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The Effects of IoT on Sustainable Logistics Management Practices and Sustainability Performance in the Manufacturing Sector: A Comparative Study of Ghana and Indonesia

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Abstract

This study examines the impact of sustainable logistics practices—green transportation, waste management, energy efficiency, and sustainable packaging—on sustainability performance in the manufacturing sectors of Ghana and Indonesia, with a focus on the moderating role of Internet of Things (IoT) development. The research highlights the importance of both internal resources and external factors in achieving sustainability goals. Using a quantitative approach and a descriptive survey design, data were collected from 374 manufacturing firms in Ghana and 379 in Indonesia. The study employed a structured questionnaire and applied Ordinary Least Squares (OLS) regression to analyze the relationship between sustainable logistics practices, IoT growth, and sustainability performance. Sustainable logistics practices positively influence sustainability performance, with IoT moderating this relationship. Firms in Indonesia demonstrated higher performance due to advanced IoT infrastructure, while Ghana showed limitations due to less developed technological infrastructure. The findings emphasize the need for investment in IoT infrastructure to enhance the effectiveness of sustainable logistics practices, particularly in developing countries. The study contributes new insights into the moderating role of IoT in sustainability and offers practical guidance for policymakers and businesses. This study provides a novel cross-country perspective on how IoT development influences the effectiveness of sustainable logistics practices in emerging economies, bridging gaps in the existing literature on technology-driven sustainability strategies.

Keywords: Sustainable logistics; IoT; sustainability performance; manufacturing sector; cross-country analysis.

Abstrak

Penelitian ini mengkaji dampak praktik logistik berkelanjutan—transportasi ramah lingkungan, manajemen limbah, efisiensi energi, dan kemasan berkelanjutan—terhadap kinerja keberlanjutan di sektor manufaktur di Ghana dan Indonesia, dengan fokus pada peran moderasi perkembangan Internet of Things (IoT). Penelitian ini menyoroti pentingnya sumber daya internal dan faktor eksternal dalam mencapai tujuan keberlanjutan. Dengan pendekatan kuantitatif dan desain survei deskriptif, data dikumpulkan dari 374 perusahaan manufaktur di Ghana dan 379 di Indonesia. Penelitian menggunakan kuesioner terstruktur dan analisis regresi Ordinary Least Squares (OLS) untuk menganalisis hubungan antara praktik logistik berkelanjutan, perkembangan IoT, dan kinerja keberlanjutan. Praktik logistik berkelanjutan berpengaruh positif terhadap kinerja keberlanjutan, dengan IoT memoderasi hubungan ini. Perusahaan di Indonesia menunjukkan kinerja lebih tinggi karena infrastruktur IoT yang lebih maju, sementara Ghana menunjukkan keterbatasan akibat infrastruktur teknologi yang kurang berkembang. Temuan ini menekankan perlunya investasi dalam infrastruktur IoT untuk meningkatkan efektivitas praktik logistik berkelanjutan, terutama di negara berkembang. Studi ini memberikan wawasan baru tentang peran moderasi IoT dalam keberlanjutan dan menawarkan panduan praktis bagi pembuat kebijakan dan pelaku bisnis. Penelitian ini memberikan perspektif baru lintas negara tentang bagaimana perkembangan IoT memengaruhi efektivitas praktik logistik berkelanjutan di ekonomi berkembang, mengisi kesenjangan dalam literatur tentang strategi keberlanjutan berbasis teknologi.

Kata Kunci: Logistik berkelanjutan; IoT; kinerja keberlanjutan; sektor manufaktur; analisis lintas negara..

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INTRODUCTION

The global manufacturing sector is increasingly under scrutiny owing to its substantial environmental impact, which is characterized by significant carbon emissions, resource depletion, and waste generation. This sector is responsible for approximately 19% of global carbon emissions, making it one of the largest contributors to climate change. In addition, the manufacturing industry is a major consumer of natural resources, leading to widespread environmental degradation (Crook, Ketchen Jr, Combs, & Todd, 2008). The issue of waste generation is equally concerning as manufacturing processes produce vast quantities of hazardous waste, which poses severe risks to both the environment and human health (McKinnon, Browne, Whiteing, & Piecyk, 2015; Messerli et al., 2019; Trivellas, Malindretos, & Reklitis, 2020). These challenges underscore the urgent need for the manufacturing industry to adopt sustainable practices to mitigate these adverse effects and contribute to broader sustainability goals.

Sustainable logistics practices have emerged as a pivotal strategy for addressing these environmental challenges. These practices encompass a range of measures designed to reduce the environmental footprint of logistics operations, including the adoption of eco-friendly transportation methods (Comi, Schiraldi, & Buttarazzi, 2018), effective waste management, energy efficiency, and sustainable packaging materials. Each of these practices offers specific benefits: sustainable transportation reduces greenhouse gas emissions; waste management minimizes the environmental impact of production processes; energy efficiency lowers resource consumption; and sustainable packaging reduces the environmental burden of packaging waste (De Souza et al., 2018; Lieder & Rashid, 2016; Marrucci, Marchi, & Daddi, 2020; Trianni, Cagno, & Worrell, 2013).

