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Research Article

Green Intellectual Capital: Boosting Sustainability via Innovation, Value Creation & Resource Efficiency

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ABSTRACT

In today's environmentally conscious marketplace, achieving business sustainability is paramount for manufacturing firms. This pressure is particularly acute in developing nations like Pakistan, where balancing economic growth with environmental responsibility presents unique challenges. Hence this study delves into the critical relationship between green intellectual capital (GIC) and business sustainability in Pakistan's manufacturing sector. The researcher also examined the mediating effects of green innovation, value creation, and resource efficiency on this association. Employing a survey instrument, data is collected from large scale manufacturing firms located in three different industrial cities of Pakistan through convenient sampling. Smart PLS SEM was used to explore the hypothesized relationships and the mechanisms through which GIC impacts business sustainability via mediating variables. The results confirmed all hypotheses as statistically significant. The first hypothesis showed a positive and significant relationship between GIC and business sustainability ($\beta = 0.101$, $p < 0.05$). The second hypothesis demonstrated that value creation effectively mediates the relationship between GIC and business sustainability ($\beta = 0.191$, $p < 0.05$). The third and fourth hypothesis found that green innovation and Resource efficiency both significantly mediates between green intellectual capital and business sustainability with ($B=0.183$, $p<0.05$) and ($B=0.120$, $p<0.05$) respectively. Hence all the hypotheses were supported. These findings hold significant implications for Pakistani manufacturing firms, offering valuable insights into strengthening their environmental practices and achieving long-term sustainability. However, the applicability of these findings to other sectors or countries may require further investigation. Further research employing more robust sampling techniques can enhance the generalizability of the findings.

KEYWORDS

Green Intellectual Capital, Green Innovation, Value Creation, Resource Efficiency, Business Sustainability, Manufacturing Sector, Pakistan

1 | INTRODUCTION

Pakistan's manufacturing sector is a vital pillar of the national economy, contributing significantly to employment and export earnings (Ahmed et al., 2023). However, concerns are mounting regarding the environmental impact of its traditional practices. Conventional manufacturing processes can lead to pollution, resource depletion, and substantial waste generation (Rehman et al., 2022). These issues not only threaten Pakistan's ecological well-being but also pose long-term risks to the sector's own sustainability (Siddiqi & Anastasiou, 2011). In light of these challenges, a pressing need exists for Pakistani manufacturers to embrace sustainable business practices. Sustainable business practices integrate environmental considerations into core decision-making, aiming to minimize negative environmental impact while maintaining economic viability (Sroufe & Kaehler, 2020). This shift towards sustainability offers several potential benefits, including cost reduction through resource efficiency enhanced brand reputation among environmentally conscious consumers and access to new markets with stringent environmental regulations (Beamon, 2021; Christmann & Taylor, 2001). For long-term success, manufacturers need to implement sustainable business practices, with green intellectual capital (GIC) playing a pivotal role in this transformation (Sroufe & Kaehler, 2020; Iqbal et al., 2023). GIC refers to the knowledge, skills, and capabilities of a firm that enable environmentally responsible operations (Shehzad et al., 2023).

These relationships foster collaboration on sustainable practices and create a market advantage for firms with a strong green reputation. By nurturing these capabilities, GIC empowers manufacturers to innovate and develop new business models and products and process that minimize environmental impact (Asif et al., 2018). Similarly, Beamon (2021) also concluded in his study that green innovation can also lead to significant cost savings through reduced resource consumption and waste generation. Ultimately, these combined effects – cost reduction, value creation, and resource efficiency – contribute directly to a firm's long-term business sustainability (Sroufe & Kaehler, 2020). Resource efficiency refers to optimizing the use of raw materials and all other resources throughout the process of production (Beamon, 2021). This encompasses practices like minimizing waste generation, employing energy-efficient technologies, and adopting closed-loop production systems. Implementing these practices directly translates to environmental benefits by reducing a firm's environmental footprint. Lower resource consumption leads to decreased pollution and resource depletion, contributing to a more sustainable future (Siddiqi & Anastasiou, 2011). This allows firms to not only thrive economically but also operate in a manner that is ecologically accountable and communally conscious. Resource efficiency practices not only reduce environmental impact but also create economic value for firms. This value creation, in turn, strengthens a firm's competitive advantage and contributes to its overall sustainability. Therefore, manufacturers seeking to build a sustainable future must prioritize resource efficiency as a core business strategy. Hence by investigating these potential mediating effects, this study aims to shed light on the specific pathways through which GIC influences business sustainability in Pakistan's manufacturing sector. Hence this paper is intended to thoroughly evaluate the mediating effect of green innovation, value creation and resource efficiency in achieving sustainability, with a specific focus on Pakistan's manufacturing sector.

