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Carbon Disclosure and Green Innovation: Evidence from High-Emission Enterprises in Vietnam

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ABSTRACT

Vietnam is facing significant pressure to reduce greenhouse gas (GHG) emissions in pursuit of its Net Zero target by 2050, while its carbon accounting system and carbon disclosure (CA) guidelines remain underdeveloped. This study develops and validates a multivariate structural model to examine the determinants of green innovation (GI) and CA among high-emission enterprises in Vietnam. Specifically, the study investigates the effects of the environmental regulation (REG) and international standards, green transformational leadership (GTL), and digital transformation (DT) on GI and CA, as well as their impacts on sustainable corporate performance (SCP). In addition, the moderating role of green competitive advantage (GCA) is assessed. The proposed research model is tested using Partial Least Squares Structural Equation Modeling (PLS-SEM). The expected findings provide quantitative evidence on how leadership, regulation, and digital technologies foster GI, enhance carbon transparency, and improve the sustainable performance of enterprises in Vietnam.

1. INTRODUCTION

Climate change and growing demands for corporate environmental responsibility have intensified the need for transparency regarding greenhouse gas (GHG) emissions and mitigation efforts. Carbon disclosure (CA) has emerged as a crucial tool for firms to monitor, report, and manage their emissions, enabling stakeholders to evaluate environmental performance [1]. The theoretical foundations explaining corporate disclosure behaviors include legitimacy theory, signaling theory, stakeholder theory, and voluntary disclosure theory, which have been extensively applied in the context of environmental and carbon emission disclosure [2].

A multitude of empirical studies have investigated the influence of CA and green innovation (GI) on firm performance, value, and reputation. Liu et al. [1] found that companies with high emissions often use CA as a reputational management tool, but elevated emissions may negatively impact financial performance. Xu et al. [3] showed that firms with transparent CA tend to achieve superior financial performance, stronger reputation, and attract institutional investors. Kurnia et al. [4] reported that CA positively affects firm value in Indonesia but not in Australia. Zhou et al. [5] applied natural language processing to analyze CA in Chinese publicly listed firms, concluding that higher-quality disclosure improves profitability, ROE, Tobin's Q, and reduces stock volatility. Other studies also indicate that integrating GI with CA not only reduces emissions but enhances sustainable corporate performance (SCP) and green competitive advantage (GCA).

In pursuit of the Net Zero 2050 commitment, Vietnam issued Decree 06/2022/ND-CP to mitigate GHG emissions and Circular 17/2022/TT-BTNMT to offer guidance on GHG inventory, while also preparing for the domestic carbon market from 2025 to 2028. Nonetheless, the carbon accounting system—the methodology for measuring, documenting, reporting, and managing emissions (GHG Protocol: Scope 1, 2, 3)—remains in its early stage.

The implementation of CA requires a coordination of various interrelated elements. The legal environment and international standards serve a fundamental role, encompassing frameworks such as CDP, GHG Protocol, IFRS S2, and ESG standards. Mandatory laws, such as the EU's CSRD, the CBAM mechanism, the Emission Trading System (ETS) by Liesen [6], and carbon taxes, provide significant pressure on enterprises to publicly publish emission data [7]. Simultaneously, accounting competencies and technology are crucial for ensuring report reliability, necessitating the capacity to analyze Big Data, implement AI, and standardize emission factors to improve accuracy [8].

In Vietnam, certain high-emission firms, such as EVN, PV Gas, BSR, Vinamilk, and SABECO, have commenced CA by inventorying and disclosing their emission levels in sustainability reports [9], adhering to GRI standards and the GHG Protocol [10]. The Vietnamese Accounting Standards (VAS) presently lack explicit norms, resulting in inconsistent openness. This underscores the necessity of establishing national standards that correspond with international

benchmarks, alongside investment in measuring technology and the improvement of human resources, particularly within the electricity, cement, oil and gas, and steel sectors, which are the largest emitters.

Although many international studies have highlighted the important roles of CA and GI in improving financial performance, reputation, and GCA, empirical evidence on this relationship in Vietnam remains limited. The research gap can be summarized according to three main criteria.

First, a contextual gap: there has been no comprehensive empirical study investigating the relationship between GI and CA among high-emission enterprises in Vietnam, particularly in the electricity, cement, oil and gas, and steel industries, which account for a large share of national emissions. Previous studies have mainly focused on developed countries or on China, Indonesia, and Malaysia [1, 3].

Second, theoretical inconsistency: the theories used to explain CA and GI, including legitimacy theory [11], signaling theory, stakeholder theory [2] và voluntary disclosure theory [12], have not been systematically tested in the Vietnamese context. As a result, there is still no unified theoretical foundation for explaining the mechanisms driving CA and GI. Some studies suggest that social pressure and regulatory requirements are the main drivers, as emphasized in legitimacy theory, whereas others stress strategic benefits and market signaling, thereby creating theoretical inconsistency regarding the reasons firms engage in CA and GI.

Third, inconsistent empirical findings: international evidence on the effects of CA and GI on SCP, GCA, and financial performance remains inconclusive. For example, previous studies show that high-quality CA improves financial performance and firm value [1, 5], whereas some researchers found that CA had a positive effect only in Indonesia and no significant effect in Australia [13]. In addition, Liesen et al. [6] indicated that the integration of GI and CA enhances SCP and GCA, but the magnitude of these effects depends on industry context and local regulatory conditions.

