat

Source: Estimated from the International Trade Centre data [36].

that the present condition of business actors is still in the transition stage from high-emission production processes to environmentally friendly production. However, the efforts to realize the technological transformation face several challenges, such as the availability of renewable energy which has not been able to meet the needs of the business actors, limited technological research and innovation, and a lack of research funding. Also, they viewed that the management of renewable energy in Indonesia is still facing obstacles both in terms of regulations and social problems [67].

Previous empirical studies suggest that the development of research and innovation in Carbon Capture Usage and Storage (CCUS) technology is considered the right strategy to deal with CBAM regulations because chemical production processes in several sectors affected by CBAM will always produce carbon emissions [68]. International funding and technology transfer are also needed by developing countries to achieve emission reduction targets which are of course in line with the objectives of implementing CBAM [66,67]. Technology transfer to support decarbonization is also considered to be able to minimize the rejection of CBAM regulations by countries outside the European Union [17].

In the context of the environmental perception, the business actors viewed that the transformation towards a low-carbon and environmentally friendly lifestyle requires major adjustments. However, implementing environmentally friendly technology requires large investments if we have to replace the technology and other production factors currently in use. Without regulatory incentives such as limiting carbon emissions and providing incentives for companies that can reduce their emissions levels, the transformation process will take longer.

In terms of the legal perspective, business actors in Indonesia generally are not yet prepared to face CBAM. Even though the production processes carried out by business actors are now starting to make changes generally, they still have high carbon emissions. This happens because there is no incentive support from the government for business actors who carry out environmentally friendly production. This condition is exacerbated by the reality that distribution costs in Indonesia are expensive due to poor infrastructure, complicated licensing, and various quite large levies reducing investors' interest in entering Indonesia [69].

The business actors also viewed that the process of supervision and law enforcement is weak and that the eradication of corruption in Indonesia is still far from expectations [70] and considered to be hampering industrial development in Indonesia. Thus, improvement of the existing conditions needs to be done by the government to face the impact of the implementation of CBAM which will be carried out in 2026.

4. Conclusions

This study had two objectives. The first was to estimate the values of Indonesian export products to the EU affected by the CBAM and their competitiveness, and the dynamic changes in the competitiveness level of the export product subject to the CBAM. The second was to examine the perceptions of the readiness of government and business actors to face the implementation of the CBAM. The results of this study are as follows.

- The export products from Indonesia to the EU that are subjected to the CBAM only cover product groups of iron and steel, aluminium, fertilizers, and cement. The average market share of each of these export products was far less than one percent. This suggests that the imposition of CBAM on these export products will have a relatively minor impact on Indonesia's trade with the EU.
- Both RCA and RSCA show that there are no Indonesian export products to the EU under CBAM that have a comparative advantage except for iron and steel products. Other products such as aluminium, fertilizers, and cement have no comparative advantage as their RCA is less than one and RSCA is negative throughout 2017–2021.
- By using the export product dynamic (EPD) method, fertilizer and cement products are in the retreat quadrant. Meanwhile, aluminium, and iron or steel products are in the lost opportunity quadrant. However, Indonesia has not been able to respond to these market demands and is still primarily focused on meeting domestic demand.
- By employing the PESTEL analysis, the readiness of Indonesia to face CBAM politically needs a specific policy regarding CBAM, economic incentives given to business actors to increase operational costs to comply with CBAM regulations, anticipate the social impact of CBAM on increasing unemployment, improved research-related to production technology in sectors affected by CBAM, funds and research supports, the availability of new and renewable energies to meet the needs of business actors, mitigates climate change conditions that disrupt the production process, and the formulation of strategies and policies related to CBAM as the detailed technicalities for implementing CBAM have not been released by the European Union.
- Indonesia can avert the effects of CBAM by ramping up its carbon price. This measure will also help it prepare for a future in which many countries have serious carbon pricing and more countries may have CBAM-type of measures. This policy also makes sense for Indonesia as one of the world's countries most vulnerable to climate change, which could be catastrophic for Indonesia (e.g. sea level rise is already accelerating, and for a country with 17,000 islands will cause a lot of problems).

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CRediT authorship contribution statement

Carunia Mulya Firdausy: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Fadhlan Zuhdi:** Writing – original draft, Software, Methodology, Investigation, Data curation. **Khoiru Rizqy Rambe:** Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation. **Reninta Dewi Nugraheni:** Writing – original draft, Software, Methodology, Investigation, Data curation, Conceptualization. **Erwidodo:** Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Delima Hasri Azhahari:** Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that there are no conflicts of interest.