2 | LITERATURE REVIEW

2.1 | Theoretical Underpinning

This study draws upon two prominent theoretical frameworks: The Natural Resource Based View (NRBV) proposed by Hart (1995) and the Intellectual Capital-based View (ICBV) articulated by Reed et al. (2006). These theories serve as foundational pillars in conceptualizing the research framework and guiding the analysis. The NRBV establishes a critical link between resource efficiency and sustainability. This theory extends the traditional Resource-Based View (RBV) by integrating environmental considerations into strategic management. Hart (1995) posits that natural resources are essential strategic assets. Efficient and sustainable management of these resources leads to cost savings, risk reduction, and the creation of new market opportunities, thereby driving competitive advantage and long-term success. A central element of NRBV is pollution prevention, which involves proactive measures to minimize waste and emissions. This approach views cleaner production techniques and resource-efficient processes not merely as compliance measures but as strategic imperatives that enhance both operational efficiency and environmental performance. Companies that invest in energy-efficient technologies or adopt waste minimization practices can significantly reduce their environmental footprint and achieve substantial cost reductions, fostering a culture of continuous improvement and innovation (Hart, 1995). The NRBV framework also advocates for sustainable development, emphasizing the creation of strategies that fulfill current needs while preserving the ability of future generations to meet their own needs. Firms that develop renewable energy solutions or adopt sustainable agricultural practices contribute to sustainable development while opening new business opportunities. This creates vast new markets for businesses, linking resource efficiency with broader socio-economic sustainability (Hart, 2005). However, it's essential to recognize that an organization's strategic assets and competencies extend beyond tangible resources to encompass intangible assets as well. Bontis (1998) highlighted the complexities involved in evaluating the worth of these intangible assets. In response to these challenges, Intellectual capital-based view (ICBV) theory was introduced by Reed et al. (2006), offering methodologies for quantifying intellectual capital. Central to the ICBV framework is the emphasis on intangible or intellectual resources. This study endeavors to broaden the conventional understanding of intellectual capital by integrating "green" principles, thereby fostering the development of intangible resources that contribute significantly to corporate sustainability.

2.2 | GIC and Business Sustainability

One of the earliest attempts to define business sustainability was made by Elkington (1994), who presented the concept of the "triple bottom line" (TBL). The Triple Bottom Line (TBL) framework, a comprehensive sustainability approach, suggests that companies should prioritize their efforts across three interconnected dimensions: People, Planet, and Profit. The People dimension emphasizes social responsibility, encompassing initiatives aimed at promoting the well-being and equity of employees, communities, and society at large. The Planet dimension underscores environmental responsibility, advocating for practices that minimize ecological impact, conserve natural resources, and mitigate climate change. Finally, the Profit dimension underscores economic responsibility, emphasizing the importance of financial viability and long-term profitability while ensuring ethical business practices and adherence to regulatory standards. By addressing all three dimensions of the TBL framework, companies can achieve holistic sustainability outcomes that balance social, environmental, and economic considerations for the benefit of stakeholders and society. Savitz (2013) mentioned that the Triple Bottom Line concept is the most realistic portrayal of what it means to practice sustainable business practices. In the early 2000s, the concept of business sustainability gained further prominence, because of growing concerns about climate change and other environmental issues. Since then, the concept of business sustainability has continued to evolve, reflecting changes in the broader social, economic, and political landscape. According to Silvius and Schipper (2014), the term "sustainability" refers to a situation in which economic sustainability, social sustainability, and environmental sustainability live in a state of balance or harmony with one another. Economic sustainability denotes an organization's capacity for growth, profitability, and other operational and production achievements. The Environmental Perspective of sustainability emphasizes the importance of reducing the negative environmental impact of business activities. It is defined as "the ability of an organization to minimize its negative impact on the natural environment while maintaining or increasing its economic performance" (Gladwin et al., 1995, p. 12). This point of view frequently places an emphasis on actions such as lowering emissions of greenhouse gases, preserving natural resources, and cutting down on waste. To reduce carbon emissions, environmental performance is termed as the capability of an organization's operations to reduce environmental incidents, enhance renewable resources, reduce waste, and reduce resource consumption (Guo et al., 2023). While the social component of sustainability concentrates on the importance of promoting socially responsible behavior and moral practices in business operations. It is defined as "the ability of an organization to meet the needs of the present without compromising the ability of future generations to meet their own needs, while also addressing the social and ethical dimensions of business conduct" (Moore et al., 2017). This perspective often focuses on practices such as fair labor standards, community engagement, and philanthropy.