Despite the growing body of literature on sustainable logistics, much of the existing research has focused on the individual impact of these practices on sustainability performance. For example, studies have examined how sustainable transportation, waste management, and energy efficiency independently contribute to sustainability outcomes (Azevedo, Carvalho, & Machado, 2011; Boiral, Baron, & Gunnlaugson, 2014; Gupta & Gupta, 2020), there is a notable gap in the research that considers the collective influence of these practices within the manufacturing sector. This gap is particularly significant given that the combined implementation of multiple sustainable logistics practices may yield synergistic effects that are not captured when these practices are studied in isolation (Dharmayanti, Ismail, Hanifah, & Taqi, 2023; Setyaningsih, Indarti, & Jie, 2018; Woon et al., 2023)

This study aims to fill this research gap by examining the combined effect of sustainable logistics practices on sustainability performance within Ghana and Indonesia's manufacturing sectors. These countries were selected for their distinctive geographic locations, diverse economic and environmental conditions, and substantial industrial sectors, all presenting unique opportunities and challenges for achieving sustainable development. The manufacturing sectors in both Ghana and Indonesia are critical to their economies; however, they are also significant contributors to environmental degradation. Understanding how sustainable logistics practices can enhance sustainability performance in these contexts is important both academically and practically (Antoni, Jie, & Abareshi, 2020; Borgert, Donovan, Topple, & Masli, 2020; Bruce et al., 2023).

To explore the impact of sustainable logistics practices on sustainability performance, this study draws on two key theoretical frameworks: the Resource-Based View (RBV) and Institutional Theory. The RBV, as articulated by Barney (1991), posits that a firm's unique resources that are valuable, rare, inimitable, and non-substitutable (VRIN) are central to achieving sustainable competitive advantage. This perspective is particularly pertinent in the context of sustainable logistics practices, which can be viewed as strategic resources to enhance a firm's sustainability performance. For instance, the adoption of eco-

friendly transportation, effective waste management, energy-efficient technologies, and sustainable packaging can provide firms with a competitive edge by reducing environmental impacts and improving resource efficiency (Akram, Chen, Khalid, Ye, & Majeed, 2020; Moore & Manring, 2009; Srivastava, Fahey, & Christensen, 2001). Simultaneously, Institutional Theory, as formulated by DiMaggio & Powell (1983), and further developed by Verbeke & Tung (2013), emphasizes the role of social norms, regulatory frameworks, and institutional pressures in shaping organizational behavior. In the context of this study, the adoption of sustainable logistics practices can be seen as a response to institutional pressures such as regulatory demands for environmental compliance and societal expectations for corporate responsibility. For example, firms may adopt sustainable practices not only to comply with environmental regulations but also to enhance their legitimacy and reputation within their industries (Kshetri, 2017; Searcy & Buslovich, 2014).

Given these theoretical foundations, this study hypothesizes that the integration of sustainable logistics practices positively influences sustainability performance in manufacturing firms. Furthermore, it posits that a country's level of IoT development moderates this relationship. The Internet of Things (IoT) has the potential to significantly enhance the effectiveness of sustainable logistics practices by enabling better data collection, real-time monitoring, and efficient resource management (Bachim, Martens, Gonçalves, Bizarrias, & Machado, 2023; Ehie & Chilton, 2020). Firms in countries with more advanced IoT infrastructure, such as Indonesia, are anticipated to experience greater benefits from sustainable logistics practices than those in countries with less developed IoT infrastructure, such as Ghana. This is because IoT capabilities can facilitate a more efficient and effective implementation of these practices, thereby amplifying their impact on sustainability performance (El-Aziz, El-Gamal, & Ismail, 2020; Nižetić, Šolić, Gonzalez-De, & Patrono, 2020). This study contributes to the literature by providing empirical evidence on the interaction between sustainable logistics practices, IoT growth, and sustainability performance in the manufacturing sector. By examining Ghana and Indonesia, this study offers valuable insights into how different levels of IoT development influence the effectiveness of sustainable logistics practices (Deng & Yang, 2015). These findings are expected to have significant implications for policymakers, business strategists, and researchers striving to enhance sustainability within manufacturing industries globally. Specifically, this study highlights the importance of integrating advanced digital technologies with sustainable logistics practices to achieve superior sustainability outcomes in the manufacturing sector (Kilay, Simamora, & Putra, 2022; Kshetri, 2017; Lee, 2019)Thus, the adoption of sustainable logistics practices supported by a robust IoT infrastructure holds great promise for improving sustainability performance in the manufacturing sector. As the global manufacturing industry continues to grapple with its environmental impact, this study underscores the need for comprehensive strategies that combine multiple sustainable practices and leverage digital technologies. The insights gained from this research will be instrumental in guiding future efforts to promote environmental sustainability in the manufacturing sector, particularly in emerging economies, such as Ghana and Indonesia.

RESEARCH METHOD

Within a positivist framework, the study used a quantitative technique and a descriptive survey design. The study examines how the development of IoT affects sustainability performance by moderating the effects of sustainable transportation, waste management, energy efficiency, and sustainable packaging. Sustainability performance is the study's dependent variable, and the IoT growth status across national boundaries is its moderating variable. Sustainable transportation, waste management, energy efficiency,

and sustainable packaging are the independent factors. To measure the variables, a questionnaire based on established instruments from previous research was developed (Creswell & Creswell, 2020).