Therefore, this study aims to explore the relationship between GI and CA among high-emission enterprises in Vietnam, analyze the factors that drive or constrain the adoption of CA, and provide practical evidence to support firms and policymakers in improving sustainable performance and GCA in the context of digital transformation (DT) and the green economy.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Regulatory environment and international standards

2.1.1 Environmental regulation → Green innovation → Sustainable corporate performance

Environmental regulation (REG) is widely recognized as an important external driver encouraging firms to adopt environmentally responsible practices and invest in GI. Regulatory policies often impose compliance requirements that increase short-term operational costs, particularly in pollution-intensive industries [3, 14]. However, well-designed regulations can also stimulate firms to develop cleaner technologies and more efficient production processes, thereby improving environmental performance and long-term competitiveness [15]. The effectiveness of regulatory environments largely depends on enforcement mechanisms such as monitoring systems, environmental courts, technical assistance programs, and financial incentives [16], as well as international market pressures from global supply chains and export standards [17]. These institutional mechanisms influence how firms respond to regulatory pressure and determine whether REG becomes a barrier or a catalyst for innovation [18].

International evidence shows that REG can enhance GI, but its effectiveness depends on context and enforcement mechanisms, such as monitoring and technical support [13]. Rules that include monitoring and technical support can turn compliance pressure into a catalyst for innovation [5]. In China, the establishment of environmental courts significantly increased the number of green patents, utilize the Environmental Policy Stringency index and determine that the impacts of emission reduction are contingent upon the specific type of policy instrument employed [19]. Shen et al. [20] identified significant impacts inside energy-intensive businesses from an industrial standpoint. Zhang et al. [21] presented supplementary evidence from developing economies regarding the correlation between REG and GI. REG serves as a GI driver solely when supplemented by monitoring, support, and a suitable policy design, providing stronger causal evidence than correlation research.

In Vietnam, the influence of REG on GI is primarily seen through internal support structures. Van et al. [22] demonstrated that REG has not been rigorously enforced. Le and Gia [23] affirmed that GI, in conjunction with green corporate social responsibility, facilitates the conversion of regulatory pressure and international standards into sustainable competitive practices.

Research in Vietnam concurs [22, 23], highlighting the critical importance of internal competencies (GTL, EMA, CSR) in the context of inadequate enforcement. Consequently, the Vietnamese setting must assess both the degree of law enforcement and internal preparedness to comprehensively comprehend the REG → GI mechanism.

H1: REG has a positive impact on GI.

2.1.2 Environmental regulation → Carbon disclosure → Sustainable corporate performance

REG, particularly reporting requirements and transparency standards, can encourage firms to disclose more environmental and carbon-related information. Regulatory pressure increases the need for firms to demonstrate compliance with environmental policies and sustainability expectations. As a result, firms tend to improve the level and quality of CA in order to reduce information asymmetry, enhance transparency, and maintain legitimacy with regulators, investors, and stakeholders.

From a signaling and transparency perspective, CA serves as an important mechanism through which firms communicate their environmental commitment and risk management practices. Greater transparency can reduce information risk, strengthen investor confidence, and improve corporate reputation, which may ultimately contribute to SCP. Prior studies suggest that improved environmental disclosure helps reduce uncertainty and strengthens corporate accountability [24]. Empirical research also indicates that CA can enhance sustainable performance, particularly when combined with GI and sustainability strategies [25]. However, some studies suggest that the relationship may not always be linear. For instance, moderate levels of disclosure can improve emission reduction efficiency, while excessive disclosure may generate

diminishing returns [24]. In addition, the interaction between REG and disclosure policies can reduce environmental risks when supported by clear policy frameworks and institutional guidance [26].

The legal framework for CA in Vietnam remains inadequate, leading many enterprises to report mainly to satisfy the demands of foreign supply chains and investors [27]. Van et al. [22] underscored the significance of green leadership and a dedicated work ethic in advancing GI, which indirectly bolsters corporate accountability. Research by Le and Gia [23] indicated that GI and green corporate social responsibility (CSR) facilitate the influence of green leadership, demonstrating that REG can improve CA and sustainable consumption practices SCP.

In contrast to countries that have strict REG frameworks that assist in the development of CA, the reduction of risks, and the increase of SCP, the REG→CA→SCP chain in Vietnam continues to rely significantly on external pressures and voluntary initiatives. At present, the primary motivating factors are international market requirements, environmental management accounting (EMA), and GTL, rather than domestic laws.

H2: REG has a positive impact on CA.

2.2 Green transformational leadership

GTL refers to a form of transformational leadership that emphasizes environmental values, vision, and motivation to achieve sustainability goals. Leaders who adopt this style encourage employees to support environmental initiatives, integrate sustainability into organizational strategies, and allocate resources for green practices. Through vision sharing, inspiration, and environmental awareness, GTL helps build an organizational culture that supports sustainable development and green transformation.

2.2.1 Green transformational leadership → Green innovation → Sustainable corporate performance

From a resource and capability perspective, leadership plays an important role in shaping firms' innovation orientation. GTL encourages employees to participate in environmental initiatives, provides training and empowerment, and supports the development of green technologies and environmentally friendly processes. By promoting environmental awareness and providing strategic direction, GTL helps firms integrate sustainability into their innovation activities. Previous studies indicate that GTL can strengthen firms' environmental capabilities and facilitate the adoption of GI practices [28, 29]. For instance, research shows that GTL combined with EMA can enhance firms' ability to identify environmental costs and opportunities, thereby supporting GI strategies and improving sustainable performance. Evidence from Vietnam also suggests that green leadership, together with corporate social responsibility initiatives, encourages manufacturing firms to implement sustainable practices and GI [22, 23]. Based on these arguments, green transformational leadership is expected to promote firms' GI activities.

H3: GTL has a positive impact on GI.

