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RESEARCH ARTICLE

Relationship between Green Entrepreneurial Orientation, Green Intellectual Capital, Green Supply Chain Management, and Sustainable Performance: The Moderating Role of Environmental Uncertainty

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ABSTRACT

With the increasing global emphasis on sustainable development, manufacturing industries, as major resource consumers and pollution emitters, are under significant pressure to achieve sustainability. Drawing on the natural foundation view and the theory of uncertainty and complexity, this study introduces environmental uncertainty (EU) as a moderating variable and proposes a higher-order theoretical model to elucidate the impact mechanisms of green entrepreneurial orientation (GEO), green intellectual capital (GIC), and green supply chain management (GSCM) on sustainable performance (SuP). A survey of 516 Chinese manufacturing managers was conducted, and the data were analyzed using partial least squares structural equation modeling (PLS-SEM) via SmartPLS. The results reveal the following key findings: (1) GEO, as a strategic model integrating environmental and economic considerations, significantly contributes to SuP; (2) Both GIC and GSCM positively influence SuP, indicating that heightened environmental awareness and proactive environmental actions within organizations are associated with superior overall performance outcomes; (3) EU negatively moderates the relationships between GIC and SuP, as well as GSCM and SuP. This finding suggests that in the face of environmental uncertainty, the effectiveness of green strategies on sustainable performance may be diminished. This study provides empirical evidence for how manufacturing industries in developing countries, externally in uncertain environments, can enhance sustainable performance through the implementation of green strategies.

INTRODUCTION

With the growing severity of global environmental problems, companies are increasingly focusing on environmental protection and sustainable development while pursuing economic benefits. Over 60.1% of participants are willing to pay extra for environmentally friendly products (Tully & Winer, 2014). Furthermore, 80% of survey respondents are more willing to spend more on green products, and they are increasingly rejecting companies that do not comply with environmental regulations or falsely claim their products are green (Laroche et al., 2001). China is pursuing a "dual-carbon" policy that requires companies to reduce their negative environmental impacts and CO_2 emissions as part of their economic development (Jia et al., 2022). The "green concept" is taking root in the manufacturing industry, with many manufacturers seeking to improve resource efficiency and pursue green economic growth while reducing negative environmental impacts, which has become a new business opportunity (Khan et al., 2022; Li & Liu, 2014). Green Entrepreneurial Orientation (GEO), a new type of corporate strategic choice, is an emerging field in entrepreneurship research. It emphasizes the integration of environmental protection in the process of corporate innovation, aiming to achieve a win-win situation in terms of economic and ecological benefits (Kraus et al., 2018). By focusing on the integration of innovation and entrepreneurship with ecological protection, GEO expands the theory of entrepreneurial orientation and creates opportunities for beneficial interactions between business development and natural ecology, further promoting sustainable economic growth.

However, the majority of existing studies concentrate on the connection between GEO and green innovation, proposing a link between GEO and both green incremental and green radical innovation(Guo et al., 2020). Some studies confirm the positive impact of GEO on corporate financial performance (Jiang et al., 2018), yet they often overlook its crucial role in SuP. Furthermore, promoting corporate sustainable development necessitates not only strategic initiatives, but also the accumulation of intellectual capital within the firm. GIC reflects the accumulation and application of knowledge, skills, and experience in environmental protection. GIC is a vital strategic resource that helps firms maintain their competitive advantage (Chen, 2008) and provides a crucial framework for sustainable development (Benevene et al., 2021). It can facilitate the production of environmentally friendly products and play a significant role in improving firms' environmental performance (Delgado-Verde et al., 2014). In the increasingly complex international ecological environment, and with growing environmental awareness, the rules of survival for the manufacturing industry are undergoing many changes. Supply chain management should be emphasised in the development of manufacturing companies (Khan et al., 2022). There has been a supportive link between sustainable performance and green supply chain (Jermsittiparsert et al., 2020). Many companies have emphasised on GSCM, green management throughout the supply chain process from raw material sourcing to product recycling, which is conducive to reducing resource wastage and environmental pollution (Waidyasekara & Sandamali, 2012). The accumulation of green resources and capabilities by firms is a means to maintain and gain a competitive advantage. Both environmental and economic performance closely relate to the concepts of GIC and GSCM.

