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Understanding Corporate Green Competitive Advantage through Green Technology Adoption and Green Dynamic Capabilities: Does Green Product Innovation Matter?

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Abstract: Our study explores the association between the adoption of green technology and the development of green dynamic capabilities to achieve green competitive advantage. This research concentrates explicitly on the mediating function of green product innovation. The study is grounded in the dynamic capabilities theory and seeks to improve understanding regarding how organizations can attain a competitive edge by employing green practices and capabilities. Data were obtained from 312 manufacturing business managers in Bangladesh. We utilized the partial least squares structural equation modeling (PLS-SEM) method to examine the data and evaluate the proposed hypotheses. The empirical evidence suggests that both green technology adoption and green dynamic capabilities significantly impact firms' green product innovation and competitive advantage. Additionally, the findings indicate that green product innovation is a mediating variable in the association between green technology adoption-green competitive advantage and green dynamic capabilities-green competitive advantage. This research adds to the current body of literature by presenting empirical findings highlighting the crucial role of green technology and dynamic capabilities in promoting green competitive advantage. Our results reveal that it would be beneficial for organizations to prioritize adopting eco-friendly technologies and cultivating dynamic capabilities to improve their overall green performance. The present study contributes significantly to the literature by offering insights into the strategies managers and policymakers can employ to attain sustainable competitive advantage in the manufacturing sector.

Keywords: green technology; green dynamic capabilities; green innovation; green competitive advantage; manufacturing companies

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1. Introduction

Organizations increasingly recognize and prioritize the importance of adopting sustainable practices to gain a competitive edge in the dynamic, fast-paced, competitive environment. Green practices have become a strategic imperative for businesses in all industries [1]. As environmental concerns gain prominence, enterprises are compelled toward green technology adoption (GTA) [2] and developing green dynamic capabilities (GDC) [3] to increase their efficiency in terms of environmental sustainability. In addition to contributing to their corporate social responsibility, these initiatives offer potential green competitive advantage (GCA) [4]. Moreover, green technology has exerted a considerable influence on firms' green product innovation (GPI). The growing adoption of sustainable practices by businesses and individuals has led to a rising need for environmentally friendly products. As mentioned above, the phenomenon has resulted in a substantial rise in developing novel and eco-friendly green products that cater to the demands of environmentally conscious individuals seeking sustainable substitutes [5–7]. Through the use of environmentally responsible practices and the integration of innovative technologies, enterprises

have successfully developed goods that are both eco-friendly and cost-effective [8–10]. The utilization of technological advancements and organizational resources, such as GDC, is helping companies differentiate themselves from their rivals in the volatile marketplace.

While the significance of GTA and GDC to sustainability is widely acknowledged [4,11–13], it is crucial to comprehend their influence on GCA and GPI. GTA is the integration and use of technologies in an organization's operations and processes that benefit the environment [14]. It includes the implementation of energy-efficient systems, strategies for pollution reduction, and the use of renewable resources [15]. Consistently, studies have demonstrated that GTA positively affects firms' GCA. By implementing green technologies, businesses can improve resource efficiency, cut costs, and satisfy the rising demand for sustainable products and services [16,17]. Likewise, the GDC concept emphasizes the organization's capacity to respond proactively and strategically to environmental challenges and opportunities. Chen et al. [18] define GDC as an organization's capacity to incorporate environmental concerns into its processes, innovation activities, and decision-making. Organizations with strong GDC can effectively identify and exploit environmental opportunities, develop sustainable business models, and adapt to changing environmental regulations and market conditions. The empirical literature demonstrates a positive correlation between GDC and GCA [3]. However, while the individual effects of GTA and GDC on GCA have been established, a gap persists in understanding their interplay with green product innovation (GPI) and how this mediates the GCA outcomes. GPI refers to developing and introducing environmentally friendly products, services, and processes that satisfy consumer demands while minimizing environmental impact [19]. It incorporates environmental considerations throughout the product development life cycle, from ideation to commercialization. GPI can improve GCA by facilitating differentiation, recruiting environmentally conscious consumers, and creating new market opportunities [4,20]. Yet, recent literature has documented GPI's rebound effect, suggesting that GPI can deteriorate environmental performance after a certain level by increasing emissions [21,22]. Hence, it is crucial to assess the role of GPI in enhancing corporate GCA.

Despite the increasing emphasis on corporate sustainability, there remains a lack of comprehensive understanding regarding the interplay between GTA, GDC, GPI, and GCA. Hence, it is essential to investigate the impact of GTA and GDC on GCA and GPI within a comprehensive research framework. This approach facilitates a deeper understanding of the interconnectedness among these factors and provides valuable perspectives on optimizing them to achieve sustainable results and gain a competitive edge [23,24]. The primary objective of this study is to address a gap in the existing literature by examining the relationships between specific factors and investigating how they interact. Specifically, we intend to determine if GTA positively impacts GCA and GPI. In addition, we assess how GDC affects environmental performance and innovation outcomes for businesses. Our study, therefore, explores the interplays between GTA, GDC, GPI, and firms' GCA. We hypothesize that GTA and GDC have a positive relationship with firms' GCA, that GTA and GTC positively impact firms' GPI, and that GPI mediates the relationship between these factors and firms' GCA.

This study contributes to the existing corpus of literature on technology adoption and corporate sustainability by providing empirical evidence of the relationship between organizations' GTA and their GCA. As previously discussed by Sarkis et al. [25], by investigating the influence of GTA on GCA, we better understand the mechanisms through which organizations can gain a competitive advantage by adopting sustainable technologies. Klassen and McLaughlin [26] note that GCA is enhanced when businesses can reduce costs, increase operational efficiency, and improve their reputation with stakeholders. Second, this paper examines the positive correlation between firms' GTA and GPI. As studied by Zeng et al. [27], by examining the impact of GTA on GPI, we gain insight into how organizations can use green technologies to promote the development of innovative and environmentally friendly products. GTA provides businesses with the information, tools, and competencies to produce and market ecologically responsible goods to satisfy consumer demand [28]. Third, this study investigates the positive correlation between GDC and

GCA for firms. It contributes to the literature on the organizational capabilities required to achieve sustainable business performance by examining GDC's role in shaping GCA [3,19].

