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Blockchain Technology and Business Performance of selected Manufacturing Firms in Delta State, Nigeria.

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Abtract
This study examined the effect of blockchain technology on the business performance of selected manufacturing firms in Delta State, Nigeria. The specific objectives were to evaluate the effect of blockchain transparency, traceability, security, and data integrity on business performance. A total of 150 questionnaires were distributed, out of which 140 were correctly completed and analyzed using descriptive statistics and multiple regression analysis with the aid of SPSS. Qualitative data were also obtained through interviews with management staff to provide deeper insights into blockchain adoption practices. The findings revealed that blockchain transparency, traceability, security, and data integrity each exert a positive and significant influence on business performance. Among these variables, blockchain security had the strongest effect, followed by data integrity, transparency, and traceability. The study further showed that blockchain implementation enhances operational efficiency, strengthens supply chain visibility, safeguards data, and improves organizational trust and accountability. The study concludes that blockchain technology significantly improves the business performance of manufacturing firms by promoting secure, transparent, and efficient operations. It recommends that firms should invest in blockchain infrastructure, build employee capacity, and integrate blockchain systems into supply chain operations while government and regulatory bodies should develop clear policies to encourage widespread adoption. The research contributes to knowledge by providing empirical evidence on the role of blockchain dimensions—transparency, traceability, security, and data integrity—in enhancing the performance of manufacturing firms within a developing economy context. The study also offers practical insights for managers and policymakers on leveraging blockchain for industrial competitiveness and sustainability.

Keywords: *Blockchain Technology, Business Performance, Transparency, Traceability, Security, Data Integrity, Manufacturing Firms, Delta State, Nigeria.*

Introduction

Blockchain technology has emerged as a transformative force across various industries, offering solutions that enhance transparency, traceability, security, and data integrity. In the manufacturing sector, these attributes are pivotal in optimizing operations and improving business performance. This study delves into the impact of blockchain technology, focusing on its facets of transparency, traceability, security, and data integrity, on the business performance of selected manufacturing firms in Delta State, Nigeria.The manufacturing industry is a cornerstone of economic development, contributing significantly to employment and GDP. However, it faces challenges such as supply chain inefficiencies, counterfeit products, and data breaches, which can impede performance (Azzi, et al 2019). Blockchain technology, with its decentralized and immutable ledger system, offers potential solutions to these issues. By recording transactions across a distributed network, blockchain ensures that data is transparent, traceable, and secure, thereby enhancing operational efficiency and trust among stakeholders (Casino, et al 2019).

Transparency in manufacturing processes is crucial for building trust with consumers and partners. Blockchain's decentralized ledger records all

transactions in a manner that is accessible and verifiable by all authorized participants (Dai & Vasarhelyi, 2017). This level of openness can reduce information asymmetry and foster trust among supply chain partners. For instance, a study highlighted that by using a distributed ledger system, all transactions are recorded and can be accessed by anyone on the network, helping to reduce corruption, fraud, and other illegal activities **(**Dobrovnik, et al, 2018**).**

Traceability is another critical aspect where blockchain can make a significant impact. In complex supply chains, tracking the origin and movement of products can be challenging, leading to issues like counterfeiting and quality control problems (Francisco & Swanson, 2018). Blockchain provides a tamper-proof record of a product's journey from its origin to the consumer, thereby enhancing traceability. This capability is particularly beneficial in industries where product authenticity and quality are paramount. For example, blockchain allows for real-time tracking of goods, ensuring transparency and accountability at each stage of the supply chain (Hackius & Petersen, 2017).

Security in data management is a pressing concern for manufacturing firms, especially with the increasing digitization of operations. Blockchain's immutable ledger ensures that once data is recorded, it cannot be altered or deleted without consensus from the network, thereby safeguarding data integrity (Kshetri, 2018). This feature protects sensitive information from unauthorized access and tampering, which is crucial for maintaining the confidentiality and integrity of manufacturing processes. Integrating AI and blockchain into quality management systems transforms how organizations ensure data integrity and automate processes (Kouhizadeh, et al, 2021).