GIC empowers manufacturers to develop and implement practices that minimize environmental impact (Iqbal et al., 2023). It comprises three key components: green human capital (GHC), green structural capital (GSC), and green relational capital (GRC) (Asif et al., 2018). GHC consists of Employee expertise in areas like eco-design, waste reduction, and pollution control (Munawer et al., 2023). This expertise allows them to develop and devise the sustainable practices within organization. Chen (2008) stated that GHC represents an organization's workforce's dedication, creativity, attitude, knowledge, and abilities. The number of qualified workers in an organization is directly correlated with its capacity to ensure environmental sustainability in its production processes (Abbas et al., 2021). GSC is defined as "organizational assets which shows concerns about environmental protection inside the company and those assets named as strategies regarding organizational commitments, organizational capabilities, reward systems, organizational culture, databases, knowledge management system, information technology, company images, copyrights, and trademarks" (Chen, 2008). For a business to be considered "Green Structural Capital," it must place a premium on environmental responsibility across the board. It involves investments in green technologies, the application of sustainable organizational processes, and the development of green products and services. Benefits include competitive advantage, cost savings, regulatory compliance, and sustainable growth, though challenges like initial investment costs, measurement difficulties, and cultural change must be addressed. Ultimately, Green Structural Capital supports long-term business viability by integrating environmental responsibility into core business processes and strategies (Keramitsoglou et al., 2020). Examples include energy-efficient machinery or closed-loop production systems that directly contribute to resource efficiency and a reduced environmental footprint. Similarly, Green relational capital encompasses strong relationships with environmentally conscious suppliers and customers (Asif et al., 2018). It includes building trust-based relationships, forming collaborative partnerships, enhancing the sustainable brand image, and maintaining constructive regulatory relationships. It helps in generating a stronger reputation, increased customer loyalty, collaborative innovation, and regulatory advantages. By leveraging these sustainable relationships, companies can achieve competitive differentiation and drive environmental sustainability. Hence, Green Intellectual Capital plays a crucial role in business sustainability by integrating environmental knowledge, innovation, and sustainable practices into an organization's intellectual assets. It acts as the cornerstone for sustainable practices in manufacturing. It equips firms with the knowledge, skills, and systems necessary to develop and implement environmentally friendly solutions. GIC not only drives operational efficiencies and cost savings but also aligns business strategies with global sustainability goals, contributing to overall economic, social, and environmental well-being (Suki, 2023). Hence in the light of literature we deduce the following hypothesis.

H1: Green intellectual capital significantly impacts the business sustainability

2.3 | Value Creation Mediates Between GIC and Business Sustainability

Value creation is a logical way that delineates the capability and identity of the firm and differentiates one organization from the other that is operating under the same environment (O'Cass & Sok, 2013). Freudenreich (2020) argued that value creation is based on relational capabilities and knowledge competencies. The empirical results verified the relationship of relational capabilities and knowledge competencies positively impact value creation. In today's dynamic competitive environment, organizations endeavor to capitalize on their accumulated knowledge and past experiences to refine their operational processes. However, it is noteworthy that attaining a competitive edge necessitates more than just leveraging existing capabilities. According to Yahya et al. (2022), organizations must demonstrate the ability to deliver products and services that possess characteristics of rarity, inimitability, and significant value to stakeholders. Building upon this perspective, Yadiati et al. (2019) advocate for the adoption of a resource-based view (RBV) framework, emphasizing the importance of crafting distinctive strategies that are not easily imitated by competitors. By strategically organizing their resources, firms can cultivate a sustainable market position. Thus, drawing from existing literature, the formulation of the following hypothesis is warranted.

H2: Value creation mediates between GIC and BS.

2.4 | Green Innovation Mediates Between Green Intellectual Capital and Business Sustainability

Green intellectual capital, which includes environmental expertise, eco-friendly technologies, and sustainable organizational practices, forms the foundation for green innovation (Chen & Chang, 2013). Hsu and Wang (2023) also found that GIC significantly influences green innovation of the firm`s, which in turn boosts eco-friendly performance and contributing to business sustainability. While Li et al. (2022) in their study demonstrated that GHC positively impacts green innovation, leading to improved business sustainability outcomes. Gholami et al. (2023) showed that companies investing in GIC tend to innovate more in green technologies, leading to better environmental performance and sustainable business practices. GIC is instrumental in improving corporate sustainability outcomes. They further noted that an effective green innovation (GI) strategy can significantly boost business performance by reducing operational costs, increasing competitive advantage, enhancing corporate reputation, retaining skilled employees, and ensuring compliance with environmental regulations (Ullah et al., 2022). Zhang et al. (2023) highlighted that GSC, such as patents and green technologies, facilitates the implementation of green innovations, directly impacting the sustainability performance of firms. This perspective highlights the potential for modern technology to drive eco-friendly innovations that not only boost a company's operational efficiency and market competitiveness but also add to environmental sustainability by reducing harmful emissions and waste (Yusliza et al., 2019). Hence, we hypothesized that;

H3: GI mediates between GIC and BS.

2.5 | Resource Efficiency Mediates Between GIC and Business Sustainability

Green intellectual capital serves as a reservoir of knowledge and expertise that empowers organizations to identify and capitalize on opportunities aimed at enhancing resource efficiency. Employees with expertise in sustainable practices can develop and implement processes that reduce energy and material usage (Zhu et al., 2023). Evaluating environmental performance has evolved into a vital metric for gauging corporate accountability to sustainability. This metric's importance extends beyond mere legal compliance, reflecting a proactive stance on environmental conservation and resource efficiency. Implementing resource-efficient practices leads to cost savings and improved operational performance, which contributes to business sustainability. Efficient use of resources reduces production costs and waste, making businesses more economically viable and environmentally friendly (Geng et al., 2022). Resource efficiency driven by GIC can lead to green innovations, such as new technologies or processes that enhance sustainability. These innovations can provide a competitive advantage by differentiating the company in the entire sector and appealing to ecologically conscious customers (Wu et al., 2023). The pursuit of sustainability shouldn't come at the expense of economic viability. By minimizing waste and optimizing resource utilization, firms can achieve cost reductions in several areas, including raw material procurement, energy consumption, and waste disposal. Furthermore, resource efficiency fosters sustainability of the business by strengthening a firm's brand image and reputation. By reducing costs, enhancing brand image, and minimizing environmental impact, resource efficiency practices contribute to all three pillars of sustainability. Hence, we hypothesize that.