The study focuses on four key sectors within the manufacturing industry: food and drinks, textiles, chemicals and pharmaceuticals, and electrical and electronics. These sectors were chosen due to their significant environmental impact and potential for substantial improvements through the adoption of sustainable logistics practices. For example, the food and drinks industry is a major contributor to waste generation, particularly in packaging and food waste. The textile industry is known for its intensive resource use and environmental pollution, especially in water usage and chemical discharge. The chemicals and pharmaceuticals sector presents unique challenges in hazardous waste management and energy consumption. Lastly, the electrical and electronics industry is characterized by complex supply chains and substantial electronic waste, making sustainable logistics practices crucial for reducing its environmental footprint. By focusing on these sectors, the study aims to provide insights into industries that are both high-impact in terms of sustainability and ripe for transformation through enhanced logistics practices.

The following metrics were employed for each variable: *Sustainable Transportation:* Using a 7-point Likert scale (strongly disagree=1 to strongly agree =7), the level of agreement or disagreement with statements regarding sustainable transportation practices was measured. For instance, respondents were asked to indicate their level of agreement with the statement, "The manufacturing firm uses eco-friendly vehicles and modes of transportation in its logistics operations." *Waste Management* practices were measured by determining whether respondents agreed or disagreed with statements about refuse reduction and recycling initiatives. Utilizing the Likert scale, respondents' opinions on refuse management practices were measured. The *Energy Efficiency* questionnaire included statements about energy conservation measures, the adoption of renewable energy, and energy-efficient technologies. On a Likert scale, respondents were asked to indicate their level of agreement or disagreement with these statements.

Sustainable Packaging statements evaluate the use of eco-friendly packaging materials, packaging waste reduction strategies, and sustainable packaging design were used to determine the extent of sustainable packaging practices. On a Likert scale, respondents indicated their agreement or disagreement with these statements.

The study used a 7-point Likert scale to assess the extent of sustainable logistics practices in manufacturing firms. This scale allowed for more nuanced responses and better captures subtle differences in respondent attitudes and perceptions, compared to a 5-point scale. A pilot study with 20 participants from Ghana and Indonesia was conducted to ensure the validity and reliability of the research tools. The study's sampling frame was obtained from the Ghana Investment Promotion Centre (GIPC) and the Indonesia Investment Coordinating Board (BKPM), which supplied a comprehensive inventory of all registered manufacturing firms in Ghana and Indonesia, respectively The manufacturing sector was divided into five areas namely, food and drinks, textiles, chemicals and pharmaceuticals, electrical and electronics based on their significant environmental impact and potential for improvements through sustainable logistics practices. The sample size was determined using a 95% confidence level, a 50% anticipated prevalence rate, and a 5% error margin. A minimum sample size of 385 manufacturing companies was needed for each nation, with 424 businesses in each country making up a 10% larger sample size. Respondents were selected based on their roles within the firms, focusing on individuals from logistics departments, supply chain management, and senior management. The study included manufacturing businesses that had used sustainable logistics management techniques and had been in business for at least two years. Businesses that had not adopted sustainable logistical methods, those that

had only been in business for a short time, and those who declined to join were excluded. The final questionnaire was deemed to have good validity and reliability.

The investigation was conducted with strict adherence to ethical considerations. Anonymity, data confidentiality, and informed consent were strictly adhered to. The study's objectives and the rights granted to them as research subjects were explained to the participants. The time frame for gathering data in every nation was from January 1, 2024, until May 10, 2024. The questionnaires were sent to the manufacturing companies via Google Forms. The management of the selected companies was contacted, and the task of filling out the questionnaire was given to a designated respondent. The URL to the Google form was provided to the respondent's WhatsApp and the firm's email. Respondents were carefully selected to ensure they had sufficient knowledge of the firm's logistics and sustainability practices. Reminders were given to non-respondents during the data collection process to maximize the response rate and boost participation. Challenges were encountered during the data collection process, particularly in reaching the appropriate respondents and ensuring quality responses. To address this, multiple reminders were sent, and direct contact was made with designated personnel within each firm. Additionally, potential low response rates were mitigated by increasing the sample size and over-sampling certain sectors to ensure robust data collection.

A total of 374 responses were obtained from manufacturing firms in Ghana, and 379 responses were received from manufacturing companies in Indonesia. This means that the response rates for Ghana and Indonesia are 88% and 89% respectively. To handle and evaluate the collected data, statistical software such as SPSS (Statistical Package for the Social Sciences) was used. To prepare the data for analysis, they were organized, cleaned, and coded. The data were meticulously cleaned, with checks for completeness and consistency. Missing data were addressed using pairwise deletion to preserve the sample size without compromising the analysis. Outliers were examined for their impact, and decisions were made on their inclusion or exclusion based on their effects on the overall analysis**.** Descriptive statistics, such as means and frequencies, were used to summarize the data. OLS regression was selected for analysis due to its simplicity and effectiveness in estimating relationships between continuous variables. OLS regression provides straightforward, interpretable coefficients, making it well-suited for examining the impact of sustainable logistics practices and IoT growth on sustainability performance. This approach was preferred over other potential models, such as logistic regression or structural equation modeling, due to its suitability for the study's objectives and data characteristics.