In addition, a stable environment is conducive to improving firm performance (Choe, 2003). Environmental uncertainty (EU) refers to the uncertainty faced by firms regarding market demand and technological changes (Wu, 2013), which may pose challenges to firms (Haarhaus & Liening, 2020). Existing studies have focused on the direct impact of GEO, GIC, and GSCM on firm performance. For example, Hu and Tresirichod (2024) investigated the role of GIC and GSCM in the mediation of SuP by GEO. However, the moderating role of the EU, an external factor, has received less attention. Currently, many companies are seeking innovation and adopting different management and operational models (Yusoff et al., 2019). However, some companies lack awareness of today's society's needs and the appropriate approaches to address these evolving needs (Ullah et al., 2021). We should study the role of moderating variables to analyze and determine the impact of SuP in depth (Pashutan et al., 2022).

This study offers novel insights by examining the extensive impacts of green entrepreneurial orientation on firm performance within the Chinese manufacturing context. It significantly contributes to the theory of green entrepreneurial orientation by unveiling the intricate relationships among GEO, GIC, GSCM, and SuP. Moreover, it pioneers in exploring the moderating role of EU on the connections between GIC, GSCM, and SuP. This theoretical model is particularly relevant for manufacturing sectors in developing countries facing environmental uncertainty.

Specifically, the study posits research hypotheses and constructs a higher-order theoretical model of sustainable development grounded in the Resource-Based View (RBV) and theories of uncertainty and complexity. Data from 516 valid questionnaires were collected and rigorously analyzed using SmartPLS. The findings not only validate the theoretical framework but also highlight the significant impacts of GEO, GIC, and GSCM on SuP, especially under conditions of environmental uncertainty. A key innovation of this study lies in its inclusion of EU within the research framework examining the relationships between GIC, GSCM, and SuP, thereby deepening our understanding of how firms can achieve sustainable performance through green strategies amidst uncertainty. Additionally, this research provides crucial theoretical and practical guidance for enhancing sustainable development in manufacturing industries in developing countries operating in complex environments. It suggests specific strategies to navigate environmental uncertainty and bolster sustainable performance. These insights not only enrich existing theories but also serve as a pivotal reference for manufacturing firms amid the global push towards sustainable development.

LITERATURE REVIEW AND RESEARCH HYPOTHESES

The RBV suggests that a firm's resources and competencies are key to its sustainable competitive advantage. This study examines the issue of SuP in China's manufacturing industry and highlights that corporate development has a significant negative impact on the environment. In response, China has issued numerous environmental policy documents requiring firms to comply with environmental regulations. Consequently, Chinese firms are fully implementing green strategies (Jiang et al., 2018) to gain more competitive advantages.

Green Entrepreneurial Orientation and Sustainable Performance

GEO refers to a firm's strategic orientation that focuses on environmental protection and sustainable development in its entrepreneurial activities (Qin et al., 2021). SuP involves the adoption of unique strategies by a firm to maintain a prioritized stance within a certain timeframe, manifested in economic, social, and environmental aspects (Zaid et al., 2018). In response to potential customer demand for green products, firms are constantly pursuing technological innovations, developing more green products and services, and greening existing products (Li et al., 2019). Through continuous product innovation and service process improvement, these developments enable firms to establish a unique differentiation advantage in the competitive market and ensure its long-term maintenance. This advantage helps firms gain a larger market share and brings long-term economic sustainability (Guo et al., 2020). GEO encourages firms to be environmentally friendly and sustainable, satisfying market demand through technological innovations and product modifications, thus achieving sustainable development (Hu & Tresirichod, 2024). Therefore, we propose the following hypothesis:

H1: Green entrepreneurial orientation has a positive impact on sustainable performance.

Green Intellectual Capital and Sustainable Performance

According to the knowledge perspective theory, knowledge is the most important resource for organizations because it creates more intangible resources, which in turn form intangible assets and promote enterprise competitiveness (Massingham, 2008). GIC refers to the total amount of all kinds of intangible assets and knowledge related to environmental protection or green innovation (Chen, 2008). Sustainability becomes the core of these intangible assets and the dominant force in knowledge generation and management. GIC is an essential resource for companies to achieve sustainable development. GIC can promote green innovation and technology application, which are linked to organizational performance (Falcó et al., 2023). It emphasizes enhancing employees' environmental awareness and skills, gaining insights into emerging ecological technologies, and strengthening the connection between employees and the organization. These enhancements can promote green innovation and technology application, leading to better firm performance. Therefore, the following hypothesis is proposed:

H2: Green intellectual capital positively influences sustainable performance.