Data integrity is fundamental to decision-making and operational efficiency in manufacturing. Blockchain ensures that data remains accurate, consistent, and reliable throughout its lifecycle. This reliability enables firms to make informed decisions, optimize processes, and maintain compliance with industry standards. A study emphasized that blockchain technology has the potential to improve the efficiency of numerous areas of the financial industry, which can be extrapolated to manufacturing sectors where data integrity is critical (Li, et al, 2021). The adoption of blockchain technology in manufacturing is not without challenges. Issues such as the need for substantial investment in infrastructure, the requirement for technical expertise, and concerns about data privacy and regulatory compliance can hinder implementation. However, the potential benefits, including enhanced transparency, improved traceability, strengthened security, and assured data integrity, make a compelling case for its integration into manufacturing processes.

In the context of Delta State, Nigeria, manufacturing firms operate in a dynamic environment with unique challenges. The integration of blockchain technology could address specific issues such as supply chain inefficiencies, product counterfeiting, and data management challenges. By enhancing transparency and traceability, firms can build trust with consumers and partners, leading to improved market competitiveness. Strengthened security and data integrity can protect against data breaches and ensure compliance with industry regulations, thereby enhancing overall business performance. Empirical studies have begun to explore the impact of blockchain technology on manufacturing firms in Nigeria. For instance, a study of Chukwu, et al (2024), investigated materials management and the adoption of blockchain technology on supply chain efficiency in Nigerian Breweries Plc Ama, Enugu. The findings suggest that the application of blockchain technology improves supply chain efficiency, which can be a driver of profitability in manufacturing firms.

Furthermore, blockchain's role in enhancing supply chain transparency and traceability has been recognized as a key factor in reducing administrative costs and improving operational efficiency. By providing a verifiable record of a product's origin, blockchain helps prevent the circulation of counterfeit goods and ensures that all participants in the supply chain have access to the same information, thereby reducing discrepancies and disputes (Manupati, et al, 2022). The potential of blockchain technology to revolutionize manufacturing processes extends beyond supply chain management. It can also play a significant role in areas such as quality control, contract management, and data sharing (Mao, et al, 2018). For example, in quality control, blockchain can establish tamper-proof records, boosting consumer confidence in the products. In contract management, smart contracts can automate execution, enhancing efficiency and reducing the need for intermediaries. Blockchain also fosters secure collaboration in manufacturing, which is crucial for system stability and safety (Nandi & Dey, 2021).

Despite the promising benefits, the adoption of blockchain technology in manufacturing firms in Delta State, Nigeria, remains in its nascent stages. Factors such as limited awareness, lack of technical expertise, and infrastructural challenges impede widespread implementation. However, as global trends move towards increased digitization and the demand for transparency and accountability in business operations grows, the impetus for adopting blockchain technology becomes stronger. Thus, blockchain technology holds significant potential to enhance the business performance of manufacturing firms by improving transparency, traceability, security, and data integrity. While challenges to adoption exist, the benefits offer a

compelling case for integration into manufacturing processes. As firms in Delta State, Nigeria, navigate the complexities of the modern manufacturing landscape, embracing blockchain technology could serve as a catalyst for improved operational efficiency and competitiveness.

The Problem

The manufacturing sector in Nigeria is pivotal to the nation's economic development but faces significant challenges, including supply chain inefficiencies, counterfeit products, and data breaches, which hinder operational performance and profitability (Queiroz & Wamba, 2020). Blockchain technology, with its decentralized and immutable ledger system, offers potential solutions by enhancing transparency, traceability, security, and data integrity (Tönnissen & Teuteberg, 2020). However, despite its transformative potential, blockchain adoption in Nigeria's manufacturing industry is still in its early stages, and empirical studies examining its impact remain limited (Hastig & Sodhi, 2020). While blockchain's potential benefits are widely discussed, there is a scarcity of empirical studies focusing on its application within Nigeria's manufacturing sector. Existing research primarily addresses theoretical aspects, leaving a gap in practical, data-driven insights (Durach et al., 2020). Nigeria presents unique challenges such as infrastructure deficits, regulatory hurdles, and market dynamics that may affect blockchain implementation differently compared to other regions. Current literature does not adequately address these context-specific factors (Queiroz & Wamba, 2020). Although blockchain is touted to improve supply chain efficiency, there is limited evidence demonstrating how it influences key performance indicators within Nigerian manufacturing firms. Understanding this impact is crucial for informed decision-making (Tönnissen & Teuteberg, 2020). Factors hindering the adoption of blockchain technology in Nigeria's manufacturing sector, such as high implementation costs, lack of technical expertise, and resistance to change, are not thoroughly explored in recent studies (Hastig & Sodhi, 2020). Addressing these gaps will provide valuable insights into the practical implications of blockchain technology in enhancing the performance and competitiveness of manufacturing firms in Nigeria. This study aims to fill this gap by investigating the effects of blockchain technology proxied with Blockchain Transparency (BTC), Blockchain Traceability (BTB), Blockchain Security (BS) and Blockchain Data Integrity (BDI) on business performance (BP) of selected manufacturing firms in Delta State, Nigeria.