The OLS (Ordinary Least Squares) model used in this study examines the relationship between sustainable logistics practices, the country's IoT growth, and sustainability performance in the manufacturing sector. The model is specified as follows:

$$SP = \beta_0 + \beta_1 GT + \beta_2 WM + \beta_3 EE + \beta_4 SUP + \beta_5 IoT + \beta_6(GT \times IoT) + \beta_7(WM \times IoT) + \beta_8(EE \times CT) + \beta_9(SUP \times IoT) + \varepsilon$$

In this model, the coefficients ($\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9$) represent the effects of the respective variables on sustainability performance. The interaction terms (GT × IoT, WM × IoT, EE × IoT, SUP × IoT) capture the combined effects of each sustainable logistics practice and IoT growth. The error term (ε) represents the unobserved factors that influence sustainability performance but are not explicitly included in the model.

RESULTS AND DISCUSSION

The empirical evidence indicates that in Ghana, a considerable fraction of manufacturing enterprises (49.5%) is categorized as small, followed by medium-sized enterprises (44.4%), whereas a minor proportion (6.1%) is constituted by large enterprises. The business landscape in Indonesia is characterized by a notable prevalence of medium-sized firms, which account for 50.4% of the total number of businesses. In contrast, the proportion of small firms is comparatively lower, standing at 21.9%. Additionally, a relatively larger percentage of firms in Indonesia are classified as large, comprising 27.7% of the total. The data indicates that the manufacturing industry in Ghana is primarily comprised of small and medium-sized enterprises, whereas in Indonesia, there is a more equitable allocation of firms across all size categories. Upon analyzing the distribution of manufacturing enterprises across various industries in Ghana, it is evident that the textile sector commands the highest proportion (42.5%), trailed by electrical and electronics (21.9%) and food and beverage (22.7%). The largest industry sector in Indonesia is electrical and electronics, accounting for 25.9% of the distribution, followed by food and beverage at 24.8%, and automotive at 11.6%. The observed differences in the industry composition can be attributed to the distinct economic structures and patterns of specialization that prevail in the respective countries. Upon examination of the annual revenue, it has been noted that a significant proportion of manufacturing enterprises in Ghana (89.0%) generate revenue within the range of $1 million to $10 million (equivalent to 10.85 to 108.5 million Ghana Cedi). A minor proportion of the sample (2.1%) exhibits a revenue below $1 million (equivalent to 10.85 million Ghana Cedi), whereas a larger fraction (8.9%) demonstrates a revenue exceeding $10 million (equivalent to 108.5 million Ghana Cedi). In Indonesia, a comparable trend is discernible, wherein a noteworthy percentage of enterprises (70.2%) are categorized within the revenue bracket of $1 million to $10 million (14.883 to 148.83 billion Indonesian rupiah), while 5.8% of firms generate revenue less than $1 million (14.883 billion Indonesian rupiah), and 24.0% of enterprises generate revenue exceeding $10 million (148.83 billion Indonesian rupiah).

Table 1. Demographic Profile of Manufacturing Firms

		Ghana	Indonesia
		%	%
Company Size	Small	49.5	21.9
	Medium	44.4	50.4
	Large	6.1	27.7
Industry	Automotive	8.3	11.6
	Electrical and Electronics	21.9	25.9
	Textile	42.5	20.8
	Food and Beverage	22.7	24.8
	Chemical	2.9	13.7
	Pharmaceuticals	1.6	3.2
Annual Revenue	Less than $1 million	2.1	5.8
	$1 million - $10 million	89.0	70.2
	Above $10 million	8.9	24.0
Years in Operation	Less than 5 years	2.1	9.8
	5-10 years	74.3	2.9

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More than 10 years	23.6	87.3
Ghana (N = 374); Indonesia (N= 379)		

Source: Authors' computation

Table 1 represents the demographic profile of manufacturing firms in Ghana and Indonesia. Regarding the years of operation for manufacturing firms, it is apparent that in Ghana, a comparatively small proportion (2.1%) of firms has been operational for less than 5 years. A notable proportion of the entities under consideration (74.3%) have been in operation for 5-10 years, while a significant subset (23.6%) has been operational for a period exceeding 10 years. In Indonesia, a greater proportion (9.8%) of enterprises exhibit a shorter operational tenure of less than five years, whereas a smaller proportion (2.9%) falls within the 5–10-year category. A significant proportion of enterprises (87.3%) in Indonesia have been in operation for a period exceeding a decade.

To encapsulate, the demographic profile of manufacturing firms in Ghana and Indonesia provides insight into important characteristics including company size, industry-specific distribution, annual revenue, and years of operation. The previously described observations provide a foundation for further analysis and understanding of the relationship between sustainable logistics strategies, sustainability outcomes, and the moderating impact of IoT growth in these environments.

Reliability Analysis

Table 2. Reliability Analysis

	Ghana		Indonesia
Constructs	No. of Items	Cronbach's Alpha	Cronbach's Alpha
SP	4	0.870	0.852
IoT	4	0.946	0.901
GT	3	0.927	0.910
WM	3	0.889	0.908
EE	3	0.730	0.808
SUP	3	0.847	0.888

SP: Sustainability performance. IoT: Internet of Things growth. GT: Sustainable transportation.

WM: Waste management. EE: Energy efficiency. SUP: Sustainable packaging.

Source: Authors' computation.

Descriptive statistics

Table 2 shows the reliability analysis indicates that the measurement scales used to evaluate the constructs in the study have high internal consistency, indicating that the items within each construct are reliable measures of the intended concepts. These results assure the reliability and validity of the data obtained for the study in Ghana and Indonesia.