H4: Resource efficiency significantly mediates between GIC and BS

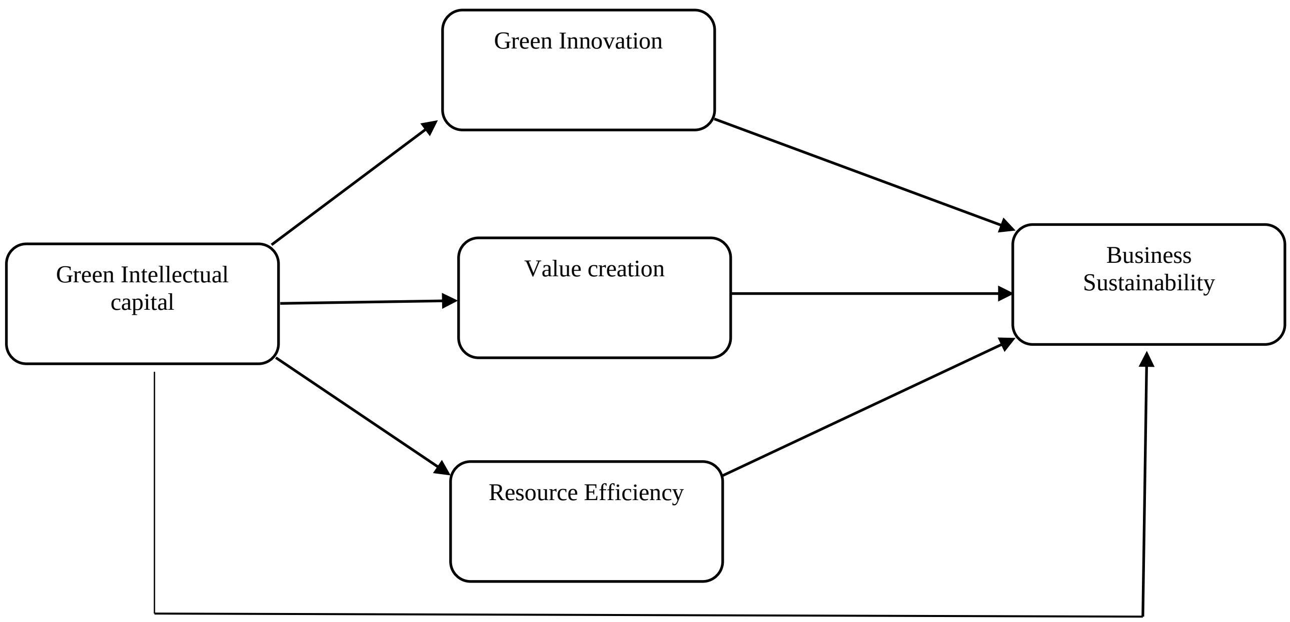

Figure 1: Research Model

3 | RESEARCH METHODOLOGY

This study is based on quantitative research methods. The purpose is to investigate how Green Intellectual Capital boost business Sustainability via Innovation, Value Creation & Resource efficiency in the manufacturing sector of Pakistan. The target population consists of employees working in large manufacturing firms located in the cities of Lahore, Faisalabad, and Sialkot, within the Punjab province. Using convenience sampling, a sample size of 553 respondents is determined based on Krejcie and Morgan's (1970) formula for sample size determination. Non Probability Convenience sampling is chosen due to its practicality in accessing the target population efficiently.

3.1 | Measurement of Instruments

The study employed a close-ended questionnaire to measure the variables. Participants responded using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). According to Sekaran and Bougie (2016), this methodology encompasses descriptive, correlational, exploratory, and explanatory studies. Specifically, to assess green intellectual capital (GIC), 19 items were adopted from Chen (2008). Green innovation (GI) was measured using eight items from Chao and Chen (2006). Value creation (VC) was evaluated with four items from Guenzi and Troilo (2006). Finally, business sustainability (BS) was measured with 22 items from Yusoff et al. (2019), while a total of five items for Resource Efficiency (REF) scale was adapted from Zhu and Sarkis (2007).

3.2 | Data Collection Method and Analysis

Data collection was carried out using a structured questionnaire, which is divided into sections to capture demographic information and GIC, BS, GI, VC, & REF. Each of these constructs were measured using a Likert scale ranging from 1 to 5. The structured questionnaires, with the researcher coordinating with the management of the selected manufacturing firms to facilitate distribution and collection. Data analysis for this study was conducted using Structural Equation Modeling (SEM) with Smart-PLS software (Alina et al., 2023; Hafeez et al., 2023; Jahangir et al., 2022; Jahangir & Hafeez, 2022; Manzoor & Jahangir, 2023; Mehtab Hameed et al., 2023). To start, descriptive statistics were used to outline the sample's demographic characteristics, giving an overview of participants' backgrounds. The reliability of the questionnaire was evaluated using Cronbach's alpha, which confirmed the internal consistency of the measurement scales. All the variables have Cronbach's alpha values exceeding the 0.70 threshold, which signifies that the measures used are highly reliable. The validity of the measurement model was assessed by examining both convergent and discriminant validity. Convergent validity was verified through Average Variance Extracted (AVE) and Composite Reliability (CR), with AVE values for each construct exceeding 0.50 and CR values surpassing 0.70, indicating sufficient convergent validity. The Heterotrait-Monotrait Ratio of Correlations (HTMT) criterion was applied to measure discriminant validity. Structural Equation Modeling (SEM) was applied to test the hypothesized relationships among the constructs. The model fit indices demonstrated an adequate representation of the data structure. Path analysis was conducted to elucidate the interactions between the constructs and supporting the study's theoretical framework. The results showed that all hypothesized relationships were significant, providing support for the proposed model.

