European Journal of Logistics, Purchasing and Supply Chain Management
Vol.12 No.1, pp.59-79, 2024
Print ISSN: 2054-0930 (Print)
Online ISSN: 2054-0949 (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

Intermix of Realities between Supply Chain Management 4.0 and Sustainability among Nigerian Quoted Logistics Companies

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doi: https://doi.org/10.37745/ejlpscm.2013/vol12n15979 Published May 21, 2024

Citation: EsangbedoC.O. and Zhang J. (2024) Intermix of Realities between Supply Chain Management 4.0 and Sustainability among Nigerian Quoted Logistics Companies, *European Journal of Logistics, Purchasing and Supply Chain Management*, Vol.12 No.1, pp.59-79

ABSTRACT: *This article examines the complex interplay between Supply Chain Management 4.0 (SCM 4.0) and sustainability, with a specific emphasis on logistics companies in Nigeria that have been cited. In the current business climate, the concept of sustainability has evolved to embrace more than just financial gain. It now incorporates a triple bottom line framework, which comprises economic, social, and environmental aspects. The importance of sustainability disclosures for organizational success has led to a growing emphasis on the deployment of disruptive technologies, namely those associated with Supply Chain Management 4.0, in the logistics sector. The present study aims to fill the existing research gap by investigating the impact of Supply Chain Management 4.0 on sustainability-related outcomes, with a specific focus on developing economies where sustainability disclosures are not mandatory. The research examines the sustainability policies of nine publicly traded logistics businesses over a span of ten years, specifically from 2012 to 2021, through the utilization of content analysis on their annual reports. The results indicate that SCM 4.0 has a noteworthy and statistically significant influence on both the social and environmental elements of sustainability. Moreover, the size of a corporation has a favorable impact on social sustainability, highlighting the importance of organizational scale in developing initiatives related to social responsibility. On the other hand, the age of a corporation does not have a substantial impact on any dimension of sustainability. This paper is a valuable contribution to the ongoing academic discussion regarding the convergence of technology adoption and sustainability. It provides valuable insights into the potential of Supply Chain Management 4.0 to facilitate sustainable results within the specific setting of a developing economy. The findings offer a helpful point of reference for logistics enterprises seeking to utilize technology in order to improve their sustainability performance.*

KEYWORDS: *Supply chain management 4.0, sustainability, Nigeria, logistics, big data analytics, cloud computing*

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INTRODUCTION

The discourse surrounding sustainability has reached its peak, to the point that it is fundamentally reshaping the definition of corporate achievement. (Thomson & Bates, 2022). There is a significant paradigm shift from economic profit only to sustainability, that is, the triple bottom, and this drive is significant for firm survival. There has been a notable shift in the prevailing paradigm, moving away from a sole focus on economic profit towards a more comprehensive consideration of sustainability, sometimes referred to as the triple bottom line. This shift holds considerable importance for the long-term viability and endurance of firms. There is an increasing demand for organizations to broaden their performance metrics beyond economic earnings by incorporating social and environmental indicators. The act of reporting in this context, formerly considered optional, is now gaining widespread acceptance due to the release of financial reporting standards (IFRS S1 and IFRS S2) for sustainability by the International Sustainability Standards Board (ISSB). This suggests that relying solely on financial performance as measured and published in yearly reports is no longer adequate for evaluating performance. While the practice of voluntary sustainability disclosure remains optional in Nigeria, some organizations have chosen to engage in this endeavour. By doing so, they provide information about their sustainability activities, which can be accessed by both current and prospective investors. This disclosure allows investors to assess the organizations' commitment to sustainability and make informed decisions regarding their investment preferences.

The field of logistics is also actively engaged in the discussion, since it is currently undergoing substantial integration of upcoming transformational technology. (Zhang et al., 2020), Promoting more accountability and transparency. The adoption and utilization of developing technologies have been increasingly prevalent, leading to significant attention being directed towards supply chain management as a crucial factor in enhancing productivity and efficiency. This attention stems from its potential to facilitate cost-cutting and cost-savings within organizations, thereby impacting global economies. The utilization of disruptive and transformative technologies in supply chain management has been influenced by various factors, including globalisation and the consequences of the COVID-19 pandemic. Consequently, this has prompted a redefinition of supply chain management as digital supply chain management, green supply chain management, or more comprehensively, Supply Chain Management 4.0. This new paradigm integrates Industry 4.0 principles into the field of supply chain management. (Hofmann et al., 2019). The impact of technology on traditional supply chain management has been extensively examined in academic research. (See Dovbischuk, 2022; Garay-Rondero et al., 2020; Ghadge et al., 2022; Haddud & Khare, 2020; Koh et al., 2019; Kunkel et al., 2022, 2022; Mastos et al., 2021; Mastrocinque et al., 2022; Rossini et al., 2022; Samper et al., 2022). However, the extent to which SCM 4.0 is facilitating sustainability-related results is constrained, particularly in developing economies

where sustainability practices are predominantly voluntary and inadequately documented.
Previous research on supply chain management and sustainable performance has predominantly emphasized the economic aspect, particularly in terms of profitability. However, it is worth noting that there are a few notable outliers, such as the work conducted by Formentini and Taticchi. (2016), Who exemplified the concept of social sustainability? This study expands the boundaries of existing knowledge by examining the comprehensive concept of sustainable performance, which encompasses the triple bottom line of economic, social, and environmental factors.