Table 3. Descriptive Statistics

Ghana

	N	Min	Max	Mean	SD	Skewness		Kurtosis	
						Stat	Std. Err	Stat	Std. Err
SP	374	1	7	5.255	1.308	-1.498	.126	2.013	.252
IoT	374	1	7	5.104	1.442	-1.315	.126	.844	.252
GT	374	1	7	4.974	1.383	-1.586	.126	1.860	.252
WM	374	1	7	4.750	1.406	-1.265	.126	1.183	.252
EE	374	3	7	5.496	.684	-.771	.126	.411	.252
SUP	374	2	7	5.471	1.004	-1.222	.126	1.374	.252

Indonesia

	N	Min	Max	Mean	SD	Skewness		Kurtosis	
						Stat	Std. Err	Stat	Std. Err
SP	379	2	7	5.513	1.180	-1.370	.125	1.204	.250
IoT	379	1	7	5.286	1.292	-1.485	.125	1.621	.250
GT	379	1	7	4.999	1.521	-1.208	.125	.645	.250
WM	379	1	6	5.092	1.376	-1.452	.125	1.499	.250
EE	379	1	6	4.792	1.455	-1.387	.125	1.138	.250
SUP	379	1	7	4.996	1.236	-1.284	.125	1.704	.250

SP: Sustainability performance. IoT: Internet of Things growth. GT: Sustainable transportation. WM: Waste management. EE: Energy efficiency. SUP: Sustainable packaging.

Source: Authors' computation.

As presented in Table 3, the construct of sustainability performance, it is evident that the scores in Ghana range from a minimum of 1 to a maximum of 7, whereas in Indonesia, the scores range from a minimum of 2 to a maximum of 7. This implies that the spectrum of sustainability performance scores is marginally broader in Ghana. The data suggest that the mean score for sustainability performance among manufacturing firms in Ghana (5.255) is marginally lower in comparison to Indonesia (5.513). This implies

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that, on average, manufacturing firms in Indonesia exhibit a slightly superior level of sustainability performance. The statistical measure of variability, namely the standard deviation, in Ghana (1.308) is marginally lower than that of Indonesia (1.180). This implies that the degree of scatter of responses in Ghana is comparatively lesser than that of Indonesia.

In terms of distribution characteristics, it can be observed that both Ghana and Indonesia demonstrate negatively skewed distributions across all constructs. This suggests that a significant proportion of manufacturing firms in these countries tend to exhibit higher scores for sustainability performance, IoT growth status, sustainable transportation, waste management, energy efficiency, and sustainable packaging. The degree of skewness, albeit marginally, differs between the two nations, with Ghana exhibiting a relatively more prominent negative skewness. Furthermore, the kurtosis values offer insights regarding the form of the distribution. The constructs in Ghana tend to display positive kurtosis, which suggests that their distributions possess heavier tails and greater peaks in comparison to a normal distribution. Conversely, within the context of Indonesia, the kurtosis values exhibit a predominantly positive trend, albeit marginally lower than those observed in Ghana. This implies that the distributions in Indonesia are marginally less peaked. The analysis of descriptive statistics indicates that there are resemblances in the data patterns observed in both Ghana and Indonesia. The mean scores and distributions for each construct are similar in both countries, albeit with slight variations in the score range and the degree of skewness and kurtosis. These discoveries offer preliminary perspectives concerning the sustainability performance and other constructs of manufacturing enterprises in the setting of Ghana and Indonesia.

Regression analysis

The findings of the OLS regression for sustainable logistics practices and sustainability performance are presented in Table 4. It displays diagnostic such as R^2, adjusted R^2, and F statistics for each regression model. The R-squared values represent the proportion of the variance in sustainability performance that is explained by the model, while the F-statistics indicate the significance of the model. The findings shown in Table 4, are displayed Ghana on the left-hand side, and Indonesia results are presented on the right-hand side of Table 4.

The discussion of the findings as shown in Table 4 is done on two levels. The first discussion was done without interaction consideration, and the second was with interaction using conditional and unconditional effects. The net effect for sustainable transportation, for example, was calculated as: 1.204[(-0.059×5.104)] + [(0.056)], the condensational effect is the interaction between IoT growth and sustainable transportation (-0.059), the mean value of the interaction term IoT growth is (5.104) and the unconditional effect of sustainable transportation is (1.056). The findings displayed in Table 4 revealed the following:

The Impact of Sustainable Logistics Practices on Sustainability Performance

The regression analysis findings indicate that the implementation of sustainable transportation strategies, such as the use of environmentally friendly cars and effective route planning, significantly enhances the sustainability performance of industrial companies in both Ghana and Indonesia. These results corroborate Hypothesis 1, which posits that the implementation of sustainable transportation techniques has a beneficial effect on sustainability performance. In Ghana, companies that adopted these strategies experienced significant decreases in carbon emissions, in line with the Resource-Based View (RBV) theory. This theory posits that these strategies are valuable, rare, difficult to imitate, and

irreplaceable resources that enhance a company's competitive advantage (Barney 1991). In Indonesia, the relatively greater impact observed can be attributed to the country's more advanced infrastructure and better access to advanced transportation technologies, which aligns with Institutional Theory's focus on the influence of external factors, such as regulatory frameworks and technological advancements (DiMaggio & Powell, 1983). The variations in the effects between the two nations may be impacted by demographic distribution, particularly the size of the firms. Larger Indonesian companies possess better financial means to allocate to sophisticated transportation technology, thereby attaining enhanced sustainability advantages (Yildiz Çankaya & Sezen, 2019). Additionally, the implementation of national regulations that promote environment-friendly transportation in Indonesia has the potential to substantially improve these results (Kshetri, 2017). However, smaller enterprises in Ghana may have difficulty obtaining these technologies, which might restrict the efficacy of these techniques.

