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Stakeholder pressure and green innovation: Pathways to competitive advantage in Vietnamese manufacturing SMEs

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Abstract

This study investigates the impact of stakeholder pressure, green innovation (GI), sustainable performance (SP), and competitive advantage (CA), with a focus on AI's moderating role between employee behavior and GI. A quantitative approach was applied, collecting multi-source data from 357 SMEs in the manufacturing sector. Structural Equation Modeling (SEM) with SmartPLS assessed variable relationships, while reliability and validity were confirmed using Cronbach's alpha and AVE. Findings reveal that normative pressure ($\beta = 0.308$, $p < 0.01$) has the strongest influence on GI adoption, while supplier pressure ($\beta = 0.083$, $p < 0.05$) has the weakest. AI positively impacts GI ($\beta = 0.190$, $p < 0.01$) and moderates the effect of employee behavior on GI ($\beta = 0.101$, $p < 0.01$). Additionally, GI enhances SP and CA, with SP mediating the GI–CA relationship. This study contributes to the literature by highlighting AI's role in driving GI and moderating employee behavior's influence on GI. Practically, it underscores the need for SMEs to consider stakeholder pressure and strategically integrate AI to foster GI, enhance SP, and strengthen CA in a rapidly evolving business landscape.

Keywords: AI, Competitive advantage, Green innovation, SMEs, Sustainable efficiency.

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1. Introduction

The enterprises applying GI in order to improve processes, technologies, products, and management systems so they can reduce the negative effects on the environment [1]. This approach helps organizations advance their organizational, environmental, and social sustainability, ultimately enhancing their sustainable performance [2]. According to Yang, et al. [3], as societal awareness of environmental performance continues to grow, organizations that align with this trend are likely to gain greater CA. Furthermore, the implementation of programs aimed at improving environmental performance not only helps industries reduce greenhouse gas emissions and hazardous solids [4] but also contributes to enhancing economic and social efficiency. Therefore, companies can enhance their CA through green process innovation [5]. However, previous studies have not yet identified the mediating role of effective sustainability between the impact of GI and CA of enterprises and require further empirical studies to test. In addition, when studying this topic, the current literature on GI has two trends: the impact of stakeholders on GI and the impact of GI on SP and CA, with few studies using the resource-based stakeholder view [6, 7]. Therefore, there is a need for empirical studies to bridge this gap.

Research on GI has explored the factors influencing it from both external and internal perspectives. Externally, IP, particularly from government environmental regulations, has received significant attention [1, 8]. However, institutional theory-based research has often overlooked other stakeholders—such as customers and competitors—that also drive GI. Specifically, customers increasingly prefer eco-friendly products and view environmental responsibility as a key factor in assessing a company's legitimacy and reputation [9]. Internal factors such as strategic orientation, resources, and organizational characteristics are key in shaping GI efforts, while stakeholder pressure drives businesses to enhance competitiveness through green product innovation [10, 11]. Leadership and employee commitment to sustainability significantly influence the adoption of sustainable practices, though most studies focus on large firms, with limited research on stakeholder pressure in SMEs.

AI, a transformative 21st-century technology, boosts performance, efficiency, and innovation in business processes, offering a competitive edge [12, 13]. Despite its growing importance, research is limited regarding AI's moderating role in the link between EC and GI, as well as its influence on SP and CA through GI. Further investigation is needed to clarify these relationships.

Climate change poses substantial economic risks to Vietnam, with estimated damages of approximately USD 23 billion annually, or about 5% of the nation’s GDP. Without timely intervention, these damages could escalate to USD 33 billion, reaching 11% of GDP by 2030. In response to these mounting concerns, manufacturing enterprises in Vietnam are increasingly focusing on GI as a strategic approach to mitigate environmental impacts. However, progress in this area remains limited. Only 5.7% of the country’s 7,646 manufacturing firms have successfully implemented GI practices. For most companies, especially SMEs, adopting environmentally sustainable practices remains challenging [14]. However, widespread adoption faces substantial obstacles, including limited financial resources, inadequate government support [15], and barriers in enterprise support structures and workforce capabilities [16]. These findings underscore important research gaps, particularly in examining the drivers and outcomes of GI, especially under the influence of an organization’s AI.

This research makes three key contributions. First, it clarifies the link between stakeholder pressure and GI, emphasizing AI’s role in shaping GI outcomes and moderating the impact of employee behavior on GI, SP, and CA. Second, it reduces ambiguity in the literature by confirming GI’s positive effects on SP and CA, as well as the mediating role of SP between GI and CA. Third, it adopts a resource-based stakeholder perspective as a theoretical framework to explore the drivers and outcomes of GI. This study supports sustainable development goals and benefits diverse stakeholders, addressing a notable research gap in the context of developing economies, such as Vietnam’s manufacturing sector.

Building on the identified theoretical and practical gaps, this study aims to address the following research questions:

Q1: Among stakeholders, which has the strongest influence on GI?

Q2: Does AI act as a moderating factor in the relationship between employee behavior and GI?

Q3: Does SP mediate the relationship between GI and CA?

The remainder of this paper is structured as follows: Section 2 presents the literature review and hypothesis development. Section 3 outlines the research methodology, followed by Section 4, which details the analysis and results. Section 5 discusses key findings, and finally, Section 6 concludes the study.