The utilization of additive technology to revolutionize and perturb supply chain management processes has been extensively documented in advanced economies. (Braglia et al., 2021; Grandinetti et al., 2020; Khan et al., 2022; Lassnig et al., 2018; Lerman et al., 2022), However, there is limited knowledge available for numerous developing economies. Moreover, a substantial body of research in the field of supply chain management has predominantly concentrated on examining the operational efficiencies associated with the use of technology and other performance metrics within the supply chain. (Barbieri et al., 2021), While there is a limited body of research on the topic of sustainability. (triple bottom line).

In conclusion, it is noteworthy that the conventional focus of business profitability is undergoing a transformation, as sustainability considerations gain prominence. Consequently, the impact of technology adoption and the integration of supply chain governance on supply chain management (SCM) practices, particularly within the context of a developing economy, holds considerable significance. This aspect has received limited attention in the context of developing economies as well. This paper addresses the existing vacuum in the literature regarding the insufficient exploration of technology adoption for the purpose of driving digital supply chain management, as well as performance measures that extend beyond economic indices.

Research objective and questions

The primary aim of this research is to investigate the correlation between Supply Chain Management 4.0 and sustainability. Furthermore, this study investigates the moderating influence of both firm age and firm size on the association between Supply Chain Management 4.0 (SCM 4.0) and sustainability. The subsequent research inquiries have been addressed:

i. What is the effect of Supply Chain Management 4.0 on sustainability among quoted logistics companies in Nigeria?
ii. To what extent does firm age control the influence of Supply Chain Management 4.0 on sustainability?
iii. To what extent does firm size control the influence of Supply Chain Management 4.0 on sustainability.

Research hypotheses

Three hypotheses are postulated in this study and stated in their null form as follows:

H_{01}: Supply Chain Management 4.0 has no statistically significant effect on sustainability among quoted logistics companies in Nigeria.

H_{02}: Firm age has no statistically significant controlling effect on the influence of Supply Chain Management 4.0 on sustainability.

H_{03}: Firm size has no statistically significant controlling effect on the influence of Supply Chain Management 4.0 on sustainability.

LITERATURE REVIEW

Sustainability

The concept of sustainability is multifaceted, with varying interpretations among stakeholders that are contingent upon specific settings (Aras & Crowther, 2008; Sikdar, 2003) The endeavor of conceptualizing and harmonizing the definition of this subject matter has proven to be an arduous undertaking since it evolves throughout time (Medel-gonzález et al., 2013). During the 1970s, there emerged a growing emphasis inside enterprises to adopt a more comprehensive approach to evaluating performance, encompassing not just financial metrics but also social and environmental considerations. This shift in focus led to the widespread adoption of the term "sustainability" in the field of management literature (Aras & Crowther, 2008). Over three decades ago, experts in the field of management held the belief that sustainability referred to the concept of continuity. This concept encompassed a firm's capacity to run over an extended duration, if not indefinitely.

The perception of corporations as an essential component of society is undergoing rapid transformation. Over the course of time, the concept of sustainability has attained widespread usage and prominence in both the context of globalization and corporate performance discussions. (Aras & Crowther, 2008). Furthermore, it has garnered considerable interest in both macroeconomic and microeconomic contexts.

The World Commission on Environment and Development (WCED) established a widely accepted definition of sustainability, which gained prominence following its endorsement by the United Nations General Assembly (UNGA) in 1987. Krechovská and Prochazkova (2014) define corporate sustainability as "…the ability of companies to positively influence environmental, social and economic development through their governance practices and market presence" (p. 1144). Sustainability necessitates that organizations have a comprehensive perspective on value creation, encompassing not only economic value generation, but also other dimensions. (Gangi et al., 2018). Sustainable enterprises, consequently, are founded upon a threefold framework encompassing the dimensions of social responsibility, environmental stewardship, and economic viability. This is achieved by implementing measures to ensure that the utilization of resources in

the present does not have detrimental effects on future anticipated outcomes. The Global Reporting Initiative (GRI) has created metrics for evaluating sustainability in its reporting efforts (Mahmood et al., 2018; Moses et al., 2020) as "reporting on how an organization contributes or aims to contribute in the future, to the improvement or deterioration of economic, environmental and social conditions, developments, and trends at the local, regional or global level" GRI, 2015, p. 17).