GDC enables businesses to respond effectively to environmental challenges, develop eco-friendly procedures, and innovate continuously to maintain an advantageous position in the marketplace [4,18,24]. This study also investigates the positive relationship between GDC and GPI. By examining this relationship, we show how businesses can integrate environmental considerations throughout the product life cycle by identifying and prioritizing opportunities and sensing emergent environmental trends, customer preferences, and regulatory requirements [20]. The presence of GDC substantially drives the GPI of businesses [29]. GDC-affiliated companies are more likely to introduce environmentally responsible products that integrate eco-design principles, use renewable materials, minimize resource consumption, and reduce environmental impacts [11,24]. This study also investigates GPI's role as a mediator in the relationship between GTA and GCA and the relationship between GDC and GCA. These observant opportunities and businesses that can effectively respond to environmental obstacles, seize viable options, and adopt and integrate green technologies could reduce resource consumption, minimize environmental impacts, and improve environmental performance overall.

To achieve these research objectives, the following is the outline for this paper. The Section 2 presents a comprehensive literature review on GTA, GDC, GPI, and GCA. The Section 3 describes the research methodology, including information on data acquisition, sample selection, and analytical tools. The Section 4 comprises the empirical analysis results concerning the proposed hypotheses. The Section 5 comprehensively analyzes the research findings, investigating their implications and addressing the study's limitations. The Section 6 concludes the paper with a summary of the findings and recommendations for future researchers interested in exploring new avenues in this field.

2. Literature Review

2.1. Theoretical Background

Dynamic Capabilities Theory

Since its inception in the 1990s, the dynamic capabilities theory (DCT) has attained widespread acceptance in the domain of strategic management. DCT, which is based on the resource-based view (RBV), highlights the significance of firm-specific resources and capabilities in achieving a competitive edge. Teece et al. [30] expanded the RBV by integrating dynamic capabilities that allow organizations to adapt to and respond to the dynamics of market conditions. Dynamic capabilities (DCs) are essential for businesses to adapt to the fast-shifting digital environment. In order to respond to the constantly changing environment, they enable businesses to recognize, develop, and evaluate technology prospects concerning customer needs and to mobilize both internal and external talents, resources, and competencies [31]. Sensing, seizing, and transforming are the three fundamental processes of dynamic capabilities, as described by Teece [32]. Sensing is the organization's capacity to recognize and utilize market signals, consumer demands, and technological developments. Information gathering, environmental monitoring, and strategic foresight are necessary to identify emerging opportunities and threats. If a company is adept at sensing, it may foresee shifts in the market and acquire a competitive edge. The ability of a business to efficiently mobilize and distribute resources to take advantage of untapped opportunities is known as seizing. Zahra and George [33] highlighted the significance of strategic decision-making, resource reconfiguration, and an entrepreneurial mindset in the context of leveraging dynamic capabilities for competitive advantage. Companies with a strong propensity for recognizing opportunities and taking calculated risks are better positioned to capitalize on them and achieve superior performance. It focuses on the organization's ability to reconfigure its resources, routines, and structures to align with emergent strategic opportunities. Teece [24] emphasized the significance of organizational ambidexterity, in which firms simultaneously investigate new opportunities and leverage existing competencies. The literature suggests that ambidextrous firms achieve a sustainable com-

petitive advantage by striking a balance between innovation and efficiency [34]. DCs are continuously required to proactively exploit new business opportunities and respond to environmental threats. This is particularly relevant in highly turbulent environments, such as digital transformation, where firms need to manage new technologies and resulting new forms of business model innovation (BMI) to remain competitive [35]. Moreover, DCs can help build resilience for circular supply chains. Resilience conceptualization requires a continuous adjustment and implementation of capabilities. Specifically, manufacturing organizations should be able to scan and mitigate potential threats through production innovation capabilities to stay competitive in unstable environments [31]. Additionally, DCT has been expanded to include environmental management and sustainability, developing "Green dynamic capabilities". GDC refers to a company's capacity to perceive, exploit, and transform environmental opportunities and challenges, achieving a competitive edge on the green market [19]. A company's capacity to outperform competitors by integrating ecological sustainability practices into its business strategies and operations is its GCA. It involves creating value for consumers, stakeholders, and the environment simultaneously. DCT provides a conceptual framework for comprehending how organizations can cultivate and employ GDC to achieve this competitive advantage [4]. Therefore, this research employs DCT as its foundational theory to develop the concept of GTA and GDC as dynamic organizational capabilities with the potential to boost GPI, resulting in GCA.

2.2. Development of Hypothesis

2.2.1. Green Technology Adoption and Firms' Green Competitive Advantage

GTA refers to incorporating and utilizing eco-friendly technologies in the business's operations, products, or services [8]. It involves the application of technologies that reduce resource consumption and pollution while promoting sustainability. The adoption of green technology is viewed as a proactive strategy that enables companies to mitigate environmental impacts, comply with regulations, and adapt to altering stakeholder expectations [34]. GCA is a company's capacity to gain a competitive advantage by aligning its business strategies and practices with environmental sustainability goals [36]. Businesses that effectively use GCA differentiate themselves in the market, attract environmentally concerned consumers, improve their brand's reputation, and achieve cost savings through enhanced resource efficiency [37]. The relationship between GTA and firms' GCA has been investigated empirically. For instance, Zhu and Sarkis [38] investigated the impact of GTA on a manufacturing company's environmental performance and competitive advantage. The findings demonstrated that companies that incorporated GTA obtained superior environmental performance and competitive advantage.

Adopting eco-friendly technologies allowed these businesses to increase resource efficiency, decrease waste production, and enhance their environmental reputation, giving them a distinct GCA advantage over their competitors. Lin et al. [34] examined the relationship between GTA and GCA within the frame of reference of sustainable supply chain management. According to their findings, businesses that integrated GTA into their supply chain operations obtained superior environmental performance and a greater competitive edge. By integrating GTA, companies can align their processes with environmental objectives, reduce their ecological footprint, and differentiate themselves in terms of sustainability practices, resulting in GCA in the flourishing sustainable market [28]. Accordingly, we postulate the following:

Hypothesis 1 (H1). *GTA positively affects firms'GCA.*

2.2.2. Green Technology Adoption and Green Product Innovation

GTA and GPI play essential roles in promoting sustainable practices and addressing environmental issues. Green technology refers to production technologies and manufacturing processes that reduce environmental contamination and consumption of raw materials [39,40]. On the other hand, GPI entails the application of innovative concepts that result

in developing, manufacturing, and distributing novel products that outperform traditional or rival products in terms of innovation and environmental sustainability [4,41]. Numerous studies have demonstrated that GTA and GPI are positively correlated. Huang et al. [42] found that firms' adoption of eco-innovations positively affected their GPI. Several authors emphasized that GTA facilitated GPI by providing businesses with the knowledge, skills, and resources necessary to develop environmentally responsible products [43]. Sarkis, Zhu, and Lai [17] explored the link between GTA and GPI in the setting of manufacturing organizations in their 2011 study. The findings indicated that companies with robust GTA were more inclined toward participating in GPI activities. GTA facilitated the acquisition of new knowledge, enhanced environmental performance, and boosted the company's capacity to develop GPI [44]. Hottenrott and Rexhauser [14] found that firms' investments in green technologies positively affected their environmental innovation outcomes. By utilizing green technologies, businesses were able to incorporate environmentally favorable features, materials, and processes into their products, resulting in the development of greener and more sustainable offerings. Similarly, Zhu and Sarkis [38] conducted a study examining how GTA affects product development and ecological efficiency in the auto industry. The findings revealed a positive correlation between GTA and GPI, indicating that firms that adopted green technologies were more likely to develop environmentally sustainable products. GTA equips companies with the skills and resources necessary to design and manufacture eco-friendly vehicles, establishing them as industry leaders in terms of sustainable innovation [45]. Thus, it is conceivable that:

Hypothesis 2 (H2). *GTA positively affects firms'GPI.*

2.2.3. Green Dynamic Capabilities and Green Competitive Advantage

GDC refers to an organization's capabilities to sense, seize, and reconfigure its resources and activities in response to environmental challenges and opportunities to obtain sustainable and environmentally beneficial outcomes [11,24] (Chen and Chang, 2013; Yousaf, 2021). These capabilities enable organizations to integrate environmental considerations into business strategies, operations, and innovation processes. On the contrary, GCA is the unique position firms achieve by implementing sustainable practices and providing environmentally friendly services or goods, which separates them from competitors and attracts customers concerned about the environment [46]. Developing GDC through strategic cooperation, resource restructuring, learning, creativity, and collaboration enables organizations to gain a competitive edge in the green market. By successfully reacting to environmental hurdles and seizing viable opportunities, enterprises can distinguish themselves in the marketplace, attract ecologically conscious consumers, reduce costs, enhance their standing among consumers, and contribute to the sustainability of the environment. Delmas and Toffel [47] examined the relationship between GDC and GCA in the U.S. hospitality sector. The results indicated that companies with stronger GDC were more likely to gain GCA through green initiatives. GDC encompasses a company's capacity to incorporate environmental considerations into its strategic decision-making, consistently improve its environmental performance, and manage its green practices effectively. Organizations with GDC demonstrate greater agility and responsiveness in instituting ecological innovations and techniques, resulting in enhanced environmental performance and a significant GCA in the market [47]. Bari et al. [12] stressed the importance of resource reconfiguration and innovation capabilities in developing GDC and achieving GCA in businesses with investments in sustainable innovation, i.e., green architecture, sustainable materials, and energy conservation, to gain a competitive edge in the economic climate [48]. Weng et al. [49] discovered that companies with solid learning capabilities and knowledge management systems were likelier to develop GDC and obtain a competitive edge through environmental sustainability. Porter and Van Der Linde [1] emphasized the significance of increasing green innovation skills and competitiveness through organizational learning and

information exchange. In addition, in a separate study, Zhu, Sarkis, and Lai [18] assessed the relationship between GDC and GCA within the framework of manufacturing factories.

The study revealed that organizations with enhanced GDC were better positioned to achieve GCA by proactively identifying and capitalizing on green business opportunities. GDC enables businesses to align their resources, processes, and capabilities with environmental objectives, fostering innovation and enhancing ecological performance [4]. Managers with strong GDCs can differentiate themselves from rivals and get a competitive edge by selling environmentally sustainable products. Utilizing green methods allows for the achievement of this benefit [3]. Therefore, we can speculate that:

Hypothesis 3 (H3). *GDC positively affects firms'GCA.*

2.2.4. Green Dynamic Capabilities and Green Product Innovation

GDC refers to a company's capacity to develop, integrate, and deploy resources and activities that facilitate the creation of environmentally favorable and sustainable products [24]. Conversely, GPI focuses on creating and introducing new or improved goods with a decreased environmental effect throughout their life cycle [50]. Integrating GDC into a company's innovation processes can result in the successful development and commercialization of environmentally friendly products [51]. By reconfiguring resources, fostering cross-functional collaboration, adopting a market-oriented strategy, and incorporating sustainable practices into the supply chain, businesses can improve their ability to develop and market environmentally responsible products [52]. Through digital transformation, GDC enables transparency in production, providing access to information such as resource consumption and underutilized assets. This contributes to resource-efficient processes and increased productivity, thereby enhancing GPI [53]. GDC enables companies to effectively address environmental challenges, satisfy customer demands for sustainability, and obtain a competitive edge in the green marketplace. GDC, such as resource reconfiguration and technological innovation, positively influenced the development of GPI, according to Del et al. [54]. The researchers argued that GDC encompassed the company's capacity to identify and seize green business opportunities, integrate environmental considerations into product development processes, and manage internal resources and capabilities for GPI. Firms with strong GDC demonstrated greater agility, flexibility, and responsiveness in developing and introducing environmentally sustainable products, giving them a market advantage [24]. Horbach et al. [55] emphasized the significance of resource adaptability and the capacity to respond to shifting environmental requirements as essential elements of GDC that drive GPI. Pagell and Wu [56] argued that developing GDC, such as incorporating environmental criteria into supplier selection and administration, plays a crucial role in fostering GPI within a sustainable supply chain. Aguilera-Caracuel et al. [57] identified the positive impact of collaboration among organizations and green supply chain practices on creating ecological products. As a result, we can formulate the following hypothesis:

Hypothesis 4 (H4). *GDC positively affects firms'GPI.*

2.2.5. Mediating Role of Green Product Innovation

In the field of sustainable business, understanding the connection between GTA, GPI, and GCA is an important area of study. Adopting green technologies permits companies to devise innovative green products, which can help them obtain a competitive advantage in a sustainability-focused market [45]. Shahzad et al. [8] indicated that adopting green technology in the manufacturing sector has a favorable effect on GPI. Adopting environmentally favorable technologies facilitated the creation of innovative green products that meet sustainability objectives. Jabbour et al. [58] advocated the positive connection between GPI and GCA.

Theoretical assumptions argue that technological innovation has the potential to facilitate the shift toward environmentally conscious lifestyles and mitigate carbon emissions.

