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The impact of dynamic capabilities on competitive advantage in Vietnamese steel exporting enterprises under the carbon border adjustment mechanism

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ABSTRACT

The European Union's implementation of the Carbon Border Adjustment Mechanism (CBAM) poses significant challenges for Vietnam's steel export sector, which heavily depends on the EU market. CBAM imposes carbon taxes on imports with high emissions, particularly steel, raising costs and demanding stricter emissions data transparency. The Vietnamese steel industry struggles with outdated technologies, limited innovation investments, and unclear institutional policies, which weaken its competitive advantage in the global market. This study explores how dynamic capabilities diversification can enhance the competitiveness of Vietnamese steel enterprises in response to CBAM. It focuses on technological and green innovation as crucial factors that can provide new competitive advantages. The study also emphasizes the role of institutional environment policies, legal frameworks, and the global business climate in shaping innovation and competitiveness. Using a mixed-methods approach, including surveys of steel-exporting enterprises and expert interviews, the research examines how firms have been leveraging innovation to adapt to CBAM. Lessons from international experiences in institutional reform, green finance, and technological innovation are also incorporated to guide Vietnamese firms in expanding their sustainable export markets. Based on these findings, the authors propose recommendations to promote green transition, boost innovation, and improve the institutional environment, helping Vietnamese steel enterprises adapt to CBAM, enhance competitiveness, and grow sustainable export markets.

Contribution/Originality: The proposed model contributes to extending the theoretical literature on the impact of dynamic capabilities (DC) on competitive advantage (CA) under the Carbon Border Adjustment Mechanism in emission-intensive sectors such as the steel industry in developing countries like Vietnam. In addition, the research aims to provide crucial insights for managers in identifying the roles of technological innovation (TI), green innovation (GI), and institutional factors (IN) to enhance the effective adaptability and sustain the competitive capacity of enterprises.

1. INTRODUCTION

Environmental regulations have emerged as crucial factors shaping national and corporate competitiveness in the era of climate change and globalized trade (European Commission, 2023; United Nations, 2024). Among the most pioneering and influential regulatory acts in contemporary international trade is the Carbon Border Adjustment Mechanism, introduced by the European Union in 2023. Designed to curb carbon leakage and encourage cleaner production, CBAM imposes a carbon levy on imported goods with high emission intensity, with the global steel industry identified as a key target as it produces 7% of all global CO2 emissions. This has placed the Vietnamese steel industry in a precarious position. Vietnamese steel is one of the main exports in the country, with a total global output of 29 million tons in 2023, of which 35% was exported, with the EU being one of the biggest customers (European Commission, 2023). However, the Vietnamese steel industry is one of the largest generators of carbon emissions in Vietnam, with outdated technology and models, and limited support and funding from institutions to transition into more environmentally friendly methods. The implementation of CBAM is projected to increase export costs by 15–35 USD per ton based on the carbon tax, which will seriously hamper the ability of Vietnamese steel companies to compete in the EU market. Consequently, the key question now facing the Vietnamese steel industry is how they can best adjust, based on the tools available to them, to meet the requirements of CBAM to ensure that the EU market remains accessible. Additionally, the question exists of how the Vietnamese steel sector can further develop itself in a world that is increasingly becoming more eco-conscious; to not only maintain its current market share but also grow and become more competitive.

The competitive advantage of Vietnamese steel enterprises is increasingly shaped by the ability to attract green consumers and apply technological innovations to optimize production processes and reduce carbon emissions, which are considered key factors in brand positioning and international market expansion (Porter & Van Der Linde, 1995; Ueda, Takenaka, Váncza, & Monostori, 2009). Simultaneously, the EU's CBAM imposes stringent requirements on emission data transparency and the adoption of clean technologies (Ślusarczyk, 2018), forcing firms to invest comprehensively in green value chains. These two pressures demonstrate the essential link between dynamic capabilities and competitive advantage in the context of the global transition to sustainable development. However, effectively responding to CBAM is not simply a matter of financial investment; firms with strong dynamic capabilities are able to identify new opportunities, adapt to policy changes, and maintain competitive advantage through continuous innovation (Ambrosini, Bowman, & Collier, 2009; Cepeda & Vera, 2007). This requires businesses to overcome outdated business models to develop new strategies, prioritize resource restructuring, adjust operating models, and improve innovation efficiency (Teece, Pisano, & Shuen, 1997; Zahra & George, 2002). However, dynamic capabilities only maximize their effectiveness in a favorable institutional environment. Transparent, stable, and innovation-friendly institutions can promote green investment, product diversification, and enhance global position (Boudreaux & Nikolaev, 2019; North, 1990) while an institutional environment lacking transparency and many administrative barriers can hinder restructuring efforts and green transformation (Williamson, 2000) as Vietnam gradually adjusts its policies to integrate with global environmental standards, assessing and improving institutional factors becomes urgent.

As of this paper, there is a lack of literature on the approaches and methods available for Vietnamese companies to adjust to policies like the CBAM, especially in the context of the steel sector. This study, therefore, aims to develop a comprehensive theoretical framework, which can elucidate the pathways through which industries can best effectively transition to maintain their influence on the market and even further develop their competitive abilities. The findings are expected to offer empirical evidence and policy implications to support Vietnamese steel enterprises in accomplishing both aforementioned goals.

This study will develop an integrated analytical model that examines how dynamic capabilities might contribute to shaping the competitive advantage of Vietnamese steel-exporting enterprises under the implementation of the CBAM. The model proposes the trusting roles of technological innovation and green innovation, along with working to diminish, or at least moderate, the influence of institutional conditions inside Vietnam. A mixed-methods approach will be employed, combining expert interviews, field investigations, and quantitative surveys of steel firms to construct an empirical framework that captures both internal capacities and the external institutional context. The findings will indicate how enterprises with well-developed dynamic capabilities tend to adopt green technologies, improve production processes, and adjust their strategic orientation in response to carbon regulations and market transitions. The institutional environment, through regulatory frameworks, policy instruments, and supportive mechanisms, will also be shown to play a critical role in enabling innovation and strengthening competitive positioning during the green transformation.

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Carbon Border Adjustment Mechanism

The Carbon Border Adjustment Mechanism, established under Regulation (EU) 2023/956, is a key policy instrument of the European Union aimed at imposing a carbon tax on imported goods with high emission intensity. CBAM plays an important role in preventing "carbon leakage" and ensuring fairness in emission costs between goods produced within the EU and imported products, particularly from sectors such as steel, cement, fertilizers, aluminum, electricity, and hydrogen (OECD, 2025).