Green Supply Chain Management and Sustainable Performance

GSCM involves integrating environmental management and sustainability concepts into the supply chain management process (Diabat & Govindan, 2011). The future competitiveness of companies depends on their resources and ability to promote sustainability concerning the environment (Hart & Dowell, 2011). Companies must continuously invest human, material, and financial resources to achieve green management at the supply chain level, ensuring full coverage from raw materials to production and distribution. The implementation of GSCM can significantly improve both the environmental(Chienwattanasook & Onputtha, 2022) and operational performance of enterprises (Green Jr et al., 2012). Furthermore, GSCM improves the firm's overall image and reputation by optimizing resource utilization and reducing environmental pollution, resulting in increased profit (Herrmann et al., 2021). Therefore, the following hypothesis is proposed:

H3: Green supply chain management positively influences sustainable performance.

The Moderating Role of Environmental Uncertainty Based on Uncertainty and Complexity Theory

Green Intellectual Capital, Sustainable Performance, and Environmental Uncertainty

Uncertainty and Complexity Theory suggests that the complexity and uncertainty of the external environment affect a firm's internal resource allocation and strategic decision-making. The EU refers to the perceived challenges arising from changing customer demands and technological changes (Wu, 2013). This uncertainty has a profound impact on firm management practices and performance. In environments characterized by uncertainty, firms face heightened external challenges and changes, making effective utilization and management of internal resources more difficult. The role of GIC may be constrained under the conditions of the EU. Chen (2008) argues that GIC enhances firms' environmental and economic performance by fostering innovative capabilities and technological applications. However, in the presence of environmental uncertainty, firms face increased market volatility and technological changes, hampering GIC's ability to translate into tangible performance improvements swiftly and effectively. Therefore, the EU may diminish the positive impact of GIC on firms' sustainable performance (SuP). Drawing from this premise, we propose the following hypotheses:

H4: Environmental uncertainty moderates the relationship between Green intellectual capital and corporate sustainable performance

Green Supply Chain Management, Sustainable Performance, and Environmental Uncertainty

External EU constraints may limit the effectiveness of GSCM implementation. Research has demonstrated that GSCM significantly improves a firm's environmental and operational performance (Wang et al., 2020). However, the EU exerts a negative impact on firm performance (Aprisma & Sudaryati, 2020), leading to potential supply chain disruptions and fluctuations in market demand. These challenges can hinder GSCM from achieving its intended goals effectively. Therefore, the EU may weaken the positive impact of GSCM on firms' sustainable performance (SuP). Drawing from this, we propose the following hypothesis:

H5: Environmental uncertainty moderates the relationship between Green supply chain management and corporate sustainable performance

In conclusion, the theoretical model diagram of this study is constructed, depicted in Figure 1.