The environmental and societal implications of logistics enterprises necessitate a broader evaluation of their total performance, as financial metrics alone are inadequate. This underscores the imperative of integrating sustainability into this research in order to have a more comprehensive foundation for assessing the influence of SCM 4.0 on organizational performance. In response to the increasing demand for corporations to incorporate social and environmental considerations into their strategic planning, firms have chosen to follow either a reactive or proactive strategy. Reactive corporations demonstrate actions that are deemed satisfactory for the purpose of evading punishment, mostly by fulfilling their duties. On the other hand, proactive enterprises purposefully include social and environmental themes into their plans, displaying a deliberate intentionality in doing so (Gangi et al., 2018).

Supply Chain Management 4.0

Supply chain management (SCM) involves the systematic movement of both human and non-human resources within a supply chain (SC). Supply chain management (SCM) encompasses the deliberate and organized alignment of various business operations, rules, and procedures inside a specific company, as well as across several businesses within the supply chain (SC). The primary objective of SCM is to enhance the overall performance of the entire supply chain and the constituent companies operating at all hierarchical levels. (Mastrocinque et al., 2022). Supply Chain Management (SCM) is a comprehensive amalgamation of several systems designed to achieve predetermined or anticipated results.

Different concepts such as "green" (Ghadge et al., 2022) "smart" (Lerman et al., 2022) "sustainable" (Samper et al., 2022) and "circular" (Del Giudice et al., 2020; Mastrocinque et al., 2022; Stocco et al., 2022) have been added to SCM transforming and redefining the concept accordingly. SCM 4.0 was first coined in 2019 (Hofmann et al., 2019) to practically capture the integration of Industry 4.0 or digital transformation and traditional supply chain management.
Industry 4.0, alternatively referred to as digital transformation, encompasses the implementation and utilization of nascent technologies with the aim of propelling operational procedures. The field of literature contains a multitude of various research that explore the utilization of technologies in order to facilitate the management of supply chain operations (Asokan et al., 2022; Braglia et al., 2021; Čater et al., 2021; Garay-Rondero et al., 2020; Ghadge et al., 2022; Koh et al., 2019; Kunkel et al., 2022; Lassnig et al., 2018; Mastrocinque et al., 2022; Patyal et al., 2022; Samper et al., 2022; Stocco et al., 2022). The inclusion of several developing technologies in the supply chain literature encompasses Blockchain, Big Data Analytics, Cloud Computing, Artificial Intelligence, and

Machine Learning, among other pertinent technologies. The advent of these technologies has caused significant disruptions in the field of supply chain management (Bischoff & Seuring, 2021) and transforming SCM into a highly technology-focused activity.

Firm age

Similar to the concept of human age, the age of a corporation similarly conveys a narrative of accumulated experience, opportunities, social connections, and market influence, which encompasses its size. The age of a firm has been determined to have a considerable impact on the control of outcomes between two factors. (Diéguez-Soto et al., 2017; Mastrocinque et al., 2022)

Firm size

Numerous studies have identified firm size as a crucial determinant (Del Giudice et al., 2020; Diéguez-Soto et al., 2017; Gimenez et al., 2015; Namazi & Namazi, 2016). The measurement of firm size includes both quantitative and qualitative measures, as well as financial and non-financial indices. In the context of this study, the magnitude of a firm is assessed by quantifying the entirety of income created by the organization.