It is commonly seen as the primary means of attaining sustainable economic growth [59]. Nevertheless, the academic literature presents a varied and often conflicting corpus of knowledge concerning the relationship between green technology and carbon emissions. This divergence might be attributed to the diverse range of scenarios and empirical analyses employed in these studies. As demonstrated by Braungardt et al. [60], the implementation of green technology has successfully addressed the inherent conflict between economic advancement and the preservation of the environment. However, it is essential to acknowledge the potential existence of a rebound effect [22]. Green innovation has a direct and scalable impact on carbon dioxide emissions. One key aspect is that green technological innovation has the potential to significantly decrease carbon emissions by enhancing energy utilization efficiency. This refers to the direct impact of green technological innovation on emissions. Another factor to consider is that the advancement of green technology contributes to economic scale and output growth, resulting in increased energy consumption and carbon emissions. This phenomenon can be referred to as the scale effect of green technology innovation on emissions [21]. Hence, the specific outcome resulting from this combined influence remains unclear.

Green innovation facilitates the improvement of a company's competitive position in the green marketplace by creating innovative green products that meet customers' demands for sustainability. Zameer et al. [61] investigated the connection between GTA, GPI, and GCA in the context of the electronics industry. They found that GTA positively affected GPI, which in turn influenced GCA. Cruz Mamani et al. [62] investigated the mediating function of GPI between GTA and GCA in the manufacturing industry. The researchers discovered that GPI partially mediated the relationship, indicating that firms implementing green technologies were more likely to develop innovative green products, enhancing one's position in the eco-friendly market.

Alternatively, empirical evidence suggests that GPI serves as a mediator between GDC and GCA. A competitive edge in the sustainable market can be gained by developing novel green products, facilitated by the firm's GDC. A study by Singh et al. [63] revealed evidence of a link between GDC and GPI. The study's conclusions showed that GDC, or an organization's capacity to integrate environmental issues into its operations, positively impacted GPI's development. Garcia-Machado et al. [29] identified a positive correlation between GPI and GCA. On the green market, firms that develop environmentally friendly and innovative products can acquire a competitive advantage. Zeng, Xie, and Tam [27] investigated the connection between GDC, GPI, and GCA within the context of manufacturing firms. They discovered that GDC positively influenced GPI, contributing to a sustainable GCA. Qiu et al. [4] examined the function of GPI in bridging the gap between GDC and GCA. GPI partially mediated the relationship, suggesting that firms with enhanced GDC were more likely to develop innovative green products, thereby attaining a competitive advantage in the green market. Thus, it is possible to hypothesize the following:

Hypothesis 5 (H5). *GPI positively affects firms'GCA.*

Hypothesis 6 (H6). *GPI mediates the relationship between GTA and GCA.*

Hypothesis 7 (H7). *GPI mediates the relationship between GDC and GCA.*

Figure 1 illustrates the conceptual model of this research.

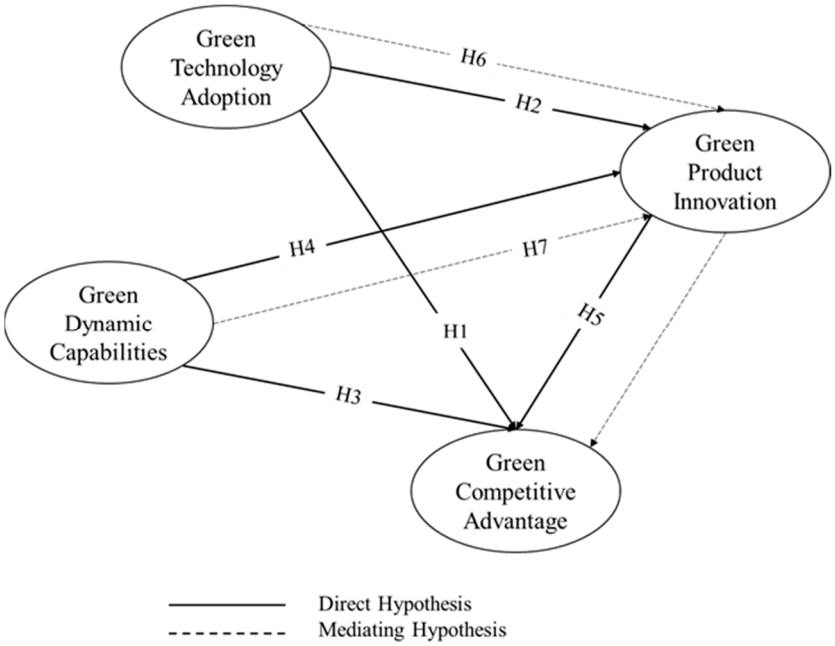

Figure 1. Conceptual Model.

3. Methods

3.1. Data Collection and Sample

The researchers surveyed Bangladesh-based manufacturing companies from eight industries to evaluate their proposed hypotheses. These sectors were selected because of the significant manufacturing value added (MVA) they contribute to overall and per capita GDP. The industries included consumer packaged goods manufacturers, steel, pharmaceuticals, automobiles, tobacco, apparel, cement, and ceramics. The manufacturing sector in Bangladesh is essential for economic development, and these businesses operate in a dynamic and competitive market that requires constant innovation [64].

A self-administered survey was developed to obtain data regarding the impact of GTA, GDC, and GPI on GCA. Minor revisions were made after the questionnaire was pre-tested with academic researchers and industrial management. The questionnaire was distributed to 450 manufacturing firms with an accompanying letter clarifying the research's goal and stressing the need for the companies' voluntary participation. These companies were targeted through a purposive sampling method, given their substantial impact on the country's economic landscape. The survey targeted chief executive officers (CEOs) as they typically significantly influence green initiative development [65]. Participants received guarantees that their replies would be kept in absolute confidence and used only for academic research. A follow-up reminder led to receiving 312 valid and comprehensive surveys, with a response percentage of 69.33%. Fincham [66] posits that when a survey attains a response rate of merely 30%, it is afflicted by a nonresponse bias of 70%. In a similar vein, when the survey's response rate is 20%, the nonresponse bias would account for the remaining 80% of the population. In order to determine the appropriate sample size, the software program G*Power was used. The output showed that a minimum of 124 samples would be adequate for the analysis. The study's data were gathered between January and March 2023.