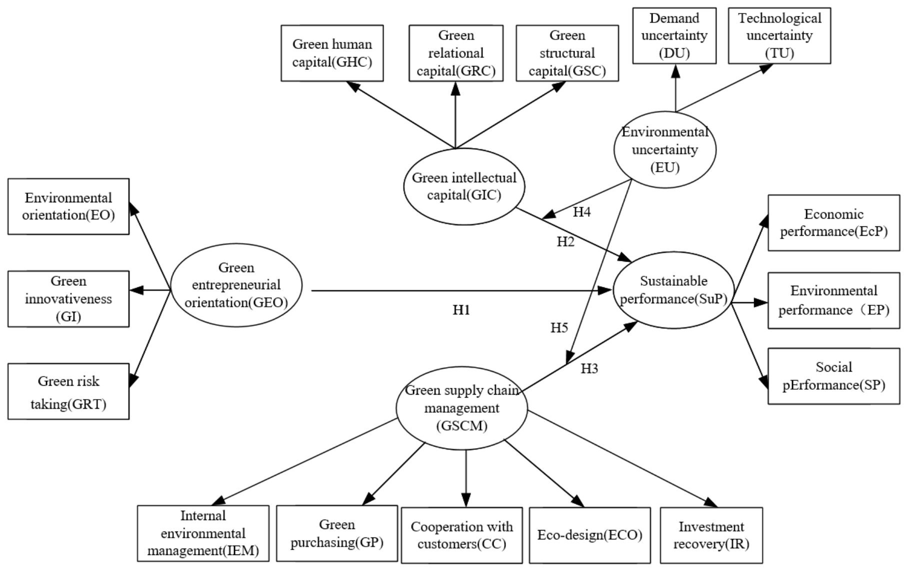


Figure 1: Conceptual Framework

MATERIAL AND METHODS

Measures

This study aims to establish the relationships among GEO, GIC, GSCM, SuP, and EU. We conceptualize GEO with three dimensions: environmental orientation (EO), green innovativeness (GI), and green risk taking (GRT), incorporating 10 items based on definitions from Golsefid-Alavi et al. (2021), Xia (2019), and Xianjiang (2018). Yusoff et al. (2019) provide guidance on GIC, which includes Green Human Capital (GHC), Green Relational Capital (GRC), and Green Structural Capital (GSC), totaling 12 items. GSCM, guided by Yusoff et al. (2019), encompasses Internal Environmental Management (IEM), Green Purchasing (GP), Cooperation with Customers, Eco-Design (ECO), and Investment Recovery (IR), comprising 17 items. SuP, referencing the definition by Habib et al. (2020), consists of Economic Performance (EcP), Environmental Performance (EP), and Social Performance (SP), totaling 13 items. EU, based on studies by Fynes et al. (2004) and Wu (2013), includes demand uncertainty (DU) and technological uncertainty (TU), comprising six items. We measure all items using Likert five-point scales.

PLS-SEM is able to provide robust estimation solutions by performing regression analyses when the data do not conform to a normal distribution (Hair et al., 2011). In addition, we adopted SmartPLS for the analysis of measurement models and structural models, recognizing the need for further improvement and enrichment of the theoretical models developed in this study. PLS-SEM effectively handles multiple relationships and potential variables in complex models, ensuring the models' reliability and validity (Hair et al., 2014; Henseler et al., 2015).

Population, sample, and data collection

The Chinese economy relies heavily on the manufacturing industry, which has a significant impact on the ecological environment (Yuan & Xiang, 2018). Balancing manufacturing development with environmental governance is a pressing issue to address. This study focuses on the Chinese manufacturing industry, utilizing a questionnaire survey method to gather data. We initially distributed and refined 30 pre-survey questionnaires. Subsequently, 1200 formal questionnaires were distributed. After two months of data collection and addressing issues of missing and inconsistent responses, we obtained 516 valid questionnaires, resulting in a response rate of 43%, which provided a sufficient and reliable sample for the study. Among the respondents, 346 were male

(67.05%), and 170 were female (32.95%). Participants were primarily concentrated in middle and senior management positions, totaling 435 individuals (84.30%), with the remainder being general management personnel. In terms of industry distribution, 110 respondents were from the textile industry (21.32%), 244 from resource processing industries (47.29%), and 162 from machinery and electronics manufacturing (31.40%).

RESULTS

This paper presents a higher-order model, characterized by a reflective-reflective structure, which we calculated using the repeated indicators method (refer to Figure 2).

