

## GREEN INTELLECTUAL CAPITAL AND CARBON PERFORMANCE: THE MODERATING ROLE OF AUDIT QUALITY

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### Abstract:

This study aims to examine the effect of Green Intellectual Capital (GIC) on carbon performance and to investigate the moderating role of audit quality in this relationship. The study employs panel data from firms from 2023 to 2024. The analysis is conducted using a panel data regression approach with a Random Effect Model (REM) and robust standard errors. The results indicate that Green Intellectual Capital does not have a significant effect on carbon performance. Furthermore, audit quality is not found to moderate the relationship between Green Intellectual Capital and carbon performance. These findings suggest that both internal capabilities and external monitoring mechanisms are insufficient to enhance a firm's carbon performance. The implications of this study highlight the need for more substantive environmental practices and stronger regulatory frameworks to improve carbon performance.

**Keywords:** Green Intellectual Capital, Carbon Performance, Audit Quality

## INTRODUCTION

In recent years, growing concerns over climate change and environmental degradation have intensified the pressure on firms to reduce carbon emissions and improve their environmental performance. Carbon performance has become a critical indicator of corporate sustainability, reflecting a firm's ability to manage and mitigate its environmental impact. Stakeholders, including investors, regulators, and the public, increasingly demand transparency and accountability in corporate environmental practices, particularly in relation to carbon emissions (Clarkson et al., 2011; Luo & Tang, 2014).

Within this context, firms are required not only to comply with environmental regulations but also to develop internal capabilities that support sustainable practices. One of the key intangible resources that has gained attention in the sustainability literature is Green Intellectual Capital (GIC). GIC encompasses a firm's knowledge, capabilities, and organizational processes related to environmental management, including green human capital, green structural capital, and green relational capital (Chen, 2007). Drawing on the Resource-Based View (RBV), GIC can be considered a strategic asset that enables firms to achieve superior environmental outcomes, including improved carbon performance (Barney, 1991).

Previous studies have primarily examined the relationship between carbon-related activities and firm performance, often positioning carbon performance as an independent variable (Luo & Tang, 2014; Matsumura et al., 2014). However, limited attention has been given to the role of internal green capabilities, such as GIC, in driving carbon performance itself. It creates a research gap in understanding how firms' internal resources contribute to environmental outcomes, particularly in emerging markets where environmental regulations and enforcement may vary.

Furthermore, the effectiveness of GIC in enhancing carbon performance may depend on the presence of external monitoring mechanisms. In this regard, audit quality plays a crucial role in ensuring the credibility and reliability of corporate disclosure, including environmental information.



High-quality audits can strengthen corporate governance by reducing information asymmetry and enhancing transparency (DeAngelo, 1981). From the perspective of agency theory, audit quality serves as a monitoring mechanism that aligns managerial actions with stakeholders' interests, thereby potentially reinforcing the impact of GIC on carbon performance (Jensen & Meckling, 1976).

Despite its importance, the moderating role of audit quality in the relationship between GIC and carbon performance remains underexplored. Firms with strong green intellectual capital may be more effective in improving their carbon performance when supported by high-quality audit, such as credible auditing, which enhances the legitimacy of environmental initiatives and disclosures. Conversely, low audit quality may weaken this relationship due to reduced stakeholder trust and weaker monitoring.

Therefore, this study aims to examine the effect of Green Intellectual Capital on carbon performance, as well as the moderating role of audit quality in this relationship. By doing so, this research contributes to the literature in several ways. First, it shifts the focus from external environmental outcomes to internal strategic resources as key drivers of carbon performance. Second, it integrates the perspective of RBV and agency theory to provide a more comprehensive understanding of how internal capabilities and external governance mechanisms interact. Third, it provides empirical evidence from an emerging market context, offering insights that are particularly relevant for policymakers and practitioners seeking to enhance corporate sustainability practices.

**Green Intellectual Capital and Carbon Performance.** Green Intellectual Capital (GIC) refers to the stock of knowledge, capabilities, and relationships that enable firms to implement environmentally sustainable practices. It consists of three main components: green human capital, green structural capital, and green relational capital (Chen, 2007). These components collectively support firms in developing environmentally friendly innovations and improving their environmental management systems.

From the perspective of the Resource-Based View (RBV), firms can achieve superior performance by effectively utilizing valuable, rare, inimitable, and non-substitutable resources (Barney, 1991). In this context, GIC represents a strategic intangible resource that enhances a firm's ability to address environmental challenges, including carbon emissions. Firms with strong GIC are more likely to adopt efficient technologies, improve environmental processes, and reduce carbon intensity.