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Data availability

Data will be made available on request.

References

[1] C. Bellora, L. Fontagné, EU in search of a carbon border adjustment mechanism, Energy Econ. 123 (2023) 106673, https://doi.org/10.1016/j.eneco.2023.106673.

[2] G. Chen, Impact of carbon border adjustment mechanism on China's manufacturing sector: a dynamic recursive CGE model based on an evolutionary game, J. Environ. Manage. 47 (2023) 119029, https://doi.org/10.1016/j.jenvman.2023.119029.

[3] J. Mooris, J.H. Henry Chen, A. Gurgel, J. Reilly, A. Sokolov, Net zero emission of greenhouse gases by 2050: achievable at what cost? Climate Change Econ. 14 (4) (2023). https://www.worldscientific.com/doi/epdf/10.1142/S201000782340002X.

[4] Q. Zou, G.P. Zeng, F. Zou, S. Zou, Carbon emission path public building based on LEAP model in Changsa City (China), Sustain. Futures 8 (100231) (2024), https://doi.org/10.1016/j.sftr.2024.100231.

[5] M. Bexell, K. Johnsson, Responsibility and the United Nations' sustainability development goals, Forum Dev Stud 44 (1) (2017) 13–29, https://doi.org/10.1080/08039410.2016.1252424.

[6] OECD, Biodiversity and the economic response to COVID-19: ensuring a green and resilient recovery, Tackling Coronavirus (COVID-19): Contributing to a Global Effort, 1 (September. 2020) 1–26. http://www.oecd.org/coronavirus/policy-responses/biodiversity-and-the-economic-response-to-covid-19-ensuring-a-green-and-resilient-recovery-d98b5a09/.

[7] D. Özekan, European Union carbon border adjustment mechanism: a swot analysis for Türkiye, Yönetim ve Ekonomi Araştirmalari Dergisi 21 (3) (2023) 265–281, https://doi.org/10.11611/yead.1339262.

[8] WEF, The global risks report 2023, World Economic Forum (2023). https://www.weforum.org/reports/global-risks-report-2023.

[9] R. Gu, J. Guo, Y. Huang, X. Wu, Impact of the EU carbon border adjustment mechanism on economic growth and resources supply in the BASIC countries, Resour. Policy 85 (PB) (2023) 104034, https://doi.org/10.1016/j.resourpol.2023.104034.

[10] D.G. Tarr, D.E. Kuznetsov, I. Overland, R. Vakulchuk, Why carbon border adjustment mechanisms will not save the planet but a climate club and subsidies for transformative green technologies, Energy Econ. 122 (106695) (2023), https://doi.org/10.1016/j.eneco.2023.106695.

[11] D. Rossetto, The carbon border adjustment mechanism: what does it mean for steel recycling? Sustain. Horizons 5 (2023) 100048 https://doi.org/10.1016/j.horiz.2023.100048.

[12] Kuusi Tero, Björklund Martin, Kaitila Ville, Kokko Kai, Lehmus Markku, M. Mehling, Oikarinen Tuuli, Pohjola Johanna, Soimakallio Sampo, Wang Maria, Carbon Border Adjustment Mechanisms and Their Economic Impact on Finland and the EU, Publications of the Government's Analysis, Assessment, and Research Activities, 2020.

[13] Y. Ren, G. Liu, L. Shi, The EU Carbon Border Adjustment Mechanism will exacerbate the economic-carbon inequality in the plastic trade, J. Environ. Manage. 332 (2023) 117302, https://doi.org/10.1016/j.jenvman.2023.117302.

[14] B. Lin, H. Zhao, Evaluating current effects of upcoming EU Carbon Border Adjustment Mechanism: evidence from China's futures market, Energy Policy 177 (2023) 113573, https://doi.org/10.1016/j.enpol.2023.113573.

[15] H. Sun, J. Yang, Optimal decisions for competitive manufacturers under carbon tax and cap-and-trade policies, Comput. Ind. Eng. 156 (107244) (2021), https://doi.org/10.1016/j.cie.2021.107244.

[16] X. Sun, Z. Mi, L. Cheng, D.M. Coffman, Y. Liu, The carbon border adjustment mechanism is inefficient in addressing carbon leakage and results in unfair welfare losses, Fund. Res. (2023), https://doi.org/10.1016/j.fmre.2023.02.026.

[17] I. Overland, R. Sabyrbekov, Know your opponent: which countries might fight the European carbon border adjustment mechanism? Energy Policy 169 (113175) (2022) https://doi.org/10.1016/j.enpol.2022.11317517.

