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RESEARCH ARTICLE

Unlocking green innovation and environmental performance: the mediated moderation of green absorptive capacity and green innovation climate

Sadaf Akhtar[1] · Cai Li[1] · Jan Muhammad Sohu[1,2] · Yasir Rasool[1] · Muhammad Iatzaz Ul Hassan[3] · Muhammad Bilal[3]

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Abstract

This study extends the foundations of the natural resource-based view (NRBV) by introducing a mediation-moderation framework by analyzing the influence of green intellectual capital (GIC) on both green innovation performance (GIP) and environmental performance (EP) while simultaneously considering the mediating role of green absorptive capacity (GAC) and the moderating influence of the green innovation climate (GICL). The data for this study was gathered from a sample of 575 participants employed within small and medium enterprises' (SMEs') manufacturing firms. This dataset was utilized to evaluate the proposed model; this study uses the PLS-SEM approach to comprehensively examine the complex interactions among these variables. This model adds to the theoretical understanding of NRBV and enhances its practical applicability. The findings of this study reveal a positive relationship between GIC, GAC, GIP, and EP within organizations. Furthermore, our investigation reveals a positive correlation between a GICL and the relationships involving GIC, GAC, GIP, and EP. Importantly, this research introduces a novel perspective by clarifying the complex relations among these variables and highlighting the positive correlation between a GICL and the relationships involving GIC, GAC, GIP, and EP. This novel approach enhances the theoretical understanding of NRBV and its practical applicability in fostering GIP and EP within manufacturing SMEs operating in Pakistan.

Keywords Green intellectual capital · Green innovation climate · Green absorptive capacity · Environmental performance · Green innovation performance · PLS-SEM

Introduction

In recent years, the global business landscape has witnessed a profound transformation characterized by a growing emphasis on environmental sustainability and adopting environmentally responsible practices. As organizations seek to respond to the challenges posed by climate change, resource scarcity, and societal expectations, the concept of "green" or environmentally sustainable innovation has gained significant importance. Today, the environment has emerged as a paramount concern for businesses, primarily driven by pressures exerted by stakeholders. Furthermore, the influence of international organizations, customers, government entities, and society has led businesses to emphasize enhancing their environmental and green innovation performance. The overarching goal is to mitigate and reduce environmental pollution (Sampene et al. 2023). These pressures have bound companies to adopt a keen responsibility toward environmental stewardship. This is reflected in stricter moves by authorities and a higher public awareness of environmental sustainability (Haldorai et al. 2022). On this basis, ecological issues are considered essential for the business as they relate to its operating processes and efficiency (Tran et al. 2023). Small and medium enterprises (SMEs) engaged in manufacturing firms in Pakistan contribute to environmental pollution and damage due to their manufacturing operations and marketing practices. This adverse aspect of the manufacturing industry hinders achieving sustainability in this sector. The industry necessitates the implementation of

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✉ Cai Li
gscaili@ujs.edu.cn

[1] School of Management, Jiangsu University, Zhenjiang, Jiangsu, China

[2] Department of Business Administration, IBA University, Sukkur, Pakistan

[3] School of Finance and Economics, Jiangsu University, Zhenjiang, Jiangsu, China

green innovation and environmental performance to ensure sustainable development (Jermsittiparsert 2021). The current study fulfills this requirement by emphasizing green innovation performance, environmental performance, and green intellectual capital. Additionally, the study seeks to investigate the mediating role of green absorptive capacity in the relationship between GIC to GIP and GIC to EP. The study aims to analyze the moderating influence of green innovation climate in the relationship between GIC to GAC, GIC to GIP, and GIC to EP. Environmental scientists have proposed GIC as an innovative concept to address ecological degradation and simultaneously function as a competitive advantage for enterprises (Benevene et al. 2021; Jirakraisiri et al. 2021). Theoretically, the concept of GIC stems from the broader notion of intellectual capital (IC). GIC is defined as intangible assets encompassing the reservoir of knowledge and, more broadly, an organization's ability to augment its value (Du & Wang 2022; Masoulas 1998). As per Ranson & Stewart. (1994), IC is characterized as the collective store of information, data, learning, relationships, intellectual property rights, and brand reputation that collectively contribute to a company's worth and value (Ali et al. 2021; Chatterjee et al. 2021). GIC has been categorized into three distinct types: human capital, relational capital, and structural capital (Khan et al. 2023a, b). GIC encompasses the knowledge, processes, capabilities, and systems that are specifically geared toward establishing and maintaining relationships with external stakeholders, where these relationships yield eco-friendly value for the business. The challenges faced by the company in implementing green relational capital practices have implications for environmental performance (EP) and green innovation performance (GIP) in their business operations and production processes (Mahmood & Mubarik 2020; Zhao et al. 2022). Human capital is defined as the accumulation of skilled employees, their creativity, and their abilities to contribute to achieving corporate objectives (Zvosec et al. 2023). Structural capital is customer loyalty, goodwill, trust, and established relationships with various stakeholders, suppliers, and other organizations (Ali et al. 2021).

Another significant variable that enhances the competitive advantage of firms is the critical capabilities and resources, with the concept of green absorptive capacity having garnered considerable attention in recent scholarly literature (Makhloufi et al. 2023; Zhang et al. 2020). GAC represents the organizational capability to identify, absorb, and effectively utilize new knowledge. This capacity enables firms to adapt and thrive in dynamic and ever-changing environments (Qu et al. 2022a). Organizations possessing a greater capacity for GAC are better equipped to identify and cultivate a broader knowledge base, which, in turn, empowers them to formulate valuable business strategies (Zhang et al. 2020). In this context, it is essential to note that GIC encourages businesses to internalize knowledge, facilitating the promotion of sustainable business strategies through GAC (Suki et al. 2023a), which implies that GAC is a mediator in the association between GIC and EP and GIP.