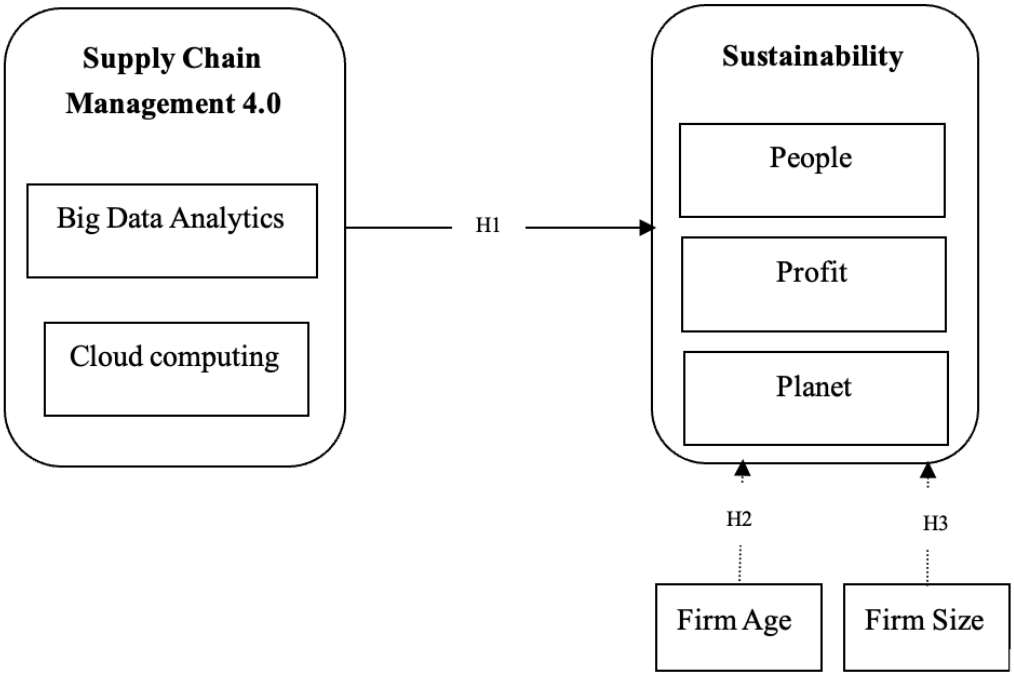

Figure 1: Conceptual Model

Theoretical grounding

Based on an initial review of relevant scholarly sources, prominent theories that have been discussed in the field of supply chain management encompass Transaction Cost Economics (TCE), Social Exchange Theory (SET), Resource Dependence Theory (RDT), Information Processing

Theory (IPT), and Behavioural Theory (Barbieri et al., 2021). Furthermore, various theories and models have been put forth in the field of governance to enhance our comprehension of supply chain governance concerns. (Barbieri et al., 2021; Hohn & Durach, 2021). The inclusion of the comprehensive sustainability variable in this study is expected to broaden the range and application of these well accepted ideas.

METHODOLOGY

The research employed a method of content analysis to examine the annual reports of a specific group of publicly traded logistics companies in Nigeria. Prior research has employed the utilization of surveys. (Ghadge et al., 2022; Hohn & Durach, 2021; Lassnig et al., 2018), interviews (Kunkel et al., 2022), case studies (Alieva & Powell, 2022; Grandinetti et al., 2020; Mastos et al., 2021) literature review (Stocco et al., 2022; Torres da Rocha et al., 2022) mixed methods (Cichosz et al., 2020; Gohil & Thakker, 2021). Considering the limitations related to data availability and response concerns, the proposed methodology entails conducting a content analysis of annual reports from publicly traded logistics companies, which are easily accessible. Quoted firms, by virtue of their public responsibility, are obligated to disclose their annual reports, which encompass their financial statements. Typically, the annual reports produced by publicly traded corporations provide all the factors pertinent to the study. This study incorporates four variables, and their corresponding measurement indices are presented in Table 1.

Table 1: Variables and measurement

Variables	Proxies	Measure
Sustainability	Economic	Financial performance (Net profit)
	Social	Index
	Environment	Index
Supply Chain Management 4.0	Big Data Analytics	Content analysis
	Cloud Computing	Content analysis
Firm age	Years from incorporation on the NGX	
Firm size	Total revenue	

Furthermore, in light of the adoption of post-empiricism, the quantitative approach emerges as the most appropriate methodology for collecting data, taking into account the variables under investigation. The data utilized in this study is of a secondary nature, specifically derived from the annual reports of the chosen companies.

The analysis encompasses the entire population of logistics companies in Nigeria that have been quoted. Given the restricted availability of logistics businesses in Nigeria, as indicated in Table 2, it is deemed reasonable to employ censor sampling. However, considering the proposed ten-year

study period (2012 – 2021) as well as the 2012 implementation of the International Financial Reporting Standards (IFRS), nine (9) quoted logistics companies in Nigeria with available data for the period were selected for the study.

Table 2: List of selected companies listed on the Nigerian Exchange Group

S/N	Name of Company	Ticker	City	Nature	Business Offerings	DOI
1	Associated Bus Company	ABS Trans	Imo	Road Transportation	Transportation by Road	April 1993
2	Caverton Offshore Support Grp Plc	CAVERTON	Lagos	Marine & Aviation	Support & Logistics	June 2008
3	C&I Leasing Plc	CI Leasing	Lagos	Support & Logistics	Equipment Leasing/Rentals and Providing Ancillary Logistics Support Services to Companies	
4	Global Spectrum Energy Services Pls	GSPEC Plc	Lagos	Transport-Related Services	Maritime Security, logistics, Energy and Engineering Services	March 2006
5	Medview Airtime	MEDVIEW		Airlines	Airline Services	Jan 1970
6	Nigerian Aviation Handling Company Plc	NAHCO	Lagos	Transport-Related Services	Provision of Aircraft, Passenger & Cargo Handling Services to Airline Operators	April 2005
7	Red Star Express Plc	REDSTAREX	Lagos	Courier/ Freight/ Delivery	Courier services, freight services, Logistics, warehousing	July 1992

					and General Haulage	
8	Skyway Aviation Handling Company Plc	SKYAVN	Lagos	Transport-Related Services	Aviation Support Services	April 2009
9	Trans-Nationwide Express Plc.	TRANSEXPRESS	Lagos	Courier/ Freight/ Delivery	Courier & Associated Services	March 1984