This mechanism is implemented in two phases: the transitional phase (2023–2025), which requires emission reporting without the obligation to purchase certificates, and the full implementation phase starting in 2026, when exporting enterprises to the EU must purchase CBAM certificates corresponding to their emission levels (European Commission, 2023).

CBAM not only affects manufacturing and exporting enterprises but also impacts the global supply chain, financial institutions, investment funds, and regulatory agencies. While enterprises are under pressure to improve technology to reduce emission costs, financial institutions must also adjust their investment portfolios to minimize risks from high-emission sectors. At the same time, regulatory agencies and industry associations in non-EU countries play a role in supporting enterprises to adapt by promoting technological innovation, improving production processes, and formulating appropriate policies.

2.2. Competitive Advantage

This study applies two main theoretical foundations: the Resource-Based Theory (RBT) and the Porter Hypothesis. According to RBT, a firm's sustainable competitive advantage does not solely stem from market conditions but primarily originates from its ability to possess and effectively exploit internal resources that are valuable, rare, inimitable, and non-substitutable (Barney, 1991; Wernerfelt, 1984). These resources include physical capital (technology, equipment, raw materials), human capital (knowledge, skills, learning capacity), and organizational capital (processes, systems, coordination capabilities) (Kozlenkova, Samaha, & Palmatier, 2014; Peteraf, 1993). However, in today's competitive and dynamic environment, possessing resources alone is not sufficient. Enterprises need dynamic capabilities, which refer to the ability to restructure, adapt, and continuously innovate in order to transform resources into practical advantages (Eisenhardt & Martin, 2000; Teece et al., 1997). This highlights the importance of aligning strategic initiatives with external environmental requirements, where steel companies must rely on internal resources while simultaneously anticipating and adapting proactively to regulatory changes such as CBAM.

In addition, the Porter Hypothesis posits that stringent environmental regulations do not reduce competitiveness but, on the contrary, can stimulate innovation and enhance operational efficiency (Porter & Van Der Linde, 1995). According to this hypothesis, when enterprises face compliance pressure, they tend to improve technology, optimize processes, and develop environmentally friendly products, thereby not only meeting regulations but also creating added value. Numerous empirical studies have confirmed the positive role of environmental policies in promoting innovation and firm performance (Jaffe, Newell, & Stavins, 2003; Lanoie, Laurent-Lucchetti, Johnstone, & Ambec, 2011; Reichenbach & Requate, 2012). This theoretical foundation has also been reinforced in the Vietnamese context, where empirical evidence suggests that environmental regulations can promote organizational innovation, improve environmental performance, and enhance firms' long-term competitiveness. Specifically, studies in the manufacturing sector in Vietnam emphasize that green innovation and proactive adaptation to regulatory pressures help businesses both ensure regulatory compliance and enhance their strategic position in the international market (Huynh, Nguyen, Doan, Tran, & Nguyen, 2024; Nguyen Van, Estalia, & Razacova, 2017). In the steel industry, where CBAM is emerging as a binding green trade mechanism, this perspective suggests the value of investing in low-emission technologies, green steel products, and value chain optimization as pathways toward sustainable export competitiveness. In the steel industry, where competition is intense and technologies are similar, competitive advantage stems not only from production scale but also from process innovation, green product development, and market adaptability (Barnett & Hansen, 1996; Kim & Mauborgne, 2005).

2.3. Dynamic Capabilities

Dynamic capabilities are one of the core concepts in modern strategic management. Teece et al. (1997) defined dynamic capabilities as a firm's ability to integrate, build, and reconfigure internal resources to effectively adapt to changes in the business environment. Unlike ordinary capabilities that maintain stable operational performance, dynamic capabilities enable firms to continuously innovate and respond flexibly to market, technological, and policy fluctuations (Eisenhardt & Martin, 2000; Helfat et al., 2009). Theoretically, the dynamic capabilities perspective argues that firms cannot sustain a competitive advantage merely by possessing resources but must develop the ability to adapt, innovate, and learn in order to enhance the strategic value of those resources (Zollo & Winter, 2002). Studies such as Leonard-Barton (1992), Helfat et al. (2009), and Teece (2007) affirm that dynamic capabilities serve as a strategic asset that enables firms to maintain a long-term competitive advantage in an ever-changing environment.

In practice, dynamic capabilities have been shown to positively influence three key strategic aspects of steel-exporting enterprises: (i) dynamic capabilities promote technological innovation by enhancing companies' abilities to absorb knowledge, integrate new technologies, and improve production processes (Wang & Ahmed, 2007; Zollo & Winter, 2002). At the same time, they facilitate creativity and experimentation, helping firms overcome outdated technologies and develop advanced products (Lawson & Samson, 2001; Zollo & Winter, 2002); (ii) Dynamic capabilities support green innovation, which is increasingly becoming a mandatory requirement in the context of policies such as CBAM. Enterprises with high dynamic capabilities can identify environmental opportunities, restructure their processes toward sustainability, and collaborate with partners to develop low-emission technologies (Aragón-Correa & Sharma, 2003; Dyer & Singh, 1998; Hart, 1995); (iii) Dynamic capabilities are the foundation for maintaining a long-term competitive advantage, not only through the ability to quickly adapt to market fluctuations but also through the capacity to reconfigure resources, establish strategic partnership networks, and nurture a culture of continuous innovation (Afuah & Tucci, 2001; Barney, 1991; Teece, 2007).

Based on this foundation, the research proposes the following hypotheses:

H_1: Dynamic capabilities have a positive impact on the technological innovation of Vietnamese steel-exporting enterprises.

H_2: Dynamic capabilities have a positive impact on green innovation of Vietnamese steel-exporting enterprises.

H_6: Dynamic capabilities have a positive impact on the competitive advantage of Vietnamese steel-exporting enterprises.

2.4. Technological Innovation

Technological innovation is the process of applying, improving, or developing new technological solutions to enhance production efficiency, product quality, and competitiveness (Dosi, 1988; Schumpeter, 1934). According to Porter and Van Der Linde (1995), technological innovation not only helps reduce operating costs but also creates added value through product improvement, thereby bringing sustainable competitive advantage to enterprises. The sustainable innovation theory of Boons and Lüdeke-Freund (2013) emphasizes that technological innovation needs to be integrated with green innovation and organizational innovation to deliver comprehensive economic, social, and environmental value. The application of technology does not solely stem from internal strategy but also depends on institutional pressure, organizational capabilities, and innovation resources, factors that are particularly important in high-emission industries such as steel.