Empirical studies have shown that firms with higher levels of green intellectual capital tend to exhibit better environmental performance and sustainability outcomes (Chen, 2007; Huang & Kung, 2011). GIC enables firms to enhance their environmental strategies and operational efficiency, which ultimately leads to improved carbon performance. Therefore, GIC is expected to have a positive effect on carbon performance.

H1: Green Intellectual Capital positively affects carbon performance

**Audit Quality and Carbon Performance.** Audit quality reflects the ability of auditors to detect and report material misstatement in financial and non-financial disclosure (DeAngelo, 1981). High-quality audits enhance the credibility and reliability of corporate reporting, including environmental and sustainability disclosures. As stakeholders increasingly rely on corporate disclosures to assess environmental and sustainability disclosures. As stakeholders increasingly rely on corporate disclosure to assess environmental performance, audit quality becomes an essential governance mechanism.

From the perspective of agency theory, conflicts of interest between managers and stakeholders can lead to opportunistic behavior and information asymmetry (Jensen & Meckling,

1976). High audit quality reduces these issues by providing independent verification of corporate disclosures, thereby improving transparency and accountability.

Prior studies suggest that firms audited by high-quality auditors, such as Big Four firms, tend to exhibit higher levels of disclosure quality and more credible sustainability reporting (Francis et al., 2004). It implies that audit quality may also influence how accurately firms report their carbon performance and implement environmental practices.

**The Moderating Role of Audit Quality.** While Green Intellectual Capital provides internal capabilities for improving carbon performance, the effectiveness of these capabilities may depend on external monitoring mechanisms such as audit quality. Audit quality can strengthen the relationship between GIC and carbon performance by ensuring that environmental practices and disclosures are properly implemented and reported.

Firms with high GIC may possess the necessary knowledge and systems to manage carbon emissions effectively. However, without strong audit quality, these practices may not be fully disclosed or may lack credibility in the eyes of stakeholders. High-quality audits enhance the transparency of environmental information, thereby increasing stakeholder trust and reinforcing the positive impact of GIC on carbon performance.

Conversely, low audit quality may weaken relationships, as inadequate monitoring reduces the reliability of environmental disclosures and allows managerial opportunism to persist. Therefore, audit quality is expected to play a moderating role in the relationship between GIC and carbon performance.

H2: Audit quality strengthens the positive relationship between Green Intellectual Capital and carbon performance

## METHODS

**Research Design.** This study employs a quantitative research design to examine the effect of Green Intellectual Capital (GIC) on carbon performance, as well as the moderating role of audit quality. The analysis is conducted using panel data regression, following prior studies on environmental performance and corporate governance.

The population of this study consists of publicly listed companies. The sample is selected using purposive sampling based on the availability of sustainability reports, annual reports, and carbon-related disclosures during the observation period. Firms with incomplete data are excluded from the final sample.

**Population and Research Sample.** Population analysis refers to the companies listed in the ESG Quality 45 IDX KEHATI Index.

The sampling used a purposive method with several criteria, namely:

1. Inclusion in the IDX KEHATI ESG Quality 45 index in 2023-2024.
2. The measurement data needed for the research were available.

**Table 1.** Variable Measurement

<i>Variables</i>	<i>Measurement</i>	<i>References</i>
<i>Carbon Performance</i> GHGP	Actual GHG emissions performance, measured by the natural logarithm of total actual GHG emissions in tonnes	(Adu et al., 2023)
<i>Green Intellectual Capital</i> GIC	$GIC = \frac{\sum_{t=1}^{n_j} X_{i,j}}{n_j}$	(Ferri et al., 2025)



Where  $n$  is the total number of items and  $X$  is a dummy variable, which codes 1 or 0, according to the presence or absence of the selected item. (The dummy variable assessment criteria can be seen in Table 3.6)

Audit quality reflects the credibility and reliability of corporate reporting. In line with prior literature, audit quality is measured using a dummy variable, where firms audited by Big Four audit firms are assigned a value of 1 and 0 otherwise. (DeAngelo, 1981; Francis et al., 2004)