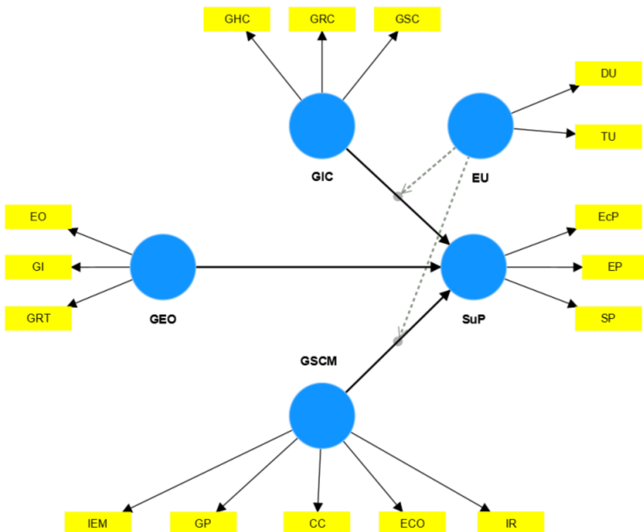


Figure 2: Reduced Form Model

Common method variance

Internal consistency is defined as reliability. This study analyzed indicator loadings (>0.7) (Hair et al., 2011), Cronbach's alpha (α>0.7), and composite reliability (CR > 0.7) (Hair Jr et al., 2010) to assess reliability. Using Partial Least Squares (PLS), this study computed these indicators, surpassing the recommended thresholds in the literature (see Table 1). Also, average variance extracted (AVE > 0.5) (Hair et al., 2012; Hulland, 1999) shows convergent validity, as shown in Table 1, where convergence values range from 0.643 to 0.786.

Table 1: Validity and Reliability of Measurement Model

	Item	Loadings	VIF	Cronbach's Alpha	CR	AVE
GEO	EO	0.850	1.834	0.784	0.788	0.698
	GI	0.861	1.772			
	GRT	0.794	1.457			
GIC	GHC	0.838	1.661	0.794	0.794	0.708
	GRC	0.838	1.671			
	GSC	0.848	1.710			
GSCM	IEM	0.810	1.859	0.861	0.864	0.643
	GP	0.800	1.858			
	CC	0.785	1.821			
	ECO	0.784	1.812			
	IR	0.829	2.015			

SuP	EcP	0.831	1.617	0.793	0.793	0.707
	EP	0.846	1.740			
	SP	0.846	1.687			
EU	DU	0.884	1.484	0.727	0.727	0.786
	TU	0.889	1.484			

Furthermore, we calculated discriminant validity to precisely measure the differentiation and independence among different constructs. We used cross-loadings and the heterotrait-monotrait ratio (HTMT) ratio methods, which were suggested by Fornell and Larcker (1981), to check the discriminant validity.

Discriminant validity gauges the extent to which the study's constructs lack correlation with each other. The diagonal values in Table 2 represent the square roots of average variance extracted (AVE), which are more significant than their corresponding correlation values. We confirmed discriminant validity using the criteria of Fornell and Larcker (1981), where the AVE scores of each construct exceed their squared interconstruct correlations.

Table 2: Fornell-Larcker Criterion

	EU	**GEO**	**GIC**	**GSCM**	**SuP**
EU	0.886				
GEO	-0.308	0.836			
GIC	-0.307	0.564	0.842		
GSCM	-0.352	0.625	0.457	0.802	
SuP	-0.329	0.569	0.516	0.617	0.841

In addition, we conducted a thorough analysis of the external loading values for each construct in cross-loading scenarios. These values (highlighted in bold) were significantly higher than all their cross-loading values on other constructs, as per the criteria outlined by Chin (1998), further confirming the distinctiveness of the structures (see Table 3).

Table 3: Cross Loading Analysis

	GEO	GIC	GSCM	SuP	EU	EU x GIC	EU x GSCM
EO	**0.850**	0.464	0.529	0.447	-0.213	-0.093	-0.080
GI	**0.861**	0.533	0.536	0.515	-0.270	-0.146	-0.088
GRT	**0.794**	0.410	0.500	0.459	-0.287	-0.070	-0.082
GHC	0.474	**0.838**	0.403	0.433	-0.285	-0.104	-0.186
GRC	0.494	**0.838**	0.355	0.429	-0.250	-0.063	-0.173
GSC	0.456	**0.848**	0.396	0.440	-0.239	-0.110	-0.116
IEM	0.508	0.327	**0.810**	0.534	-0.262	-0.221	-0.052
GP	0.476	0.375	**0.800**	0.484	-0.312	-0.116	-0.027
CC	0.485	0.320	**0.785**	0.457	-0.233	-0.128	-0.032
ECO	0.496	0.360	**0.784**	0.455	-0.254	-0.123	-0.017
IR	0.536	0.447	**0.829**	0.531	-0.343	-0.162	-0.021
EcP	0.459	0.429	0.525	**0.831**	-0.289	-0.323	-0.200
EP	0.471	0.428	0.508	**0.846**	-0.263	-0.333	-0.263
SP	0.505	0.444	0.523	**0.846**	-0.279	-0.309	-0.266
DU	-0.270	-0.238	-0.312	-0.289	**0.884**	0.040	0.025
TU	-0.277	-0.305	-0.311	-0.295	**0.889**	0.025	0.041
EU x GIC	-0.126	-0.110	-0.190	-0.382	0.037	**1.000**	0.463

EU x GSCM	-0.099	-0.187	-0.038	-0.289	0.038	0.463	**1.000**

We also used the heterotrait-monotrait ratio (HTMT < 0.9) criterion suggested by Henseler et al. (2015) to fully evaluate discriminant validity. Through PLS computation, we found that all HTMT ratios for the constructs were below 0.9. This result reaffirms the discriminant validity of the model we constructed (see Table 4).