In addition to optimizing operations, technological innovation is also a driving force for promoting green innovation. Recent studies indicate that enterprises with high technological capabilities are able to improve production processes, reduce energy consumption, and develop environmentally friendly products (Guo, Xie, & Wu, 2021). This not only helps comply with emission regulations such as CBAM but also expands opportunities to access green markets and enhances brand image (Cheng, Li, Choi, Guo, & Wang, 2024).

Based on this foundation, the research proposes the following hypothesis:

H_3: Technological innovation has a positive impact on the competitive advantage of Vietnamese steel-exporting enterprises.

H_5: Technological innovation has a positive impact on green innovation of Vietnamese steel-exporting enterprises

2.5. Green Innovation

Green innovation is a sustainable development strategy in which enterprises integrate environmental factors into the process of improving products, services, or production processes (Rennings, 2000). According to Chen, Lai, and Wen (2006), green innovation is divided into two types: green product innovation and green process innovation. Both aim to reduce resource consumption, limit emissions, and enhance energy efficiency (Horbach, Rammer, & Rennings, 2012).

Green innovation can be classified based on the driving motivation: Proactive or reactive (Zhang, Wang, & Zhou, 2019). Proactive innovation stems from strategic orientation, while reactive innovation responds to pressure from the market or policy (Bansal & Roth, 2000). In addition, green innovation can also be categorized by the level of impact: incremental innovation and radical innovation, corresponding to minor improvements and transformative changes, respectively (Ghisetti, 2014; Kemp & Pearson, 2007).

According to Demirel and Kesidou (2019), green innovation not only helps enterprises improve environmental performance but also expand markets, enhance their brand image, and meet the increasing expectations of customers and investors. Therefore, green innovation is not merely a trend but also a strategic factor in enhancing competitiveness.

Based on this foundation, the research proposes the following hypothesis:

H_4: Green innovation has a positive impact on the competitive advantage of Vietnamese steel-exporting enterprises.

2.6. Institutions

According to the Institutional Economics theory by North (1990), institutions are systems of formal rules such as laws, public policies, and tariffs, as well as informal elements such as social norms, cultural values, and business ethics. These factors shape economic behavior and influence the competitiveness of enterprises. An effective institutional system helps reduce transaction costs, enhance transparency, and create incentives for enterprises to innovate in technology to maintain a competitive advantage (Acemoglu & Robinson, 2012; Williamson, 2000). In contrast, weak institutions can increase compliance costs, hinder innovation, and reduce motivation for investment and development (North, 1990).

In the context of the steel industry facing increasingly stringent environmental barriers such as CBAM, institutions act as a "regulatory system" that influence how enterprises approach innovation and leverage dynamic capabilities. Specifically, supportive policies such as tax incentives, R&D funding, and intellectual property protection can encourage enterprises to invest in green technologies and innovative activities (Acemoglu, Johnson, & Robinson, 2005; Audretsch et al., 2002). At the same time, cultural factors such as creativity, risk tolerance, and societal cooperation also contribute to shaping innovation behavior within enterprises (Helmke & Levitsky, 2004; Shane, 2003).

Therefore, institutions not only have a direct impact on innovation but also play a moderating role in the relationship between dynamic capabilities and innovation. In a favorable institutional environment, enterprises are more capable of effectively leveraging dynamic capabilities to develop new technologies and achieve green transformation.

Based on this foundation, the research proposes the following hypothesis:

H_{7a}: Institutions moderate the relationship between dynamic capabilities and technological innovation.

H_{7b}: Institutions moderate the relationship between dynamic capabilities and green innovation.

From all the hypotheses, we suggest the research model.

Figure 1: The proposed research model illustrates the relationship between dynamic capabilities, technological innovation, and green innovation in achieving a competitive advantage, with institutions serving as a moderating factor. This model informs the development of the study's hypotheses and conceptual framework.

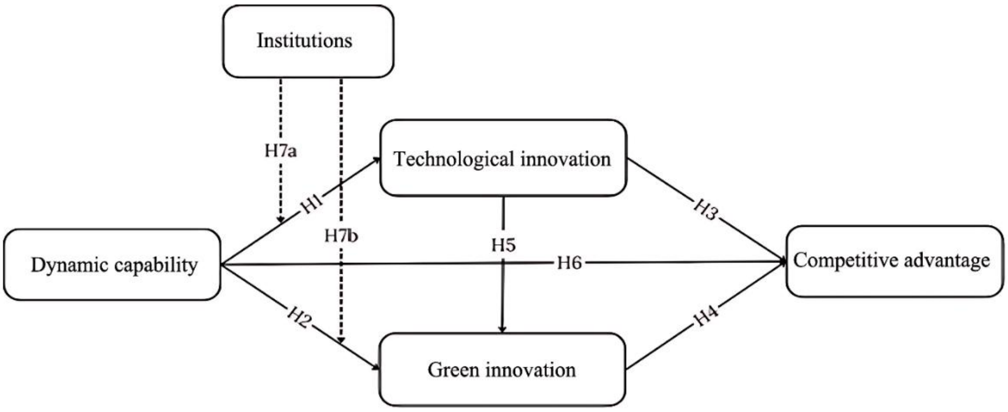

Figure 1. Research model proposed.

3. RESEARCH METHODOLOGY

3.1. Data Collection

3.1.1. Primary Data

For the qualitative phase, in-depth interviews with seven experts, including executives from steel associations, academics specializing in environmental policy, and production managers from foreign-invested enterprises, were conducted. These interviews were conducted either face-to-face or via online platforms. The aim was to explore important factors in the context of the Vietnamese steel industry under the impact of CBAM, thereby adjusting the initial research model, selecting appropriate variables, and completing the official survey questionnaire. The results from the interviews helped confirm the suitability of some theoretical concepts and at the same time adjusted some measurement variables that are not close to business practice.

Table 1 presents the background information of experts participating in the in-depth interviews. It provides their titles, academic or professional expertise, and affiliated institutions, which help validate the qualitative phase of the study.

Table 1. Information on experts participating in in-depth interviews.