[18] B. Lim, K. Hong, J. Yoon, J.I. Chang, Cheong I. Pitfalls of the EU's carbon border adjustment mechanism, Energies 14 (21) (2021) 1–18, https://doi.org/10.3390/en14217303.

[19] Y. Chang, Y. Tian, G. Li, J. Pang, Exploring the economic impacts of carbon tax in China using a dynamic computable general equilibrium model under a perspective of technological progress, J. Clean. Prod. 3862022 (2023) 1–14, https://doi.org/10.1016/j.jclepro.2022.135770.

[20] European Commission, Summary Report: Public consultation On the Carbon Border Adjustment Mechanism (CBAM), European Commission, 2021.

[21] S. Perdana, M. Vielle, Making the EU Carbon Border Adjustment Mechanism acceptable and climate-friendly for least-developed countries, Energy Policy 170 (113245) (2022), https://doi.org/10.1016/j.enpol.2022.113245.

[22] N. Korpar, M. Larch, R. Stöllinger, The European carbon border adjustment mechanism : a small step in the right direction. International Economics and Economic Policy, Springer, Berlin Heidelberg, 2023, https://doi.org/10.1007/s10368-022-00550-9.

[23] M. Chepeliev, Possible implications of the European carbon border Adjustment Mechanism for Ukraine and other EU trading partners, Energy Res. Letters 2 (1) (2021) 1–6, https://doi.org/10.46557/001c.21527.

[24] H. Xiaobei, Z. Fan, M. Jun, The global impact of a carbon border adjustment mechanism: a quantitative assessment, Task Force on Climate, Dev. TInternat. Monetary Fund. (2022) 1–20.

[25] P. Rocchi, M. Serrano, J. Roca, I. Arto, Border carbon adjustments based on avoided emissions: addressing the challenge of its design, Ecol. Econ. 145 (2018) 126–136, https://doi.org/10.1016/j.ecolecon.2017.08.003.

[26] Gang H., Qilin Z., Xin Y. MANDARINABLE: Journal of Chinese Studies Language, Literature, Culture, and Journalism Trade Cooperation Between China and Indonesia in the Context of Carbon Border Tax: Current Situation and Prospect. 2023; 2(1): 39–52. https://journal.uns.ac.id/marble/index.

[27] D.P. Ramadhani, Y. Koo, Comparative analysis of carbon border tax adjustment and domestic carbon tax under general equilibrium model: focusing on the Indonesian economy, J. Clean. Prod 377 (2022) 134288, https://doi.org/10.1016/j.jclepro.2022.134288.

[28] P. Promsuwan, S.Y. Chua, The performance of Thailand's manufacturing export competitiveness with six selected East Asian countries using shift-share analysis, in: Asian Academic Society International Conference (AASIC) Proceeding Series, 2018, pp. 481–486.

[29] S. Anam, A. Solikin, Dampak Kebijakan Bea Masuk Tindakan Pengamanan terhadap Poteksi dan Daya Saing Produk Baja Lapis Aluminium Seng, Indonesian Treasury Review 5 (3) (2020) 235–253.

[30] C.A. Cahyani, Analisis daya saing industri besi baja dalam rangka menghadapi ACFTA, Econ. Dev. Anal. J. 3 (2) (2014) 337–344.

[31] E. Ervani, T. Widodo, M.E. Purnawan, Comparative advantage and trade specialization of East Asian countries : do East Asian countries specialize on product groups with high Comparative advantage ? Int. Business Res. 12 (2) (2019) 113–134, https://doi.org/10.5539/ibr.v12n2p113.

[32] L. Eicke, S. Weko, M. Apergi, A. Marian, Pulling up the carbon ladder? Decarbonization, dependence, and third-country risks from the European carbon border adjustment mechanism', Energy Res. Social Sci. 80 (2021) 102240 https://doi.org/10.1016/j.erss.2021.102240.

[33] T. Huang, Z. Liu, T. Zhao, Evolutionary game analysis of responding to the EU's carbon border adjustment mechanism, Energies 15 (2) (2022), https://doi.org/10.3390/en15020427.

[34] G. Mörsdorf, A simple fix for carbon leakage? Assessing the environmental effectiveness of the EU carbon border adjustment, Energy Policy (2022) 161, https://doi.org/10.1016/j.enpol.2021.112596.

[35] UNDP. The SDGs in Action, 2024. https://www.undp.org/sustainable-development-goals.