Table 4: Heterotrait-Monotrait Ratio (HTMT)

	EU	GEO	GIC	GSCM	SuP	EU x GSCM	EU x GIC
EU							
GEO	0.407						
GIC	0.403	0.712					
GSCM	0.442	0.759	0.551				
SuP	0.434	0.719	0.650	0.743			
EU x GSCM	0.044	0.112	0.211	0.040	0.324		
EU x GIC	0.044	0.140	0.123	0.202	0.430	0.463	

Data Analysis

We used PLS-SEM for data analysis in this study. Firstly, we typically assess multicollinearity using variance inflation factors (VIF) to address collinearity issues. According to Hair et al. (2011), VIF values reaching or exceeding 5 indicate potential collinearity, while values below 0.2 suggest low collinearity. In our study, VIF values ranged from 1.457 to 2.015 (see Table 1). The collinearity present in this research does not have an adverse effect on the structural model's path coefficients.

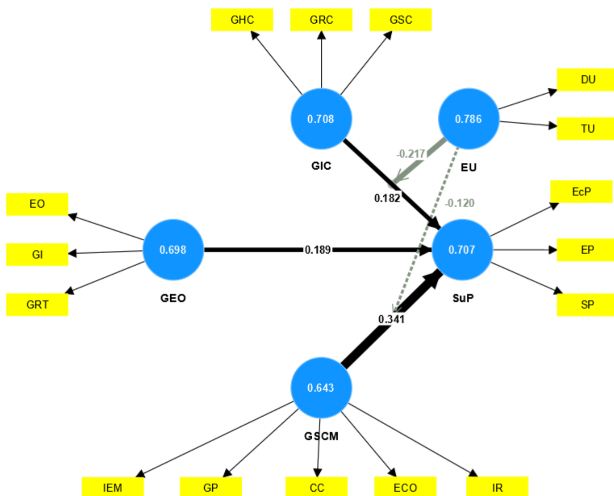
In assessing model fit, we utilized cross-validated redundancy (Q2), R-square (R2), and effect size (f2). We employed the Stone-Geisser test (Q2) to evaluate predictive accuracy, with a value greater than 0 indicating acceptable predictive relevance (Stone, 1974).. Our study found Q2 for SuP to be 0.532, demonstrating predictive relevance. When analyzing the predictive capability of the endogenous structure, an important indicator of interest was R-square (R2), which measures the explanatory power of the model. The R2 value for SuP was 0.556, indicating moderate explanatory power based on the classification criteria by Hair Jr et al. (2014). Another critical metric, effect size (f2), assesses the magnitude of the impact of explanatory variables on endogenous variables. According to Cohen (1988), we found that the effect of GSCM on SuP was approaching a medium effect size, while others showed small effects (see Table 5). In summary, despite the small effect sizes (f2) observed, the model exhibits reliable explanatory power and predictive accuracy, as indicated by the R2 and Q2 results.

In addition, this study further analyzed model fit. The SRMR of this model is 0.056 (<0.08) (Hu & Bentler, 1998), indicating a satisfactory fit. Moreover, d_ULS is 0.422 (<0.95) and d_G is 0.217 (<0.95) (Dijkstra & Henseler, 2015), also suggesting that the model fits well with the sample data. Based on these fit indices, we can conduct hypothesis testing.