2.2.2 Green transformational leadership → Carbon disclosure → Sustainable corporate performance

Besides influencing innovation activities, leadership can also affect corporate transparency and environmental reporting practices. Leaders with strong environmental awareness tend to prioritize environmental accountability and encourage firms to disclose environmental and carbon-related information to stakeholders [30]. From a transparency perspective, GTL can influence CA through two main mechanisms. First, environmentally oriented leaders often integrate carbon measurement and disclosure into corporate sustainability and CSR strategies, thereby increasing the level of environmental transparency. Second, GTL may support the adoption of management tools such as EMA, which improves the accuracy and reliability of emission data and facilitates carbon reporting. Empirical studies suggest that leaders with strong environmental commitment are more likely to promote environmental disclosure and sustainability reporting practices [29, 31, 32]. In addition, low-carbon leadership has been found to encourage emission-reduction initiatives and increase the level of CA within firms [33]. These findings indicate that leadership orientation plays an important role in shaping firms' environmental transparency. Therefore, green transformational leadership is expected to enhance CA practices in firms.

H4: GTL has a positive impact on CA.

2.3 Digital transformation → Carbon disclosure → Sustainable corporate performance

DT plays an important role in improving corporate transparency and environmental reporting. Through data digitalization and automated reporting systems, firms can collect, process, and disclose environmental information more efficiently, thereby improving the transparency of corporate accountability [34]. In addition, digital technologies enhance internal governance and monitoring systems, which support emission management and environmental reporting practices [35]. Empirical studies also suggest that DT facilitates sustainability reporting and emission monitoring by improving data accuracy and accessibility [36, 37]. However, the effectiveness of DT in promoting CA often depends on institutional conditions such as regulatory frameworks and disclosure requirements.

In Vietnam, DT in environmental reporting remains at an early stage and is largely driven by pressures from international supply chains and export markets. Limited regulatory enforcement and governance mechanisms may constrain the potential impact of DT on CA and SCP.

H5: DT has a positive impact on CA.

2.4 Green innovation

2.4.1 The impact of green innovation on carbon disclosure

GI has been widely recognized as a key driver for improving firms' environmental performance and environmental transparency. By adopting cleaner technologies and environmentally friendly production processes, firms can reduce emissions and enhance the credibility of their environmental information disclosure. As a result, firms engaging in GI are more likely to provide transparent carbon-related information to stakeholders. Empirical studies provide evidence supporting the relationship between GI and CA. Previous research shows that firms with stronger GI capabilities tend to achieve higher efficiency in emission reduction and greater transparency in environmental reporting [38]. In addition, the integration of GI with environmental management practices such as EMA can enhance sustainability performance and improve environmental

disclosure [39]. Studies in emerging markets further suggest that GI helps firms respond to climate policies, reduce environmental risks, and strengthen the transparency of CA [25, 40]. Other studies highlight the role of governance mechanisms and stakeholder pressure in strengthening the relationship between GI and environmental transparency [41]. Evidence from Vietnam also indicates that innovation strategies in the carbon credit market contribute to the development of CA practices [42]. Overall, the literature suggests that GI not only reduces emissions but also promotes greater transparency in CA, particularly when supported by effective governance and regulatory frameworks.

H6: GI has a positive impact on CA.

2.4.2. The impact of green innovation on sustainable corporate performance

GI is widely recognized as an important driver of SCP. By adopting environmentally friendly technologies and improving resource efficiency, firms can reduce production costs, enhance environmental performance, and strengthen their competitive advantage. These improvements contribute to enhanced long-term economic, environmental, and social performance.

Empirical evidence supports the positive relationship between GI and SCP. Previous studies indicate that environmental commitment, EMA, and GI jointly enhance SCP [43]. Research in Malaysia also shows that GI and innovation capability significantly improve sustainable competitive performance [44]. Other studies highlight that the effectiveness of GI is strengthened when firms demonstrate strong environmental awareness and leadership commitment [45]. In addition, green transformational leadership can enhance SCP indirectly through GI and environmental performance, highlighting the mediating role of GI in sustainability outcomes [46]. Studies in Vietnam also confirm the importance of GI in enhancing SCP [22, 23, 47]. Overall, the literature indicates that GI significantly contributes to improving firms' SCP.

H7: GI has a positive impact on SCP.

2.5 The impact of carbon disclosure on sustainable corporate performance

CA is increasingly recognized as an important factor influencing SCP. By providing transparent information about firms' carbon emissions and environmental practices, CA improves environmental transparency. This transparency reduces information asymmetry and enhances stakeholder trust, which may improve firms' reputation and access to capital.

Empirical studies generally support the positive relationship between CA and SCP. Prior research indicates that CA, together with green accounting practices and green leadership, can strengthen SCP [48]. Other studies highlight that the effectiveness of environmental disclosure increases when firms adopt comprehensive green strategies and environmental management practices [49]. Furthermore, transparent environmental reporting improves the reliability of corporate information and enhances stakeholder confidence, thereby contributing to better sustainability performance [50, 51]. Integrated reporting that includes carbon-related information may also create market-recognized green advantages and improve long-term corporate value [52].

However, the effectiveness of CA may depend on institutional and governance conditions. In countries with strong legal and regulatory frameworks, CA helps reduce information risk, facilitate access to capital, and improve firm value. In contrast, in developing economies such as Vietnam, the impact of CA may depend on supporting mechanisms such as green accounting, governance quality, and strategic environmental management [51, 53]. Overall, the literature suggests that CA contributes to improving SCP.

H8: CA has a positive impact on SCP.

2.6 Green competitive advantage and the moderating role

GCA refers to a firm's ability to gain competitive benefits from environmentally friendly strategies, technologies, and capabilities. Recent research suggests that GCA plays an important moderating role in the relationship between environmental practices and firm performance.