2. Literature Review and Hypothesis Development

Stakeholder theory addresses two key questions that firms should consider when meeting their stakeholders’ wants: What is the primary objective of a firm? What obligations do firms hold toward their stakeholders? [17, 18]. Stakeholder power theory has been explaining the motivation and strategy of a firm’s environmental initiatives [18-20]. In it, stakeholders are defined as “any group or individual that can affect or be affected by the achievement of a firm’s objectives” [21]. Stakeholder pressure refers to external pressures created by environmental regulations and customer demands, or internal pressures that come from employees and suppliers [11]; this is reflected in the power and influence of stakeholders on business decision-making processes. A positive relationship between stakeholder pressure and (GI) was highlighted in the study by Guoyou, et al. [22]; stakeholder pressure serves as a driving force that motivates firms to adopt green initiatives, compelling businesses to develop environmentally friendly products [23]. Therefore, this study argues that firms must comply with stakeholder pressure.

Barney [24] resource-based theory argues that sustainable CA can be achieved through emerging skills or assets that are highly valued, inimitable, non-substitutable, and non-transferable. Firms face both external and internal pressures to implement environmentally friendly actions, making the development of GI capabilities increasingly important [11]. This compels companies to adopt green technologies, green products, and implement green supply chain management practices [25]. From the view of the resource-based theory, environmental regulations and GI strategies have driven GI. These factors constitute a critical intangible resource that is valuable to enterprises and difficult for other organizations to imitate. Over time, GI enables organizations to increase their economic, environmental, and social sustainability while also enhancing their CA [2]. The environmental performance of the firms that implement GI based on their resources will be improved [26]. Environmental costs will be offset by entering new markets and increasing resource utilization efficiency, but with a lower financial performance [27] as GI often leads to higher costs [28]. Research highlights uncertainties about whether firms adopt GI due to internal motivations or external stakeholder pressure [11, 29].

In order to integrate the above two theories, Sodhi [6] introduced a theory called the resource-based stakeholder perspective, which combines the theory of stakeholder [17] and resource-based [24]. This perspective emphasizes leveraging resource-based competitive advantage (CA) under stakeholder influence. It serves as a theoretical framework to examine the drivers and outcomes of green innovation (GI) in enterprises. Despite its potential, research on this topic remains limited [6, 7]. This study aims to understand the impact of stakeholders on GI, SP, and CA of small and medium-sized enterprises (SMEs). Notably, prior studies have not clarified the role of mediating performance in linking GI to corporate CA. While stakeholder pressure is a key driver of corporate sustainability efforts, the interaction between stakeholder pressure, GI, and the moderating effect of AI on EC remains understudied.

According to stakeholder theory, businesses organize their operations according to new norms to satisfy their key stakeholders. Business managers are interested in understanding internal and external factors to promote GI implementation, such as customer requirements or government environmental regulations as the main factors affecting GI; how businesses can comprehensively address stakeholder concerns to achieve business goals [11]. GI involves making improvements in production processes and product design to address environmental impact. The goal of GI is to minimize the negative effects on the environment [30]. In addition, stakeholder pressure influences enterprises to adopt GI activities for the goods and services they provide in the market. Stakeholder pressure can generally be categorized as legal pressure (LP), normative pressure (NP), and imitative pressure [31], which are created by the government, customers, and competitors respectively, along with pressure from employee behavior [32]. Specifically, LP usually comes from the government, NP mainly comes from customers, while imitative pressure arises from competitors, innovation NP, and employee behavior [32].

2.1. Regulatory Pressure and Green Innovation

Regulatory pressure relates to which regulatory agencies expect to raise environmental performance [33]. Strict policies are a major driver for firms to engage in environmental protection and pursue green initiatives [8]. Environmental regulations from the government may require firms to adopt pollution control technologies and reduce environmental impacts [34]. Studies by Li, et al. [35]; Johnstone and Labonne [36] and Kassinis and Vafeas [37] identified RP as a key determinant of organizations in green product as well as process innovation. The government can introduce mandatory laws or regulations to guide enterprises toward GI. Testa, et al. [38]point out that enterprises would invest more in GI under regulatory pressure. In addition, the government supports enterprises' GI through different forms of support in finance or policy for green research and development. Darnall et al. [34] pointed out that state management agencies often require enterprises to apply pollution control technologies and reduce environmental impacts. From the above observations, this study hypothesizes.

H_1: RP has a positive impact on corporate GI.

2.2. Normative Pressure and Green Innovation

NP or customer pressure can increase firms' motivation to implement GI [39]. Customer pressure refers to customers who expect or force firms to enhance their environmental performance. It is considered an important driving force for firms to adopt GI [40, 41]. Environmentally friendly customers may consider environmental protection a key factor in product selection [42]. Businesses can meet their expectations and customers' needs by reducing their environmental impact through innovative processes and green products [43]. Consumers are more inclined to refuse goods from producers who apply environmentally harmful production practices [18]. Furthermore, they may actively contribute to GI by providing businesses with support and valuable feedback.

H_2: NP has a positive impact on corporate GI.