Organizational climate refers to the inherent characteristics of a firm, encompassing attitudes, behaviors, and collective emotions, which persist independently of the perceptions and understandings held by individual members within the organization (Ekvall 1996a; Li et al. 2023). Put differently, an innovative climate prevails when organizations exhibit specific qualities such as a significant level of trust, openness among their members, a willingness to take risks, and a solid commitment to engaging in creative tasks (Ekvall 1996a). Ye et al. (2022) described an innovation climate that arises from the connection between staff and top-level management. These components encompass leadership's concern for staff, the level of intimacy in management-staff interactions, the connections among co-workers, the collective accomplishment of staff, leaders serving as role models, fostering team spirit, incentives provided by leaders to employees, and ensuring a fair distribution of workload among the workforce (Naseer et al. 2021). The study fills the gap in the GIC literature on GIP and EP. The previous literature needs to be more conclusive regarding the impact of GIC on EP and GIP. The previous literature and indirect impact of GIC on EP and GIP. Therefore, the current study offers the direct and indirect impact of GIC on EP and GIP. Secondly, the mediation of green absorptive capacity is not evaluated by the previous studies, and the undertaken research has measured the moderating impact of green innovation climate (GICL) in a relationship between GIC and GIP, EP. Lastly, the current research contributes to the natural resource-based view theory.

1) To evaluate the direct effect of GIC on EP and GIP.
2) To examine the mediation role of GAC on the relationship between GIC and EP, GIP.
3) To investigate the moderation effect of green innovation climate on the connection between GIC and GAC

Scholars argue that the manufacturing sector is counted as one of the energy-intensive sectors, significantly increasing carbon emissions. To restrict emissions, the sector must design policies that could improve environmental quality. SMEs are widely acknowledged as essential in economic growth and development catalysts, making substantial contributions to GDP and employment creation (Soomro et al. 2019). This holds in Pakistan, where SMEs have significantly fostered technological progress and expanded international market access. SMEs in Pakistan contribute 14–16% of the country's GDP, with over 90% of global business

coming from them, and 3.2 million SMEs engaged in the industry, significantly improving people's lifestyles and societal standing.

This study offers distinctive contributions on multiple fronts. Firstly, it advances the body of research in GIC by substantiating empirically that it assumes a supportive role in attaining GIP and EP. Secondly, this study establishes and thoroughly analyzes the mediation mechanism of GAC in the relationship between GIC, GIP, and EP. This contribution offers a more intricate empirical perspective on the concepts of NRBV. Finally, this research study extends the scope of the boundary conditions associated with the relationship between GIC, GAC, GIP, and EP, thereby providing a more comprehensive comprehension of the GICL.

Theoretical background and hypothesis development

Natural resource–based view

The NRBV theory was introduced to expand the resource-based view theory (RBV). While the RBV theory primarily encompasses internal resources, the NRBV theory extends its purview by incorporating external natural resources alongside internal assets, thereby stimulating the firm's capacity to safeguard and sustain competitive advantages (Barney 1991; S. et al. 1995; Rehman et al. 2021). The NRBV theory is grounded in a triple framework of environmental strategies, encompassing pollution prevention, product stewardship, and sustainable development (Begum et al. 2023; O. Hart 1995a, b). This deliberate inclusion of environmental considerations will ultimately yield dividends, aiding organizations in achieving their operational excellence objectives and gaining a competitive advantage (Rehman et al. 2021). As an illustration, the ability to consistently refine and enhance industrial processes leads to reduced emissions and lower operational costs (Hart 1995a, b).

Additionally, the capability of strategic proactivity enables organizations to capitalize on first-mover advantages and engage in more proactive environmental protection initiatives (Shahzad et al. 2021). In the NRBV theory, the natural environment is the central element, prompting firms to cultivate capabilities and mechanisms for pollution prevention, waste reduction, and advancing environmentally friendly production methods. These endeavors are undertaken to attain superior EP and GIP outcomes (Rehman et al. 2021).

NRBV theory underscores the importance of environmental stewardship in the organizational decision-making processes and the formulation of strategic initiatives (Begum et al. 2023; Hart 1995a, b)**.** NRBV accentuates firms' capacity to cultivate resources and competencies for efficiently utilizing natural resources (Amores-Salvado et al. 2021). It also advocates the development of capabilities aimed at pollution prevention, waste reduction, and advancing environmentally sustainable production practices (Rehman et al. 2021). Built upon the foundation of NRBV theory, we present our conceptual framework, suggesting that green intellectual capital plays a crucial role in enabling employees within manufacturing SMEs to attain green absorptive capacity, which can result in green innovation performance and environmental performance. According to this point of view, companies get green knowledge through GIC, which boosts their GAC and helps them do better than their competitors. So, this study used NRBV to examine how GAC, GIC, and the climate for green innovation affect how sound companies do regarding the environment and green innovation. The current research represents a significant advancement and augmentation of the existing work on GAC, GIC, GIP, and EP. It sheds light on how firms can enhance their environmental performance by engaging with and understanding the interplay of these variables.

Moreover, stakeholders can offer mechanisms and strategies that assist firms in improving their EP and GIP. According to the empirical findings of this study, policy interventions have been recommended to foster the advancement of EP and GIP through the utilization of GIC. Firms that emphasize a GICL tend to mitigate environmental pollution from their business operations.

Green intellectual capital and green absorptive capacity

The academic literature has primarily focused on larger firms rather than SMEs regarding organizational sustainability and the responsible utilization of resources (Fassin et al. 2011). Although SMEs collectively contribute significantly to the environmental effects of commercial activities (Boiral et al. 2019), limited research has been conducted on this aspect (Tang & Tang 2012). GIC constitutes a valuable organizational asset that can be cultivated through training, the dissemination of knowledge (Huang et al. 2021), and the effective utilization of employees' skill sets (Nguyen & Doan 2020). GIC encompasses individuals' capacity to contribute to environmental preservation effectively (Olarewaju & Msomi 2021), and employees possessing knowledge about the external environment can augment their GIC (Asiaei et al. 2023).

The concepts of GIC and GAC emerge as pivotal considerations for firms aspiring to attain sustainable development and a competitive advantage. GI encompasses GHC, GSC, and GRC. These components

contribute to a firm's capacity to innovate and effectively manage environmental resources (Mahmood & Nasir 2023; Zhao et al. 2019; Shehzad et al. 2023). Indeed, GAC pertains to a firm's proficiency in acquiring, assimilating, and applying environmental knowledge to enhance its green innovation capabilities and overall performance (Makhloufi et al. 2023; Yusoff et al. 2019). The association between GIC and GAC holds paramount significance for firms striving to advance their initiatives in green innovation and sustainability (Aboelmaged & Hashem 2019).