Title	Field of expertise / Academic rank	Institution
Members of the board of directors	Green steel and sustainable manufacturing	Vietnam Steel Associations
Professors	Sustainability and environmental policy	Research institutes
Production managers	Metallurgy technology	FDI enterprises

For the quantitative phase, data were collected through a survey to test the published theoretical model. The questionnaire was designed based on the synthesized theory and adjustments drawn from qualitative research. The questionnaire content includes two parts: descriptive information about the respondent and the enterprise (workforce size, operating time, business type, enterprise headquarters, exported steel products, proportion of export revenue), and a system of observed variables measuring the main concepts in the model, using a Likert scale from (1) "completely disagree" to (5) "completely agree". These key concepts include dynamic capabilities, technological innovation, green innovation, institutional factors, and competitive advantage. Each was measured using multiple observed variables adapted from previous studies. Specifically, dynamic capabilities were measured using six items reflecting the ability to sense change, adapt strategies, and integrate technologies (Eisenhardt & Martin, 2000; Pavlou & El Sawy, 2011; Teece, 2007). Technological innovation includes five items based on investment in low-emission technology, R&D, and process improvements (Li & Atuahene-Gima, 2001; Tsai, 2001). Green innovation was assessed via five items related to clean technology and environmentally friendly practices (Chen et al., 2006; Porter & Van Der Linde, 1995). Institutional factors captured perceptions of policy and support related to CBAM (Kostova, 1997; Peng, Wang, & Jiang, 2008). Competitive advantage was measured through five items reflecting positioning, green branding, and export capacity (Delmas & Toffel, 2008; Porter & Van Der Linde, 1995). A structured questionnaire was administered from June to September 2024 across the Northern, Central, and Southern regions of Vietnam to steel firms. The target respondents included middle and senior-level managers, such as directors, heads, and deputy heads of departments in export, production, quality management, technological innovation, and strategic development. Participants were required to possess a certain level of understanding regarding export operations and international environmental standards, with a particular emphasis on the CBAM. A total of 259 responses were collected, of which 183 were validated and included in the analysis. The survey captured information related to gender, educational attainment, geographical location, and enterprise size. Sampling was conducted using a convenient random sampling approach, focusing on firms exporting to the European Union, where CBAM regulations are actively enforced. The objective was to ensure diversity and adequate representation of Vietnam's steel-exporting sector amid the global transition toward low-carbon production.

3.1.2. Secondary Data

The study utilizes secondary data on the current state of Vietnam's steel exports, international carbon adjustment policies, institutional characteristics, and enterprise competitiveness under the CBAM. Key areas of focus include export performance, international carbon regulation frameworks, institutional dynamics, and firm-level competitiveness. Sources were collected from statistical records, policy documents, and peer-reviewed research issued by authoritative bodies such as the General Statistics Office of Vietnam, the Ministry of Industry and Trade, the Vietnam Steel Association, the European Commission, the World Bank, the OECD, and the World Steel Association. Additionally, the academic literature addressing dynamic capabilities, technological and green innovation, institutional factors, and competitive advantage under carbon regulatory regimes was extensively reviewed. These materials served to ground the theoretical framework, inform the research model, refine measurements, and contextualize the interpretation of quantitative findings.

3.2. Data Analysis

The research data were processed and analyzed using SPSS 25.0 and SmartPLS 4.0. The analytical process incorporated both qualitative and quantitative data to ensure methodological coherence, logical consistency, and alignment with the specific characteristics of the research model.

Qualitative data from expert interviews were analyzed using content analysis to identify core themes related to the key concepts in the research model. These findings were used to refine the theoretical framework, adjust the measurement scale, and place the research model in the practical context of the Vietnamese steel export industry under pressure from CBAM. Quantitative data were analyzed using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach, which is suitable for models with multiple latent constructs, complex interrelationships, and medium sample sizes. First, descriptive statistical analyses were conducted to summarize the characteristics of the survey sample, including the size and duration of business operations, legal form, geographical area, and key export product groups, to determine the representativeness and suitability of the sample for the research context. Next, the reliability of the scales was assessed through Cronbach's Alpha and Composite Reliability, thereby checking the internal consistency between observed variables in the same concept and eliminating variables that did not meet the requirements to ensure the stability of the measurement tool. Based on the remaining variables, Exploratory Factor Analysis (EFA) was implemented to determine the latent structure between groups of observed variables, and at the same time provide an empirical basis for refining the measurement model before testing with the structural model. Based on the EFA results, the measurement model is evaluated by examining the convergence of theoretical concepts using the average variance extracted (AVE) and outer loadings to determine the representativeness of each observed variable for the latent variable. Finally, the structural model is tested to evaluate the research hypotheses through path coefficients analysis, coefficient of determination (R^2) showing the model's explanation level for dependent variables, and the variance inflation factor (VIF) index to control multicollinearity between independent variables, ensuring the accuracy and inferential value of the theoretical model. Figure 2 illustrates the trends in Vietnam's steel exports and annual growth rates from 2019 to 2024, showing key fluctuations and reflecting the industry's sensitivity to global shocks and regulatory changes such as CBAM.

4. RESEARCH RESULTS AND DISCUSSIONS

4.1. Current Situation of Vietnam's Export Steel Industry

The period from 2019 to 2024 witnessed significant fluctuations in Vietnam's steel export activities, clearly reflecting both the strategic role and the high sensitivity of the industry to global economic, political, and environmental changes. Specifically, in 2019, Vietnam exported approximately 4.59 million tons of steel, laying the foundation for subsequent development. However, in 2020, export volume dropped to 3.24 million tons, a decline of 29.5%, likely due to the impact of the COVID-19 pandemic and disruptions in global supply chains. In 2021, steel exports surged dramatically to 12.2 million tons, the highest level during the entire period, representing a 277.1% increase from the previous year. This remarkable recovery partially reflects the flexible and adaptive capacity of Vietnamese enterprises in responding to global demand, particularly amid supply shortages in major economies. However, this growth momentum was not sustained. In 2022, export volume declined to 8.397 million tons (−31.2%), as various geopolitical instabilities such as the Russia–Ukraine conflict, rising input prices, and, notably, increasing pressure from non-tariff barriers related to carbon emissions imposed by major importing markets began to arise. Although a partial recovery occurred in 2023 with 11.1 million tons exported (+32.2%), the figure dropped again in 2024 to 8.042 million tons (−27.6%). Despite this volatility, Vietnam's steel exports have consistently remained within the range of 8 to 12 million tons per annum, reinforcing the sector's pivotal role in the country's export portfolio. However, as one of the most carbon-intensive industries, steel manufacturing is now at the forefront of the international decarbonization movement. The European Union's implementation of CBAM a landmark climate policy serves as a clear signal that environmental compliance will increasingly dictate market access.