2.3. Imitation Pressure and Green Innovation

Competition can be an effective driver for GI. Under pressure from competitors, GI has become an ideal option for the sustainable performance of companies. Competitors' implementation of market-oriented environmental management has motivated business owners to engage in pro-environmental behaviors [29]. Competitors' pro-environmental behaviors put pressure on businesses to engage in GI [44]. In response to competition, businesses apply similar technologies, products, or strategies to those of their competitors and compete by offering a lower price or advantages such as energy savings, which are favored by customers.

H_3: IP has a positive impact on GI of enterprises.

2.4. Supplier Pressure and Green Innovation

Suppliers play a critical role in shaping the development and market responsiveness of manufacturers [45], as factors such as lead time and risks in raw material supply directly affect production costs. A firm's GI is largely determined by its "upstream" environmental effects. This means that the quality, design, and competitiveness of a firm's products can be significantly influenced by the materials and sourcing practices of its suppliers. Furthermore, suppliers may refuse to provide materials to companies they consider harmful to the environment [46, 47]. Geffen and Rothenberg [48] point out that establishing strong connections with suppliers can enhance a firm's GI and environmental performance. These findings indicate the significant role of suppliers in driving innovation within organizations. Based on this, Hypothesis 4 is proposed.

H_4: PS has a positive impact on GI.

2.5. Employee Conduct and Green Innovation

Huang and Li [47]argued that if a firm's senior managers clearly understand the position of environmental protection as well as their responsibility in environmental management planning, it will drive innovation and enhance organizational performance. However, companies will face challenges in achieving environmental goals without employees' consensus [49]. Therefore, it is essential for companies to attract suitable employees, enhance their commitment to environmentally friendly activities, and provide continuous training on environmental issues. The cited studies demonstrate that businesses can be motivated to adopt GI activities under pressure from both management and employees.

H_5: EC has a positive impact on corporate GI.

2.6. AI, Employee Conduct and Green Innovation

AI enhances resource and energy efficiency through advanced analytics and predictive modeling, reducing waste and making processes more eco-friendly [50, 51]. It significantly impacts green innovation (GI) by accelerating the development of sustainable technologies, fostering collaboration, and enabling knowledge sharing [52, 53]. AI integration aligns with market demands and operational challenges, driving green innovations and adding business value while promoting sustainability [54]. Innovative companies are more likely to adopt green product ideas early, with AI influencing GI and shaping employee behavior in GI activities.

H_6: AI has a positive impact on firm GI.

H_7: AI positively moderates EC toward GI activities.

2.7. Green Innovation and Competitive Advantage

CA is defined as the condition in which competitors cannot copy the competitive strategies implemented by a company, nor can they obtain the benefits that a company achieves through its competitive strategies [55, 56]. Value, scarcity, lack of imitation, and lack of substitution are resource characteristics of firms that are conducive to innovation and that firms can exploit to gain CA. GI increases CA because green product innovation helps firms improve the design, quality, and reliability of products related to environmental issues, which can provide better opportunities to differentiate their green products, allowing firms to charge higher prices and generate better profit margins. Therefore, enterprises can enhance their CA through green process innovation [5]. GI focuses on products and customers and positively affects the factors that drive competition [57]. From the above observations, this study hypothesizes.

H^8: GI has a positive impact on the CA of enterprises.

2.8. Green Innovation and Sustainability Performance

Elkington [58] looks at sustainability as the nexus of economic, environmental, and social factors in the "Triple Bottom Line model" [59]. All three dimensions have been studied in the organizations selected for the current study, as organizations cannot establish truly sustainable improvements without these dimensions, which are essential for sustainability. SP is considered from social, environmental, and economic aspects [2]. Businesses will achieve SP when implementing GI because GI reduces adverse environmental impacts while also improving the economic and social performance of organizations by reducing waste and costs. GI has a significant impact on SP, including community development and environmental activities [2, 60]. From the above observations, this study hypothesizes.

H_9: GI has a positive impact on corporate SP.

2.9. Green Innovation, Sustainable Performance, and Competitive Advantage

According to Asadi, et al. [2], most businesses set their goals primarily based on economic benefits. To achieve this, businesses must utilize resources effectively, maximize stock value through investor satisfaction, and fulfill their responsibilities to stakeholders, among other strategies, to increase revenue. Consequently, businesses can create value and benefits for shareholders and society in a sustainable and long-term manner through the satisfaction and engagement of stakeholders. Thus, the core value encompasses not only economic benefits but also sustainable development, which is what positions businesses in the market [2, 25, 61]. Businesses that implement the principles of sustainable development have achieved breakthrough innovations, improved operations, products, and profits. Green innovation (GI) assists businesses in developing and maintaining competitive advantages (CAs), leveraging resources and CAs for superior performance. The study by Chiou, et al. [25]provided empirical evidence on the implementation of green supply chains and GI to enhance environmental performance, thereby aiding businesses in improving their CAs in the global market. Based on this, we propose the hypotheses:

H_{10}: SP has a positive impact on the CA of enterprises.

H_{11}: GI has a positive impact on firm CA through the mediating role of SP.