[36] International Trade Centre, Bilateral Trade Between Indonesia and the European Union (EU 28), International Trade Centre, 2023. https://www.trademap.org/Bilateral_TS.aspx?nvpm=1%7C360%7C%7C%7C14719%7C%7C215563%7C%7C4%7C1%7C1%7C2%7C2%7C1%7C1%7C1%7C1%7C1.

[37] Indonesia Iron and Steel Industry Association, Dashboard Export and Import of Indonesian, Indonesia Iron and Steel Industry Association, 2023. http://katalogbaja.iisia.or.id/index.php/public-dashboard/#step-.

[38] I.I. Danja, X. Wang, Matching comparative advantages to special economic zones for sustainable industrialization, Heliyon 10 (14) (2024) e34411, https://doi.org/10.1016/j.heliyon.2024.e34411.

[39] B. Balassa, Revealed comparative advantage revisited: an analysis of relative export shares of the industrial countries 1953-1971, Manchester School 45 (4) (1977) 327–344. https://onlinelibrary.wiley.com/doi/10.1111/j.1467-9957.1977.tb00701.x.

[40] J.C. Ninaquispe, M. María, A.L.P.S. Jugo, D.A.L. Muñoz, J.C.F. Rodriguez, B.H. M. Elera, K.C.V. Huatay, Peruvian agro-exports' Competitiveness: an assessment of the export development of its main products, Economies. 12 (6) (2024), https://doi.org/10.3390/economies12060156.

[41] A.D.B. Tarihoran, M. Hubeis, S. Jahroh, N. Zulbainarni, Competitiveness of and barriers to Indonesia's exports of ornamental fish, Sustainability (Switzerland) 15 (11) (2023), https://doi.org/10.3390/su15118711.

[42] F. İzgi, M. Kavacik, Analyzing global competitiveness of Turkish air conditioning industry, Turkish J. Eng. 8 (2) (2024) 209–234, https://doi.org/10.31127/tuje.1372141.

[43] Nabi I., Luthria M. Building competitiveness: a roadmap and policy guide. 2008.

[44] A.H.H. Mohamad, R. Ab-Rahim, Europe Union ban on palm oil: the trend of palm oil competitiveness and the Co-integration on the soybean and rapeseed oil, Int. J. Business Society 25 (1) (2024) 260–283, https://doi.org/10.33736/ijbs.6911.2024.

[45] B. Dalum, K. Laursen, G. Villumsen, Structural change in OECD export specialisation patterns: de-specialisation and "stickiness, International Review of Applied Economics 12 (3) (1998) 423–443, https://doi.org/10.1080/02692179800000017.

[46] R. Saxena, A. Kumar, R. Singh, R.K. Paul, M.S. Raman, R. Kumar, M.A. Khan, P. Agarwal, Examining export advantages in Indian horticulture: an approach based on product mapping and seasonality, J. Agribusin. Dev. Emerg. Econ. 14 (2) (2024) 161–192, https://doi.org/10.1108/JADEE-12-2021-0310.

[47] S. Shukla, K. Sadykova, J. Tian, Research on India-China agriculture trade dynamics: a comparative advantage analysis, PLoS One 18 (11) (2023) 1–22, https://doi.org/10.1371/journal.pone.0294561.

[48] E.N. Amalina, E. Yusida, F. Wijayanti, Indonesia's export comparative and competitiveness advantages in the 'emerging market' scheme during the pandemic, R-Economy 10 (1) (2024) 74–90, https://doi.org/10.15826/recon.2024.10.1.005.

[49] M.A. Wardani, S. Mulatsih, W. Rindayati, Competitiveness and factors affecting Indonesian food industry's export to regional comprehensive economic partnership, Etikonomi 17 (2) (2018) 185–198.

[50] Suharno Immanuel, A. Rifin, The Progressive Export tax and Indonesia's palm oil product export competitiveness, Buletin Ilmiah Litbang Perdagangan 13 (2) (2019) 211–232, https://doi.org/10.30908/bilp.v13i2.417.

[51] R. Destiningsih, R.R. Sugiharti, L. Togar Laut, S. Nur Safiah, A. Achsa, Competitiveness identification of fisheries export in Indonesia, in: IOP Conference Series: Earth and Environmental Science 530, 2020, https://doi.org/10.1088/1755-1315/530/1/012017.