4 | DATA ANALYSIS AND RESULTS

Table 1
Demographic Statistics

Gender	Frequency	Percent
Female	407	74%
Male	146	26%
Age (in Years)		
Less than 30	37	07%
31 - 40	186	34%
41 - 50 .	204	37%
51 & above	124	23%
Experience (in years)		
< 10 .	223	44%
11 – 20	200	36%
> 20 .	110	20%
Education		
Undergrad	74	14%
Graduate	255	46%
Grad	152	28%
Others	72	13%
Departments of respondents		
Production & Operations	174	30%
Marketing & Sales	139	27%
Human Resource	103	19%
Finance	85	15%
Others	54	10%

Table 1 indicates details about the demographics of the respondents. The sample consisted of 553 respondents, with a majority being female (74%) and males comprising 26%. Age distribution showed that 7% were under 30 years, 34% were aged 31-40, 37% were aged 41-50, and 23% were 51 and above. In terms of experience, 44% had less than 10 years, 36% had 11-20 years, and 20% had over 20 years. Regarding education, 14% had an undergraduate

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degree, 46% were graduates, 28% had graduate-level education, and 13% had other educational backgrounds. The respondents were primarily from Production & Operations (30%), Marketing & Sales (27%), Human Resources (19%), Finance (15%), and other departments (10%).

4.1 | Measurement Model

In this research, the measurement model was rigorously evaluated to ensure the validity and reliability of the constructs. Key indicators such as Average Variance Extracted (AVE) and Composite Reliability (CR) were employed to assess the model's adequacy. AVE values greater than 0.50 indicate that the constructs explain more than half of the variance of their indicators, thereby confirming convergent validity. Similarly, CR values exceeding the 0.70 threshold Ramayah et al. (2018); Hair et al. (2021) demonstrate high internal consistency among the items within each construct. Since all the values are above 0.70 hence confirming the reliability of all constructs.

Table 2
Heterotrait-Monotrait Ratio (HTMT)

Variables	BS	GI	GIC	REF	VC
BS					
GI	0.806				
GIC	0.500	0.551			
REF	0.528	0.564	0.459		
VC	0.841	0.780	0.433	0.543	

In table no 2 the HTMT value between BS and GI is 0.806, indicating good discriminant validity as it is below 0.85. Similarly, the HTMT values for BS vs. GIC (0.500), BS vs. REF (0.528), and BS vs. VC (0.841) also fall below the 0.85 threshold, though the value for BS vs. VC is right on the limit, suggesting it is acceptable but close to the threshold. For the GI construct, the HTMT values with GIC (0.551), REF (0.564), and VC (0.780) are all well below 0.85, indicating good discriminant validity. The GIC construct shows HTMT values with REF (0.459) and VC (0.433) that are also comfortably below 0.85, ensuring distinctiveness. Lastly, the REF and VC constructs have an HTMT value of 0.543, which is well within acceptable limits. Overall, the HTMT values in this table suggest that all constructs exhibit good discriminant validity, as their inter-construct HTMT values are below the conservative threshold of 0.85.

Table 3
Collinearity (VIF)

Items	VIF
BS1	2.567
BS10	2.649
BS11	2.933
BS12	2.776
BS13	2.901
BS14	2.638
BS15	2.907
BS16	2.670
BS17	2.561
BS18	2.687
BS19	2.737
BS2	2.761
BS20	2.865

BS21	2.723
BS22	3.112
BS3	2.992
BS4	2.693
BS5	2.688
BS6	2.981
BS7	2.569
BS8	2.919
BS9	2.830
GIC1	2.521
GIC10	2.676
GIC11	2.546
GIC12	2.677
GIC13	2.696
GIC14	2.515
GIC15	2.509
GIC16	2.686
GIC17	2.649
GIC18	2.642
GIC19	2.510
GIC2	2.596
GIC3	2.643
GIC4	2.623
GIC5	2.630
GIC6	2.580
GIC7	2.593
GIC8	2.360
GIC9	2.757
GNIN1	1.717
GNIN2	1.501
GNIN3	1.556
GNIN4	1.629
GNIN5	1.730
GNIN6	1.585
GNIN7	1.690
GNIN8	1.636
REF1	1.921
REF2	2.340
REF3	2.474
REF4	2.446
REF5	2.178
VC1	1.924
VC2	1.887