3.2. Survey Instrument Development

To evaluate the model's hypotheses, multiple questionnaire items based on prior research were employed. Certain items were altered in accordance with the scope of the investigation. A five-point scale was used to evaluate the exogenous variables. Prior to the primary data collection, the instrument was constructed in conformity with the recommendations of Mishra et al. [67] and Hair et al. [68]. A panel of five academic scholars

and eight managers was presented with a comprehensive set of the study's findings. Their objective was to determine how precisely these items represented the intended concepts. Using a 3-point Likert scale, with "3" representing a high degree, "2" representing a moderate degree, and "1" representing no degree, they rated the items appropriately. The survey instrument only included items that received a score of "3" from at least two professionals and were not scored as "1" by any of them. The measurement instruments employed in this study were derived from relevant literature sources. Prior research by Afum et al. [28] and Lee et al. [69] was utilized to evaluate the GTA of companies using five measures (Table 1). The metrics were used to determine whether the companies utilized technology-enabled capabilities to enhance their industrial performance. Five items from Chen and Chang's [11] and Chen et al.'s [18] research were used to calculate the GDC of the companies. The metrics used in this analysis looked at how a company's GDC relates to the innovation and performance of its green products. Four items adapted from Chen's [70] research were used to evaluate the mediator GPI. In addition, the company's GCA was estimated using four items derived from the research of Chen and Chang [16].

Table 1. Measurement items.

Variables	Codes	Items	Sources
Green Technology Adoption	GTA1	Eco-technology changes rapidly in our firm.	Afum et al. [28]; Lee et al. [69]
	GTA2	We are eco-technologically competitive.	
	GTA3	We use up-to-date/new technology in the process.	
	GTA4	We are fast in adopting the latest technological innovations.	
	GTA5	We use cleaner technologies.	
Green Dynamic Capabilities	GDC1	The firm is able to exploit, integrate, combine, create, acquire, share, and convert new environmental technology.	Chen and Chang [11]; Chen et al. [18]
	GDC2	The firm is able to effectively deploy resources for the development of green innovations.	
	GDC3	The firm is able to effectively coordinate employees to generate green knowledge.	
	GDC4	The firm is able to effectively manage and assimilate specialized environmental technology within the firm.	
	GDC5	The firm can quickly observe the environment and recognize new environmental opportunities.	
Green Product Innovation	GPI1	We choose the materials of the product that produce the least amount of pollution for conducting the product development or design.	Chen [70]
	GPI2	We choose the product's materials that consume the least energy and resources for conducting the product development or design.	
	GPI3	We use the least amount of materials to comprise the product for conducting the product development or design.	
	GPI4	We would circumspectly deliberate whether the product is easy to recycle, reuse, and decompose for conducting the product development or design.	
Green Competitive Advantage	GCA1	Compared to our major competitors, we have the competitive advantage of low-cost environmental management or green innovation.	Chen and Chang [16]
	GCA2	The quality of the green products or services we offer is better than that of our major competitor.	
	GCA3	We are more capable of environmental R&D and green innovation than our major competitors.	
	GCA4	We are more capable of environmental management than our major competitors.	

3.3. Data Analysis Technique

This study's hypotheses were investigated using PLS-SEM. This methodology was selected due to its suitability for analyzing complex evaluating ties between variables and their intermediate effects. In addition, PLS-SEM is advantageous because even with a small sample size, it can generate reliable results [71,72]. PLS-SEM is a variant of structural equation modeling (SEM) that assesses statistical models with a concentration on causality

and prediction [73]. Its structure is intended to provide causal explanations while placing emphasis on predictive abilities [72,74]. We performed the PLS-SEM analysis using SmartPLS Version 4.0, and our model was formed from a causal perspective. [75]. This software provides a variety of statistical techniques for analyzing complex relationships between predictors and dependent variables. Five thousand subsamples and the bootstrap method were used to test the hypotheses. Using structural equation modeling (SEM), a measurement and a structural model were developed [7]. While the structural model investigated the relationships between these underlying constructs, the measurement model aimed to identify the relationships between observed variables and these underlying constructs [64]. After estimating and eliminating random errors, only the total variance remained. The reliability of the structural model specification was assessed using convergent and divergent validity criteria [7].

To investigate the probable existence of the common method bias (CMB) in the study, further statistical analysis was carried out. Podsakoff et al. [76] delineate the single-factor testing method of Harman, which was utilized for this purpose. All variables were subjected to exploratory factor analysis, which produced a single factor that explained 43.75% of the total variance. This percentage, however, fell below the 50% threshold. Thus, the analysis revealed that the study lacked a substantial method bias. The investigation findings are presented in detail below.

4. Findings

4.1. Measurement Model

The statistical analysis was conducted utilizing SmartPLS version 4.0. The PLS-SEM analysis was utilized to test all six study hypotheses. Several scholars, such as Hair [75] and Sarstedt et al. [77], have suggested that the PLS-SEM approach is appropriate for research due to its capacity to examine "mediation effects", its capacity to rapidly advance the testing of a hypothesis with the goodness of fit, and its capacity to enable scholars to explore multiple relationships among factors. The utilization of PLS-SEM was considered especially appropriate for the present research due to the presence of a mediating variable (GPI) within the structural framework (refer to Figure 1), which was evaluated for its positive mediating impact on other variables. The resulting analytical outcomes were deemed acceptable regarding the model's reliability, the variables' distinctiveness, and the measurements' consistency and are elaborated extensively in the subsequent section.

Table 2 presents each latent variable's AVE, CR, and alpha values and the factor loadings for all measured variable elements. To determine the presence of collinearity, the variance inflation factor (VIF) was calculated for each latent variable using the suggested range of <3.3 or <5 [76]. The results indicated an absence of significant collinearity. The factor loadings of the selected measurements are displayed in Table 2. All items had factor loadings greater than 0.6. All CRs surpassed the recommended cutoff of 0.70 [78]. The reliability presumption, as defined by Hair et al. [76], was confirmed as the CA values for each construct surpassed the 0.70 criterion. Fornell and Larcker [79] propose that to establish convergent validity (CV), it is recommended that the AVE values surpass 0.5. The present investigation has additionally validated the construct validity (CV) of the measurement instrument, as evidenced by the substantial and statistically significant standardized loadings of each item in the model on its target construct [72]. The AVE values of the model constructs, which vary from 0.574 to 0.829, support the CV of the data (Table 2).

Table 2. Results of the measurement model.

Constructs	Items	Outer Loadings	Alpha	CR	AVE
Green Technology Adoption	GTA1	0.770	0.843	0.843	0.614
	GTA2	0.805			
	GTA3	0.769			
	GTA4	0.794			
	GTA5	0.779			
Green Dynamic Capabilities	GDC1	0.678	0.762	0.780	0.510
	GDC2	0.788			
	GDC3	0.759			
	GDC4	0.657			
	GDC5	0.680			
Green Product Innovation	GPI1	0.785	0.813	0.815	0.641
	GPI2	0.809			
	GPI3	0.824			
	GPI4	0.784			
Green Competitive Advantage	GCA1	0.751	0.834	0.833	0.668
	GCA2	0.839			
	GCA3	0.852			
	GCA4	0.825			

Note: Alpha = Cronbach's Alpha, CR = Composite Reliability, AVE = Average Variance Extracted.