Previous studies indicate that GCA strengthens the impact of GI on SCP. Firms that possess strong GCA are better able to convert GI activities into market value and long-term sustainability outcomes [53-56]. Similarly, GCA may enhance the effectiveness of CA. By leveraging environmental information strategically, firms can improve their reputation, attract environmentally conscious stakeholders, and strengthen their competitive position [51].

Other studies also highlight the importance of green capabilities and green accounting tools in enhancing firm value and sustainability performance [50, 52]. These findings suggest that environmental initiatives such as GI and CA do not automatically improve SCP. Instead, firms must possess sufficient green capabilities to transform environmental initiatives into competitive advantages.

In emerging economies such as Vietnam, the moderating role of GCA may be particularly important. Due to weaker regulatory enforcement and institutional constraints, firms with stronger green capabilities are more likely to transform environmental practices into sustainable performance outcomes.

Therefore, GCA is expected to strengthen the impact of both GI and CA on SCP.

H9: GCA positively moderates the relationship between GI and SCP.

H10: GCA positively moderates the relationship between CA and SCP.

2.7 Sustainable corporate performance

SCP is a framework for evaluating a company's performance beyond financial metrics, encompassing environmental efficiency and social responsibility, thereby illustrating the equilibrium among economic, environmental, and social advantages over the long term [57, 58]. In the research setting, the term SCP is favored over exclusively emphasizing financial performance or corporate environmental performance because the objective is to evaluate the holistic influence of environmental management policies and practices, such as CA and GI, on SCP. SCP facilitates the incorporation of financial metrics, resource efficiency, ecological performance, and social influence, thereby more precisely representing the intermediary function of environmental accounting instruments and GCA in advancing GI and improving information transparency [31, 61]. Consequently, employing SCP as an output indicator in

the study facilitates a comprehensive analysis of the REG→CA→SCP process, while distinctly illustrating the interconnected influence of financial, environmental, and social issues on enhancing corporate performance in emerging economies.

Building upon the theoretical foundations and hypotheses developed above, this study proposes an integrated model illustrating the relationships among REG, GTL, DT, GI, CA, GCA, and SCP, as presented in Figure 1.

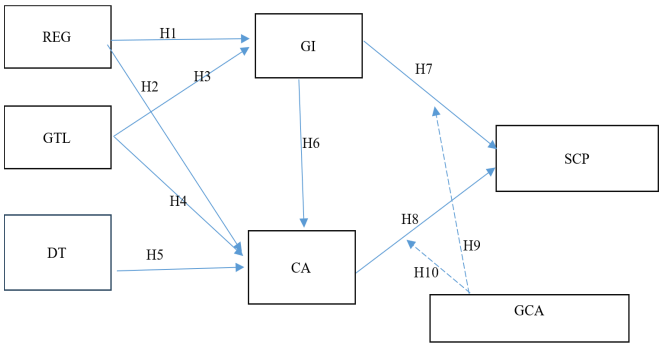

Figure 1. Research model

3. RESEARCH METHODOLOGY

The authors used a mixed research method to explore both theoretical depth and practical feasibility, including:

3.1 Qualitative research methodology

Objective: To establish a theoretical foundation, validate the measurement scales, and test the hypothesis model in the context of Vietnam.

Subjects: Environmental management experts, financial directors, heads of ESG departments, and leaders of high-emission enterprises (energy, electricity, cement, steel, oil, and gas).

Expected Results: To identify the influencing factors and the underlying relationships between GTL, REG, DT, GI, CA, SCP, and GCA, while refining the measurement scales and adding context-specific variables suitable for the Vietnamese context.

3.2 Quantitative research methodology

Objective: To test the structural model and hypotheses H1–H9.

Survey subjects: A total of 400 survey questionnaires were distributed to high-emission enterprises in Vietnam, of which 321 were valid, representing a response rate of 80.25%. The data collected from accounting staff accounted for 42.35%, while the leadership team accounted for 22.75%, including the Board of Directors at 3.18% and the Chief Accountant at 19.65%; the Environmental Department accounted for 12.07%.

Measurement tool: A questionnaire based on a 5-point Likert scale, adapted from validated international studies and refined based on qualitative results.

Data analysis: The SMART PLS _SEM software was used to assess the direct and indirect relationships between variables, while also examining the moderating role of GCA.

In Vietnam, secondary data on CA and sustainability reports are still limited and inconsistent. Therefore, the authors collected primary data through surveys. Qualitative research was used to build standardized scales and understand the practical context, while quantitative research helps validate the theoretical relationships accurately and broadly.

4. RESEARCH RESULTS

4.1 Assessing the reliability of the scale

The results of the reliability and convergence analysis indicate that all measurement scales meet the required standards. The evaluation results show that the Cronbach's Alpha of each factor ranges from 0.813 to 0.928 meeting the reliability requirements of the scale. The Cronbach's Alpha indexes of each observed variable are all greater than 0.7 [59]. The results of the reliability assessment of the scale, in which some observed variables "GTL_5 = 0.642"; "CA_5 = 0.651" have loading factors less than 0.700, so they are eliminated from the model. The composite reliability (CR) values range from 0.877 to 0.949, exceeding the recommended threshold of 0.7, indicating a high level of consistency among the observed variables within each measurement scale. The average variance extracted (AVE) value ranges from 0.642 to 0.823, so the scales of each variable in the model all achieve convergent value. The analysis results are shown in Table 1.