We followed the procedure of Kartadjumena and Rodgers (2019) in analysing panel secondary data we collected using Partial Least Squares Structural Equation Modeling (PLS-SEM). PLS-SEM is preferred for its ability to handle complex models without imposing distributional assumptions on the data. In order to do this study, it is necessary to evaluate the measurement and assessment models. To assess multicollinearity, we employed correlation matrices and variance inflation factors (VIF). VIF values below 10 were indicative of the absence of multicollinearity. (Hair et al., 2014, 2019). Construct validity was evaluated using factor weights with values. Internal consistency reliability was examined through composite reliability (CR), with values exceeding 0.7 but less than 0.95 considered desirable. In this case we used Average Variance Extracted (AVE) to test for convergent validity for only SCM 4.0 and sustainability because only those had more than one measure. The threshold used was ≥ 0.50 indicating that the construct explains at least 50% of its items' variance. For the structural model, we focused on The structural R^2 values, P-values, beta coefficients, effects size (f^2) and t-statistics in line with Kartadjumena and Rodgers (2019).

RESULTS

Table 3 provides a statistical summary of the research variables. The table gives useful information about a company's financial and non-financial performance. It contains information on Net Profit, Social Performance, Environmental Performance, Big Data Analytics (BDA), Cloud Computing (CC), Firm Size, and Firm Age (natural log).

Net profit varied significantly, ranging from a huge loss to a profit, with an average of roughly 221.35 million Naira. This broad range shows that the companys' financial performance were volatile. Net profit is generally independent of other factors, as indicated by the low Variance Inflation Factor (VIF) of 1.1, making it a potential outcome variable. Social Performance and Environmental Performance values range from 0 to 3, indicating how the company addresses social and environmental responsibility. Both variables have low VIF values, signifying their independence from other factors.

On the other hand, Big Data Analytics and Cloud Computing exhibit limited ranges (0 to 1) and high standard deviations compared to their means. This suggests the potential presence of multicollinearity issues as it is above 5, the rule of thumb. However, the values are below 10 which, according to Hair et al. (2014) and Kartadjumena and Rodgers (2019), suggests no multicollinearity issues. Firm size, measured in Naira, shows substantial variability, and Firm Age (logged) indicates stability within its transformed values.

Table 3: Descriptive statistics

	Min	Max	**Mean**	Standard Dev	VIF
Net profit	-10357133000	4336665000	221350133	1584947697	1.1
SP	0	3	0.833	0.792	1.8
EP	0	3	0.678	0.772	1.9
BDA	0	1	0.378	0.39	9.8
CC	0	1	0.344	0.355	9.8
Firm size	0	3.6962E+10	9661593989	9324652438	1
Firm Age	1.61	3.78	2.969	0.558	1

Note: SP-social performance, EP-environmental performance, BDA- big data analytics, CC-cloud computing

Source: SmartPLS Output (2023)

Table 4 presents correlations between various variables. Notable correlations include a strong positive relationship between Social Performance and Environmental Performance (0.675**), indicating that improvements in one often correspond with improvements in the other. Social Performance is also strongly positively correlated with Big Data Analytics (0.492**), as is Environmental Performance (0.349**). Big Data Analytics shows a robust positive correlation with Cloud Computing (0.948**), suggesting a close connection between these technological aspects. While Cloud Computing is positively related to Social Performance (0.073) and Environmental Performance (0.332**), these correlations are weaker compared to other relationships. Lastly, Firm Size is negatively correlated with Net Profit (-0.116), implying that larger firms tend to have lower net profits.

Table 4: Indicator correlations

s/n		1	2	3	4	5	6	7
1.	Net Profit	1	-0.129	-0.25*	-0.131	-0.157	0.14	0.009
2.	Social Performance		1	0.675**	0.492**	0.501**	0.471**	0.207*
3.	Environmental performance			1	0.349**	0.405**	0.251**	0.15
4.	Big data analytics				1	0.948**	0.097	0.364**
5.	Cloud computing					1	0.073	0.332**
6.	Firm size						1	-0.116
7.	Firm Age							1

Source: SmartPLS Output (2023)

Table 5 shows the weights, composite reliability and average variance extracted. SCM 4.0 demonstrates significant reliability (CR = 0.987) and strong convergent validity (AVE = 0.974), making it a robust and reliable construct. Big Data Analytics and Cloud Computing had weights of .489 and .525, respectively. The weight for net profit was, however, low (-0.012). Sustainability, with a moderate weight of 0.70, has reasonable convergent validity (AVE = 0.569). Firm Size and Firm Age are controls, assigned weights of 1, indicating their role in controlling for other variables.

Table 5: Results of Outer model

Variables	**Weights**	**CR**	**AVE**
Supply chain management 4.0		.987	.974
Big data analytics	0.489		
Cloud computing	0.525		
Sustainability		.70	.569
Net profit	-0.012		
Social performance	0.654		
Environmental performance	0.432		
Controls			
Firm Size	1		
Firm Age	1		

Source: SmartPLS Output (2023)

To test the hypotheses postulated, we conducted two types of analysis. The first was a disaggregate analysis, analysing the effects of SCM 4.0 on each of the sustainability dimensions while controlling for firm size and firm age. The second analysis was the aggregate analysis, testing the effect of SCM 4.0 on the total average of the sustainability dimensions.