The existing literature implies that GAC is pivotal in propelling green innovation and performance. Robust absorptive capacity positively influences a firm's capacity to benefit from green innovation activities (Qu et al. 2022a). Furthermore, research indicates that green absorptive capacity exerts a more pronounced influence on green process innovation compared to its impact on green product innovation (Wang et al. 2023). We proposed the first hypothesis that GIC directly and indirectly impacts GAC. In conclusion, the references' mixture indicates that GIC and GAC are essential for firms aiming to achieve sustainable development and competitive advantage (Table 1).

H1. GIC will positively and significantly relate to GAC.

Green intellectual capital and environmental performance

The consensus among scholars is that organizational engagement in green management and environmental initiatives has the potential to reduce production waste and enhance productivity. Chuang and Huang (2018) argued that improved environmental performance results from an organization's active engagement in acquiring green-related knowledge and resources. In the remainder, Asiaei et al. (2023) of this section, in the context of manufacturing SMEs in Pakistan, green intellectual capital refers to the knowledge, skills, and resources related to environmentally friendly practices and technologies the organization possesses. On the other hand, environmental performance refers to how an organization's activities align with sustainable and eco-friendly practices. Our second hypothesis proposes a positive relationship between the possession and utilization of GIC and the environmental performance of manufacturing firms in Pakistan. GIC is the total stock of all kinds of intangible assets, knowledge, capabilities, and relationships related to environmental

Table 1 Literature of hypothesized variables

References	Focus (IV and DV)	Categorization	Focus (mediator and moderator)	Categorization	Method	Sample	Application area/research setting
A. Khan et al. (2023a, b)	GIC/GIP/EP	IV/DV	GICL	Moderator	PLS-SEM	451 SME firms	China
Asamoah et al. (2023)	_____	____	GAC	Mediator	Structural equation modeling	368 manufacturing firms	Ghana
Boso et al. (2023)	GIC/EP	IV/DV	_____	_____	PLS-SEM	245 manufacturing firms	Ghana
C. H. Wang and Juo (2021)	GIC/GIP	IV	_____	_____	PLS-SEM	138 high-tech firms	Taiwan
Begum et al. (2023)	GIC	IV	GAC	Mediator	PLS-SEM	268 manufacturing firms	Pakistan
Albort-Morant et al. (2018)	GIP/GIC	DV/IV	_____	_____	PLS-SEM	112 Spanish firms	Spain
Al Issa et al. (2023)	GIC	IV	GAC	Mediator	PLS-SEM	387 at healthcare organizations	Iraq
Asiaei et al. (2023)	EP	DV	_____	_____-	PLS-SEM	105 Iranian companies	Iran
Mady et al. (2022)	_____	___	GAC	Mediator	PLS-SEM	268 manufacturing firms	Pakistan
Zaragoza-Sáez et al. (2023)	GIC	IV	_____	_____	PLS-SEM	120 Spanish hotel	Spain
Ning et al. (2023)	GIP	DV	GAC	Mediator	OLS	1116 manufacturing firms	China

protection. These assets can exist at a company's individual and organizational levels. GIC encompasses the collective environmental knowledge, expertise, skills, and networks available within a company to promote and implement sustainable practices (Chen 2008). Haldorai et al. (2022) Previous study observed the role of structural, human, and relational capital in services industries and mentioned that it results in enhanced organizational productivity.

Previous scholarly investigations recognize that the cultivation of green human capital engenders a constructive interplay between corporate environmental ethics and both (1) learning within green relationships and (2) performance in green innovation (Asiaei et al. 2022a, b). Numerous studies have used the NRBV hypothesis to explain the connection between GIC and EP (C.-H. Wang 2019). (C.-H. Wang 2019). It is planned by the NRBV that instead of being influenced by an industry's structure, superior performance is run by a company's internal resources and competencies (Alkhatib & Valeri 2022). GIC can support the development of green products and sustainable production processes. Companies that can create eco-friendly products or processes may gain a competitive advantage, attracting environmentally conscious consumers and reducing their environmental impact.

H2a. GIC will be positively related to EP

Green intellectual capital and green innovation performance

The existing academic literature stresses how important it is for employees to learn more about the environment and develop new skills in order to help the organization develop environmentally friendly processes and products. The second hypothesis is that the three dimensions of GIC (human capital, structural capital, and relational capital) play a key role in enhancing the GIP of the Pakistani manufacturing industry. For instance, Suki et al. (2023b) underline the interconnection between GIC and social innovation, emphasizing the pivotal role of intellectual capital and innovation in fostering beneficial social and environmental transformations. Additionally, Asiaei et al. (2022a, b) explore the impact of green intellectual capital on ambidextrous green innovation and its subsequent influence on environmental performance, highlighting the mediating role of ambidextrous green innovation in the relationship between green intellectual capital and the environmental performance of iron manufacturing companies. Moreover, Fang et al. (2022) explore the mediating functions of green innovation and green culture in the correlation between green human resource management and environmental performance. The study underscores the indirect impact of green human resource management on environmental performance, mediated through the role of green innovation.

In order to develop GIP, organizations must prioritize the cultivation of their GHC to foster the generation of innovative ideas and novel opportunities (Chang 2016). GSC comprises various components, including organizational structure (Jardon & Dasilva 2017), corporate culture (Dost & Badir 2019), and databases, all of which enable firms to directly enhance the efficiency of GHC, thereby increasing their capacity to formulate and implement GIP (Marco-Lajara et al. 2023). Firms with a strong GSC learn how to improve their organizational learning, which helps them increase their GIP (Albort-Morant et al. 2018). Therefore, companies strengthening their GSC can significantly improve innovation performance (Sarwar & Mustafa 2023). The integration of the referenced literature underscores the intricate and direct linkage between GIC and GIP. This connection is pivotal in propelling innovation initiatives towards environmental sustainability and positively influencing firms' competitive advantage.

H2b. GIC will be positively related to GIP

Green absorptive capacity and environmental performance

Green absorptive capacity is the organizational mechanism facilitating firms to acquire, transform, and apply external green technological knowledge. They say that companies with more absorptive capacity are better able to use green knowledge from outside their operations, which could lead to better environmental performance (Du & Wang 2022; Marrucci et al. 2022). To find out how green absorptive capacity and environmental performance are related, it is essential to look at the existing literature on the subject.