[52] A. Niky Pinandhita, N. Agustina, Analysis of potential export diversification of rubber tire derivative products to 9 nontraditional countries, in: 3rd International

Conference on Trade, 2019, in: https://www.atlantis-press.com/proceedings/icot-19/125918444.
[53] F.J. Aguilar, Scanning the Business Environment, Macmillan Company, New York, 1967.
[54] T. Sammut-Bonnici, D. Galea, PEST analysis. Wiley Encyclopedia of Management, Wiley, 2015, https://doi.org/10.1002/9781118785317.weom120113, 1–1.
[55] N. Rastogi, M.K. Trivedi, PESTLE technique-a tool to identify external risks in construction projects, Int. Res. J. Eng. Technol. (2016). www.irjet.net.
[56] W. Pan, L. Chen, W. Zhan, PESTEL analysis of construction productivity enhancement strategies: a case study of three economies, J. Manage. Eng. 35 (1) (2019), https://doi.org/10.1061/(asce)me.1943-5479.0000662.
[57] I. Yüksel, Developing a multi-criteria decision making model for PESTEL analysis, Int. J. Business Manag. 7 (24) (2012) 52–66, https://doi.org/10.5539/ijbm.v7n24p52.
[58] I. Marinović-Matović, L. Arsić, Ecological dimension of PESTEL analysis in small enterprises in the Republic of Serbia, Reciklaza i Odrzivi Razvoj 13 (1) (2020) 63–71, https://doi.org/10.5937/ror2001063m.
[59] M. Maliszewska, M. Chepeliev, C. Fischer, E. Jung, How developing countries can measure exposure to the EU's carbon border adjustment mechanism. Trade Post, 2023. https://blogs.worldbank.org/en/trade/how-developing-countries-can-measure-exposure-eus-carbon-border-adjustment-mechanism.
[60] M. Hanafi, D. Wibisono, K. Mangkusubroto, M. Siallagan, M.J.K. Badriyah, Designing smelter industry investment competitiveness policy in Indonesia through a system dynamics model, J. Sci. Technol. Policy Manag. 10 (3) (2019) 617–641, https://doi.org/10.1108/JSTPM-06-2018-0064.
[61] The Indonesian Iron & Steel Industry Association. Dampak CBAM Terhadap Ekspor Produk Baja RI, 2024 (January 17). https://iisia.or.id/news/dampak-cbam-terhadap-ekspor-produk-baja-ri.
[62] C. Gomes, D.O. Arbiningrum, E. Blanco, A.M. Firdaus, Who is benefitting from fertilizer subsidies in Indonesia? Policy Res. Work. Paper Series 5758 (2011). http://econ.worldbank.
[63] A. Gupta, R. Pandey, S. Sapatnekar, Potential Implications of the EU's Carbon Border Adjustment Mechanism (408), National Institute of Public Finance and Policy working paper series, 2024, p. 408. https://nipfp.org.in/media/medialibrary/2024/03/WP_408_2024.pdf.
[64] Kementerian Energi dan Sumberdaya Mineral. INDONESIA: National Energy General Plan (RUEN) (Presidential Regulation No. 22/2017 of 2017). 2020. https://www.esdm.go.id/en/media-center/news-archives/national-energy-grand-strategy-to-ensure-energy-availability.
[65] I. Durant, C. Contreras, R. Hamwey, G. Mott, A. Nicita, R. Peters, C. Razo, D. A. Vivas, European Union Carbon Border Adjustment mechanism: implications for developing countries, in: United Nations Conference on Trade and Development, 2021. https://www.greenfinanceplatform.org/research/european-union-carbon-border-adjustment-mechanism-implications-developing-countries.
[66] G. Magacho, E. Espagne, A. Godin, Impacts of CBAM on EU trade partners: consequences for developing countries, AFD Res. Paper Issue 238 (2022) 1–20. https://www.cairn-int.info/journal-afd-research-papers-2022-238-page-1.htm?contenu=article.
[67] S.Y. Kalpikajati, S. Hermawan, Hambatan Penerapan Kebijakan Energi Terbarukan di Indonesia, Batulis Civil Law Review 3 (2) (2022) 187, https://doi.org/10.47268/ballrev.v3i2.1012.
[68] M. Jakob, Why carbon leakage matters and what can be done against it, One Earth 4 (5) (2021) 609–614, https://doi.org/10.1016/j.oneear.2021.04.010.
[69] P.S Johnson Kennedy, Analisis tingginya biaya logistik Di indonesia ditinjau dari dwelling time, J. Econ. Resour. 1 (2) (2019) 136–145, https://doi.org/10.33096/jer.v1i2.161.
[70] W.H. Suyatmiko, Memaknai turunnya skor indeks persepsi Korupsi Indonesia Tahun 2020, Integritas 7 (1) (2021) 161–178, https://doi.org/10.32697/integritas.v7i1.717.