The discriminant validity (DV) was evaluated using the Fornell and Larcker criterion and the heterotrait-monotrait ratio of correlations (HTMT) criterion, as outlined by Hair et al. [78]. The square roots of the relevant average variance extracted (AVE) measurements derived from the correlation matrix are displayed in Table 3. The discriminant validity of the correlation matrix between the latent variables was demonstrated by diagonal values exceeding those below the diagonal. The HTMT values were found to be below the threshold value of 0.90, indicating the presence of DV [78,80] (Table 3).

Table 3. Discriminant validity.

Fornell Larcker Criterion				
	Green Technology Adoption	Green Dynamic Capabilities	Green Product Innovation	Green Competitive Advantage
Green Technology Adoption	0.784			
Green Dynamic Capabilities	0.611	0.714		
Green Product Innovation	0.584	0.524	0.801	
Green Competitive Advantage	0.673	0.599	0.516	0.817
HTMT Criterion				
	Green Dynamic Capabilities	Green Technology Adoption	Green Product Innovation	
Green Technology Adoption	0.739			
Green Product Innovation	0.648	0.704		
Green Competitive Advantage	0.726	0.798	0.621	

4.2. Structural Model

The structural model and proposed hypotheses were evaluated using the SmartPLS 4.0 software, as depicted in Figure 2. Using the bootstrapping method involved the generation of 5000 subsamples in ascertaining the statistical significance of the connections between

the latent constructs [81]. According to Wasko and Faraj [82], PLS does not provide detailed metrics of the model's overall goodness of fit. As a result, the R^2 and Q^2 metrics are commonly used to assess the predictive capacity of the structural model. Table 4 demonstrates that the R^2 values surpass 0.1, with GPI R^2 at 0.385 and GCA R^2 at 0.518. Consequently, the ability to make predictions has been established [64]. Furthermore, the Q2 metric shows the predictive relevance of the endogenous components since a value greater than 0 indicates their predictive significance. The study's results show that the constructs examined possess significant predictive relevance, as evidenced by the GPI Q^2 (0.518) values and GCA Q^2 (0.337) presented in Table 4 [74].

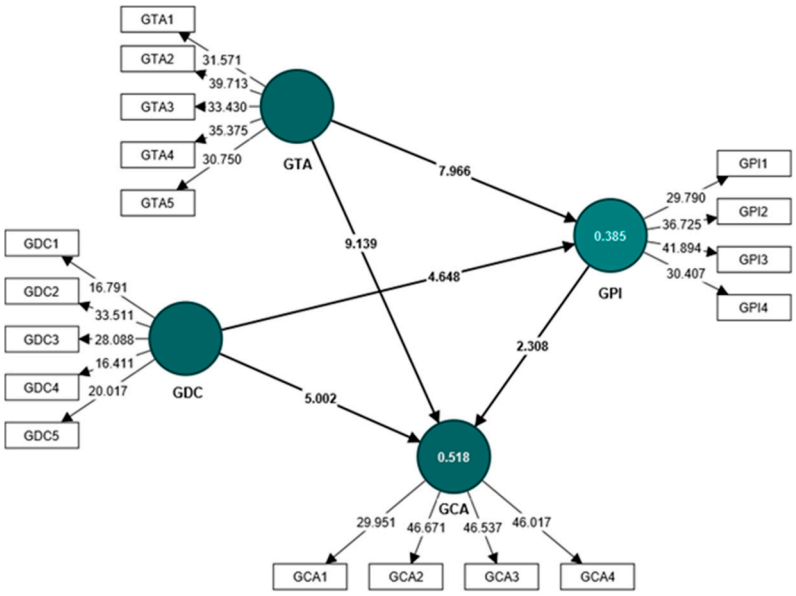

Figure 2. Structural model.

Table 4. The predictive power of the model.

Constructs	R^2	Q^2
Green Product Innovation	0.385	0.242
Green Competitive Advantage	0.518	0.337

The direct and indirect effects of model constructs are detailed in Table 5. The initial observation indicates a positive influence of GTA on firms' GCA, as evidenced by the significant beta coefficient ($\beta_1 = 0.440$), *t*-value ($t = 9.139$), and *p*-value ($p = 0.000$), thereby validating hypothesis H1. Furthermore, the GTA of firms has a significant impact on their green products innovation ($\beta_2 = 0.422$, $t = 7.966$, $p = 0.000$), providing support for hypothesis H2. Subsequently, it has been noted that there exists a positive association between GDC and firms' GCA, as evidenced by the significant coefficient β_3 (0.268) with a t-value of 5.002 and a *p*-value of 0.000, thereby providing support for H3. Moreover, we observed that GDC significantly impacts corporations' GCA ($\beta_4 = 0.266$, $t = 4.648$, $p = 0.000$), which supports hypothesis H4. The final direct impact indicates that GPI directly influences firms' GCA ($\beta_5 = 0.119$, $t = 2.308$, $p = 0.021$), corroborating hypothesis H5.

Table 5. Results of hypotheses testing.

Hypotheses	Coefficients	SE	T Statistics	*p* Values	Remarks
Direct Effects					
H1: GTA→GCA	0.440	0.048	9.139	0.000	Supported
H2: GTA→GPI	0.422	0.053	7.966	0.000	Supported
H3: GDC→GCA	0.268	0.054	5.002	0.000	Supported
H4: GDC→GPI	0.266	0.057	4.648	0.000	Supported
H5: GPI→GCA	0.119	0.051	2.308	0.021	Supported
Indirect Effects					
H6: GTA→GPI→GCA	0.050	0.023	2.206	0.027	Supported
H7: GDC→GPI→GCA	0.032	0.016	1.995	0.046	Supported

The study's findings indicate that the GPI serves as a significant mediator in the linkage between GTA and GCA, as evidenced by the mediation analysis (β_6 = 0.050, t = 2.206, p = 0.027), thereby confirming the sixth hypothesis. Additionally, it was discovered that GPI functions as a mediator for the connection between a company's GDC and GCA (β_7 = 0.032, t = 1.995, p = 0.046), thus confirming hypothesis H7. Figure 2 depicts the structural model of this research.