2.10. AI, Employee Conduct, Green Innovation Sustainable Performance, and Competitive Advantage

AI enhances green innovation (GI) and sustainable business development by accelerating research, reducing experimentation costs, and creating green technologies [52, 62]. Advanced AI algorithms enable real-time environmental monitoring and compliance with regulations [63, 64], fostering sustainable development and enhancing CA [12]. AI also promotes collaboration and idea sharing, refining green innovations [53]. However, further research is needed to explore the impact of EC on SP and CA, with AI as a moderator and green innovation (GI) as a mediator.

H_{12}: EC positively impacts SP, moderated by AI and mediated by GI.

H_{13}: EC positively impacts CA, moderated by AI and mediated by GI.

From thirteen research hypotheses, the proposed research model includes nine variables (see Figure 1).

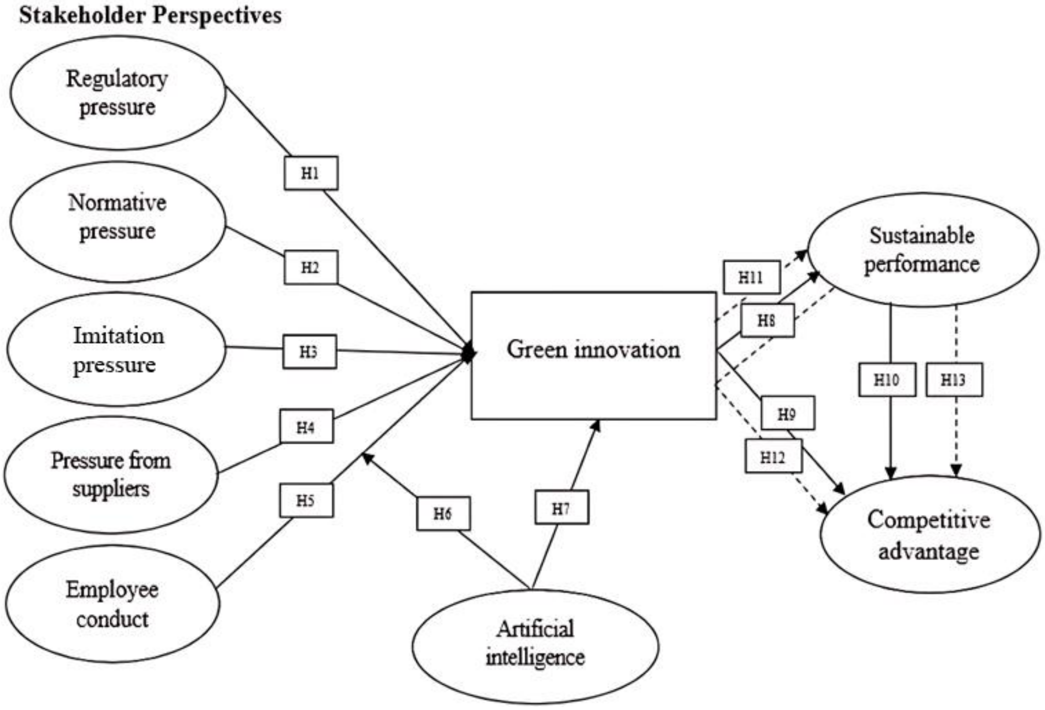

Figure 1.
Research framework.
Note: ⟶ Direct relationship, - - -▸ Indirect relationship.

3. Methodology

3.1. Sample and Data Collection

To ensure robust analyses, the research aims to collect between 200 and 250 observations. The surveys were conducted through intermediaries, specifically the Management Boards of Industrial Parks and the Vietnam Chamber of Commerce and Industry (VCCI), to facilitate direct surveys and distribute survey links (via Google Docs links sent through email, Zalo, and Messenger) to managers of SMEs in the manufacturing and processing sector. After two months (from August 26 to October 26, 2024), 413 responses were collected from SMEs in the manufacturing and processing sector. After excluding 56 invalid responses, 357 valid responses remained, achieving a response rate of 86.4%. This sample size exceeds the minimum recommended by Hoyle [65].

3.2. Measurement

The measurement scales in this research were adopted from previous studies (see Appendix) using a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree). RP, NP, and IP were derived from Zhang and Zhu [50] and Rui and Lu [29]; PS was measured using a four-item scale adapted from Feng, et al. [66]; we measure “EC” using Lindell and Karagozoglu [67] and Weng, et al. [11]; “AI” using the scale of Belhadi, et al. [68]and Khan, et al. [69]. GI was measured using the items developed by Chang [61]. SP was determined regarding the items developed by Asadi, et al. [2]; Chiou, et al. [25]; Li, et al. [70] and Maletič, et al. [71] for measuring all three dimensions of SP. To assess CA, seven items were developed by Chang [72] and Utterback and Abernathy [73]. The research designed the questionnaire with two main sections. The first section consists of 51 questions focusing on nine variables of the model. The second section includes four questions on demographics. A pilot survey was conducted with 20 managers currently working in SMEs in the manufacturing and processing sector in Vietnam to ensure that the respondents interpreted the questionnaire consistently.