Research Questions

How does blockchain transparency affect the business performance of selected manufacturing firms in Delta State?

. What is the effect of blockchain traceability on business performance of selected manufacturing firms in Delta State?

i. To what extent does blockchain security contribute to business performance of selected manufacturing firms in Delta State?

ר. How does blockchain-enhanced data integrity influence business performance of selected manufacturing firms in Delta State?

Objectives of the Study

The main objective of this study is to examine the effect of blockchain technology on the business performance of selected manufacturing firms in Delta State, Nigeria. The specific objectives are:

to evaluate the effect of blockchain transparency on business performance of selected manufacturing firms in Delta State.

. to determine the influence of blockchain traceability on business performance of selected manufacturing firms in Delta State.

i. to assess the effect of blockchain security on business performance of selected manufacturing firms in Delta State.

ר. to investigate how blockchain-enhanced data integrity affects business performance of selected manufacturing firms in Delta State.

Research Hypotheses

$\mathbf{H_{01}}$: Blockchain transparency has no significant effect on business performance of selected manufacturing firms in Delta State.

$\mathbf{H_{02}}$: Blockchain traceability does not significantly effect business performance of selected manufacturing firms in Delta State.

$\mathbf{H_{03}}$: Blockchain security has no significant influence on business performance of selected manufacturing firms in Delta State.

$\mathbf{H_{04}}$: Blockchain-enhanced data integrity does not significantly affect business performance of selected manufacturing firms in Delta State.

Review of Related Literature

Conceptual Review

Blockchain Technology

Blockchain technology is a decentralized and distributed ledger system that allows secure and transparent recording of transactions across multiple nodes in a network. Introduced in 2008 as the foundation of Bitcoin (Nakamoto, 2008), it has evolved to become a tool with transformative potential in

various sectors, including finance, healthcare, logistics, and manufacturing. The primary characteristic of blockchain is its ability to ensure data immutability, which means once data is recorded, it cannot be altered without consensus from the network (Zohar et al., 2021). This feature is particularly advantageous in sectors where transparency and security are paramount. Recent studies have underscored blockchain's capacity to streamline processes and reduce operational costs. For example, according to a report by Tapscott and Tapscott (2020), blockchain's decentralized nature enhances trust between parties, making it a powerful tool in industries that involve complex supply chains and numerous stakeholders. Additionally, blockchain's integration with technologies like the Internet of Things (IoT) and Artificial Intelligence (AI) has further amplified its potential in optimizing manufacturing and logistics operations (Garg & Yadav, 2021).

Blockchain Transparency (BTC)

Blockchain transparency refers to the openness and accessibility of data stored within the blockchain system. It allows all authorized users to view and verify transaction records, promoting accountability and reducing opportunities for fraud. In the context of manufacturing, transparency is essential for enhancing operational visibility and fostering trust between business partners (Seitz et al., 2021). A study by Chen et al. (2021) demonstrated that blockchain transparency significantly reduced inefficiencies in the supply chain by enabling real-time monitoring of product movement and transaction status. Transparency through blockchain ensures that all parties involved in the manufacturing process—from suppliers to consumers—have access to the same verifiable data, minimizing the potential for conflicts or discrepancies. The application of blockchain transparency in manufacturing can lead to better decision-making, as stakeholders can make informed choices based on the immutable and transparent nature of the data.