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VC3	2.130
VC4	1.988

Table 4
Model Fit Summary

	Saturated Model	Estimated Model
SRMR	0.031	0.096
d_ULS	1.602	15.933
d_G	0.690	1.026
Chi-Square	2065.750	2705.091
NFI	0.920	0.895

Table 4 presents a detailed comparison of the model fit indices between the Saturated Model and the Estimated Model, highlighting a consistently better performance by the Saturated Model. Specifically, the Saturated Model exhibits a Standardized Root Mean Square Residual (SRMR) of 0.031, which is well within the acceptable range, indicating an excellent fit. In contrast, the Estimated Model shows an SRMR of 0.096, which slightly exceeds the ideal threshold, suggesting a less optimal fit. The d_ULS and d_G values for the Saturated Model (1.602 and 0.690, respectively) are significantly lower than those for the Estimated Model (15.933 and 1.026), indicating better fit. The Chi-Square value is also lower for the Saturated Model (2065.751) compared to the Estimated Model (2705.091), further supporting its superior fit. Additionally, the NFI for the Saturated Model (0.920) is higher than for the Estimated Model (0.895), suggesting a better overall fit for the Saturated Model.

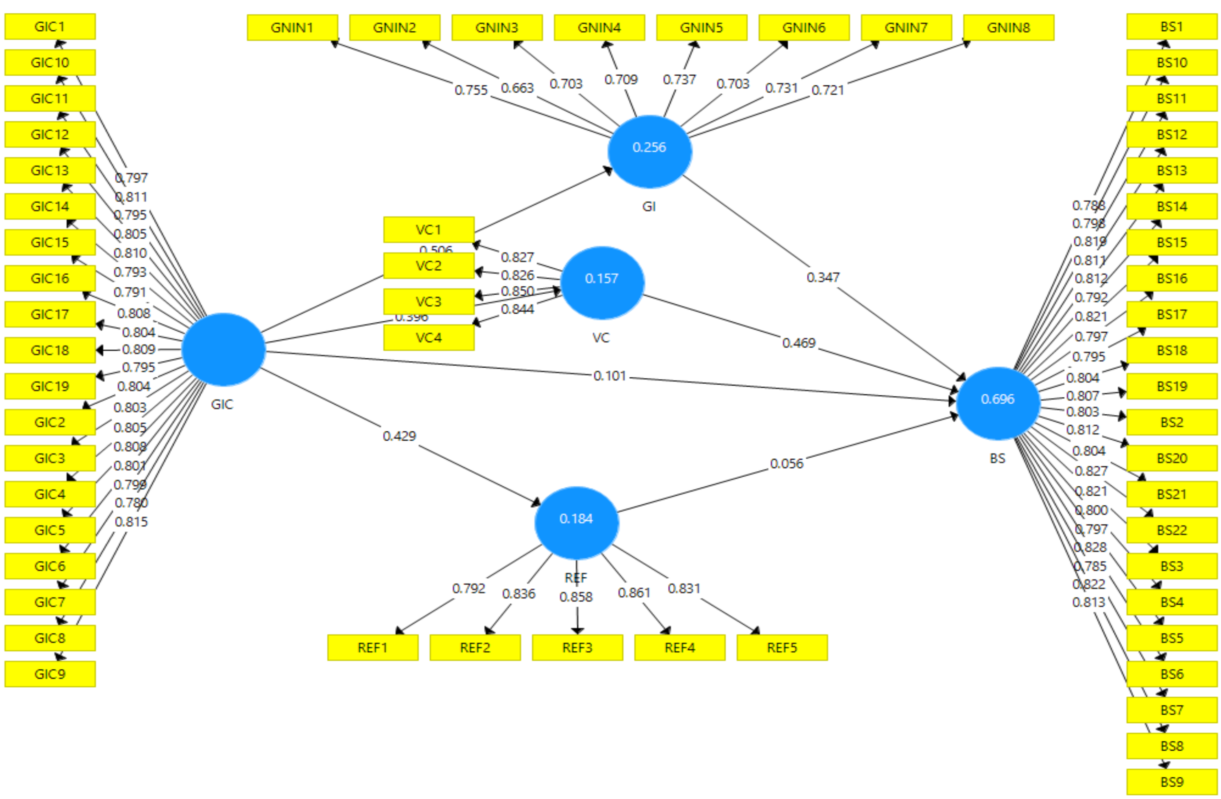

Figure 2: Measurement Model

Table 5
Coefficients

Relationships	Original Sample (O)	Sample Mean (M)	Standard Deviation	T Statistics	P
GI → BS	0.347	0.346	0.047	7.341	0.000
GIC → BS	0.101	0.101	0.043	2.493	0.002
GIC → GI	0.506	0.506	0.042	11.575	0.000
GIC → REF	0.429	0.427	0.031	9.032	0.000
REF → BS	0.056	0.055	0.026	2.508	0.012
VC → BS	0.469	0.468	0.040	11.434	0.000

Table 5 represents statistical analyses of various samples, examining the relationship between different variables. The first comparison, GI and BS, demonstrates a sample mean of 0.347 with a standard deviation of 0.047. The calculated T statistic of 7.341 indicates a strong deviation from the null hypothesis, suggesting a significant relationship between GI and BS. The p-value of 0.000 further supports this conclusion, indicating that the observed difference is highly unlikely to have occurred by chance alone. Moving on to the GIC and BS relationship, the sample mean, and standard deviation are both 0.101 and 0.043 respectively. While the T statistic of 2.493 suggests a less pronounced difference compared to the previous comparison, the p-value of 0.002 still indicates statistical significance, though to a lesser degree.