Table 6 details the findings of the path analysis. Given the low R^2 for economic performance, the findings are not reported as it fails to satisfy the model fit condition (See Table 6). The findings for social and environmental performance were reported. SCM 4.0 had a positive and significant effect on social performance ($\beta = .426, t = 4.515, f^2 = .283, p < 0.05$) and environmental performance ($\beta = .344, t = 3.769, f^2 = .127, p < 0.05$). The effects size ($f^2$) values indicate that SCM 4.0 had a stronger effect on social performance than environmental performance. According to Cohen (1988), the threshold is 0.02 threshold for small effects, 0.15 for medium effects and 0.35 for large effects. By implication, the effect on social performance is closer to the medium effects threshold, whereas the effect on environmental performance is closer small effects threshold. For the control variables, firm size had a significant effect on social performance ($\beta = .228, t = 4.259, f^2 = .351, p < 0.05$) but not on environmental performance ($\beta = .228, t = 1.826, f^2 = .063, p > 0.05$). The f^2 is an indication that firm size has a medium effect on social performance. Firm age did not have significant effects on any of the sustainability dimensions (See Figure 2).

Table 6: Pathway analysis

Pathways	*Beta*	*T*	f^2	*p*
Disaggregate analysis				
SCM_4.0 -> Social performance	0.426	4.515	0.283	0.000
SCM_4.0 -> Environmental performance	0.344	3.769	0.127	0.000
SCM_4.0 -> Economic performance	-0.195	4.259	0.035	0.000
Firm Size -> Social performance	0.447	5.09	0.351	0.000
Firm Size -> Environmental performance	0.228	1.826	0.063	0.068
Firm Size -> Economic performance	0.168	0.878	0.029	0.38
Firm Age -> Social performance	0.109	1.414	0.018	0.157
Firm Age -> Environmental performance	0.055	0.612	0.003	0.54
Firm Age -> Economic performance	0.097	1.431	0.009	0.153
R^2 (Economic performance)		0.053		
R^2 (Social performance)		.448		
R^2 (Environmental performance)		.197		
Aggregate analysis				
SCM_4.0 -> Sus	0.43	3.848	0.262	0.000
Firm size -> Sus	0.389	3.22	0.241	0.001
Firm age -> Sus	0.094	1.221	0.012	0.222
R^2 (sustainability		0.393		

Source: SmartPLS Output (2023)

The results in Table 6 and Figure 3 also details the aggregate analysis. The results show that SCM 4.0 has a positive and significant effect on sustainability ($\beta = .43, t = 3.848, f^2 = .262, p < 0.05$) of logistics companies in Nigeria. The f^2 of .262 is an indication that the effect is above

small but slightly below the medium effects threshold. Firm size had a significant and positive effect on sustainability ($\beta = .389, t = 3.22, f^2 = .241, p < 0.05$) whereas firm age did not have a significant effect. The f^2 of .241 is also an indication that the effect is above small but slightly below the medium effects threshold.

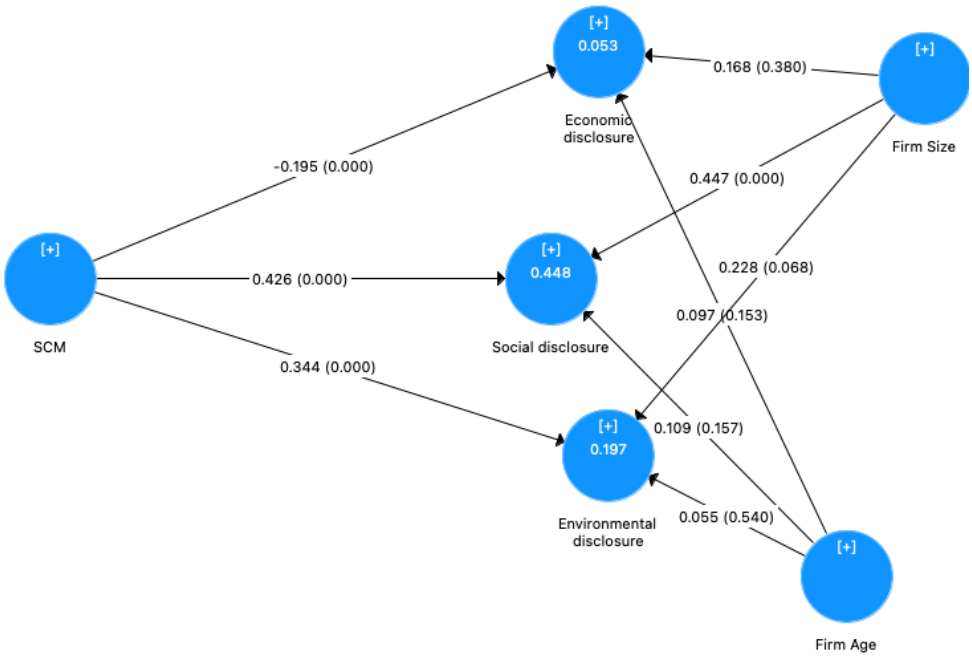

Figure 2: Path Diagram for disaggregate analysis

Source: SmartPLS Output (2023)