Numerous studies have delved into the role of absorptive capacity in propelling green innovation and influencing environmental performance. Furthermore, Asamoah et al. (2023) contribute empirical evidence that enhances comprehension of the determinants of green innovation performance. They underscore the pivotal role of green absorptive capacity, shedding light on the significance of absorptive capacity in driving green innovation. This, in turn, is posited to impact environmental performance positively. This study suggests that GAC plays a substantial role in propelling green innovation and firm performance. This, in turn, is anticipated to impact both environmental and green innovation performance positively.

H3a. GAC will positively relate to EP

Green absorptive capacity and green innovation performance

Green innovation performance can be defined as the enhancement of an enterprise's product design or production process with a focus on environmental protection and effective environmental management (Jiang et al. 2023; L. Wang et al. 2022). The significance lies in firms strategically merging internal expertise with external knowledge as a green innovation strategy. This underscores the pivotal role of absorptive capacity in shaping GIP. By effectively leveraging both internal capabilities and external insights, companies can enhance their capacity to innovate in environmentally sustainable ways (Qu et al. 2022a). The connection between GAC and GIP is a critical study area in sustainable development and environmental management. This study proposes that GAC plays an essential role in deriving the GIP for manufacturing SMEs in Pakistan.

H3b. GAC will be positively related to GIP

The mediating role of green absorptive capacity

GIC is the set of skills, knowledge, expertise (Chen 2008), and supplier and customer relationships that are needed to develop and share ecological knowledge within a company's knowledge base (Yusoff et al. 2019). GIC is pivotal in establishing sustainability-focused management practices to mitigate the adverse consequences of environmental harm (Yusliza et al. 2020). GI is characterized as a knowledge-intensive endeavor (Stojčić, 2021). The advancement of GIP demands that enterprises acquire and assimilate intricate knowledge, frequently divergent from their existing knowledge base. The development of GIP necessitates enterprises to acquire.

Furthermore, they integrate complicated knowledge, often distinct from their pre-existing knowledge base (Albort-Morant et al. 2018).

In this context, GAC can facilitate enterprises' seamless acquisition of outward green knowledge, including environmental protection technologies (Hashim et al. 2015). Galbreath (2019) argues that GAC is a learning mechanism facilitating adaptation to external knowledge. Businesses can improve their ability to combine new and existing knowledge more effectively with GAC. This will allow them to use integrated knowledge more effectively, which will increase production efficiency and lower waste (Delmas et al. 2011; Galbreath 2019; Kuss 2009; Zhou et al. 2021). Ning et al. (2023) also say that absorptive capacity is significant for making sure that an organization fully understands external knowledge. As a result, managers are better equipped to oversee product development processes, thereby minimizing adverse environmental impacts (Qu et al. 2022b).

H4a. GAC mediates the relationship between GIC and GIP.
H4b. GAC mediates the relationship between GIC and EP.

Moderation of green innovation climate

Organizational climate covers the essential attributes of a company, including attitudes, behaviors, and emotions that persist autonomously, regardless of the perceptions and interpretations of its organizational members (Ekvall 1996b; Maitlo et al. 2022; C.-H. Wang 2019). The adaptability and receptivity of an organization's culture in response to external market dynamics can considerably influence the firm's consequences (Chen et al. 2012; Qu et al. 2022b). A green innovation climate denotes an organizational culture that fosters and reinforces creating and adopting environmentally sustainable initiatives.

GIC relates to the collective knowledge and expertise employees possess concerning environmental sustainability. GAC denotes a company's competence to comprehend, assimilate, and leverage external knowledge to enhance performance (Song et al. 2020). So, the research shows that a GICL can mess up the connection between GIC and GAC and between GIP and EP (Khan et al. 2022). Businesses must have an excellent organizational culture in order to use their GIC and GAC effectively, which will improve their environmental performance and reputation (Khan et al. 2022).

H5a. GICL positively moderates the relationship between GIC and GAC.
H5b. GICL positively moderates the relationship between GAC and EP.
H5c. GICL un significantly moderates the relationship between GAC and GIP.

Methodology

Sample and data collection

To examine our proposed hypotheses, we selected a diverse group of industries, including surgical instrument manufacturers, sports goods manufacturers, textile manufacturers, and sugar manufacturers, as sources for data collection. We determined to use manufacturing firms as our research focus, given that sustainable manufacturing systems are

Fig. 1 Symmetric model

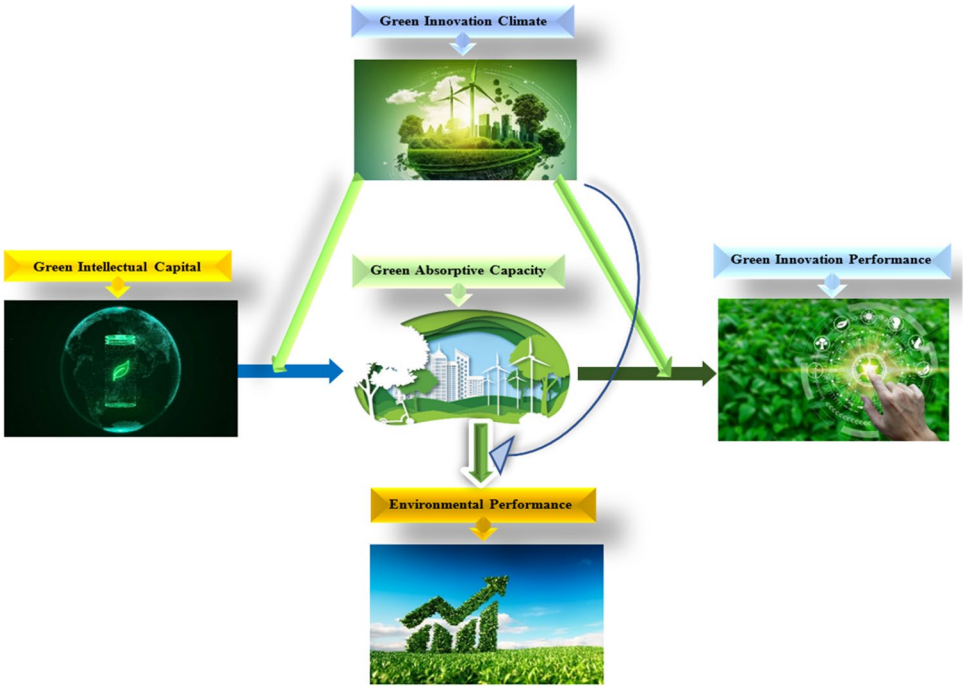

Table 2 Demographic information

Distributions	Numbers	Distributions	Numbers
Gender		Educational background	
Male	325	Graduate	403
Female	250	Post-graduate	93
		Ph.D	79
Age(years)		Job experience	
20–30	263	5–10 years	203
31–40	144	11–15 years	184
41–50	113	16–20 years	112
51–60	55	21–25 years	76

widely regarded as a remedy for addressing environmental concerns. (Fig. 1).