5. Discussion

The purpose of this study was to examine the effect of GTA and GDC on GCA as mediated by GPI. The empirical testing of the relationships between GTA and GCA, and GPI, GDC, and GCA, and GDC and GPI was based on the DCT framework. In addition, the study investigated the role of GPI as a mediator in these associations.

The first hypothesis of this study posited that adopting green technology positively influences business's GCA. Previous research has repeatedly demonstrated that cleaner technologies enhance environmental and financial performance, aligning business strategies with sustainability objectives [34,83]. The results of the SEM analysis support hypothesis H1, indicating that the GTA considerably improves the GCA of Bangladeshi manufacturing firms. GTA enables businesses to save money, improve operational efficiency, and differentiate themselves in the marketplace. According to previous studies, companies can reduce energy consumption, waste production, and carbon emissions by integrating green technologies into their operations, reducing operational costs, and enhancing environmental performance [8]. GTA contributes in multiple ways to firms' GCA. It helps organizations comply with environmental regulations and satisfy the rising demand for sustainable products and services, positioning them as environmentally responsible organizations [2,13]. This positive brand image attracts eco-conscious consumers and increases customer loyalty. Secondly, GTA increases operational efficiency by optimizing resource utilization, reducing waste, and spurring process innovation. These efficiency enhancements result in cost reductions, enabling businesses to allocate resources effectively and invest in additional strategic initiatives [37]. GTA improves a company's capacity for innovation, thereby facilitating the creation of environmentally responsible products, services, and business models [58]. These innovations give firms a competitive edge in the market by offering unique value propositions and addressing sustainability concerns.

As stated in H2, GTA has a positive effect on GPI. This outcome is in line with earlier studies evaluating the role of GTA in raising the GPI of enterprises [8,14,28]. The literature also suggests that by adopting environmentally responsible technologies, businesses be-

come privy to new opportunities and resources that facilitate the development of GPI [43]. GTA provides businesses with the tools and capabilities to integrate environmental considerations into their product design, manufacturing processes, and supply chains. GPI is the result of their facilitation of exploring alternative materials, energy-efficient production methods, and environmentally responsible disposal practices. GTA positively influences the various phases of GPI. It improves firms' ability to identify and evaluate market opportunities for environmentally friendly products by enhancing their knowledge of customer requirements and sustainability trends [84]. GTA also enables companies to improve their research and development capabilities, facilitating the creation of eco-friendly materials, packaging, and production methods [42]. In addition, it encourages collaboration and knowledge sharing among stakeholders, nurturing partnerships with suppliers, customers, and research institutions to accelerate the adoption and integration of green technologies throughout the innovation process [85]. Integrating GTA and GPI is a strategic approach for organizations committed to sustainability and those who want to create a positive environmental impact while attaining business success.

Next, our findings revealed a positive relationship between GDC and GCA. Multiple studies corroborated the powerful effect of GDC on GCA in firms [12,24,47,48,61,86] (Bari et al., 2022; Dangelico, 2016; Delmas and Toffel, 2008; Gürlek and Tuna, 2018; Yousaf, 2021; Zameer et al., 2020). Firms with strong GDC are proficient in identifying emerging environmental trends, customer preferences, and regulatory requirements, which enables them to anticipate and respond to market demands for eco-friendly products and services, resulting in GCA [20]. According to previous studies, implementing GDC allows businesses to manage their resource usage effectively, minimize waste generation, and reduce environmental impacts throughout their operations [4,24]. Moreover, GDC promotes collaboration and partnerships with stakeholders, such as suppliers, consumers, and communities, creating sustainable solutions [49]. The adoption of GDC positively influences the overall GCA of businesses. Businesses can set themselves apart from competitors by offering environmentally responsible products, reducing their ecological footprint, and demonstrating their commitment to sustainability through their capabilities. Improved brand image and consumer loyalty, expanded market opportunities, reduced operating expenses from more efficient use of resources, and adherence to environmental standards all play a role in GCA. [4]. Companies with robust GDC can leverage these advantages to gain a competitive edge, secure market share, and achieve long-term financial success [3].

Furthermore, our research revealed a favorable correlation between a company's GDC and GPI, which aligns with previous studies and confirms our predictions [24,55]. Firms with strong GDC demonstrate more significant innovation and the introduction of environmentally friendly products. These capabilities enable businesses to identify and prioritize opportunities for GPI by sensing emerging environmental trends, customer preferences, and regulatory requirements [51]. By seizing these opportunities, businesses can introduce innovative and sustainable products that address environmental concerns and satisfy the evolving needs of environmentally conscious consumers [52]. GDC includes reconfiguring internal resources and activities to support GPI [87]. Companies with GDC invest in R&D, foster collaboration with suppliers and partners, and cultivate a culture of innovation and sustainability. These capabilities enable businesses to incorporate environmental considerations throughout the life cycle of the products, from design and sourcing to production and disposal, resulting in the GPI [15]. The presence of GDC has a positive effect on firms' GPI. Firms with GDC are more likely to introduce environmentally responsible products that incorporate eco-design principles, use renewable materials, minimize resource consumption, and minimize environmental impacts [51].

Finally, we incorporated GPI into the model as a mediator to see how it impacted the correlation between GTA and GCA, as well as the correlation between GDC and GCA. The findings revealed that businesses that effectively adopt and integrate green technologies are able to reduce resource consumption, minimize environmental impacts, and enhance environmental performance as a whole. However, the direct effects of GTA

on GCA may be limited if innovative green products are not developed. GPI serves an essential role as a mediator between GTA and GCA [8]. GTA provides companies with the framework and resources required to create GPI that meet environmental standards and consumer expectations [11]. GPI permits businesses to differentiate themselves on the market, attract environmentally conscious consumers, and attain GCA [62]. In the expanding green economy, companies should prioritize GPI as a strategic initiative to leverage their GTA and achieve GCA [36]. GPI additionally acts as an essential mediator between GDC and GCA [27]. GDC provides the foundation for firms to develop innovative environmental solutions [87], whereas GPI enables firms to translate these capabilities into commercially viable, environmentally responsible products [29]. By leveraging their GDC and investing in GPI, businesses can distinguish themselves, attract environmentally conscious consumers, and attain a sustainable GCA. To drive GPI and obtain a competitive edge in the evolving green economy, businesses should prioritize the development of GDC and foster an innovative culture [4].