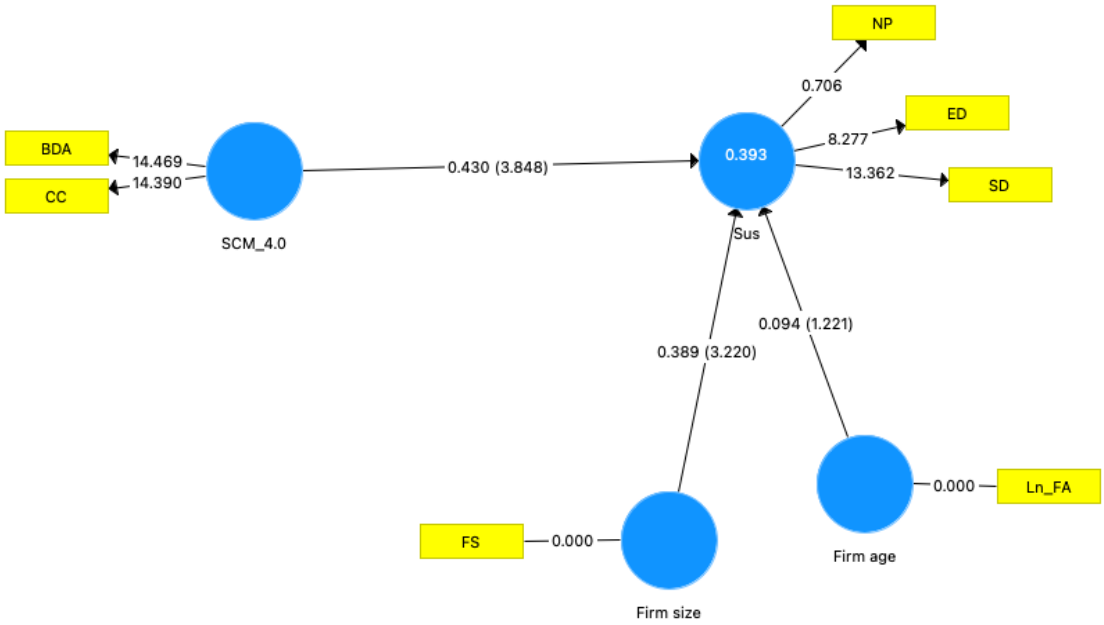

Figure 3: Path diagram for aggregate analysis

Source: SmartPLS Output (2023)

DISCUSSION

The findings of this study offer valuable insights into the correlation between Supply Chain Management 4.0 and sustainability, specifically within the logistics industry of Nigeria. The aforementioned findings align with the broader discourse surrounding the incorporation of technology and sustainability into corporate operations.

The initial hypothesis posited that the implementation of SCM 4.0 may not yield a significant influence on sustainability among logistics companies in Nigeria. The outcomes of the study, however, refute the null hypothesis. The implementation of SCM 4.0 has yielded positive and significant effects on sustainability, indicating that the integration of digital technology and novel tools in supply chain management contributes to the overall sustainability of logistics companies. The findings of this study align with an increasing corpus of scholarly research that acknowledges the importance of technology in augmenting the sustainability of supply chains. As Sarkis et al. (2018) point out, integrating digital technologies such as Big Data Analytics and Cloud Computing allows businesses to improve their environmental and social performance. It allows for improved data collecting, analysis, and decision-making, which leads to more responsible and sustainable business practises (Asokan et al., 2022; Braglia et al., 2021). Furthermore, SCM 4.0 is consistent with Industry 4.0 concepts, which emphasise the use of technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) to optimise operations and minimise resource consumption

(Shrouf et al., 2014). In the logistics context, these technologies enable real-time tracking of shipments, route optimization, and inventory management, which can result in reduced emissions and resource wastage (Mastrocinque et al., 2022; Patyal et al., 2022; Stocco et al., 2022).

Regarding the second hypothesis, the results suggest that the link in question was not significantly influenced by the age of the firm. Put simply, the implementation of Supply Chain Management 4.0 has a beneficial influence on sustainability results irrespective of a company's age. The absence of a substantial impact attributed to the age of a corporation aligns with the notion that the adoption of technology and its influence on sustainability are not dependent on the historical heritage of a company. In the contemporary era characterized by swift technological advancements, even long-standing and established corporations possess the capacity to utilize novel technologies in order to augment their sustainability endeavours. (Seuring & Gold, 2012). This supports the notion that Industry 4.0 and SCM 4.0 are disruptors that can affect all players in the industry, irrespective of their age.