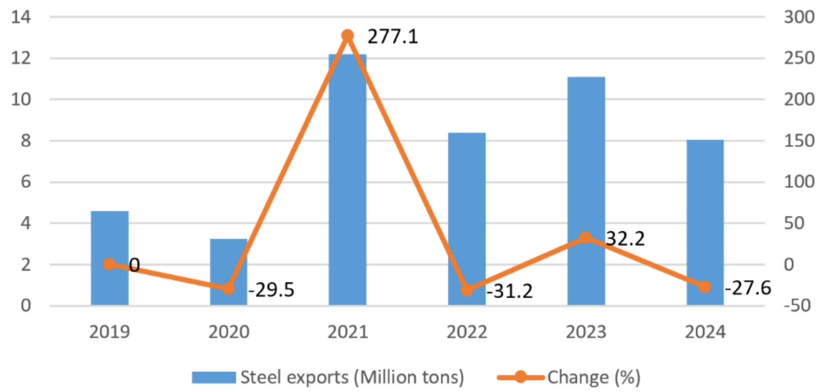

Figure 2. Vietnam's steel exports and annual growth rate 2019–2024.

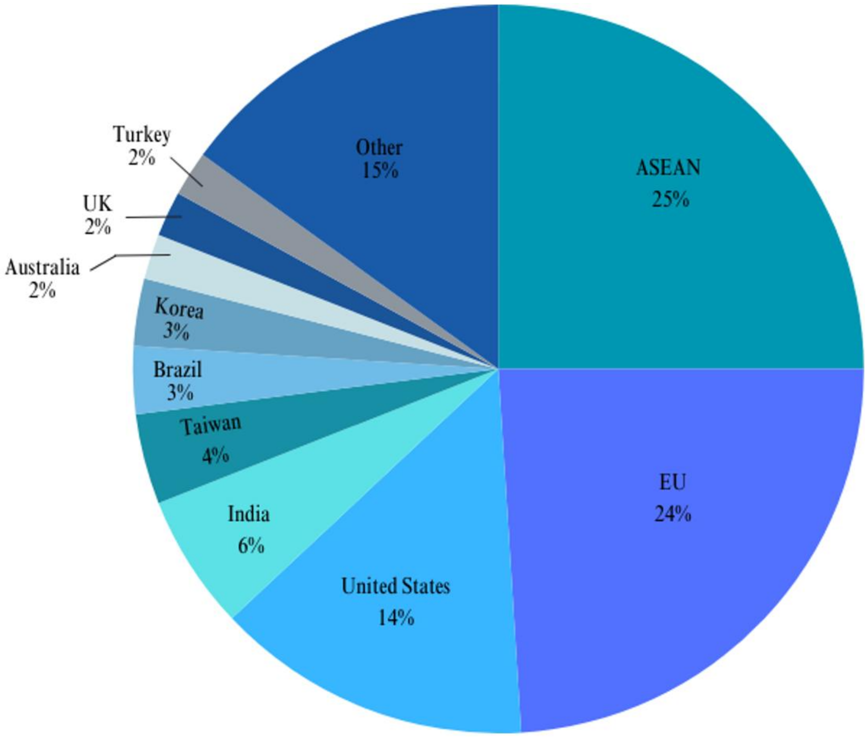

Figure 3. Top 10 steel export markets of Vietnam in 2024.

The data presented in Figure 3 illustrate a highly concentrated export landscape, wherein ASEAN and the European Union (EU) emerge as the two dominant markets. While ASEAN remains the largest export destination, absorbing 25% of Vietnam's total steel exports due to its geographical proximity, reduced logistics costs, and long-standing regional trade ties, the EU follows closely, accounting for 24%. However, the significance of the EU market extends well beyond its economic volume. The European Union is not only a key consumer but also a global regulatory trendsetter, particularly in the realm of climate-related trade measures. Its implementation of the CBAM, the world's first carbon-based trade policy instrument, positions the EU as both a strategic market and a critical regulatory gatekeeper. This dual function underscores the growing subservience of Vietnamese steel exports to shifting compliance requirements originating from Europe.

Given this context, Vietnam's considerable export reliance on the EU represents largely not economic opportunity but rather regulatory exposure. The imminent operationalization of CBAM marks a pivotal turning point that will likely redefine international steel trade patterns and impose new competitive constraints. For Vietnam's steel industry, adapting to this evolving regulatory environment is not optional but imperative. Proactive alignment with CBAM requirements is essential to maintaining market access and safeguarding export competitiveness in the European market. In sum, the EU's centrality as both a major export destination and a source of transformative policy innovations renders it the most strategically consequential market for Vietnam's steel sector moving forward.

4.2. International Experiences in Responding to CBAM

In the context of CBAM posing increasingly stringent requirements on carbon emissions, many countries have proactively adjusted their policies, technologies, and institutions to adapt. These international experiences help minimize trade risks while simultaneously offering a comprehensive approach to the industrial transformation process toward sustainable development. Referring to policies on carbon pricing, investment in green technology, renewable energy, business support, and dialogue with the EU will help Vietnam have a more practical basis to build a suitable roadmap in the new context.

4.2.1. Establishing a Carbon Pricing System

A key strategy adopted by many countries in response to the CBAM is the development of carbon pricing systems. These are policy-based mechanisms designed to assign a monetary value to greenhouse gas emissions, thereby encouraging firms to reduce their carbon footprint through market-based incentives. By doing so, they prepare enterprises for emissions-related financial obligations prior to the imposition of carbon tariffs when exporting to the EU. China implemented a national Emissions Trading System (ETS) in 2021, allowing firms in heavy industries to trade emissions allowances. Before scaling up nationwide, China piloted ETS in seven major regions including Beijing, Shanghai, and Guangdong starting in 2013, enabling policy refinement based on localized results (Chen & Wu, 2022; World Bank, 2024). South Korea launched its national ETS in 2015, becoming the first country in Asia to adopt a fully operational system. The scheme familiarizes enterprises with emissions monitoring and reporting, while facilitating allowance trading to reduce mitigation costs (Gogger, 2024). India is developing a carbon credit trading platform where firms that reduce emissions can sell surplus credits, creating financial incentives for the green transition.

4.2.2. Investing in Green Steel Technologies

Steel production technology significantly increases national carbon emissions. As a result, investment in green steel solutions has become a key strategy for many countries to comply with CBAM requirements. South Korea, for example, launched the HYBRIT program, which replaces coking coal with hydrogen in the iron ore reduction process, achieving substantial CO_2 reductions. POSCO, the country's leading steelmaker, has pledged to achieve carbon neutrality by 2050 and aims to cut emissions by 50% by 2040 through the development of HyREX technology. The HyREX pilot facility in Pohang currently produces 24 tons of molten iron per day with considerably lower emissions than conventional methods. This technological shift enables South Korea to maintain its steel export competitiveness in the EU market under CBAM (GMK Center, 2024).