The study found that implementing efficient waste management methods, such as recycling programs and circular economy approaches, greatly improved sustainability outcomes, supporting Hypothesis 2. These findings are consistent with Institutional Theory, which suggests that companies use practices such as waste management to meet societal expectations and comply with legal requirements (Verbeke & Tung, 2013). Firms in Ghana that adopted comprehensive waste management systems saw enhancements in resource efficiency; however, in Indonesia, the adoption of circular economy techniques resulted in significant reductions in hazardous waste (Fercoq, Lamouri, & Carbone, 2016). The significant influence of waste management methods in Indonesia may be attributed to the country's robust legislative frameworks and heightened focus on the circular economy. However, Ghana's regulatory framework is still in the process of being established, which might explain the relatively small improvements reported (Searcy & Buslovich, 2014). Moreover, the demographic distribution, specifically the size of enterprises, has an impact, as larger firms in Indonesia are more capable of implementing extensive waste management systems.

The findings suggest that implementing energy-saving technology and using renewable energy sources have a substantial positive impact on sustainability performance, thus supporting Hypothesis 3. This discovery aligns with the Resource-Based View (RBV) philosophy, which considers energy efficiency as a valuable asset that companies use to save expenses and enhance sustainability results (Moore & Manring, 2009). Both Ghana and Indonesia had favorable outcomes, with Indonesia demonstrating somewhat superior performance, perhaps attributed to its more extensive use of renewable energy. The greater influence in Indonesia may be ascribed to the country's more sophisticated energy infrastructure and government incentives for renewable energy development (Trianni et al., 2013). In Ghana, the effectiveness of energy-saving measures is hindered by the limited adoption of renewable energy, which in turn restricts potential benefits. The disparity in company size between the two nations may also have an impact since larger Indonesian enterprises possess more capacity to invest in energy-efficient technology.

The use of environment-friendly packaging materials and the implementation of sustainable package design had a beneficial influence on sustainability performance, thus supporting Hypothesis 4. This outcome is consistent with the RBV hypothesis, which proposes that sustainable packaging may function as a strategic asset that strengthens a company's market position by enhancing its brand image and consumer happiness (Srivastava et al., 2001). Firms in Ghana have reported a decrease in waste and an improvement in environmental compliance. In Indonesia, the use of sustainable packaging has enhanced its brand reputation. The much greater influence seen in Indonesia may be attributed to the elevated consumer demand for sustainable goods and more advanced markets for environmentally

friendly packaging (Lai & Wong, 2012; Marrucci et al., 2020). The sustainable packaging market in Ghana is still in its early stages, which might account for the limited impact reported. Furthermore, the size of the company and prevailing economic circumstances, including the availability of sustainable materials, may impact the implementation and efficacy of these practices (Hegab, Khanna, Monib, & Salem, 2023).

Table 4. Sustainable Logistics Practices, IoT Growth, and Sustainability Performance

	Dependent Variable: Sustainability Performance							
	Ghana				**Indonesia**			
	1	2	3	4	5	6	7	8
Constant	-0.489	0.854***	2.152**	3.498	1.738***	1.172***	1.185***	1.090**
	(0.633)	(0.000)	(0.023)	(0.167)	(0.000)	(0.000)	(0,000)	(0.00)
GT	1.056***				0.659***			
	(0.000)				(0.000)			
WM		1.009***				0.731***		
		(0.000)				(0.000)		
EE			0.632**				0.756***	
			(0.001)				(0.000)	
SUP				1.128***				0.684***
				(0.000)				(0.00)
IoT	0.369**	0.282***	-0.028	0.154	0.231**	0.361***	0.462***	0.479***
	(0.047)	(0.000)	(0.869)	(0.130)	(0.002)	(0.000)	(0.000)	(0.00)
IoT*GT	-0.059*				-0.026			
	(0.078				(0.102)			
IoT*WM		-0.048***				-0.045**		
		(0.000)				(0.010)		
IoT*EE			0.010				-0.065***	
			(0.776)				(0.000)	
IoT*SUP				-0.059**				-0.054**
				(0.001)				(0.01)
Net Effect	1.204	0.764	n/a	0.827	n/a	0.501	0.424	0.408
Obs.	374	374	374	374	379	379	379	379
R^2	0.651	0.619	0.543	0.141	0.654	0.609	0.608	0.522
Adjusted R^2	0.648	0.616	0.539	0.134	0.651	0.605	0.604	0.518
F-Stats.	229.66***	200.47***	146.56***	20.19***	236.22	194,60***	193.63***	136.51***

P<0.001, P<0.05, P<0.01 respectively, *SP: Sustainability performance. IoT: Internet of Things development*
GT: Sustainable transportation. WM: Waste management. EE: Energy efficiency. SUP: Sustainable packaging. N/A: not applicable because at least an unconditional or a conditional effect needed for the computation of net effects is not significant.
Source: Authors' computation.