Similarly, the path coefficient from Green Intellectual Capital to Green Innovation is 0.506, indicating a strong positive effect. The very high T statistic (11.575) and a P value of 0.000 suggest this relationship is highly statistically significant. The path coefficient from Green Intellectual Capital to Resource Efficiency is 0.429, indicating a positive and significant effect. The T statistic (9.032) and a P value of 0.000 confirm that this relationship is statistically significant suggesting a significant difference between these groups. In contrast, the relationship between REF and BS shows a smaller T statistic of 2.508 and a p-value of 0.012, indicating a comparatively weaker but still significant relationship between REF and BS. Lastly, the association between VC and BS is 0.469, indicating a strong positive effect. The very high T statistic (11.434) and a P value of 0.000 suggest this relationship is highly statistically significant. Hence, all the paths demonstrate that the relationships among all the variables are statistically significant, as indicated by T statistics well above the threshold of 1.96 and P values less than 0.05. Green Intellectual Capital significantly affects Green Innovation and Resource Efficiency, which in turn positively impact Business Sustainability, while Green Innovation, Resource Efficiency, and Variable C all positively and significantly contribute to Business Sustainability.

Table 6
Mediation Analysis

Relationships	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values
GIC → VC → BS	0.191	0.190	0.037	6.703	0.000
GIC → GI →BS	0.183	0.182	0.031	5.947	0.000
GIC → REF → BS	0.120	0.120	0.019	2.362	0.019

Table 6 contains the results of examining the indirect effects of green intellectual capital (GIC) on business sustainability (BS) through three mediating variables. The pathway from GIC to BS via value creation (VC) shows a standardized coefficient of 0.191, with a sample mean of 0.190 and a standard deviation of 0.037 with the T statistic value 6.703, and the P value is 0.000, conferring a highly significant effect. Similarly, the pathway from GIC to BS through green innovation (GI) has a standardized coefficient of 0.183, with a sample mean of 0.182 and a standard deviation of 0.031. The T statistic value is 5.947, with $P < 0.05$, demonstrating a significant impact. Lastly, the pathway from GIC to BS via resource efficiency (REF) shows a standardized coefficient of 0.120, with a sample mean of 0.120 and a standard deviation of 0.019. The T statistic for this path is 2.362, with $P < 0.05$, indicating a statistically significant effect, though less strong compared to the other two pathways. Overall, these results indicate that GIC significantly contributes to business sustainability via the mediating effects of value creation, green innovation, and resource efficiency.

5 | DISCUSSION AND CONCLUSION

The study underscores the pivotal role of green intellectual capital (GIC) in fostering green innovation (GI), Value creation (VC) and resource efficiency (REF), which all are critical for achieving business sustainability (BS). The path analysis reveals that GIC significantly enhances GI, VC and REF, which in turn positively impact BS. This highlights the indirect yet powerful influence of GIC on sustainability through innovation and efficient resource use. Additionally, the direct contribution of GIC to BS, although smaller, reinforces the importance of intellectual resources in sustainable business practices. GIC enhances environmental performance by equipping firms to implement sustainable practices that reduce environmental impact, comply with regulations, and minimize waste and emissions (Chen, 2008). Additionally, firms with substantial GIC gain a competitive advantage by differentiating themselves through green products and services, thereby catering to a market increasingly conscious of sustainability (Yusoff et al., 2019). Moreover, high levels of GIC can bolster a firm's reputation and build stakeholder trust, translating into long-term sustainability (Del Río et al., 2016).

Green innovation is critical in playing a mediating part between GIC and business sustainability. GI is defined as the development of new products, processes, or practices that reduce environmental impacts; green innovation drives eco-friendly solutions. Firms with robust green intellectual capital (GIC) are more inclined to allocate resources towards research and development that drive green innovations. This proactive investment results in the creation of new products and processes designed to minimize environmental harm. By leveraging their GIC, these companies can develop cutting-edge technologies and implement sustainable practices that not only reduce their ecological footprint but also enhance their competitive advantage in an increasingly eco-conscious market. This commitment to innovation and sustainability fosters long-term business viability and demonstrates a genuine dedication to environmental stewardship (Chang, 2011). This innovation not only meets the demand for sustainable products but also enhances operational efficiency by optimizing resource use, thereby reducing costs and waste, which are direct contributors to business sustainability (Nidumolu et al., 2009). Value creation is another significant mediator in this relationship. Sustainable value creation involves generating economic value while simultaneously creating environmental and social value. Firms with high GIC can design business models that integrate sustainability into their core operations, creating value for both the company and society (Hart & Dowell, 2011). This alignment of stakeholder interests fosters long-term sustainability, as it encourages engagement from customers, employees, suppliers, and communities. Furthermore, sustainable value creation promotes innovation and market differentiation, thereby enhancing a firm’s sustainability credentials (Porter & Kramer, 2011). Resource efficiency also mediates the relationship between GIC and business sustainability by ensuring the optimal use of natural resources, thereby minimizing environmental impact and reducing operational costs. Efficient resource use, including energy, water, and raw materials, directly reduces costs, enhances profitability, and supports sustainability (Dangelico & Pujari, 2010). Additionally, firms with strong GIC can implement practices that minimize waste, contribute to environmental sustainability, and ensure compliance with regulatory standards. Developing sustainable supply chains through resource efficiency reduces the overall environmental footprint, further enhancing business sustainability (Pagell & Wu, 2009).