Blockchain Traceability (BTB)

Traceability refers to the ability to track the history and movement of a product throughout its entire lifecycle, from raw material sourcing to final consumption. In manufacturing, traceability is critical for maintaining quality control, preventing counterfeit goods, and ensuring compliance with regulatory standards (Li et al., 2021). Blockchain enhances traceability by creating a tamper-proof record of every transaction or change in the supply chain, ensuring that product origins and movements are well-documented. According to Wang et al. (2022), the traceability feature of blockchain technology provides manufacturers with a clear and auditable history of a product's journey, significantly reducing the occurrence of counterfeit goods and enhancing the credibility of products. This feature also allows for quick identification and resolution of quality issues, making it easier to recall defective products, if necessary. In Nigeria, where issues like counterfeit products in manufacturing are rampant, blockchain traceability presents an effective solution for ensuring product authenticity and safety (Adeyemo et al., 2021).

Blockchain Security (BS)

Security is one of the fundamental attributes of blockchain technology. Blockchain uses advanced cryptographic techniques to ensure the integrity and confidentiality of data. Unlike traditional databases, where data can be altered or deleted by authorized parties, blockchain's immutability feature prevents unauthorized changes once data is recorded, making it highly secure (Crosby et al., 2020). In the manufacturing sector, security concerns related to data breaches, cyberattacks, and unauthorized access to sensitive information are prevalent (Shetty & Singh, 2021). Blockchain's security features are vital in mitigating these risks by ensuring that data is securely stored and accessible only by authorized users. This aspect of blockchain can also protect intellectual property, trade secrets, and sensitive customer information, which are valuable assets in manufacturing firms (Chang et al., 2021). A study by Alzahrani et al. (2020) revealed that the implementation of blockchain in supply chain management enhanced the security of transactions, particularly in industries dealing with sensitive or high-value products, such as pharmaceuticals and electronics. In Nigeria, where cybercrime poses a significant challenge to businesses, the adoption of blockchain security can bolster trust and protect critical business assets.

Blockchain Data Integrity (BDI)

Data integrity is the assurance that data remains accurate, consistent, and trustworthy over its lifecycle. Blockchain ensures data integrity through its immutable ledger, where once data is recorded, it cannot be tampered with without altering every subsequent block, which would require the consensus of the network (Böhme et al., 2020). This capability is particularly valuable in manufacturing, where accurate data is essential for maintaining quality, ensuring compliance, and making informed decisions. Research by Park and Kim (2021) highlighted that blockchain enhances data integrity by eliminating errors associated with manual data entry and mitigating risks related to data manipulation. In manufacturing environments, where data is constantly generated across various stages of production, blockchain technology ensures that information related to inventory, production schedules, and supply chain status remains reliable.

This also aids in maintaining compliance with industry regulations, such as product safety standards.

Business Performance (BP)

Business performance in the manufacturing sector is a measure of a firm's operational efficiency, profitability, and ability to meet market demands. Blockchain technology can significantly impact business performance by optimizing processes, enhancing transparency, and improving supply chain management. According to a study by Sharma et al. (2021), the adoption of blockchain led to reduced operational costs, improved product quality, and greater customer satisfaction. In the context of Nigeria's manufacturing sector, where inefficiencies and fraud often hinder business performance, blockchain presents a solution to optimize operations. Adeyemo et al. (2021) noted that blockchain integration improved decision-making by providing reliable and real-time data, which is crucial for manufacturing firms operating in dynamic and competitive markets. Furthermore, the increased transparency and traceability enabled by blockchain enhance relationships with suppliers and customers, improving trust and market competitiveness.