Control Variable		
<i>Company Performance</i>	Percentage of operating profit to total assets (ROA)	(Adu et al., 2023)
<i>Company size FSIZE</i>	Natural logarithm of the company's total assets	(Adu et al., 2023)
<i>Leverage LEV</i>	Total debt to total assets ratio	(Adu et al., 2023)

**Table 2.** GIC Analysis Content Criteria

Items	Description
G_SC_1	Code of Ethics
G_SC_2	Materiality matrix
G_SC_3	Environmental mission
G_SC_4	Environmental vision
G_SC_5	Sustainability committee
G_SC_6	Environmental culture
G_SC_7	Environmental data sets
G_SC_8	Environmental investment
G_SC_9	Environmental protection technology
G_SC_10	Environmental protection rules
G_SC_11	Management system for environmental protection
G_SC_12	Reward system for completing environmental tasks
G_SC_13	R&D in environmental protection
G_SC_14	Sharing knowledge about environmental management
G_HC_1	Number of employees involved in environmental protection
G_HC_2	Environmental competencies/skills
G_HC_3	Employees are qualified in environmental/sustainability issues.
G_HC_4	Employee collaboration on environment/sustainability
G_HC_5	Employee training in environmental activities
G_HC_6	Sustainability manager
G_HC_7	Sustainability function
G_RC_1	Customer satisfaction in environmental protection
G_RC_2	Sustainable supply chain
G_RC_3	Environmental cooperation with strategic partners
G_RC_4	Environmental performance control
G_RC_5	Green brands and reputation



G_RC_6	Stakeholders and environment/sustainability
G_RC_7	Corporate awards for environment/sustainability
G_RC_8	Sustainability reporting

This research was performed by checking the content analysis items conducted by several other parties, and the model included the following.

$$CP = \beta_0 + \beta_1 GIC + \beta_2 AQ + \beta_3 (GIC \times AQ) + \beta_4 ROA + \beta_5 SIZE + \beta_6 LEV + \varepsilon$$

Where:

- CP: Carbon Performance
- GIC: Green Intellectual Capital
- AQ: Audit Quality
- GIC x AQ: Interaction term
- ROA, SIZE, LEV: Control Variable
- ε: Error

## RESULTS AND DISCUSSION

### Population and Sample.

**Table 3.** Population and Sample

No	Sample Criteria	Number of Samples
1	The company was consecutively included in the IDX KEHATI ESG Quality 45 index in 2023-2024.	34
2	The measurement data needed for the research were available	0
<b>Total Company</b>		<b>34</b>
<b>Total Sample (Number of Companies x 2 years)</b>		<b>68</b>

### Descriptive Statistics.

**Table 4.** Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GHGP	68	5.68	1.40	2.74	10.66
GIC	68	0.97	0.04	0.79	1
AQ	68	0.80	0.40	0	1
ROA	68	0.32	1.90	-0.00	15.74
SIZE	68	18.69	4.00	12.57	30.93
LEVERAGE	68	0.68	1.14	0.00	6.84

The Hausman test result shows a probability value of 0.8013, which is greater than 0.05, indicating that the random effect model is more appropriate than the fixed effect model. Therefore, this study employs the random effect model for hypothesis testing.

**Table 5.** Results of Hypothesis I Testing

Variables	Sample Period 2023-2024	
	GHGP	
	Coef	VIF



	<b>(t-value)</b>	
(constant)	7.20 (3.70)	
GIC	-2.85 (-1.45)	1.08
SIZE	0.06 (0.99)	1.09
LEVERAGE	0.1503* (1.90)	1.90
ROA	(0.0061)** (2.34)	1.84
N	68	
Prob > F	0.0002	
R-squared (within)	0.0421	

\* , \*\* , \*\*\* significance at 10%, 5%, and 1% levels.

Multicollinearity was initially detected, particularly in the interaction term, with VIF values exceeding the acceptable threshold. To address this issue, mean-centering was applied to the independent and moderating variables before constructing the interaction term. After transformation, all VIF values fell below 10 (mean VIF =1.38), indicating that multicollinearity is no longer a concern.

**Table 6.** Results of Hypothesis II Testing

<b>Variables</b>	<b>Sample Period 2023-2024</b>	
	<b>GHGP</b>	
	<b>Coef</b>	<b>VIF</b>
(constant)	6.69 (2.02)	
GIC	-2.3141 (-0.70)	1.08
AQ	0.62 (0.15)	1.21
GIC*AQ	-0.6531 (-0.17)	1.16
SIZE	0.06 (1.00)	1.09
LEVERAGE	0.1506* (1.90)	1.90
ROA	0.0062** (2.16)	1.84
N	68	
Prob > F	0.0000	
R-squared (within)	0.0427	

\* , \*\* , \*\*\* significance at 10%, 5%, and 1% levels.