The third hypothesis investigates whether business size serves as a controlling factor in the relationship between SCM 4.0 and sustainability. The findings suggest that the size of a corporation has a notable and favourable influence on sustainability. In addition, it was shown that logistics enterprises of greater magnitude exhibited correspondingly elevated sustainability scores. This finding resonates with the literature highlighting the advantages of larger firms in implementing sustainable practices (Kartadjumena & Rodgers, 2019; Walker et al., 2008). Larger companies often have more resources and capabilities to invest in sustainability initiatives and adopt advanced technologies (Lo et al., 2018; Smith & Sharicz, 2017). Their economies of scale can allow for greater sustainability investments, including the adoption of SCM 4.0 technologies.

Implications for theory and practice

The results of this investigation carry substantial ramifications, encompassing both theoretical and practical domains. The paper provides theoretical support for the notion that SCM 4.0 is an essential framework in the process of digitally transforming supply chain processes. This statement underscores the significance of incorporating emerging technologies such as Big Data Analytics and Cloud Computing in order to advance sustainability in supply chains. It offers actual evidence to substantiate the theoretical underpinnings of Supply Chain Management (SCM) 4.0 as a catalyst for fostering sustainable business practices. Furthermore, this study presents a critique of conventional beliefs pertaining to the influence of both company age and firm size. The study revealed that firm size exerted a notable and favourable influence on sustainability, although firm age did not have a comparable effect. This highlights the fluidity of corporate operations in the contemporary digital era, when the significance of historical heritage may be diminished in comparison to a company's scale and flexibility to allocate resources towards pioneering technologies that promote sustainability.

The practical ramifications of these results are similarly significant. This study can be utilized by logistics organizations, both in Nigeria and globally, to prioritize the implementation of SCM 4.0 technology. The adoption of these technologies can enable organizations to improve their environmental and social accountability while optimizing supply chain operations. The development of effective plans for the application of new technologies is imperative for companies. The research further underscores the significance of conducting thorough sustainability reporting. It is imperative for companies to not solely concentrate on quantifying and communicating their financial achievements, but to additionally proactively divulge their endeavours pertaining to social and environmental matters. This phenomenon has the potential to provide favourable consequences for their brand, entice conscientious investors, and align with the overarching objectives of the global sustainability agenda.

Another practical implication is the role of firm size. Logistics firms of greater magnitude generally exhibit elevated sustainability scores, perhaps affording them a competitive edge. Smaller enterprises have the opportunity to engage in collaborations, partnerships, or industry-specific initiatives as a means to acquire the requisite resources and technology essential for achieving sustainability. The results highlight the potential benefits of business scale in promoting sustainability. Moreover, authorities in Nigeria and other emerging economies should utilize these insights to promote and facilitate the implementation of SCM 4.0 technology. Policymakers may make a significant contribution to economic growth and environmental responsibility by advocating for the adoption of digital tools in supply chain management, thereby aligning with global sustainability objectives.

Limitations and suggestion for further studies

It is important to acknowledge the limitations of this study. The exclusive utilization of content analysis of annual reports as the principal data source may potentially fail to encompass the complete scope of a company's sustainability endeavours. Although yearly reports offer significant insights, they may not comprehensively capture all sustainable actions, thereby overlooking undisclosed projects. Subsequent investigations may contemplate augmenting the existing dataset by incorporating supplementary information obtained through surveys, interviews, or direct access to internal sustainability reports.

Another constraint pertains to the exclusive emphasis on logistics businesses operating in Nigeria. The limited focus of this study may have limitations on the extent to which the results can be applied to different sectors or geographical areas. In order to broaden the generalizability of the findings, it is recommended that future studies investigate a wider range of industries and geographic locations. In conclusion, although firm size and firm age are acknowledged as control variables, this study does not incorporate additional contextual elements that exert an influence on sustainability results, such as regulatory regimes and industry-specific characteristics.

Given the aforementioned constraints, future research endeavours may delve into the intricacies of sector-specific dynamics within the realm of the logistics business. This would provide a more comprehensive comprehension of the impact of Supply Chain Management 4.0 on sustainability across different subdomains. Furthermore, conducting comparative studies across various developing economies might provide insights into regional disparities in the adoption of digital technologies and their effects on sustainability. The use of qualitative research methodologies, such as interviews and case studies, might yield more profound understandings regarding the motives, obstacles, and determinants of success in the adoption of technology for sustainability.

In conclusion, further research endeavours may delve into the examination of micro-level variables within organizational settings, such as the level of dedication exhibited by leaders, the degree of employee involvement, and the prevailing organizational culture. By doing so, scholars can gain a comprehensive understanding of how these variables impact the correlation between Supply Chain Management 4.0 and the attainment of sustainability objectives. The primary objective of these recommendations is to enhance the scope and magnitude of research conducted in this particular domain. This will facilitate the development of a more holistic comprehension of the intricate relationship between the adoption of technology and the sustainability aspects within the realm of supply chain management.

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