The manufacturing industry exerts a significant impact on the environment. For our survey-based approach, we assembled a list of manufacturing firms by accessing data from the chamber of commerce and the industry (Awan et al. 2021). We physically distributed a total of 1185 questionnaires to the HR managers to further distribute the questionnaires among top management who have sound knowledge of green practices. Out of the 1185, we received 692 responses, and a further 575 were adequately filled and considered for further analysis (see Table 2). Initially, the questionnaire was developed in English and subsequently translated into Urdu to ensure the reliability of the survey instrument (G. Zhao et al. 2015).

Measurement development

The measurement items utilized in this study were adapted from prior literature and rated on a 5-point Likert scale, where one represented the lowest (strongly disagree) and five signified the highest (strongly agree) level of agreement. The questionnaires were formulated in Urdu since our research predominantly focused on examining Pakistani employees' performance. Translation and back-translation methodologies ensured that the questionnaire retained consistent meaning (Sperber et al. 1994).

Constructs and items

The majority of the scales we used were well-defined and proven to work. All of the measurement items were created by reading much research in the field. We have adapted six items of GIC from GIC (Zaragoza-Sáez et al. 2023). Likewise, four items of GAC (Zhou et al. 2021), four items of GIP (Ullah et al. 2023), five items of GICL (Maitlo et al. 2022), and four items of EP (Momayez et al. 2023).

Data analysis tools

For data analysis, this study utilized PLS through SmartPLS, version 4 (Liu et al. n.d.). PLS-SEM was chosen for this study because it can look at both the measures or constructs and the basic structural model at the same time. This quality renders it suitable for exploratory, survey-based analyses (Hair et al. 2012). PLS-SEM is also more reliable,

even when used on smaller samples that are not distributed normally (Ernst et al. 2011), and it works well for reflective models.

Measurement model

The measurement model's validity was assessed by conducting convergent and discriminant validity tests. Convergent validity was evaluated through the examination of factor loadings (outer loadings), composite reliability, Cronbach's alpha, and AVE (Hair et al. 2020). Chin et al. (2008) argue that the analysis indicates that all item loadings exceeded the threshold of 0.70 (Table 3). The CR values, which show how well the construct indicators match the underlying latent construct, were higher than the important level of 0.7. Moreover, the AVE, which captures the overall variance explained by the latent construct indicators, surpassed the recommended threshold of 0.5 (Hair et al. 2020). Cronbach's alpha was employed to assess internal consistency, which gauges reliability through the interrelatedness of the observed item variables. The obtained values exceeded the requisite threshold of 0.70 (Hair et al. 2019). This study used well-known standards to check how reliable the measurement model was. These standards included AVE, discriminant validity, and convergent validity. The reliability assessment consistently met the criterion of 0.70 across all constructs (Hair et al. 2021).

Discriminant validity

Two different criteria predict discriminant validity: the Heterotrait-Monotrait ratio and the Fornell-Larcker criterion (Fig. 2). Both criteria are under threshold and successfully evaluated to ensure that all constructs in the model are distinct from each other and measure different underlying concepts (Henseler et al. 2015). Hence, it supports the discriminant validity established. To further check for discriminant validity, Table 4 has highlighted the results.

F square

F square is used to measure the proportion of variance explained in the dependent variable or effect size by adding a specific independent variable to the model. Higher *F* square values indicate a more significant proportion of variance in the underlying constructs. Table 5 provides for the endogenous construct, the *F* square values for GAC and EP (1.955), and the *F* square values for GAC and EP (0.137). The remaining *F* square values are highlighted in Table 5

Table 3 Reliability and validity

Items	Loadings	Variable	Alpha	CR	AVE	VIF
EP1	0.837	Environmental performance	0.833	0.889	0.667	1.956
EP2	0.815					1.861
EP3	0.846					1.978
EP4	0.766					1.630
GAC1	0.783	Green absorptive capacity	0.874	0.914	0.728	1.689
GAC2	0.842					2.096
GAC3	0.901					3.556
GAC4	0.883					3.235
GIC1	0.800	Green intellectual capital	0.908	0.929	0.688	2.229
GIC2	0.779					2.144
GIC3	0.879					3.521
GIC4	0.889					3.981
GIC5	0.874					3.281
GIC6	0.745					1.868
GICL1	0.895	Green innovation climate	0.909	0.932	0.734	4.866
GICL2	0.892					4.741
GICL3	0.754					1.815
GICL4	0.865					3.496
GICL5	0.869					3.522
GIP1	0.775	Green innovation performance	0.757	0.845	0.577	1.980
GIP2	0.792					2.032
GIP3	0.674					1.256
GIP4	0.792					1.385