Subsequently, the structural equation model was calculated using SmartPLS with a bootstrap sample size of 5000 and a significance level of 0.05. This showed the path relationships (β), t-values (t), and p-values (p) between the variables. The results indicate that GEO has a positive impact on SuP (β= 0.189, t = 4.321, p = 0.000), supporting Hypothesis 1. GIC also positively influences SuP (β= 0.189, t = 4.357, p = 0.000), supporting Hypothesis 2. Additionally, GSCM positively affects SuP (β= 0.341, t = 8.101, p = 0.000), supporting Hypothesis 3. Furthermore, EU negatively moderates the impact of GIC on SuP (β= -0.217, t = 5.676, p = 0.000), supporting Hypothesis 4. Lastly, EU negatively moderates the impact of GSCM on SuP (β=-0.120, t=3.422, p=0.001), supporting Hypothesis 5 (see Table 5). Figure 3 illustrates the final structural model.

Table 5 Hypotheses Testing Results and Effect Size (f^2)

Relationship	β	t-value	p-value	f^2	Evaluation
GEO -> SuP	0.189	4.321	0.000	0.041	Supported (H1)
GIC -> SuP	0.182	4.357	0.000	0.047	Supported (H2)
GSCM -> SuP	0.341	8.101	0.000	0.144	Supported (H3)
EU x GIC -> SuP	-0.217	5.676	0.000	0.078	Supported (H4)
EU x GSCM -> SuP	-0.120	3.422	0.001	0.025	Supported (H5)



Note:Thicker arrow line means that the effect of independent variable on dependent variable is higher.

Figure 3: Evaluation of the Structural model

DISCUSSIONS AND IMPLICATIONS

Discussion

Based on the RBV theory, this study investigates the sustainable performance of the manufacturing industry in China. RBV posits that scarce resources and capabilities can create unique competitive advantages and lead to higher performance for enterprises. This study identifies GEO, GIC, and GSCM as sources of unique resources that propel green development within enterprises. Additionally, this research incorporates the moderating effect of EU, making a significant contribution to the sustainable development of manufacturing enterprises.

The research findings indicate that GEO can significantly enhance SuP, which is not surprising (Frare & Beuren, 2022). Firms that consistently implement green strategies are more likely to achieve higher benefits on economic, environmental, and social levels (Floyd & Zubevich, 2010). However, this discussion remains relatively limited in developing countries. By implementing green entrepreneurial strategies, manufacturing industries not only mitigate adverse environmental impacts and enhance environmental performance, but also positively influence social and financial performance. Recent research supports this assertion, indicating that GEO strategies enable firms to streamline operations through innovative environmental technologies and practices that optimize resource utilization while reducing waste and emissions (Frare & Beuren, 2022). Furthermore, these strategies contribute to social performance by fostering community and stakeholder relations through the creation of green jobs and strengthening corporate social responsibility efforts (Deslatte & Swann, 2020).

GIC also has a significant positive impact on SuP. This is in line with the study of Yusoff et al. (2019) who found that green intellectual capital positively affects the economic, environmental and social performance of Malaysian manufacturing industry. This suggests that GIC plays an important role in driving overall firm performance regardless of the country or industry. This is different from the findings of Jermsittiparsert (2021), who based on Thai SMEs, found that GIC does not fully contribute to SuP, and that green relational capital and green structural capital significantly affect sustainable performance, while green human capital has no effect on sustainable performance. This difference may stem from the differences in industry characteristics and environmental contexts of the different study participants. The increase in green intellectual capital not only enhances the environmental technology level of enterprises, but also promotes more efficient resource utilisation and waste management, thus significantly reducing the ecological footprint of enterprises. In addition, the accumulation of green intellectual capital promotes firms' performance in social responsibility, enhances their relationships with stakeholders, and further improves overall performance (Zhang et al., 2020). Taken together, this study supports the positive role of GIC in enhancing corporate SuP.

The study also demonstrates that GSCM positively influences SuP. GSCM enables firms to adopt more efficient and environmentally friendly operational practices by optimizing resource utilization, reducing waste generation, and enhancing product life cycle management. This finding aligns with research by Novitasari and Agustia (2021), who identified GSCM's significant contribution to business performance and its role in mitigating environmental impacts in Indonesia. GSCM integrates green procurement, customer collaboration, and eco-design synergies. Green Jr et al. (2012) further illustrated that GSCM enhances both environmental and economic performance, thereby enhancing overall organizational performance.