Hence it can be concluded that the significant effect of green intellectual capital on business sustainability is well-established, with green innovation, value creation, and resource efficiency serving as crucial mediators in this relationship. Firms that effectively leverage their GIC can foster green innovation, create sustainable value, and optimize resource use, all of which contribute to long-term business sustainability. This integrated approach not only improves environmental performance but also provides a competitive edge and builds a sustainable future for the firm and its stakeholders.

6 | THEORETICAL IMPLICATIONS

The findings of this study make a substantial contribution to the existing body of knowledge on green intellectual capital (GIC) and business sustainability. These contributions are firmly grounded in the principles of the natural resource-based theory (NRBT) and the intellectual capital-based view (ICBV). By integrating these theoretical frameworks, the study elucidates how GIC, encompassing the knowledge, skills, and competencies related to environmental management, can drive sustainable business practices. The research highlights the critical role of GIC in fostering green innovation and improving resource efficiency, thereby enhancing overall business sustainability. This comprehensive approach not only enriches the theoretical understanding of GIC and its impact on sustainability but also provides practical insights for businesses aiming to leverage their intellectual capital for long-term environmental and economic benefits. Firstly, the research highlights the crucial role of GIC in driving business sustainability, underscoring the importance of intellectual assets related to environmental management in enhancing a firm's sustainable performance. This extends the resource-based view (RBV) by incorporating environmental dimensions, suggesting that firms with strong GIC can achieve sustained competitive advantage through superior environmental practices (Hart, 1995; Barney, 1991). The natural resource-based theory, which emphasizes that competitive advantage stems from the firm's ability to manage natural resources sustainably, provides a foundation for understanding how GIC contributes to business sustainability. This study extends NRBT by showing how GIC, as a form of intangible resource, can enhance a firm's capability to innovate and utilize resources efficiently, thereby supporting sustainable development (Hart, 1995). The intellectual capital-based view (ICBV) underscores the importance of intellectual capital in creating value and achieving competitive advantage. It identifies three key components: human capital, which includes employees' knowledge and skills; structural capital, which encompasses the organizational infrastructure and processes; and relational capital, which involves relationships with external stakeholders. These elements collectively drive innovation, improve operational efficiency, and foster collaboration, positioning firms to achieve sustained competitive advantage in a dynamic business landscape. This study contributes to the ICBV by demonstrating how GIC, a specialized form of intellectual capital, influences business sustainability through green innovation, value creation, and resource efficiency.

The study elucidates the mediating roles of green innovation, value creation, and resource efficiency in the GIC-sustainability nexus. By demonstrating that green innovation acts as a bridge linking GIC to improved sustainability outcomes, the research supports and extends innovation diffusion theory (Rogers, 2003), which posits that the adoption of innovations can lead to significant organizational benefits. The findings also integrate Porter and Kramer (2011) concept of shared value, showing that value creation through sustainable practices not only benefits the firm but also society at large. Lastly, the study's emphasis on resource efficiency as a mediator adds a new dimension to the discourse on sustainable operations. Mol and Sonnenfeld (2000) also suggested that economic and environmental objectives can be simultaneously achieved through technological advancements and efficient resource utilization.

7 | FUTURE RESEARCH DIRECTIONS

Building on the theoretical implications, several avenues for future research emerge. Firstly, future studies could explore the specific components of GIC—human, structural, and relational capital—individually to determine their distinct impacts on business sustainability. This granularity could provide deeper insights into which aspects of GIC are most influential and how they can be effectively managed and developed. Secondly, longitudinal studies could be directed to examine the effects of GIC on business sustainability. Such studies would help to understand the dynamics of GIC over time and its sustained impact on environmental and financial performance. Thirdly, comparative studies across different industries and geographical regions could offer valuable insights into how the role of GIC and its mediators might vary in different contexts. This could help to identify industry-specific or region-specific strategies for enhancing business sustainability through GIC. Additionally, future research could investigate the role of external factors such as government policies, market conditions, and stakeholder pressures in moderating the relationship between GIC and business sustainability. Understanding these external influences could help firms to better navigate the complexities of sustainability in various regulatory and market environments. Finally, the interplay between digital transformation and GIC presents a promising area for research. As firms increasingly adopt digital technologies, examining how digital tools and platforms can enhance GIC and its impact on sustainability could provide innovative insights into the future of sustainable business practices. In nutshell, this study provides a robust framework for boosting business sustainability with green intellectual capital, mediated by green innovation, value creation, and resource efficiency. Future research should continue to explore these relationships, offering deeper, more nuanced insights that can guide both academic inquiry and practical implementation in the pursuit of sustainable development.

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