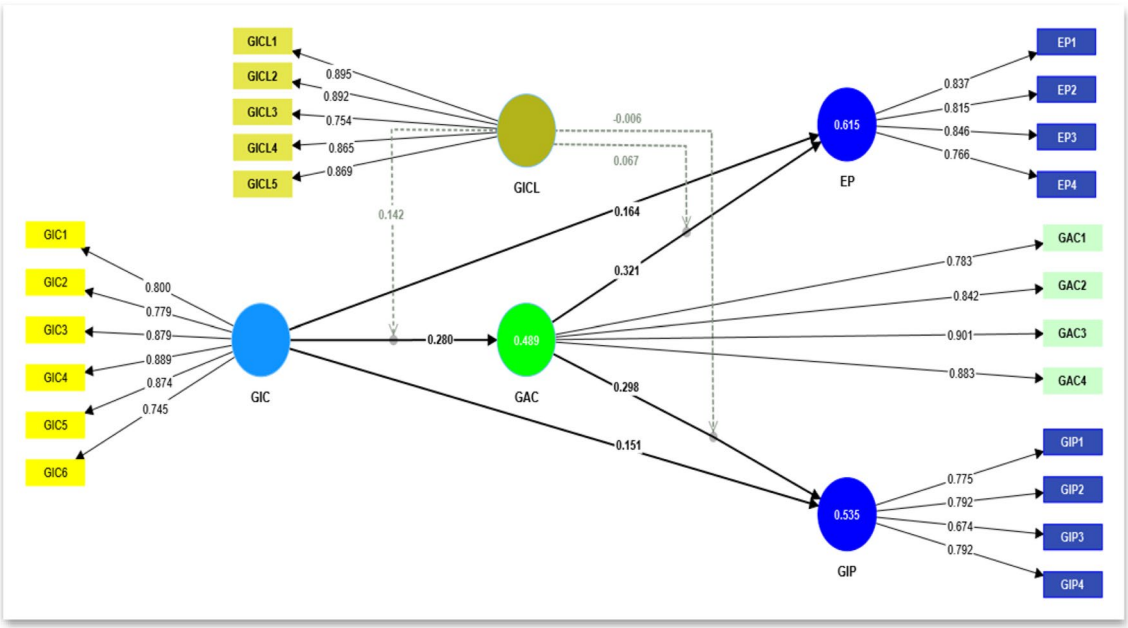

Fig. 2 Measurement model

Table 4 Discriminant and correlations

	EP	GAC	GIC	GICL	GIP
Heterotrait-Monotrait ratio of correlations					
EP					
GAC	0.803				
GIC	0.699	0.643			
GICL	0.810	0.726	0.716		
GIP	0.845	0.761	0.679	0.783	
GICL × GIC	0.115	0.156	0.084	0.041	0.096
GICL × GAC	0.285	0.306	0.154	0.205	0.195
Fornell and Larcker criterion					
EP	0.817				
GAC	0.687	0.853			
GIC	0.613	0.578	0.829		
GICL	0.716	0.653	0.656	0.857	
GIP	0.688	0.634	0.575	0.677	0.760

Table 5 Variance inflation factor and *F* square

	EP	GAC	GIP
Variance inflation factor (inner VIF)			
GAC	1.955		1.955
GIC	1.886	1.768	1.886
GICL	2.189	1.763	2.189
F square			
Green absorptive capacity	0.137		0.097
Green intellectual capital	0.037	0.086	0.026
Green climate innovation	0.176	0.242	0.146

Table 6 R^2 and Q^2

	R-square	*R*-square adjusted	Q^2 predict	RMSE
EP	0.615	0.612	0.552	0.672
GAC	0.489	0.486	0.552	0.728
GIP	0.535	0.532	0.48	0.724

R square and adjusted R square

Values of *R*-squared (R^2) and adjusted *R*-squared (R^2 adjusted) estimate the model's fitness. They provide information about how well the independent variables explain the variance in the dependent variable. The explanatory power of a model can be quantified by calculating its R^2 value. For the GAC and EP, the R^2 values are 0.489 and 0.615, respectively. To evaluate the predictive power of the model, researchers used the Q^2 value technique (Shmueli et al. 2019). Q^2 helps determine how much an exogenous construct influences an endogenous construct. Q^2 values of EP and GAC are 0.552 and 0.552, respectively, which imply substantial predictive importance of the model. All other values are shown in Table 6.

Structural model

The assessment of model fitness, conducted using the bootstrapping method, encompassed the computation of the SRMR score. The structural model employed in this study yielded an SRMR value of 0.069, which lies within

Table 7 Direct path analysis

		Beta	CIBC 2.5%	CIBC 97.5%	*T*-value	*P*-values
Direct hypothesis						
H1	*GIC—> GAC*	0.279	0.201	0.355	7.077	0.000
H2a	*GIC—> EP*	0.164	0.097	0.231	4.844	0.000
H2b	*GIC—> GIP*	0.149	0.066	0.225	3.695	0.000
H3a	*GAC—> EP*	0.321	0.245	0.390	8.887	0.000
H3b	*GAC—> GIP*	0.299	0.218	0.381	7.232	0.000

the acceptable range of 0–1 and the NFI of 0.805. This study delved into contemporary aspects, including GIP, EP, GICL, GAC, and GIC. The research involved data collection, hypothesis testing, and the elucidation of path coefficients. The path coefficient serves as an indicator of the direct influence of one variable, conceptualized as a causal factor, on another variable designated as an outcome. The findings of the structural equation modeling using PLS for the proposed model are presented in Table 7. All hypotheses (H1 to H3) are positive and significant. H1 suggests that GIC has a positive effect on GAC, and the *T*-value (7.077) and *P*-value (significant at the 0.000 level) confirm a significant relationship. Similarly, H3a shows that GAC has a positive effect on EP, supported by a *T*-value of 8.887 and a significant *P*-value (0.000).H3b shows that GAC has a positive impact on GIP, supported by a *T*-value of 7.232 and a significant *P*-value (0.000). Further results are shown in Table 7

Mediation analysis

Following modern practices, this study used a bootstrapping method to thoroughly test for the mediating role of H4a and H4b (Hayes 2013). For the mediating effect to be established, the indirect effect must also be of substantial significance (Gaskin & Godfrey 2014). All mediating paths (H4a to H4b) are positive and significant. H4a shows that the mediating effect of GIC on GIP through GAC is positive and significant (*T*-value: 4.872, *P*-value: 0.000). Further results are shown in Table 8. Here, total indirect path analysis suggests partial and full mediations. All the total indirect paths are significant, so all the mediating relations are partially mediated.

Moderation analysis

To explore the moderating influence, the current research initially computed the effect of GICL on GIC—> GAC, GAC—> EP, and then GAC—> GIP (Fig. 3). Findings revealed a positive and significant moderating impact of the GICL on the association between GIC and GAC, as well as GAC and EP (*T*-value = 5.909, *P*-value = 0.000 and *T*-value = 2.598, *P*-value = 0.009) (Fig. 4). Furthermore, GICL has an insignificant impact on the association of GAC and GIP as a *P*-value > 0.05. No matter how vital the coefficients are in other pathways that are connected, a moderator can only be shown to be necessary when the interaction effect is enormous (Henseler and Fassott 2010) (Table 9).