3.3. Analysis

The data was collected, cleaned, and analyzed using SPSS 26 for descriptive statistical analysis and Smart PLS 4 for scale validation. The research model and hypotheses were tested through structural equation modeling (SEM) and bootstrapping analysis. A key distinction from previous studies is the comprehensive structural model analysis, which examines the moderating role of AI in the relationship between employee behavior and green innovation (GI), as well as the mediating role of sustainable performance in linking green innovation to competitive advantage.

4. Results

4.1. Respondent’s Profile

Table 1 provides a breakdown of the demographics of 357 directors from SMEs in Vietnam’s manufacturing sector. Of these, 75.9% are male and 24.1% are female. The majority fall within the age group of 36-45 years (35.6%), followed by 25-35 years (29.7%), over 46 years (21.8%), and under 25 years (12.9%). The highest educational level is a bachelor’s degree (55.4%), followed by a college diploma (21.3%), master's degree (12.9%), vocational certificate (8.7%), and doctoral degree (1.7%). Work experience is primarily between 6 to 10 years (61.1%), followed by over 11 years (27.2%) and less than 5 years (11.7%).

Table 1.
Demographic characteristics.

Variable	Items	Frequency	Percent (%)
Gender	Male	271	75.9
	Female	86	24.1
Age	Below 25	46	12.9
	25-35	106	29.7
	36-45	127	35.6
	46 or above	78	21.8
Educational Qualification	Vocational	31	8.7
	College	76	21.3
	Bachelor	198	55.4
	Master	46	12.9
	Doctoral	6	1.7
Experience	< 5 years	42	11.7
	6-10 years	218	61.1
	>11 years	97	27.2

4.2. Measurement Model Analysis

According to Bollen [74], Hair, et al. [75] and Fornell and Larcker [76], four observed variables with outer loading coefficients below 0.7 were excluded: specifically, IP1, CA5, CA6, GI7, SP7, SP8, SP10, and SP13. Table 2 shows the revised measurement model results. Cronbach's alpha ranged from 0.795 to 0.902, with composite reliability (rho_a and rho_c) above 0.7 and AVE indices above 0.5 for all variables. These results confirm the reliability and internal consistency of the research model's scales [77].

Table 2.
Reliability and validity analysis.

Factors	Items	Outer loadings	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Competitive advantage	CA1	0.744	0.853	0.860	0.895	0.630
	CA2	0.794				
	CA3	0.790				
	CA4	0.795				
	CA7	0.842				
Employee conduct	EC1	0.803	0.795	0.808	0.866	0.619
	EC2	0.841				
	EC3	0.708				
	EC4	0.788				
Green innovation	GI1	0.746	0.875	0.881	0.906	0.617
	GI2	0.840				
	GI3	0.795				
	GI4	0.718				
	GI5	0.796				
	GI6	0.812				
Artificial intelligence	AI1	0.866	0.892	0.895	0.925	0.755
	AI2	0.887				
	AI3	0.882				
	AI4	0.839				
Imitation pressure	IP2	0.905	0.882	0.901	0.908	0.812
	IP3	0.762				
	IP4	0.922				
Normative pressure	NP1	0.806	0.869	0.878	0.910	0.717
	NP2	0.874				
	NP3	0.875				
	NP4	0.830				
Pressure from suppliers	PS1	0.858	0.818	0.852	0.880	0.649
	PS2	0.719				

Factors	Items	Outer loadings	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
	PS3	0.768				
	PS4	0.869				
Regulatory pressure	RP1	0.782	0.819	0.823	0.880	0.648
	RP2	0.805				
	RP3	0.821				
	RP4	0.811				
Sustainable performance	SP1	0.764	0.902	0.911	0.913	0.601
	SP2	0.790				
	SP3	0.800				
	SP4	0.763				
	SP5	0.781				
	SP6	0.806				
	SP9	0.724				
	SP11	0.808				
	SP12	0.736				

The results in Table 3 indicate that the HTMT values for each construct meet these requirements, thereby establishing the criteria for discriminant validity [78].

Table 3.
HTMT indicators.

Variables	CA	EC	GI	AI	IP	NP	PS	RP	SP	AI x EC
CA										
EC	0.533									
GI	0.762	0.673								
AI	0.568	0.498	0.621							
IP	0.316	0.203	0.359	0.303						
NP	0.606	0.514	0.791	0.507	0.356					
PS	0.259	0.209	0.246	0.227	0.073	0.201				
RP	0.641	0.384	0.725	0.516	0.265	0.676	0.103			
SP	0.700	0.537	0.734	0.597	0.336	0.694	0.255	0.681		
AI x EC	0.169	0.305	0.054	0.338	0.153	0.059	0.074	0.092	0.092	

4.3. Measurement Model Structural

To test the model and research hypotheses, path coefficients (β) for endogenous latent variables, T-Value, P-Value, effect size (f^2), and coefficient of determination (R^2) were used. Based on the indices shown in Table 4 and Fig. 2, 9 out of 10 hypotheses were accepted with P-value < 0.05 and T-Value > 1.65; hypothesis H4 was rejected due to P-value = 0.243 > 0.05, which did not meet the requirements. This indicates that "RP," "NP," "IP," and "EC" each have direct impacts on GI in manufacturing SMEs (H1, H2, H3, and H5). Among these factors, "NP" exerts the strongest influence on GI, with β = 0.308 (H2), followed by "EC" with a positive impact coefficient of β = 0.290 (H5), and "RP," which positively affects GI with β = 0.259 (H1). Lastly, "IP" demonstrates a positive effect on GI, with β = 0.083 (H3). Moreover, "AI" moderates the relationship between "EC" and "GI," with β = 0.101 (H6), and "AI" directly and positively influences "GI," with β = 0.190 (H7).