Table 1. Reliability and convergence analysis of factors

Factors	Observation Variable	Factor Loading	CA	CR	AVE
Regulatory Environment and International Standards (REG)	REG1 - Firms exhibit strict adherence to mandatory environmental regulations	0.725	0.911	0.931	0.694
	REG2 - International standards exert pressure that fosters GI and CA	0.879			
	REG3 - Supervisory and managerial mechanisms increase the efficiency of implementing environmental regulations	0.894			
	REG4 - Firms are provided with technical assistance or financial subsidies to facilitate the implementation of GI and CA	0.853			
	REG 5 - The stringency of environmental policies fosters investment in GI and CA	0.855			
	REG 6 - Pressure from international markets promotes CA and GI reporting	0.778			
	GTL1 - Inspirational leadership oriented towards GI and CA objectives	0.886	0.928	0.949	0.823

Green Transformational Leadership (GTL)	GTL2 - Leadership promoting the adoption of GI and CA management tools	0.915			
	GTL3 - Leadership supporting training and empowerment for GI and CA	0.922			
	GTL4 - Leadership prioritizing carbon emission measurement and reporting	0.906			
	GTL5 - Leaders actively promote sustainability-oriented initiatives and CSR within the organization	0.642			
Digital Transformation (DT)	DT1 - Digitalization of environmental data and carbon reporting	0.891	0.908	0.935	0.783
	DT2 - Application of automation in sustainable management	0.907			
	DT3 - DT helps reduce emissions and enhance transparency	0.913			
	DT4 - DT improves carbon emission disclosure	0.826			
Green Innovation (GI)	GI1 - Development of green products, processes, or technologies	0.724	0.813	0.877	0.642
	GI2 - Improving production to reduce emissions and energy use	0.796			
	GI3 - Application of GI to enhance carbon disclosure transparency	0.826			
	GI4 - Improving sustainability performance and operational outcomes	0.854			
Carbon Disclosure (CA)	CA1 - Firms comprehensively disclose carbon emission information	0.872	0.894	0.926	0.759
	CA2 - Integrated carbon reporting with environmental management and green accounting	0.844			
	CA3 - Comprehensive disclosure of carbon emission information	0.887			
	CA4 - CA enhances firm value and competitive advantage	0.880			
	CA5 - Trustworthy information for management support	0.651			
Sustainable Corporate Performance (SCP)	SCP1 - Firms reduce emissions and optimize resources effectively	0.858	0.846	0.897	0.685
	SCP2 - Achieving environmental objectives through the use of carbon accounting information	0.813			
	SCP3 - Firms achieve improvements in value and competitiveness via sustainability initiatives	0.743			
	SCP4 - Improving performance and operational outcomes through carbon information	0.889			
Green Competitive Advantage (GCA)	GCA1 - Firms possessing green capabilities and resources for optimizing GI/CA impacts	0.821	0.851	0.899	0.691
	GCA2 - Green governance promotes GCA to enhance GI/CA effectiveness towards SCP	0.840			
	GCA3 - Carbon reporting quality and management improve the regulatory role of GCA	0.781			
	GCA4 - Pressures from the market and stakeholders enhance GCA's influence on SCP	0.881			

4.2 Collinearity of observed variables

The results of the multicollinearity test of the observed variables are shown in the Table 2.

Table 2. Summary of VID magnification factors

Observation Variable	VIF	Observation Variable	VIF	Observation Variable	VIF
CA1	2.302	GCA3	1.870	REG2	2.583
CA2	2.298	GCA4	2.967	REG3	2.923
CA3	2.804	GI1	1.451	REG4	2.687
CA4	2.534	GI2	1.627	REG5	2.766
DT1	3.109	GI3	1.828	REG6	2.179
DT2	3.281	GI4	2.032	SCP1	2.220
DT3	3.267	GTL1	2.964	SCP2	1.981
DT4	2.355	GTL2	3.294	SCP3	1.604
GCA1	1.849	GTL3	3.280	SCP4	2.385
GCA2	2.490	GTL4	3.209	GCA x GI	1.000
		REG1	1.625	GCA x CA	1.000

When reporting the VIF index to check for multicollinearity, assuming that all values below 5 meet the standard [60]. In accordance with the stringent criteria [61], the model satisfies all requirements, as no variable surpasses the VIF threshold of 3.3. Consequently, the model does not contravene multicollinearity and may persist in its application inside PLS-SEM analysis. The interaction variables (GCA x GI, GCA x CA) have a VIF of 1, indicating no multicollinearity. Therefore, the model can be used without the need to remove any variables.

4.3 Difference value test

The results of the Correlation between the variables are shown in Table 3 and Table 4.

Table 3. Correlations between variables

	CA	DT	GCA	GI	GTL	REG	SCP
CA	0.871						
DT	0.551	0.885					
GCA	0.574	0.563	0.832				
GI	0.797	0.746	0.549	0.802			
GTL	0.749	0.698	0.526	0.853	0.907		
REG	0.578	0.831	0.573	0.693	0.579	0.833	
SCP	0.821	0.665	0.604	0.808	0.738	0.663	0.828

Table 4. Heterotrait-Monotrait Ratio (HTMT)

	CA	DT	GCA	GI	GTL	REG	SCP	GCA × CA	GCA × GI
CA									
DT	0.600								
GCA	0.651	0.640							
GI	0.816	0.888	0.664						
GTL	0.818	0.755	0.589	0.874					
REG	0.625	0.837	0.647	0.824	0.622				
SCP	0.881	0.763	0.706	0.872	0.837	0.751			
GCA × CA	0.209	0.152	0.363	0.274	0.215	0.186	0.184		
GCA × GI	0.256	0.146	0.328	0.204	0.173	0.240	0.217	0.840	

The correlation matrix shows that the research variables have moderate to high relationships, indicating that they are related but still maintain distinctions, with no excessively strong correlations causing multicollinearity. The values on the diagonal (> 0.8) indicate a high internal consistency within each group of variables, demonstrating that the model is reasonable and the variables have good discriminant validity.

Table 4 shows that all research variables have coefficients < 0.9, indicating that the variables are well differentiated and the model has reliable discriminant validity. The interaction variables (GCA × CA, GCA × GI) have a low HTMT with all other variables, confirming that there is no multicollinearity and that they are suitable for inclusion in the analysis.