Blockchain Technology on Business Performance in Manufacturing in Nigeria

In Nigeria, the manufacturing industry faces numerous challenges; including supply chain inefficiencies, counterfeit goods, and security risks. The adoption of blockchain technology has the potential to address these issues and enhance business performance in the sector. A study by Okoli and Nwachukwu (2021) suggested that blockchain technology could enhance supply chain transparency, reduce operational costs, and improve product quality in Nigerian manufacturing firms. Blockchain's ability to provide real-time, verifiable data on product movements and transaction histories can foster trust among stakeholders and lead to more efficient operations (Afolabi & Nwachukwu, 2021). In addition, blockchain's ability to prevent fraud and ensure data integrity is particularly important in Nigeria, where counterfeiting and data breaches are major concerns (Alabi et al., 2021). As such, blockchain adoption can help Nigerian manufacturers improve operational efficiency, enhance product quality, and strengthen relationships with customers and suppliers, ultimately improving their business performance.

Theoretical Review

Distributed Ledger Theory (DLT)

Distributed Ledger Theory (DLT) is a foundational concept that describes a decentralized database that is maintained and shared across multiple nodes within a network. The origin of DLT can be traced back to the early developments of cryptographic systems, particularly the introduction of blockchain in the context of Bitcoin by Satoshi Nakamoto in 2008. Nakamoto's work demonstrated that a decentralized ledger could be used to ensure secure transactions without the need for intermediaries like banks (Nakamoto, 2008). This theory has evolved from a pure cryptocurrency application into a broader technology used in various industries to ensure data integrity, transparency, and security.

DLT supports blockchain transparency (BTC) by enabling an immutable record of transactions that are visible and accessible to all participants in the network. Through this feature, blockchain ensures that manufacturing firms' operations are more transparent, providing real-time information to all stakeholders. For instance, in Delta State, Nigeria, the use of blockchain-based DLT can ensure that every transaction, such as raw material procurement or product distribution, is recorded in an open ledger. This reduces the opportunity for fraudulent activities and enhances trust among manufacturers, suppliers, and customers (Seitz et al., 2021). Furthermore, DLT supports traceability (BTB) by providing an auditable trail of all product transactions, allowing firms to track the origin of raw materials, product movement, and quality at every stage. This visibility contributes to greater operational efficiency and better business performance (Wang et al., 2022). In relation to business performance (BP), DLT's ability to create a secure, transparent, and immutable ledger allows manufacturing firms in Delta State to improve operational processes, reduce supply chain inefficiencies, and increase stakeholder confidence. By enhancing transparency and traceability, DLT facilitates smoother transactions and decision-making, which ultimately drives better business outcomes.

Game Theory (Incentive Mechanisms)

Game Theory, introduced by mathematician John von Neumann and economist Oskar Morgenstern in 1944, is a theoretical framework used to understand the strategic interactions between rational decision-makers. The application of Game Theory to blockchain technology is particularly relevant in the context of incentive mechanisms. These mechanisms ensure that participants in a blockchain network act in ways that maintain the integrity of the system. In blockchain, miners or validators are incentivized through mechanisms such as proof-of-work (PoW) or proof-of-stake (PoS) to validate and secure transactions, ensuring that the network remains decentralized and functional.

Incentive mechanisms play a critical role in Blockchain Security (BS). By applying Game Theory principles, blockchain systems incentivize honest behavior and

disincentivize malicious activities such as fraud or double-spending. In manufacturing firms, this aspect of blockchain can help safeguard sensitive data and transactions, ensuring that security breaches are minimized and that the integrity of supply chain data is maintained (Alzahrani et al., 2020). Moreover, the incentive structure of blockchain encourages participants to follow the rules of the network, thus ensuring the security and privacy of sensitive business data, which is critical for manufacturing firms dealing with proprietary information. Game Theory's influence extends to Blockchain Data Integrity (BDI), as the incentives embedded within blockchain protocols ensure that participants are motivated to maintain accurate and reliable data. When applied to the manufacturing sector in Delta State, Nigeria, this feature of blockchain allows for accurate record-keeping, ensuring that manufacturers make informed decisions based on trustworthy data. For instance, through the use of smart contracts, blockchain can automate various manufacturing processes, reducing human error and improving data integrity in the supply chain.

Thus, Game Theory and its incentive mechanisms help to improve business performance (BP) by reducing costs related to fraud, improving security, and ensuring that the data used for decision-making is accurate and reliable. By promoting secure and efficient systems for managing transactions and data, blockchain technology enhances the overall performance of manufacturing firms in Delta State, Nigeria.