Table 4.
Hypotheses testing with direct effect.

Hypotheses	Std. Beta	Std. Error	T-value	P-value	VIF	f^2	Supported
H1: RP -> GI	0.259	0.044	5.933	0.000	1.511	0.176	Yes
H2: NP -> GI	0.308	0.051	6.035	0.000	1.000	0.228	Yes
H3: IP -> GI	0.083	0.035	2.339	0.019	1.029	0.059	Yes
H4: PS -> GI	0.036	0.031	1.168	0.243	1.000	0.006	No
H5: EC -> GI	0.290	0.042	6.927	0.000	1.591	0.085	Yes
H6: AI x EC -> GI	0.101	0.028	3.576	0.000	1.179	0.083	Yes
H7: AI -> GI	0.190	0.048	3.943	0.000	1.748	0.041	Yes
H8: GI -> SP	0.673	0.030	22.750	0.000	1.584	0.507	Yes
H9: GI -> CA	0.445	0.051	8.722	0.000	1.296	0.136	Yes
H10: SP -> CA	0.332	0.054	6.166	0.000	1.511	0.214	Yes

The analysis demonstrates that "GI" exerts a direct, significant effect on "SP" (β = 0.673), supporting H8. Additionally, "GI" directly and significantly influences "CA" (β = 0.445), aligning with H9. The results further reveal that "SP" has a direct, significant impact on "CA" (β = 0.332), confirming H10. The VIF for the remaining hypotheses is all less than 5, indicating that multicollinearity is not present in the research model [75]. The P-values of 0.000 and 0.019 are both below the 0.05 threshold, indicating statistical significance. Additionally, the T-values for all hypotheses are greater than 1.65, meeting the required criteria. Regarding the effect size (f^2) of exogenous variables on endogenous variables, the obtained values of 0.02, 0.15, and 0.35 represent small, medium, and large effect sizes, respectively (see Table 4).

4.4. Result of Mediating Effect

Table presents the results when applying Bootstrapping technique with 5,000 resamples, the results show that all three hypotheses were accepted. Specifically, AI moderates the relationship between EC and SP, with GI acting as a mediator (β = 0.169). AI moderates the relationship between EC and CA, with GI as a mediator (β = 0.146); GI influences CA through the mediating role of SP (β = 0.897). All coefficients are statistically significant ($p < 0.05$, T-Value > 1.65) and lie within the confidence intervals, confirming the acceptance of hypotheses H11, H12, and H13.

Table 5.
Confidence Interval for indirect effects.

Hypotheses	Std. beta	Indirect effects - β	Total effect - β	Std. Error	T-value	P-value	Supported
H11: AI x EC -> GI -> SP	0.101	0.068	0.169	0.014	3.579	0.000	Yes
H12: AI x EC -> GI -> CA	0.101	0.045	0.146	0.019	3.296	0.001	Yes
H13: GI-> SP -> CA	0.673	0.224	0.897	0.038	5.851	0.000	Yes

As per Cohen [79] guidelines, R^2 values exceeding 0.4 indicate a strong effect, values between 0.25 and 0.4 indicate a medium effect, and values below 0.1 suggest a weak effect. Figure 2 presents the adjusted coefficient of determination (R^2) values as follows: The adjusted R^2 for "GI" is 0.675, indicating a large effect; the adjusted R^2 for "CA" is 0.508, reflecting a medium effect; and the adjusted R^2 for "SP" is 0.454, also indicating a medium effect. This means that the independent variables—namely, RP, NP, IP, and EC—along with the moderating variable, AI, account for 67.5% of the variance in "GI." Additionally, "GI" and "SP" together explain 50.8% of the variance in "CA." Finally, "GI" alone explains 45.4% of the variance in "SP" within Vietnamese SMEs in the manufacturing sector.