In India, companies such as Tata Steel and JSW Steel are heavily investing in green hydrogen-based steelmaking to reduce reliance on coking coal and cut CO_2 emissions during production. The adoption of green hydrogen aligns with EU environmental standards and offers a long-term competitive edge as global trade increasingly favors low-emission manufacturing (Kumar, 2024). China has also promoted low-emission steel production by offering R&D funding packages and tax incentives for green steel projects. These policy measures encourage technological upgrades and should accelerate the transition toward sustainable industrial practices (Eversheds Sutherland, 2025).

4.2.3. Developing Renewable Energy

Expanding renewable energy capacity plays a crucial role in supporting low-emission steel production and aligning national strategies with CBAM requirements. China leads globally in wind and solar power generation and aims to reach 1,200 gigawatts (GW) of renewable capacity by 2030. As one gigawatt is defined as equal to one billion watts, that substantial number is equivalent to nearly the entire current electricity capacity of the United States, demonstrating China's strong commitment to building a large-scale clean electricity system. This facilitates the decarbonization of industry, especially in the high-emission steel sector that is directly affected by CBAM (Russell, 2024).

India has committed to achieving 500 GW of non-fossil energy capacity by 2030, with at least half from renewable sources. These solar and green hydrogen incentives are facilitating a shift toward cleaner steelmaking practices (Ministry of Power Government of India, 2023). In South Korea, renewable energy is being developed alongside nuclear power to ensure a stable and low-carbon electricity supply for green steel production, reducing reliance on fossil fuels while meeting emissions targets (World Nuclear Association, 2024).

4.2.4. Financial Support for Enterprises

Transitioning to low-emission steel production in line with CBAM standards requires substantial investment, prompting many governments to introduce financial support schemes to assist domestic industries. In China, firms benefit from tax exemptions, R&D subsidies, and financial assistance targeting clean energy and low-carbon technologies, allowing them to pursue emission reductions without compromising competitiveness (Huld, 2024). India has allocated a 600 million USD support package specifically for the steel sector to ease financial constraints associated with green technology adoption (Press Information Bureau Government of India, 2024). South Korea has mobilized both public funding and international investment sources to finance decarbonization projects, while also offering tax incentives and subsidies to firms investing in clean steel technologies, thereby enhancing their ability to compete in CBAM-regulated markets (Kweon, 2024).

4.2.5. Negotiating EU Recognition of Domestic Measures

Several countries have actively engaged in negotiations with the EU to ensure that domestic emission reduction mechanisms are recognized under the CBAM framework, thereby avoiding excessive carbon taxation on exports. China has enhanced transparency in its monitoring, reporting, and verification system and has proposed the acceptance of domestic carbon credits to ease financial burdens on exporters (Zhou & Zhao, 2023). South Korea has pursued the alignment of its national ETS with EU standards, seeking mutual recognition to prevent unnecessary carbon charges (World Bank, 2024). India, viewing CBAM as a potential trade barrier, has advocated for EU acceptance of its domestic mitigation efforts or a more flexible implementation timeline to safeguard the continuation of exports (Russell, 2024).

International experience shows a fundamental shift in the way countries approach CBAM. Rather than simply viewing it as a trade barrier, many countries have turned CBAM into a driver of industrial transformation and green innovation. China has prioritized the establishment of a national emissions trading system and the expansion of renewable energy deployment. South Korea has made notable progress in developing carbon-neutral steel production technologies; meanwhile, India has prioritized financial support and policy dialogue. Importantly, these measures are implemented as part of an integrated national strategy that combines policy reform, infrastructure investment, and institutional support. This coordinated approach helps countries mitigate risks associated with CBAM while strengthening their competitiveness in the rapidly expanding green supply chains.

For Vietnam, international lessons are not only for reference but also show practical directions for effective adaptation to CBAM. Protecting export capacity to the EU requires a comprehensive policy, combining carbon pricing tools, low-emission steel technology, clean energy, financial support, and international negotiations. If implemented synchronously, this will be the foundation for Vietnam to transform into a low-carbon industrial model, enhance resilience to trade risks, and establish a position in a greener global value chain.

4.3. Research Findings

4.3.1. Measurement Model

This study utilizes Cronbach's Alpha and Composite Reliability (CR) to evaluate the reliability of measurement scales for each factor in SmartTPLS 4. As shown in Table 2, all constructs demonstrated high internal consistency, with Cronbach's Alpha and CR values exceeding the threshold of 0.7 (Hair, Hult, Ringle, & Sarstedt, 2014). Specifically, the scores for competitive advantage (CA) were 0.864 and 0.902; for dynamic capabilities (DC), 0.904 and 0.926; for green innovation (GI), 0.849 and 0.890; for technological innovation (TI), 0.897 and 0.922; and for institutions (IN), 0.943 for both indices. The constructs CA, DC, GI, TI, and IN demonstrated high reliability, with both Cronbach's Alpha and composite reliability exceeding 0.7. The research team also assessed convergent validity using the average variance extracted (AVE), and found that all constructs (CA, DC, GI, TI, IN) met the required threshold, with AVE values greater than 0.5.

Table 2. Measurement model.

Determinants	Attributes	Outer loading	Cronbach's Alpha	CR	AVE
Dynamic capability (DC)	DC1. Identify changes in the business environment quickly	0.816	0.904	0.926	0.676
	DC2. Monitor market trends for environmental compliance	0.831			
	DC3. Have a dedicated unit for tracking international trade policy changes	0.788			
	DC4. Restructure operations to meet CBAM requirements	0.838			
	DC5. Develop long-term strategies for environmental regulations	0.847			
	DC6. Rapidly adopt technologies to reduce environmental impact	0.814			
Technological innovation (TI)	TI1. Invest in low-emission steel technology	0.891	0.897	0.897	0.704
	TI2. Apply advanced waste treatment technology	0.784			
	TI3. Collaborate on green technology development	0.805			
	TI4. Formulate R&D strategy for technological improvement	0.843			
	TI5. Generate revenue from new products	0.868			
Green innovation (GI)	GI1. Prioritize the use of recycled materials	0.818	0.849	0.890	0.618
	GI2. Use renewable energy in steel production	0.763			
	GI3. Apply international environmental standards	0.806			
	GI4. Adopt environmentally friendly technologies	0.784			
	GI5. Enhance competitiveness through green innovation	0.757			
Institution (IN)	IN1. Receive financial support for CBAM	0.881	0.943	0.943	0.769
	IN2. Comply through domestic carbon tax	0.859			
	IN3. Obtain technical support for innovation	0.845			
	IN4. Follow clear CBAM roadmap	0.870			
	IN5. Receive CBAM advice from trade bodies	0.926			
Competitive advantage (CA)	CA1. Maintain stable export market share in the EU	0.825	0.865	0.902	0.647
	CA2. Gain advantage from green steel products over international competitors	0.786			
	CA3. Build environmentally friendly brand recognition	0.821			
	CA4. Implement balanced pricing strategy for CBAM compliance	0.793			
	CA5. Receive high EU customer appreciation for sustainability commitment	0.797			

4.3.2. Structural Equation Modeling

To validate the proposed hypotheses, the structural model was tested using path coefficients, variance inflation factors, confidence intervals, and bootstrapping procedures. Additionally, the model's quality was assessed using R^2, Cohen's effect size, and the PLS-Predict procedure to ensure predictive relevance, as recommended by Sarstedt, Ringle, and Hair (2021). The research team used the bootstrapping analysis method, and the results are presented in Table 3 and Figure 4.