**Direct Effect of Green Intellectual Capital on Carbon Performance (H1).** The first hypothesis (H1) examines the effect of Green Intellectual Capital (GIC) on carbon performance (GHGP). The

regression results show that the coefficient of GIC is -2.8515 with a p-value of 0.146, indicating that the relationship is not statistically significant.

This finding suggests that Green Intellectual Capital does not have a significant impact on carbon performance. Although GIC represents a firm's internal capability in managing environmental knowledge and practices, it does not necessarily translate into measurable improvements in carbon emission performance.

One possible explanation is that the implementation of GIC within firms may still be limited to symbolic actions or disclosures rather than substantive environmental practices. Additionally, firms may lack the necessary technological or financial resources to convert green knowledge into effective carbon reduction strategies.

**Moderating Effect of Audit Quality (H2).** The second hypothesis (H2) investigates whether Audit Quality moderates the relationship between Green Intellectual Capital and carbon performance. The regression results show that the interaction term between GIC and Audit Quality (GIC \* AQ) has a coefficient of -0.6531 with a p-value of 0.869, indicating that the moderating effect is not statistically significant.

This result indicates that Audit Quality does not strengthen or weaken the relationship between Green Intellectual Capital and carbon performance. In other words, the presence of high-quality auditors does not enhance the effectiveness of GIC in improving environmental outcomes.

The findings of this study indicate that Green Intellectual Capital (GIC) does not have a significant effect on carbon performance, and audit quality does not moderate this relationship. These results provide important insights into the limitations of both internal and external mechanisms in improving environmental performance.

From the perspective of the Resource-Based View (RBV), firms are expected to leverage intangible resources such as knowledge, capabilities, and organizational processes to achieve superior performance (Barney, 1991). In the context of environmental management, Green Intellectual Capital is considered a strategic asset that can enhance sustainability outcomes (Chen, 2007). However, the insignificant relationship found in this study suggests that the existence of green intellectual resources alone is not sufficient to improve carbon performance without effective implementation (Yusoff et al., 2019).

Furthermore, the results show that audit quality does not moderate the relationship between GIC and carbon performance. According to agency theory, high-quality audits are expected to reduce information asymmetry and enhance transparency (Jensen & Meckling, 1976). However, in practice, external audits tend to focus primarily on financial reporting rather than environmental disclosure (DeFond & Zhang, 2014). As a result, even firms audited by high-quality auditors may not experience improved environmental accountability.

This finding aligns with previous research suggesting that audit quality has a limited role in influencing non-financial performance, particularly environmental outcomes (Simnett et al., 2009). It also indicates that carbon performance may be strongly influenced by external pressures such as regulatory enforcement, stakeholder demand, and industry standards rather than internal intellectual capital or audit mechanisms (Clarkson et al., 2011).

Overall, the results suggest that both internal capabilities (GIC) and external governance mechanisms (audit quality) are not sufficient to drive improvements in carbon performance. It highlights the importance of stronger institutional and regulatory frameworks in encouraging firms to adopt substantive environmental practices.

## CONCLUSION

This study examines the effect of Green Intellectual Capital on carbon performance and the moderating role of audit quality. The empirical results show that Green Intellectual Capital does not have a significant impact on carbon performance. Additionally, audit quality is found to have no moderating effect on the relationship between GIC and carbon performance.

These findings indicate that neither internal green capabilities nor external audit mechanisms are sufficient to improve a firm's carbon performance. Therefore, the study concludes that other factors, particularly external pressures and regulatory frameworks, may play a more dominant role in shaping environmental performance.

This study extends the Resource-Based View and agency theory by showing that Green Intellectual Capital and audit quality do not necessarily influence carbon performance, highlighting the limitations of both internal resources and external governance in environmental contexts. Firms should focus on the effective implementation of green practices rather than relying solely on knowledge and audits. Regulators are encouraged to strengthen environmental policies to improve corporate carbon performance. Future studies are recommended to use larger samples and longer observation periods to improve generalizability. Additionally, future research may incorporate other moderating variables, such as environmental regulation or corporate governance, and explore alternative measurements of Green Intellectual Capital and carbon performance.

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