Discussion

Findings reveal that GIC and GAC are vital in enhancing GIP and EP and maintaining the SME manufacturing industry. It has been observed that GIC can improve SMEs' innovative performance through GAC, which can enhance the skills and knowledge of green human capital. NRBV are very effective in enhancing green performance and EP when integrated with GIC and GAC. Furthermore, we have elaborated the discussion part in more detail in Table 10.

Table 8 Specific indirect path analysis/mediation

		Beta	CIBC 2.5%	CIBC 97.5%	*T* value	*P* values
Mediation						
H4a	*GIC—> GAC—> GIP*	0.084	0.054	0.122	4.872	0.000
H4b	*GIC—> GAC—> EP*	0.090	0.060	0.125	5.421	0.000
Total indirect effect						
	GIC—> EP	0.090	0.060	0.125	5.421	0.000
	GIC—> GIP	0.084	0.054	0.122	4.872	0.000
	GICL—> EP	0.150	0.112	0.193	7.396	0.000
	GICL—> GIP	0.140	0.101	0.187	6.423	0.000

Fig. 3 GICL × GIC—> GAC

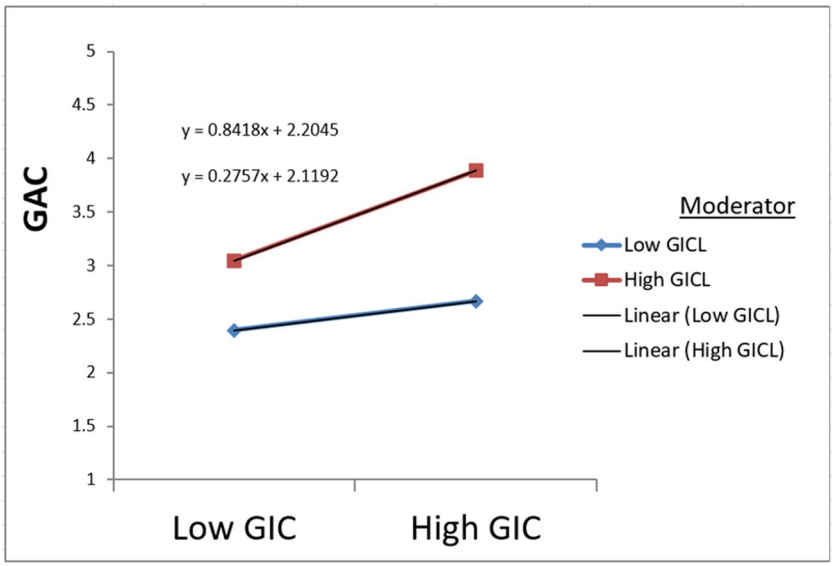

Fig. 4 GICL × GAC—> EP

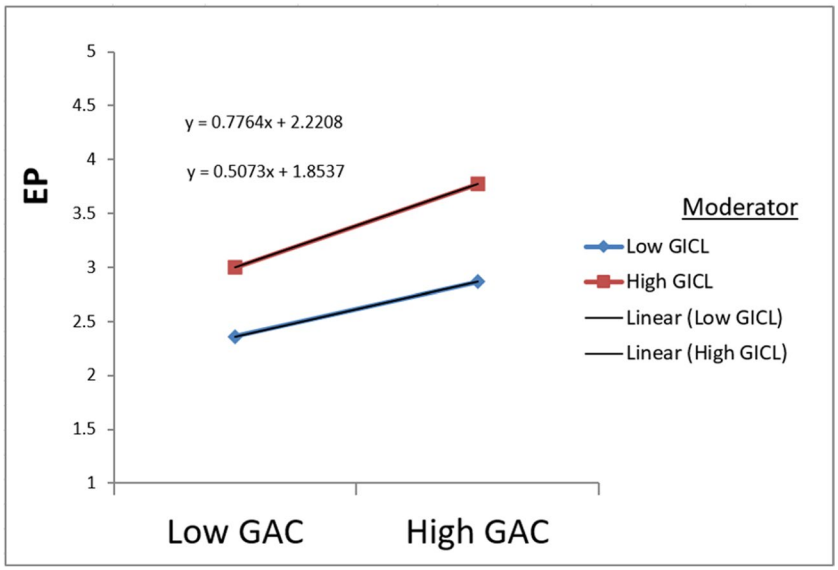

Table 9 Moderation

		Beta	CIBC 2.5%	CIBC 97.5%	*T* value	*P* values
H5a	GICL × GIC—> GAC	0.142	0.094	0.188	5.909	0.000
H5b	GICL × GAC—> EP	0.067	0.017	0.118	2.598	0.009
H5c	GICL × GAC—> GIP	−0.004	−0.062	0.054	0.152	0.879

Conclusion

In this study, we employed the framework of the NRBV theory to investigate the intricate relationships among GIC, GAC, and GICL on GIP and EP of SMEs in Pakistan. The analysis revealed several significant findings with important implications for theory and practice. This study successfully achieves its objectives by shedding light on the intricate relationships among GIC, GAC, GI, and environmental performance within manufacturing SMEs'. Firstly, the research also tested the direct and indirect impact on GIP and EP. (1) To evaluate the direct and indirect effect of GIC measured with green human capital, relational, and structural capital on EP and GIP. (2) Green absorptive capacity positively impacts the GIP and