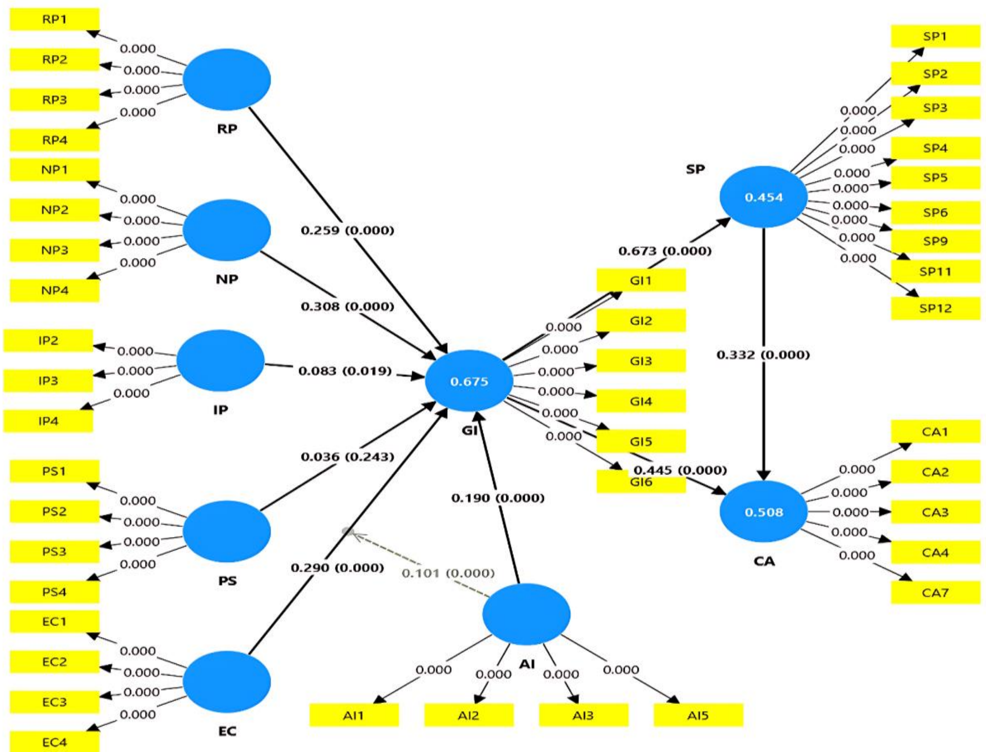

Figure 2.
Measurement model.

5. Discussions

This study offers valuable contributions to both theoretical knowledge and managerial practices:

Firstly, it reveals that stakeholder pressure has a direct and significant impact on GI of SMEs in Vietnam's manufacturing sector. The findings indicate that as stakeholder pressure intensifies, so do innovation activities. These results align with previous research conducted by Weng, et al. [11], Zhang and Zhu [50], Rui and Lu [29], which highlight the role of stakeholder pressure in driving the implementation of GI. Furthermore, this study extends prior findings by revealing that various types of stakeholder pressure affect GI outcomes in distinct ways [80, 81]. Notably, the study identifies PS as having the most significant impact on GI among SMEs in the manufacturing sector in Vietnam. These findings contrast with Weng, et al. [11] and Rui and Lu [29], who identified imitation and regulatory pressures as the strongest influences, respectively. In Vietnam's manufacturing sector, however, customer demand is decisive, as continued purchases depend on firms' adherence to GI and environmental regulations. Consumer pressure and RP exert distinct influences on green product and process innovation. Specifically, consumer pressure has been shown to significantly impact green product innovation, whereas RP is more strongly associated with green process innovation [50]. Additionally, RP plays a crucial role in driving GI, as government regulations and environmental policies, along with increasing consumer demand for eco-friendly products and services, compel entrepreneurs to adopt environmentally sustainable practices [29]. These findings support the assertion made by Gallego-Álvarez and Ortas [82] that "companies gradually adjust their environmental strategies to better fit the characteristics of the social and institutional environment." Furthermore, both imitation pressure and EC positively influence GI by enhancing the capabilities necessary for implementing green initiatives [11]. Our results show that imitation pressure has the weakest influence on GI, contrasting with other research that showed regulatory and NPs as least impactful [11, 29]. In Vietnam, suppliers mainly meet the raw material demands set by manufacturing firms, reducing their capacity to exert pressure. The findings also reveal that AI positively affects GI, consistent with the research by Appiah and Essuman [83]. This study highlights AI as a moderator between employee behavior and GI. AI moderates, while GI mediates, the relationships between employee behavior and both sustainable development and CA. AI also helps organizations overcome challenges in adopting new systems, products, and processes. The impact of AI on sustainability depends on how effectively businesses leverage its potential through innovative processes and new practices. GI, the adoption of methods and creation of new products that promote environmental sustainability, plays a pivotal role [52, 60]. Businesses striving toward global sustainability goals particularly rely on this, making AI an essential tool to help them achieve those objectives [12], thereby enhancing their competitive advantage. This is a standout contribution of the study, which explores the role of AI in the relationships between EC, GI, SP, and CA, helping to bridge the gap in research on these connections.

Second, the findings of this research indicate that the implementation of GI enables small and medium-sized enterprises (SMEs) in the manufacturing sector to attain competitive advantage (CA) and enhance sustainable performance (SP), particularly within the context of promoting sustainable development [11, 29]. A novel contribution of this study lies in its ability to clarify existing ambiguities in the literature by validating the benefits of GI on CA and identifying the mediating role of SP in this relationship. The empirical evidence demonstrates that when companies prioritize sustainable green practices [11, 50], they can significantly strengthen their competitive position in the market. Furthermore, senior managers play a pivotal role in fostering GI by leveraging IO and allocating resources effectively to achieve sustainable development goals [29].

Third, our study suggests that SMEs can collaboratively align their GI objectives to achieve CA and enhance SP through stakeholder pressure. Moreover, these findings contribute to a deeper understanding of the resource-based stakeholder theory framework within the context of SMEs, illustrating how stakeholder pressure can facilitate CA through GI and SP [7, 84].