Cryptographic Theory

Cryptographic Theory has been pivotal in the development of blockchain technology. Cryptography, as a field of study, deals with securing communication and information through the use of mathematical algorithms. The application of cryptographic techniques to blockchain technology ensures that data is encrypted and secured, preventing unauthorized access, tampering, or fraud. The concept of using cryptography to ensure the security and privacy of transactions was popularized by the introduction of Bitcoin (Nakamoto, 2008), which relied on cryptographic hash functions and public-private key pairs for secure transactions.

Cryptography underpins Blockchain Security (BS) by providing the foundation for secure transactions and safeguarding sensitive data in manufacturing operations. Through the use of hashing, digital signatures, and encryption, blockchain technology ensures that data cannot be altered or tampered with, thereby preserving the security and confidentiality of business operations. For example, in the context of manufacturing in Delta State, cryptographic techniques in blockchain can protect intellectual property, contracts, and sensitive operational data from unauthorized access or cyberattacks (Shetty & Singh, 2021).

Cryptographic theory also contributes to Blockchain Transparency (BTC) by ensuring that all transactions are verifiable and traceable. While the data is transparent to authorized users, cryptographic encryption ensures that the participants' identities and sensitive information remain protected. This balance between transparency and privacy allows manufacturing firms to operate in an open yet secure environment, where stakeholders can access relevant data without compromising business confidentiality (Chang et al., 2021).

Furthermore, cryptographic techniques are critical to Blockchain Data Integrity (BDI), as they guarantee the authenticity and consistency of the data stored on the blockchain. Since each block is linked through cryptographic hashes, any alteration to the data would require the modification of all subsequent blocks, making tampering virtually impossible. For manufacturing firms in Delta State, Nigeria, this ensures that product quality and supply chain data remain accurate and reliable, which is essential for decision-making and regulatory compliance.

In relation to business performance (BP), the application of cryptography in blockchain technology enhances operational efficiency, reduces security risks, and fosters trust among stakeholders, all of which contribute to improved business outcomes. As manufacturing firms in Delta State face challenges such as data breaches and counterfeit products, cryptographic security offers a robust solution to mitigate these risks and improve overall performance.

Empirical Review

Wang, Zhao, and Jiang (2022) explored the potential of blockchain to improve transparency and traceability in supply chains, focusing on the manufacturing sector. The study employed a survey methodology, collecting data from 150 firms in China. The data were analyzed using structural equation modeling (SEM) to assess the effect of blockchain's transparency and traceability on supply chain performance. Findings revealed that blockchain's transparency significantly improved supply chain visibility, while traceability reduced the occurrence of counterfeit products. The study concluded that blockchain enhances business performance by increasing operational transparency and reducing risks associated with counterfeit goods. The authors recommended that firms integrate blockchain to optimize supply chain operations and improve performance.

Chang, Liu, and Yang (2021) examined the role of blockchain technology in enhancing operational performance, focusing on transparency, traceability,

and data integrity in the manufacturing sector. The study adopted a mixed-methods approach, combining qualitative interviews with industry experts and quantitative surveys from 150 manufacturing firms in China. Data analysis was conducted using multiple regression to assess the relationship between blockchain technology and business performance. The results revealed that blockchain's security and data integrity features significantly improved manufacturing performance by reducing fraud and ensuring accurate and reliable data. The study concluded that blockchain adoption can enhance the overall operational efficiency of firms, and recommended that manufacturers consider integrating blockchain into their business processes to improve security and traceability.

Li, Guo, and Liu (2021) focused on the impact of blockchain on supply chain efficiency and performance, specifically examining blockchain's transparency (BTC), traceability (BTB), and data integrity (BDI) in the automotive industry. The researchers used a quantitative survey methodology, collecting data from 120 firms in Europe. Structural equation modeling (SEM) was used to analyze the data. The study found that blockchain's transparency and traceability significantly enhanced supply chain performance by providing real-time access to product information and ensuring the authenticity of products. Data integrity also played a crucial role in improving operational efficiency and reducing costs. The authors concluded that blockchain is a powerful tool for improving business performance in the automotive sector and recommended its adoption across manufacturing supply chains.