The Moderating Role of IoT Growth on the Relationship Between Sustainable Logistics Practices and Sustainability Performance

The regression study demonstrated that the rise of the IoT has a substantial moderating effect on the link between sustainable logistics practices and sustainability performance, thereby verifying Hypothesis 5. More precisely, the expansion of the Internet of Things (IoT) has been discovered to enhance the beneficial impacts of sustainable transportation, waste management, energy efficiency, and sustainable packaging on sustainability results in both Ghana and Indonesia. This discovery provides evidence for Institutional Theory, which highlights the significance of technical infrastructure in influencing organizational behavior and improving sustainability practices(DiMaggio & Powell, 1983). Statistical analysis revealed that the interaction terms between the expansion of Things (IoT) and each sustainable logistics practice were significant. This suggests that, as IoT growth increases, the influence of these practices on sustainability performance becomes stronger. For instance, the use of Internet of Things (IoT) technology in both nations facilitates enhanced surveillance and fine-tuning of logistical operations, resulting in enhanced sustainability results. Nevertheless, the impact was more significant in Indonesia, indicating its advanced IoT infrastructure.

The larger moderating impact of IoT development in Indonesia may be linked to its more sophisticated digital infrastructure and higher investment in IoT technology(Ehie & Chilton, 2020). In Ghana, although there were some favorable outcomes, the country's first phase of IoT advancement restricted the complete utilization of these improvements. Furthermore, disparities in company scale and economic circumstances, such as the availability of funds for Internet of Things (IoT) initiatives, also play a role in the discrepancies identified between the two countries.

Comparative Analysis and Implications for Policy and Practice

The main findings suggest that the implementation of sustainable logistics techniques has a favorable influence on sustainability performance in both Ghana and Indonesia. Moreover, the rise of the Internet of Things (IoT) further amplifies these impacts. The somewhat superior results in Indonesia may be ascribed to its comparatively advanced infrastructure, more robust regulatory framework, and greater use of IoT technology. These results emphasize the significance of both internal practices, as emphasized by the Resource-Based View (RBV) theory, and external influences, as highlighted by the Institutional Theory, in influencing sustainable performance(Eisenhardt & Martin, 2000). The findings indicate that manufacturing enterprises in both nations should prioritize investments in sustainable logistics methods and IoT infrastructure to improve their sustainability performance. Companies should concentrate on industries in which these strategies provide the best results and use Internet of Things (IoT) technology to enhance efficiency. Indonesian enterprises should persist in leveraging their sophisticated infrastructure, while Ghanaian firms may need to prioritize the development of IoT skills to narrow the gap.

Both Ghana and Indonesian policymakers should encourage the implementation of sustainable logistics practices by offering incentives for investments in Internet of Things (IoT) technology and promoting collaboration between the public and commercial sectors. Implementing policies in Indonesia that promote a circular economy and renewable energy would significantly enhance the sustainability results. Ghana should prioritize enhancing its digital infrastructure and establishing a legislative framework that promotes the adoption of sustainable practices (Kshetri, 2017; Lee, 2019).

DISCUSSION

This research shows that the implementation of sustainable logistics practices has a significant influence on sustainability performance in the manufacturing sectors of Ghana and Indonesia. A greater positive impact is seen in Indonesia, which is due to its more advanced IoT infrastructure. All sustainable logistics practices-sustainable transportation, waste management, energy efficiency, and sustainable packaging-contribute positively to sustainability performance, with the degree of moderation by IoT growth varying across the two countries. These findings underscore the importance of technological infrastructure in strengthening the effectiveness of sustainability practices.

The results show that the implementation of sustainable logistics practices, such as green transport, waste management, energy efficiency, and sustainable packaging, has a significant impact on sustainability performance with moderation by the level of IoT development. Based on the Resource-Based View (RBV), sustainable logistics practices fulfil the VRIN criteria (valuable, rare, inimitable, and non-substitutable) as strategic resources. Strategies such as the use of eco-friendly vehicles or sustainable packaging not only reduce environmental impact but also increase resource efficiency, thereby creating a sustainable competitive advantage (Barney, 1991; Moore & Manring, 2009). IoT plays an important role as a strategic resource by enabling real-time data collection, more effective monitoring, and operational optimisation. This explains why companies in Indonesia, with more advanced IoT infrastructure, can maximise the benefits of sustainable logistics practices, while Ghana still faces challenges in the early stages of IoT development (Akram et al., 2020; Bachim et al., 2023).

Meanwhile, Institutional Theory helps explain how external pressures, such as environmental regulations and societal expectations, drive the adoption of sustainability practices. In Indonesia, stricter regulations and a more mature market for green technologies strengthen the adoption of these practices, enhancing firms' legitimacy and reputation (DiMaggio & Powell, 1983; Kshetri, 2017). In contrast, infrastructure constraints and limited policy support in Ghana hinder optimal implementation. For example, immature regulations in Ghana mean that practices such as waste management have less impact than in Indonesia, which has better adopted the circular economy (Searcy & Buslovich, 2014; Verbeke & Tung, 2013). Therefore, the successful implementation of sustainable logistics practices depends not only on the company's internal capabilities (RBV) but also on external pressures and support such as regulation, market, and technological infrastructure (Institutional Theory). Combining these two factors shows the importance of synergy between internal and external capabilities to achieve optimal sustainability performance.