6. Implications

6.1. Theoretical Implications

This study makes a substantial theoretical contribution to existing knowledge by examining GCA through the lens of the dynamic capabilities theory. This study provides valuable and profound insights into the intricate mechanisms that enable businesses to acquire and maintain a competitive edge in the dynamic green marketplace by comprehensively analyzing the interaction between GTA, GDC, GPI, and GCA. This research advances our understanding of the interrelationships among these variables. It casts light on their significance in the context of corporate sustainability and market success by integrating multiple theoretical perspectives. Utilizing the DCT, this study expands the theoretical comprehension of dynamic capabilities and their role in generating GCA and applies them to environmental sustainability [88]. This research also bridges the divide between GTA and GPI. Prior research has acknowledged the significance of both factors, but more attention needs to be paid to their interdependence and the mediating effect of GPI on GCA [89]. Recognizing this gap, the present investigation focuses on the role of GPI as a mediator that enables firms to transform their GTA into a competitive advantage.

Additionally, this study examines environmental sustainability and innovation strategies in greater depth. This study incorporates GTA and GDC into the innovation process, promoting GPI. Examining the role of GPI as a mediating force contributes to developing a firm theoretical foundation. This study provides a theoretical framework for the positive impact of an environmentally sustainable innovation strategy on competitive advantage by investigating the role of GPI as a mediator. This integration contributes to understanding how firms combine innovation and sustainability to establish a unique competitive advantage [90].

6.2. Managerial Implications

Our research provides businesses seeking a competitive edge in the green market with actionable insights. By examining the relationships between GTA, GDC, GPI, and GCA, our study provides managers with actionable recommendations to enhance their sustainability strategies. This study contributes to the management discipline by highlighting the positive relationships between these variables. The findings indicate that implementing GTA can positively influence GPI, which positively impacts GCA. Consequently, companies can strategically leverage GTA to stimulate innovation and fortify their competitive position within the green market. By incorporating eco-friendly technologies into their business practices, companies have the potential to not only mitigate their impact on the environment but also foster a culture of innovation. These innovative endeavors can materialize in developing green goods, distinguishing companies from their rivals and appealing to consumers with a focus on sustainability. The discernible advantages encompass en-

hanced reputation, improved market share, and fortified competitive positioning within the green market.

Furthermore, the study's findings underline the significance of incorporating sustainability considerations into an organization's dynamic capacities. Our findings have substantial implications for the managers and entrepreneurs of small and medium enterprises (SMEs) and startups. SMEs and startups face numerous obstacles in improving their market share because of a lack of financial and other resources. However, since dynamic capabilities can drive value proposition innovation in startups [91], founders and managers of these ventures can develop GDC to boost green innovation performance and competitive advantage. Managers can nurture GDC by proactively identifying and seizing environmental opportunities while reconfiguring resources to address sustainability challenges effectively. This adaptive approach allows organizations to respond adeptly to ecological shifts and capitalize on emerging green technologies, ultimately bolstering their ability to achieve a competitive advantage. In addition, the study highlights the mediating role of GPI in the relationship between GTA and GCA. Managers can use GPI to convert their efforts to incorporate environmentally friendly technologies into tangible competitive advantages.

By developing innovative green products, businesses can differentiate themselves from competitors, attract environmentally conscious consumers, and increase their market share. This study's managerial contributions have implications for firms looking to strengthen their sustainability strategy and gain a competitive advantage in the green market. It highlights managers' need to prioritize GTA and promote GDC within their organizations. In addition, it emphasizes the significance of incorporating sustainability factors into the innovation process and actively pursuing GPI. By implementing their strategies and practices with the findings of this study, managers can create an all-around approach to corporate sustainability that positively affects their GCA. Managers can use the provided insights in making informed decisions regarding resource allocation, innovation investments, and sustainability initiatives, thereby contributing to their organization's long-term success and sustainability. Finally, when considering the study from a more comprehensive standpoint, the insights obtained hold considerable implications for formulating national or regional policies regarding green technology and innovation. Policymakers may use these findings to facilitate the advancement of green technologies and the innovation of sustainable products. This approach can cultivate a competitive landscape that promotes both environmental responsibility and sustainable development.

7. Conclusions, Limitations, and Future Research Directions

This study sought to ascertain how GTA, GDC, and GPI affected Bangladesh's manufacturing sector's competitive advantage in the green market. The study's validity, reliability, model fit, and structural model were evaluated using PLS-SEM techniques. Managers working in Bangladeshi manufacturing companies provided primary data for this evaluation. The study's primary purpose was to test the hypotheses and examine the relationships between the variables, including the mediating effects of the mediator variable. The results supported all the hypotheses, demonstrating positive connections between the independent factors, the dependent variable, and the mediator variable's mediating role. These findings highlight the significance of integrating GTA, GDC, and GPI for environmental sustainability and competitive advantage. The paper also explored the limitations, potential future research directions, and theoretical and practical consequences.

While the research findings provide valuable insights, it is crucial to acknowledge the limitations and identify potential future research avenues in this field to advance our understanding of corporate sustainability and competitive advantage. This study's emphasis on the manufacturing sector is a noteworthy limitation that may limit the applicability of the findings to a wide range of other businesses. Future research should examine the relationships between GTA, GDC, GPI, and GCA across different industries, including services and technology, to improve our understanding of this area. Additionally, expand-

ing the geographical scope would provide a more comprehensive understanding of these constructs' interplay in different regional and cultural contexts. This study utilized self-administered surveys, which may introduce biases in the responses obtained. Respondents might provide socially desirable answers or inadvertently misinterpret certain questions. Future research may consider alternative data collection methods, such as interviews or observations, to mitigate these biases. The use of cross-sectional data in this study is still another drawback. It is essential to move past cross-sectional data and perform longitudinal research to demonstrate causal linkages and obtain a more thorough understanding of how these associations change over time. Furthermore, more research is required to understand the feedback loops and delay effects connected to GTA, GDC, GPI, and GCA.

By adopting a temporal perspective, we can uncover insightful information and illuminate the complex relationship between these constructs, opening up new research avenues. To gain deeper insights into these complex dynamics, future research should explore the temporal perspective explicitly by analyzing how these constructs interact and influence each other over time, considering potential delays and cumulative effects. Additionally, it would be beneficial to investigate contextual factors extensively. Organizational culture, external stakeholder pressures, and regulatory frameworks define these interactions, encouraging scholars to explore these uncharted waters. In addition, while the present study focuses on the positive correlations between the variables, future research should examine the trade-offs and obstacles organizations may face in pursuing GCA. By addressing these limitations and conducting additional research, scholars can considerably advance our understanding of the intricate connections between GTA, GDC, GPI, and GCA. This knowledge will equip managers with a thorough understanding of integrating sustainability into their strategic decision-making. With this valuable knowledge, businesses can navigate the complexities of the green market and establish a solid competitive position.

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