Furthermore, this study focuses on the negative moderating effect of the EU on the relationship between GIC and SuP, as well as GSCM and SuP. Other scholars have ignored the influence of the external environment when studying the causal relationship between SuP. However, firms may face more challenges in utilizing green intellectual capital and implementing green supply chain management to enhance sustainable performance when there is uncertainty in firm demand and technology. The increased uncertainty in markets and policies amplifies the uncertainties and risks that firms encounter when implementing green strategies (Mangla et al., 2015). This situation poses greater risks and uncertainties for firms practicing GSCM in areas such as green procurement, customer collaboration, and eco-design. Under such circumstances, firms may adopt a more cautious approach to investing in and executing green projects to avoid potential financial losses and operational risks, thereby weakening the positive impacts of GIC and GSCM on SuP. Moreover, when confronted with uncertain external environments, firms may prioritize short-term financial stability (Abu Afifa & Saleh, 2022), potentially overlooking investments in green technologies and knowledge accumulation, thus affecting the positive roles of GIC and GSCM on SuP.

Theoretical and managerial implications

This study enriches the existing knowledge base by exploring the relationships between GEO, GIC, GSCM, and SuP. The novelty lies in applying the RBV theory to explain these relationships, emphasizing the significance of scarce resources and unique capabilities in gaining competitive advantage. It underscores that firms can enhance performance by effectively utilizing and managing their green resources. These findings offer crucial guidance for firms in implementing green entrepreneurial strategies, accumulating GIC, and practicing GSCM, thereby enhancing sustainable performance even amidst environmental uncertainties. The study establishes the significant impacts of GEO, GIC, and GSCM on SuP. It also introduces the EU factor into the literature framework of GIC, GSCM, and SuP, investigating how GIC and GSCM influence SuP under the influence of EU. This research expands the understanding of corporate sustainability, deepening insights into implementing green strategies, executing green management, and accumulating green capital to achieve SuP in manufacturing industries.

Moreover, this study offers practical managerial insights. Against the backdrop of global attention to sustainable development, especially in developing countries, promoting and implementing GEO contributes to the comprehensive enhancement of SuP in enterprises. This study provides direction for China's manufacturing sector towards ecological conservation and "dual-carbon" goals, aiming to drive comprehensive transformation towards environmental protection. Executives, employees, suppliers, and customers recognize the importance of corporate sustainable development and the necessity of environmentally friendly practices. Adopting this model in developing countries' manufacturing enhances organizational capabilities in green production. Enterprises should prioritize accumulating GIC, enhancing employees' environmental awareness and skills through training and knowledge sharing, and actively guiding R&D personnel towards green technological innovation. Encouraging employee involvement in green project development and implementation, while acknowledging outstanding contributions in green development by employees and teams, enhances R&D efficiency and effectiveness. Recommendations include implementing green standards in procurement, production, and sales processes, as well as optimizing resource utilization and waste management across supply chain stages through collaboration with suppliers and customers, thereby strengthening market competitiveness and corporate reputation to improve overall SuP.

Considering EU negative moderating effect on the relationships between GIC, GSCM, and SuP, adjustments to corporate strategies and operational models are recommended to enhance green resource accumulation and execute green development, improving organizational flexibility and adaptability to further enhance core competitive advantages against demand and technological uncertainties. However, government actions play a crucial role in facilitating the transition from a traditional to green economy. Recommendations include strengthening environmental regulations, providing fiscal subsidies, tax incentives, and technological support to help enterprises reduce costs and risks associated with green transformation, and promoting sustainable development in the manufacturing industry.

Limitation and future research

This study has two limitations. Firstly, due to constraints in data availability, the use of questionnaire surveys to gather data may be subject to respondents' subjective perceptions, which could influence survey outcomes. Future research could employ more objective methodologies. Secondly, to examine the impact of GIC and GSCM on SuP, this study selected EU as a moderating variable. Future studies could consider other factors, such as industry type and regulatory background, as moderators to uncover their effects on sustainable performance in manufacturing. This approach would provide targeted guidance for enhancing risk resilience and sustaining operations in the manufacturing sector.

AUTHOR CONTRIBUTIONS

Conceptualization, W.H. and T.T.; methodology, W.H.; software, W.H. and T.T.; validation, W.H. and T.T.; formal analysis, W.H.; investigation, W.H.; resources, W.H.; data curation, W.H.; writing—original draft preparation, W.H.; writing—review and editing, W.H. and T.T.; visualization, W.H.; supervision, T.T.; All authors have read and agreed to the published version of the manuscript.

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