Table 10 Discussion and findings

Authors (years)	Research objectives	Key findings	Similarities and dissimilarities with our research findings
Marco-Lajara et al. (2023)	The primary objective of this research is to examine the impact of green intangible assets possessed by wineries and their constituents, specifically GIC, on GIP	The research findings demonstrate a statistically significant positive relationship between GIC and GIP, underscoring their pivotal roles in the environmental management practices within SMEs	The purpose of our study is to examine the relationship between GIC and GIP, EP; results are similar to the previous study GIC and GIP
Asamoah et al. (2023)	This study delves into the role of GAC as a critical intervening variable, shedding light on the connection between GSCM practices and FP	Moreover, the findings indicate that the presence of GAC positively mediates the relationships between GSCM and EP	GAC is positively mediated in our findings between GIC EP and GIP
Zhang et al. (2020)	This article examined the mediating effect of external knowledge adoption and the moderating role of green absorptive capacity	The adoption of external knowledge serves as a complete mediator in these constructive relationships. Furthermore, GAC exclusively amplifies the beneficial effect of market-based regulations on the adoption of external knowledge	Our results, dissimilar to previous studies, entirely positively mediated the between GIC and EP, GIP
Begum et al. (2023)	This study extends the NRBV view by introducing a mediation-moderation framework, which investigates the impact of GIC on the development of a green business strategy. This influence is examined through the mediating role of GAC	The results indicate that GIC positively influences GAC and the formulation of green business strategies within organizations	This study extends the NRBV view, and GIC has a positive influence on both GAC and the formulation of GIP and EP
Ning et al. (2023)	This study aims to develop and empirically examine a conceptual model that elucidates the relationship between digitalization and GIP and the mediation role of GAC	This study offers valuable theoretical insights and practical guidance for the more effective promotion of the GIP OLS method to empirically investigate whether enterprise digitalization has a positive impact on GI while also assessing the mediating role of GAC in this relationship	This research offers the PLS_SEM method to investigate the GIC positive impact on EP and GIP
Marco-Lajara et al. (2023)	The study's objective is to examine the influence of GIP by GIC, with a particular focus on the mediating roles of Knowledge Management and CSR as intervening variables	The research findings reveal a statistically significant positive relationship between GIC and GIP	Our research is similar to the previous study. GIC has a positive and significant relationship with GIP
Khan et al. (2023a, b)	The primary objective of this research is to examine the impact of GIC by manufacturing and their constituents, specifically, GIC, on GIP and the mediation role of GCLI	The study's findings explained that an innovative green climate moderates the relationship between green core competence and green corporate image	Our results are dissimilar to the previous study, which is a positively significant moderate between GIC and GAC, EP, and GIP
Engelman et al. (2017)	The primary objective of this research is to examine the impact of GIC on a firm's absorptive capacity and, in turn, the influence of ACAP on product innovation	The study's findings indicate that GIC indeed affects GAC, though with varying degrees across each dimension of GAC. Meanwhile, the transformation of knowledge is influenced relatively equally by structural and human capital, with a moderate influence from social capital	Our research is dissimilar to previous studies; in our research, NRBV theory and GIC have positively affected GAC without dimensions
Engelman et al. (2017)	The primary objective of this research is to examine the impact of GIC on a firm's absorptive capacity and, in turn, the influence of ACAP on product innovation	The study's findings indicate that GIC indeed affects GAC, though with varying degrees across each dimension of GAC. Meanwhile, the transformation of knowledge is influenced relatively equally by structural and human capital, with a moderate influence from social capital	Our research is dissimilar to previous studies; in our research, NRBV theory and GIC have positively affected GAC without dimensions

EP. GAC partially mediates between GIC and GIP, EP. (3) Green innovation climate is moderated negatively and significantly moderate between GAC and GIP. Moreover, the GICL positively moderated between GIC and EP, GIC and GAC. The findings of our study are different in the case of the moderation effect because it is negatively significantly moderated. These findings challenge conventional resource-based assumptions and underscore the importance of resource heterogeneity in achieving competitive advantage in sustainability and innovation. Secondly, the mediating role of GAC was confirmed, highlighting the critical function of an organization's ability to assimilate and apply green knowledge effectively. This mediation mechanism deepens our understanding of transforming resources into performance outcomes. Thirdly, the moderating effect of GICL emphasized the significance of the organizational context in shaping the relationship between GIC, GAC, and EP.

Theoretical implications

This study contributes to the enrichment of the NRBV domain and extends its applicability to the realms of organizational-level research. This study emphasizes the significance of GIC in advancing EP and GIP and seeks to fill the research gap regarding internal environmental strategies within manufacturing firms. GIC has been ascertained as a critical factor in the development and execution of sustainability strategies spanning diverse business functions, encompassing areas such as raw material selection, manufacturing processes, waste management, and supply chain governance. This study unveils that GIC fosters GAC by empowering enterprises to identify, assimilate, and harness sustainability knowledge. This extends the NRBV theory by demonstrating how the utilization of green resources impacts performance. This, in turn, assists in alleviating environmental pressures and facilitates the development of an all-encompassing GIP. Lastly, this study contributes to the literature on green innovation climate by examining its moderating influence in the specified relationships. This aspect represents a novel dimension of this research, asserting that cultivating an innovation-oriented culture is imperative for modern firms to enhance or sustain their desired levels of organizational performance. NRBV theory by acknowledging the importance of the organizational climate for innovation in leveraging green resources.

Managerial implications

SMEs are emerging trends in developing countries that aim to contribute to the country's financial development**.** The study advocates that those businesses consider the adoption of GHC, GSC, and GRC as crucial components for formulating green innovation performance in response to escalating environmental pressures. It is imperative for companies to actively attract and invest in green knowledge as a means to instill a culture of environmental sustainability. Managers should cultivate relationships with strategic partners, academia, customers, suppliers, and other relevant institutions to facilitate knowledge-sharing about environmentalism and enhance their firms' environmental performance. Managers escalating sustainability challenges have prompted the consideration of integrating GIC and GAC within organizations to foster sustainability knowledge and to improve comprehension of environmental issues. Organizations can stimulate the adoption of sustainability-oriented solutions by offering incentives, integrating environmental ethics into their operations, and establishing dedicated positions for low-carbon management by aligning with Sustainable Development targets.

Limitations and future recommendations

Our study has contributed valuable insights into the relationships between GIC, GAC, GICL, EP, and GIP within the framework of the NRBV theory, and it is important to acknowledge several limitations. Our study relies on cross-sectional data, which restricts our ability to establish causality and infer temporal relationships among variables. Future research can employ longitudinal designs to understand the dynamic interactions over time better. The data collected through surveys could be subject to self-report bias, as respondents' perceptions might influence their responses. Combining survey data with objective performance measures could enhance the robustness of our findings. Despite using established measurement scales, the validity and reliability of constructs may vary across different contexts. Further modification of measurement instruments could enhance the accuracy of our results. Conduct longitudinal studies to investigate the causal relationships between GIC, GAC, GICL, EP, and GIP over time. Explore in-depth the mechanisms through which GAC mediates the relationship between GIC and performance outcomes. This could involve qualitative research methods to uncover the underlying processes.

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Data availability Data will be made available on request.

Declarations

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