6. Conclusions

This study enhances our understanding of GI adoption in small and medium-sized enterprises (SMEs) within emerging markets by highlighting several key findings. First, stakeholder pressures significantly drive GI adoption, with normative pressure exerting the strongest influence. Second, innovation orientation serves as a critical moderating factor between employee behavior and GI outcomes, emphasizing the role of organizational culture in fostering sustainability. Third, sustainability performance emerges as a key mediator, translating GI efforts into competitive advantage. These insights deepen theoretical and practical knowledge on how SMEs can integrate sustainability-driven strategies to enhance their market position.

6.1. Theoretical and Managerial Implications

This research contributes to both theory and practice in several ways. Theoretically, it integrates stakeholder and resource-based perspectives in sustainability research, providing a more comprehensive framework for understanding GI adoption. Additionally, it clarifies the mechanisms through which SMEs can leverage green practices to gain a competitive edge. From a managerial standpoint, the findings offer valuable guidance for business leaders and policymakers in emerging markets.

6.2. Limitations and Future Research Directions

Despite its contributions, this study has limitations. First, its cross-sectional design limits insights into the dynamic evolution of GI adoption, highlighting the need for longitudinal studies. Second, focusing on SMEs in a single emerging market may affect generalizability, warranting research across diverse cultural and economic contexts. Lastly, future studies should explore additional moderating or mediating factors, such as technological capabilities or government incentives, to deepen the understanding of GI adoption. Addressing these gaps will enhance knowledge on how SMEs can leverage GI for sustainable performance and long-term competitiveness.

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Appendix:

Variables and measurement scales.

Code	Items	Source
Competitive advantage		
CA1	The quality of the products or services that the company offers is better than that of the competitor's products or services	Chang [72] and Utterback and Abernathy [73]
CA2	The company is more capable of R&D than the competitors	
CA3	The company has better managerial capability than the competitors	
CA4	The company's profitability is better	
CA5	The corporate image of the company is better than that of the competitors	
CA6	Competitors are difficult to take the place of the company's competitive advantage	

Code	Items	Source
CA7	The quality of the products or services that the company offers is better than that of the competitor's products or services	
Employee conduct		
EC1	Degree of pro-activeness	Lindell and Karagozoglu [67] and Weng, et al. [11]
EC2	Redesigning production systems	
EC3	Product design decisions	
EC4	Employees' environmental education and training	
Green innovation		
GI1	The company chooses the materials of the product that produce the least amount of pollution for conducting the product development or design	Chang [72] and Utterback and Abernathy [73]
GI2	The company uses the least amount of materials to comprise the product for conducting product development or design.	
GI3	The company would circumspectly deliberate whether the product is easy to recycle, reuse decompose for conducting the product development	
GI4	The company would circumspectly deliberate whether the product is easy to recycle, reuse decompose for conducting the product design	
GI5	The manufacturing process of the company effectively reduces the emission of hazardous substances or waste	
GI6	The manufacturing process of the company reduces the consumption of water, electricity, coal, or oil	
Artificial intelligence		
AI1	We possess the infrastructure and skilled resources to apply AI information processing system	Belhadi, et al. [68] and Khan, et al. [69]
AI2	We use AI techniques to forecast and predict environmental behavior	
AI3	We develop statistical, self-learning, and prediction using AI techniques	
AI4	We use AI outcomes in a shared way to inform decision-making	
Imitation pressure		
IP2	Most of our competitors think green products are important to society	Zhang and Zhu [50] and Rui and Lu [29]
IP3	Most of our competitors regard environmental performance as an important indicator to compare with other enterprises	
IP4	Most of our competitors are very concerned about environmental responsibility	
Normative pressure		
NP1	Most customers are very environmentally conscious when choosing products	Zhang and Zhu [50] and Rui and Lu [29]
NP2	Most customers think green products are important to the whole society	
NP3	Most customers regard environmental performance as an important indicator to evaluate their company's reputation	
NP4	Most customers are very concerned about enterprises' environmental practices	
Pressure from suppliers		
PS1	We involve key suppliers in the product design and development stage.	Feng, et al. [66]
PS2	Our key suppliers have a major influence on the design of new products.	
PS3	There is a strong consensus in our firm that supplier involvement is needed in product design/development.	
PS4	We have continuous improvement programs that include our key suppliers.	
Regulatory pressure		
RP1	Local governments have made environmental protection one of their top priorities	Zhang and Zhu [50] and Rui and Lu [29]
RP2	Local governments believe that environmental protection is important to the whole society	
RP3	Local governments are very concerned about enterprises' environmental practices	
RP4	Local governments regard environmental performance as an important indicator to evaluate the reputation of enterprises	
Sustainable performance		
SP1	Company has achieved important environment-related certifications	Asadi, et al. [2]; Chiou, et al. [25]; Li, et al. [70] and Maletič, et al. [71]
SP2	On average, the overall environmental performance of our company has improved over the past five years.	
SP3	The resource consumption e.g. water, electricity, and gas has decreased	
SP4	Improvement of environmental compliance	
SP5	Complying with environmental regulations (i.e., emissions, waste disposal)	
SP6	Decrease of cost for energy consumption	
SP9	Decrease of penalty costs for environmental accident.	
SP11	The customers' motivation has increased during the last 3 years	
SP12	Our industry serving more beneficiaries (disadvantaged people) or solving environmental issues	