Table 3. Hypothesis testing results.

Hypothesis	Relationship	VIF	Beta	t-Value	P values	Result
H1	DC -> TI	1.046	0.404	5.624	0.000	Supported
H2	DC -> GI	1.273	0.294	3.576	0.000	Supported
H3	TI -> CA	1.458	0.285	3.546	0.000	Supported
H4	GI -> CA	1.484	0.241	2.968	0.003	Supported
H5	TI -> GI	1.395	0.252	3.293	0.001	Supported
H6	DC -> CA	1.413	0.334	3.901	0.000	Supported
H7b	IN x DC -> GI	1.079	0.300	4.677	0.000	Supported
H7a	IN x DC -> TI	1.024	0.187	2.753	0.006	Supported

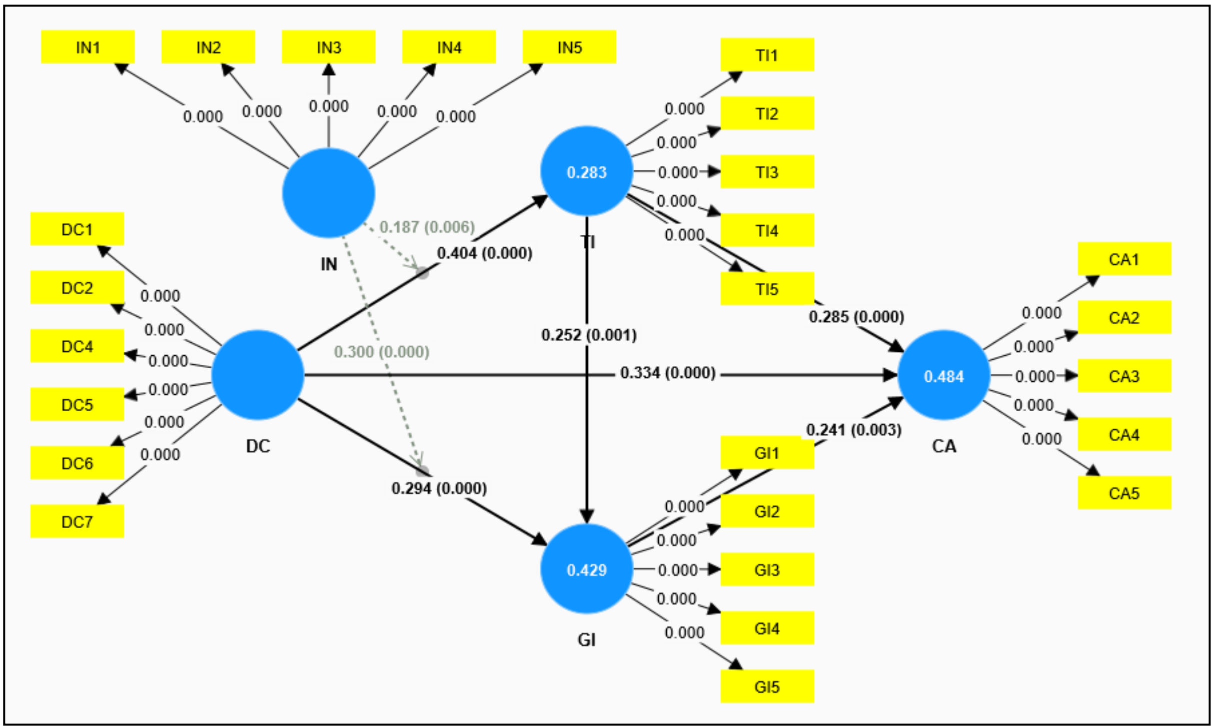

Figure 4. Structural measurement model.

The results confirm that dynamic capabilities exert strong and statistically significant effects on both technological innovation ($\beta = 0.406$, $p < 0.001$) and green innovation ($\beta = 0.294$, $p < 0.001$). These findings highlight the foundational role of firms' adaptive capacity and strategic reconfiguration in fostering dual innovation trajectories, consistent with theoretical propositions by Teece et al. (1997) and Zahra and George (2002). The structural pathway from dynamic capabilities to competitive advantage does not operate in a linear or isolated fashion; rather, it unfolds through complementary innovation mechanisms, each representing distinct but interconnected forms of capability deployment.

Technological innovation and green innovation each contribute meaningfully to competitive advantage, with green innovation showing a more pronounced effect ($\beta = 0.449$) compared to technological innovation ($\beta = 0.226$). This differential impact reinforces the assumptions of the Porter Hypothesis (Porter & Van Der Linde, 1995) suggesting that environmental innovation not only mitigates regulatory risk but also generates tangible strategic returns. Recent empirical research (e.g., (Cheng et al., 2024; Guo et al., 2021)) corroborates the growing role of green innovation in shaping firm performance amid rising carbon constraints. Notably, the positive influence of technological innovation on green innovation ($\beta = 0.252$, $p < 0.001$) demonstrates a sequential, mutually reinforcing dynamic: firms investing in technological capabilities tend to enable more profound environmental transformation. This layered interaction supports the interpretation of innovation as a cascading process rather than a set of disparate activities. Institutional conditions serve both as moderators and direct enablers. They enhance the effects of dynamic capabilities on technological innovation (β = 0.187) and green innovation (β = 0.300), while also exerting a direct influence on green innovation outcomes (β = 0.129). These findings align with institutional economic theory (North, 1990) which posits that regulatory clarity, policy incentives, and institutional coherence lower adjustment costs and expand firms' opportunity space for innovation-driven responses.