4.4 R^2 and adjusted R^2

Table 5. R^2 and adjusted R^2

	R^2	R^2 Adjusted
CA	0.683	0.679
GI	0.788	0.786
SCP	0.806	0.804

The results in Table 5 show that the research models achieve a high level of explanation. Specifically, the R^2 of CA is 0.683 (Adjusted R^2 = 0.679), GI is 0.788 (Adjusted R^2 = 0.786), and SCP is 0.806 (Adjusted R^2 = 0.804). The independent variables in the model explain over 68% of the variance in CA, nearly 79% in GI, and more than 80% in SCP. Compared to previous studies in the field of green management and CA, the result is a relatively high R^2, confirming that the model has a good fit and the proposed relationships are convincing.

4.5 Specific indirect effects

Table 6 presents the indirect effects, with T statistics > 2 and P values < 0.01, indicating that these indirect effects are statistically significant. For example, GTL indirectly affects CA through GI with a value of 0.388 (T = 4.477, P = 0.000) and affects SCP through GI with a value of 0.198 (T = 6.282, P = 0.000). REG indirectly affects CA through GI at 0.171 (T = 3.652, P = 0.000) and affects SCP through GI at 0.087 (T = 4.694, P = 0.000). The paths through CA to SCP are also noteworthy, such as GI → CA → SCP = 0.327 (T = 4.801, P = 0.000) and GTL → CA → SCP = 0.200 (T = 3.232, P = 0.001). Thus, the mediating variables, including GI and CA, play a crucial role in transmitting the effects from GTL, REG, and DT to SCP, while affirming that the indirect model in the study is highly reliable and convincing.

Table 6. Specific indirect effects

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
GTL -> GI -> CA	0.388	0.391	0.087	4.477	0.000
REG -> GI -> CA	0.171	0.173	0.047	3.652	0.000
REG -> GI -> CA -> SCP	0.098	0.099	0.026	3.781	0.000
DT -> CA -> SCP	-0.212	-0.217	0.061	3.451	0.001
GTL -> GI -> SCP	0.198	0.198	0.032	6.282	0.000
REG -> GI -> SCP	0.087	0.087	0.019	4.694	0.000
GI -> CA -> SCP	0.327	0.329	0.068	4.801	0.000
GTL -> CA -> SCP	0.200	0.199	0.062	3.232	0.001
GTL -> GI -> CA -> SCP	0.223	0.224	0.049	4.580	0.000
REG -> CA -> SCP	0.169	0.174	0.062	2.739	0.006

4.6 Official model

The author uses PLS - SEM Bootstrapping analysis, after the first test, the P Values of the hypotheses GCA × GI -> SCP = 0.062 have a significance level (P value) > 0.05, proving that hypotheses H9 are not statistically significant and should be eliminated from the model.

After eliminating Hypotheses H9 (Figure 2), the official research model was shown in Table 7.

The analysis results indicate that GTL positively impacts GI (Beta = 0.680, T = 21.622, P = 0.000) and CA (Beta = 0.349, T = 3.478, P = 0.001), indicating that GTL not only promotes GI but also enhances the level of CA within the enterprise, thereby indirectly improving SCP. These results are consistent with previous findings [28, 29], as well as observations in Vietnam [22, 23]. Additionally, the impact of GTL → CA aligns with the international trend of "Low-Carbon Transformational Leadership" [30] and is supported by evidence from Huynh and Nguyen [32] regarding carbon governance. Thus, the current study supports and expands upon both international and domestic evidence, while highlighting the indirect role of GTL through GI and CA before impacting SCP, thereby supporting the validation and acceptance of hypotheses H3 and H4. GTL is essential for

building a sustainable company culture, developing a flexible green value chain, and helping achieve low-carbon economic development goals in Vietnam.

Table 7. Results of coefficient testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T statistics (|O/STDEV|)	P Values
CA -> SCP	0.574	0.574	0.046	12.405	0.000
DT -> CA	-0.369	-0.378	0.101	3.658	0.000
GCA -> SCP	0.135	0.136	0.033	4.139	0.000
GI -> CA	0.570	0.575	0.121	4.699	0.000
GI -> SCP	0.291	0.291	0.044	6.562	0.000
GTL -> CA	0.349	0.346	0.100	3.478	0.001
GTL -> GI	0.680	0.679	0.031	21.622	0.000
REG -> CA	0.295	0.302	0.100	2.939	0.003
REG -> GI	0.299	0.299	0.035	8.473	0.000
GCA x CA -> SCP	0.057	0.058	0.019	2.996	0.003