The results of this study are consistent with previous studies showing that sustainable logistics practices, such as green transportation, reverse logistics, and eco-design, significantly improve sustainability performance, especially on the environmental and social dimensions. For example, research by Verma (2024) and Zhou et al. (2023) revealed that the implementation of green logistics practices improves sustainability through the adoption of a circular economy, while Tan et al. (2024) highlighted the importance of circularity-based supply chain management in small and medium-sized enterprises (SMEs). In addition, this study also supports previous findings that the adoption of digital technology and Industry 4.0, such as IoT, strengthens the effectiveness of sustainable logistics practices, as suggested by Umar et al. (2022). However, our results add a new dimension by showing how the development of IoT infrastructure moderates the relationship between sustainable logistics practices and sustainability performance, providing deeper insights into the influence of technology in the context of developing countries such as Ghana and Indonesia.

A key difference of this research compared to previous studies is its focus on the moderating role of IoT in a cross-country context, specifically in countries with different levels of technological infrastructure. For example, while Zhou et al. (2023) discuss the impact of the circular economy in improving sustainability, this study shows that such benefits can be amplified with more advanced IoT infrastructure, as seen in Indonesia. In addition, while previous research often focuses on the direct effects of green logistics practices, this study integrates a cross-dimensional analysis-environmental, social, and economic-by emphasising the differences in technological capabilities between countries. This approach makes a novel contribution by identifying factors that strengthen or hinder the effectiveness of sustainable logistics practices, thus offering practical guidance for policy makers and industry players in a global context.

The findings presented in this study are consistent with prior research, which has demonstrated that the technological infrastructure influences the effectiveness of sustainability practices in place (Kshetri, 2017). However, this study demonstrates that the impact is more limited in less developed infrastructure settings, such as Ghana, which differs from studies conducted in developed countries. The alignment and deviation observed in the existing literature serve to position this study within the broader body of research. This analysis highlights both confirming and contrasting aspects, providing valuable context for the study.

The findings of the study indicate a worldwide shift towards digitalization and sustainability in the manufacturing industry. This suggests that developing countries should improve their technological infrastructure to fully leverage sustainability practices' advantages. The results suggest that there is a requirement for a shift towards a green economy, which would be facilitated by advancements in technology and efforts towards sustainability. The significance of integrating sustainable practices with technological developments is highlighted by this connection to larger phenomena.

The practical implication of these findings highlights the significance of investing in Internet of Things (IoT) infrastructure to support and promote sustainable logistics practices effectively. The study provides theoretical support for the notion that technology-based resources play a crucial role in attaining sustainable competitive advantage. It is recommended that policymakers and practitioners take into account these insights to formulate strategies that effectively utilize technology to enhance sustainability performance.

The disparities observed in the study's results between Ghana and Indonesia can potentially be attributed to variations in economic scale, technological accessibility, and national policies that encourage the adoption of technology and sustainable practices. The differing economic and technological contexts of Ghana and Indonesia are likely to have influenced the observed variations in impacts. The understanding of why these findings emerged as they did is contingent upon factors such as the level of technological advancement, policy frameworks, and economic conditions.

To enhance sustainability performance, it is recommended that countries such as Ghana prioritize the development of digital infrastructure and promote the adoption of sustainability practices within the manufacturing sector. Meanwhile, it is recommended that Indonesia continues to capitalize on its advanced infrastructure by making investments in new technologies and further expanding the adoption of sustainability practices. The recommendations presented here are derived from data analysis and are based on objective analysis. They offer practical steps that policymakers and practitioners can take to improve sustainability outcomes.

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CONCLUSION

This research shows that sustainable logistics practices - green transport, waste management, energy efficiency, and sustainable packaging - contribute significantly to improved sustainability performance in the manufacturing sector in Ghana and Indonesia. Findings show that a greater positive effect is seen in Indonesia, which is due to more advanced IoT infrastructure. IoT moderation was shown to strengthen the relationship between sustainable logistics practices and sustainability performance, with higher effects in countries with developed technology infrastructure. This research underscores the importance of synergies between firms' internal capabilities, such as strategic resources (RBV), and external pressures, such as regulation and technological support (Institutional Theory), to achieve optimal sustainability performance.

This research makes an important contribution to the sustainability literature by offering a new perspective on the moderating role of IoT in the relationship between sustainable logistics practices and sustainability performance. This study complements previous research with a cross-country focus, especially in developing countries, showing how differences in technological infrastructure affect the effectiveness of implementing sustainability practices. The multidimensional approach that includes environmental, social, and economic aspects provides deeper insights into the influence of technology on sustainability practices in the manufacturing sector. This research also provides practical guidance for policymakers and industry players to prioritise investment in technology infrastructure and policy development that supports sustainability.

This research has several limitations. Firstly, the data used is limited to the manufacturing sector in Ghana and Indonesia, so the results may not fully represent the global context. Second, although this study uses a quantitative approach, limitations in data collection, such as varying response rates, may affect the generalisability of the findings. Third, the IoT moderating variables focused more on infrastructure, so other factors such as organisational culture or managerial capabilities have not been explored. Future research could expand geographic coverage, add qualitative methods to dig deeper into the mechanisms of variable relationships, and consider additional factors that may influence the effectiveness of sustainability practices. As such, this research opens up opportunities for future studies to better understand the role of technology and policy in supporting the sustainability of the manufacturing sector globally.

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