Findings from expert interviews offer robust contextual support for the quantitative model. Respondents consistently observed that firms with greater internal dynamism tend to lead in technological adoption, organizational restructuring, and proactive alignment with international carbon regulations. Institutional mechanisms, especially fiscal incentives, standards harmonization, and inter-agency coordination, were viewed as essential to unlocking innovation capacity and overcoming structural inertia. This convergence between statistical findings and qualitative insights strengthens the internal validity of the model and underscores its contextual relevance to the Vietnamese steel sector. Altogether, the results affirm the proposed framework in which dynamic capabilities influence competitive advantage through innovation pathways, with institutional quality shaping both the depth and direction of these linkages. The study advances existing literature by integrating dynamic capability theory with institutional and innovative perspectives, contributing new understanding to sustainable competitiveness in emission-intensive industries under emerging carbon trade regimes.

5. CONCLUSION

The findings highlight the pivotal role of dynamic capabilities in shaping how Vietnamese steel enterprises respond to the pressures posed by the CBAM. These capabilities strengthen firms' ability to adapt to external changes and pursue innovation, particularly in advancing technological development and transitioning toward low-carbon production. The greater the impact of green innovation on competitive advantage, compared to technological innovation, signals a structural change in how firms create value. Environmental regulatory alignment is emerging as a core component of competitiveness, especially in markets governed by carbon-related trade measures. Institutional conditions influence both the efficacy of internal capabilities and the success of innovation. A policy environment characterized by clarity, consistency, and strategic alignment is vital for enabling the transition toward sustainable business practices.

Insights from expert interviews reinforce the empirical findings by illustrating how firms with strong dynamic capabilities actively revise production strategies, invest in clean technologies, and implement emissions monitoring systems aligned with emerging regulatory expectations. The interviews further reveal that the effectiveness of these capabilities depends on an enabling institutional environment, where regulatory clarity, policy coherence, and financial accessibility play a decisive role in reducing transition costs and encouraging innovation-oriented practices. These insights closely mirror international experiences in economies that have established carbon pricing frameworks, promoted green steel technologies, expanded renewable energy supply, and introduced financial support mechanisms to accelerate industrial decarbonization.

A strategic response to CBAM necessitates institutional readiness at both regulatory and operational levels. Experiences from countries with advanced carbon governance underscore the pivotal role of strong policy leadership in facilitating industrial adaptation. For Vietnam, this entails a proactive approach by state agencies, extending beyond the formulation of technical standards to include the removal of structural and financial barriers that impede enterprise alignment with international carbon expectations. A key priority is the development of a comprehensive regulatory framework tailored to high-emission industries such as steel. This ought to involve the establishment of a nationally recognized emissions accounting methodology that aligns with the CBAM reporting requirements, underpinned by a centralized digital platform to support verification and compliance processes. Rather than relying on fragmented procedures dispersed across multiple agencies, the certification process should be consolidated under a single, authoritative body integrated into the national electronic trade infrastructure.

At the same time, financial systems must also evolve to support the transition. To address this, the government should expand state-backed credit mechanisms, establish environmental guarantee funds, and develop co-investment schemes in partnership with international development agencies. Public resources should be strategically leveraged to unlock private sector participation, especially in pilot programs and industrial demonstrations.

At the institutional level, establishing a green standard system for steel is critical. Without clear definitions of acceptable emissions thresholds or technology classifications, domestic firms remain uncertain about investment priorities. A standardized, enforceable framework would provide clarity for compliance while also enhancing credibility in foreign markets. Vietnam should concurrently invest in domestic testing and certification centers with internationally recognized protocols, enabling firms to meet CBAM obligations without relying solely on external verification services.

Institutional coordination must transcend regulatory functions to encompass broader dimensions essential for a successful green transition. A successful green transition also depends on knowledge diffusion, workforce readiness, and inter-ministerial collaboration. Capacity-building initiatives should be launched across the public and private sectors to ensure technical teams are equipped with skills in emissions monitoring, environmental auditing, and green finance. Higher education and vocational programs should be updated accordingly. Public–private platforms focused on industrial decarbonization can further accelerate collective learning and cross-sector alignment. These reforms, grounded in international experience and reinforced by domestic consensus, will enable Vietnamese authorities not only to mitigate CBAM-related risks but to redefine industrial competitiveness in an increasingly carbon-constrained global economy.

As CBAM increasingly influences global trade norms, competitive advantage no longer depends on scale or output but on the ability to comply with strict emission standards and to restructure business strategies toward sustainability. Expert interviews conducted during the study indicate that several Vietnamese enterprises remain constrained by short-term thinking, limited emission control systems, and a lack of access to international green finance. To address these challenges, firms should initially focus on restructuring operational scale in a more efficient and financially balanced manner. Regarding market orientation, experts emphasize the need to shift from volume-based growth to product repositioning. Firms must prioritize low-emission product lines, adopt transparent environmental reporting practices, and pursue internationally recognized certifications such as ISO 14067 and Environmental Product Declarations. This approach will facilitate integration into global supply chains, especially in markets with increasing carbon-based import requirements. On the technological front, transitioning to electric arc furnace systems using recycled materials and renewable electricity has become a critical pathway. Integrating smart control systems and advanced waste treatment technologies further reduces emissions and enhances cost-efficiency. Technical and environmental finance experts highlight the shortage of qualified personnel as a key bottleneck. Upgrading production technologies without parallel investments in workforce capacity will undermine the effectiveness of green transformation. Enterprises must therefore invest in specialized training and collaborate with international partners to build operational expertise. Risk management also plays a central role. Real-time monitoring tools, scenario-based planning, and financial hedging instruments provide necessary safeguards against fluctuations in raw material prices, exchange rates, and environmental regulations. A comprehensive strategy that integrates innovation, financial resilience, and human capital development is essential to building long-term competitiveness. Vietnamese firms that internalize these lessons and act decisively will not only withstand the pressures of CBAM but also elevate their position in the emerging low-carbon industrial landscape.

While this study offers timely contributions to the understanding of how Vietnamese steel-exporting enterprises are responding to CBAM, its scope remains bound by certain limitations. The relatively short observation period limits insights into long-term strategic adjustments, particularly as the policy enters full enforcement. A longitudinal design would allow for deeper analysis of how firms evolve in response to sustained carbon regulation. The sample's concentration on small and medium-sized enterprises, though representative of a major segment, may not fully reflect the strategic heterogeneity present across the sector. Broader inclusion of firm sizes and clearer segmentation by product type would enhance both analytical precision and generalizability. Extending this research framework to other CBAM-regulated sectors could further contribute to a more comprehensive understanding of how carbon border policies reshape global value chains and industrial competitiveness.

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