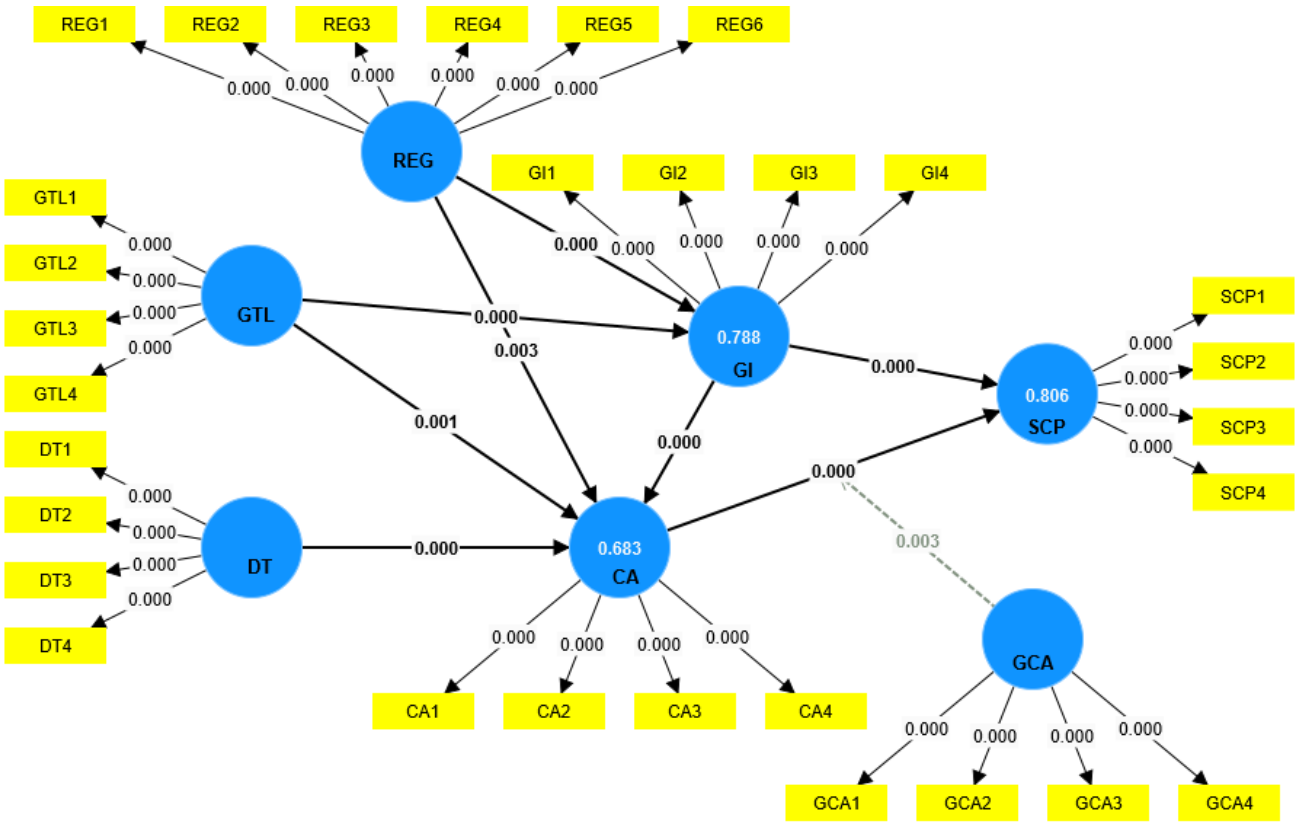

Figure 2. Final research model

Analysis indicates that the relationship GI → CA has a Beta coefficient of 0.570, T = 4.699, P = 0.000, and GI → SCP has a Beta of 0.291, T = 6.562, P = 0.000. This indicates that GI promotes transparency in CA and enhances SCP. This finding is consistent with the previous studies [38-40], where the authors assert that GI helps reduce climate policy risks and increases transparency in emerging markets. Regarding SCP [43, 44, 46] emphasizes the bridging role of GI → CA and GI → SCP. In Vietnam, previous studies [22, 23, 47] also indicate that GI improves SCP, but the effectiveness is influenced by internal capacity, leadership orientation, and the legal framework. Thus, this research consolidates both domestic and international evidence and affirms the central role of GI in linking CA with SCP, while emphasizing the importance of institutions and corporate governance in realizing the value of GI, help establish credibility, transparency, and long-term value in the process of international integration.

The analysis of the current research results indicates that REG → GI has a beta coefficient of 0.299, T = 8.473, and P = 0.000, and REG → CA has a beta of 0.295, T = 2.939, and P = 0.003, demonstrating that REG plays a positive role in promoting GI and CA in enterprises. These findings are consistent with international evidence [5, 13, 19]. Van et al. [22] and Le and Gia [23] emphasized that REG promotes GI and CA primarily through internal capabilities, green leadership, EMA, and CSR, due to limited enforcement mechanisms. This result suggests that combining legal pressure with enhanced governance capacity will help improve transparency and corporate value. REG plays a role as the institutional foundation guiding corporate behavior, but to achieve sustainable effectiveness, there needs to be coordination between policies, governance, and green leadership capabilities. The interaction between REG, GI, and CA is the key that helps companies transform compliance into

innovation, aiming for green growth and long-term sustainable development.

The analysis results indicate that DT has a negative relationship with CA (Beta = -0.369, T = 3.658, P = 0.000), suggesting that, in the Vietnamese context, the application of DT to CA remains limited. These findings may be associated with the fact that many firms currently focus on using DT primarily for operational optimization, cost reduction, and process automation, while information technology infrastructure and corporate governance systems are still evolving, investment costs remain high, and mandatory legal mechanisms supporting CA have not yet been fully developed. These explanations are only suggestive and require further verification in future studies, rather than treating statistical significance as evidence of an underlying mechanism. This finding differs from international evidence [34-37], which asserts that DT promotes sustainable reporting through data digitization and report automation, but it aligns with the context of Vietnam, as pointed out [62], where the impact of DT on CA and SCP remains limited. DT generates genuine value solely when directed by sustainable development objectives. Companies must realign their digital strategy to facilitate corporate accountability and transparent governance while integrating DT with GI and leadership to establish a robust foundation for sustainable success in the future digital-green economy.

Data analysis indicates that CA has a strong and positive impact on SCP (Beta = 0.574, T = 12.405, P = 0.000), affirming that carbon transparency is a crucial factor in enhancing a company's SCP. This finding is consistent with international studies [48-52], which emphasize that CA, along with green accounting, green strategies, and green intellectual capital, can increase company value and SCP. However, unlike the context of countries with strong legal frameworks and governance, in Vietnam, this positive impact is only truly realized when CA is accompanied by a carbon accounting system, clear governance mechanisms, and green strategies; otherwise, it may lead to superficial disclosures. The research findings demonstrate that CA exerts a significant and favorable influence on SCP. The integration of CA with transparent governance processes and green policies is recognized as a crucial element in converting transparent data into sustainable value, while also markedly improving SCP. The research findings establish a scientific basis for informing the formulation of policies and laws aimed at enhancing carbon transparency, given the evolving legal framework and governance structure of Vietnam.

The regulatory role of GCA in the GI → SCP relationship: The analysis results indicate that the regulatory effect of GCA in the GI → SCP relationship is not statistically significant (Beta = -0.076, T = 1.863, P = 0.062). This suggests that GCA is not yet strong enough to reinforce the role of GI in enhancing SCP in Vietnam. This result contrasts with international studies [43, 46] which assert that GCA increases the positive impact of GI on SCP. This difference may be explained by the context of Vietnam, where resources and technology for GI are still limited, leading to GCA not fulfilling its supportive role as strongly as in countries with more developed institutional and market frameworks.

The regulatory function of GCA in the relationship between CA and SCP: In contrast, GCA demonstrates a positive and statistically significant regulatory effect on the relationship between CA and SCP (Beta = 0.057, T = 2.996, P = 0.003). This finding indicates that the presence of GCA in a company not only improves transparency but also plays a crucial role in enhancing SCP. This finding aligns with previous studies which highlighting the necessity of connecting carbon transparency with GCA to convert reporting initiatives into tangible strategic value [53-56]. In contrast to the international context, where corporate accountability typically operates within a stringent legal framework, findings in Vietnam suggest that corporate governance serves as a catalyst, enhancing the significance of CA and preventing superficial reporting.

The direct influence of GCA on SCP: Beyond its regulatory function, GCA exerts a direct, positive, and statistically significant effect on SCP (Beta = 0.135, T = 4.139, P = 0.000). This signifies that GCA not only indirectly augments sustainable value via CA but also exerts a direct influence on total efficacy. This finding aligns with earlier research [31, 32] which confirms that GCA is a fundamental component propelling organizations toward the attainment of sustainable development goals. In Vietnam, GCA functions as an internal strategic catalyst and a mechanism that aids enterprises in optimizing CA, underscoring the necessity of incorporating GCA into sustainable management plans.

Hypothesis H9 (GCA x GI → SCP) was removed from the research model because the PLS-SEM bootstrapping results showed a p-value of 0.062, which exceeds the 0.05 significance threshold, indicating that this relationship is not statistically significant. The exclusion of H9 does not weaken the model; rather, it helps clarify the model's depth by demonstrating the selective moderating effect of GCA, which is strong for CA but weak for GI. Robustness checks comparing the models with and without H9 showed that the coefficients and significance levels of the remaining relationships did not change substantially, confirming that the removal of H9 is justified. This represents an important difference from previous studies and, at the same time, constitutes a novel contribution to the literature.

5. CONCLUSION AND POLICY IMPLICATIONS

5.1 Conclusion

This article analyzes the roles of CA, GI, GTL, REG, DT, and GCA concerning SCP in high-emission enterprises within the context of Vietnam's emerging economy. The analysis results indicate that (i) CA significantly influences SCP positively, underscoring the importance of carbon transparency in sustainable development; (ii) GI enhances SCP both directly and indirectly via CA, emphasizing its critical role; (iii) GTL and REG are essential in fostering GI and CA, thus improving SCP; (iv) DT in Vietnam has not yet effectively supported carbon transparency, diverging from global trends; and (v) GCA directly affects SCP and mediates the CA → SCP relationship but does not mediate the GI → SCP relationship, illustrating the selective nature of the Vietnamese context. This research reinforces existing theories and evidence while providing new findings that illustrate the specificity of GCA in the relationships among sustainable business factors.

5.2 Policy implication

Theoretical implications: This research enhances the theoretical framework about the function of carbon accounting

in sustainable management in emerging economies while clarifying the selective and uneven effects of GCA in connection to SCP. This discovery provides a novel viewpoint on GCA theory, suggesting that not all environmental initiatives produce equivalent value, since their performance is contingent upon the interplay of GI, CA transparency, and business strategy. This study clarifies how GCA serves as a strategic instrument while strengthening the relationship among CA, GI, and SCP within emerging economies.

Management implications: For Vietnamese enterprises, establishing a systematic carbon accounting framework that is closely linked to green strategies and GCA is essential to avoid superficial disclosures. Business leaders need to play a central role in promoting GI and transparency in emissions, while leveraging GCA as a strategic tool to transform CA into substantive GCA. Additionally, policymakers need to refine the legal framework, monitoring mechanisms, and support for businesses in applying DT in carbon accounting, aiming to turn DT from a potential barrier into a driving force for transparency and SCP. The coherent integration of green strategies, GCA, and DT will help businesses optimize value from sustainable initiatives while enhancing their competitive position in both domestic and international markets.

5.3 Limitation

The research has some limitations: (i) the survey data focuses only on high-emission enterprises in Vietnam and does not cover many other industries; (ii) the model primarily relies on PLS-SEM analysis with cross-sectional data, so it does not reflect the impact over time; (iii) variables such as revenue or GCA are measured based on perception and do not integrate many objective quantitative indicators.

5.4 Future research

Future research may (i) broaden the scope to encompass additional emerging nations for comparative analysis, (ii) integrate longitudinal panel data to examine the enduring effects of CA, GI, and DT on SCP, (iii) refine quantitative metrics for DT, GCA, and CA to improve objectivity, and (iv) undertake more in-depth investigations into the synergistic influence of EMA and CSR on the relationship between CA and SCP, thereby offering holistic solutions for sustainable management within emerging economies.

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