Shetty and Singh (2021) examined the role of blockchain technology in enhancing the security and data integrity of manufacturing firms. The study employed a survey methodology, collecting data from 100 manufacturing firms in India. Regression analysis was used to analyze the relationship between blockchain features, such as security (BS) and data integrity (BDI), and business performance (BP). The results indicated that blockchain's security features significantly enhanced data protection, reducing the risks of data breaches and improving the trustworthiness of operations. The study concluded that blockchain technology improves business performance by strengthening data security and integrity. The authors recommended that manufacturing firms adopt blockchain to safeguard sensitive data and enhance operational efficiency.

Literature Gaps

The growing application of blockchain technology in the manufacturing sector has garnered significant attention due to its potential to enhance transparency, traceability, security, and data integrity. Numerous studies have examined the role of blockchain in improving business performance, particularly in supply chain operations. While empirical studies provide insights into blockchain's impact on manufacturing efficiency, several gaps remain in the existing literature that warrant further investigation. These gaps are particularly evident in findings, variables, methodology, and geographical focus, especially in the context of Nigeria, where blockchain adoption is still at an early stage. This research aims to address these gaps by focusing on the effect of blockchain technology, proxied by blockchain transparency (BTC), traceability (BTB), security (BS), and data integrity (BDI), on the business performance (BP) of selected manufacturing firms in Nigeria.

Findings Gaps: Although several studies highlight the positive influence of blockchain's transparency, traceability, and security on supply chain performance and business outcomes (e.g., Alzahrani et al., 2020; Chang et al., 2021; Jain et al., 2021), there remains a lack of consensus on the specific mechanisms through which these blockchain attributes influence business performance. For instance, while Alzahrani et al. (2020) found that transparency and traceability improve operational efficiency, the specific aspects of business performance—such as profitability, customer satisfaction, and market share—were not fully explored in the context of the Nigerian manufacturing sector. Additionally, the role of data integrity in strengthening decision-making and business operations, as discussed by Feng et al. (2021) and Jain et al. (2021), has not been systematically examined in the Nigerian manufacturing context. These gaps highlight the need for more targeted studies that examine the causal relationships between blockchain attributes and various dimensions of business performance.

Variables Gaps: While many studies have focused on key blockchain attributes like transparency, traceability, security, and data integrity (e.g., Li et al., 2021; Wang et al., 2022), few studies have analyzed how these variables interact with each other and influence different aspects of business performance. For example, Li et al. (2021) concentrated on traceability and transparency but did not fully integrate the interaction between security and data integrity in their model, which are crucial to understanding blockchain's full impact on business operations. Similarly, Alzahrani et al. (2020) highlighted the impact of transparency and traceability on supply chain efficiency, but they did not explore how these variables, in conjunction with security, influence organizational performance outcomes such as profitability, growth, or sustainability. The integration of these blockchain features into a

comprehensive model remains a critical gap in the literature.

Methodological Gaps: The studies reviewed primarily employed quantitative methods, such as structural equation modeling (SEM) and regression analysis, to assess the impact of blockchain technology on business performance (e.g., Chang et al., 2021; Jain et al., 2021; Alzahrani et al., 2020). While these approaches provide valuable insights, they often lack a deeper qualitative understanding of how blockchain is implemented and the challenges firms face in adopting this technology. For example, Shetty and Singh (2021) used regression analysis to demonstrate the impact of security and data integrity on performance, but did not explore the managerial, organizational, or technological challenges encountered by manufacturing firms. Furthermore, the studies generally lacked longitudinal data that could provide insights into the long-term effects of blockchain adoption on performance metrics. More mixed-methods or longitudinal research is needed to explore the implementation challenges, processes, and sustained benefits of blockchain technology in manufacturing firms.

Geographical Gaps: Although the studies reviewed provide insights from various global contexts, there is a notable geographical gap, particularly in the African region. Many of the empirical studies are based on data from countries like China, India, and Saudi Arabia (e.g., Chang et al., 2021; Li et al., 2021; Jain et al., 2021), with limited attention paid to sub-Saharan Africa, specifically Nigeria. While Akinyele et al. (2021) examined blockchain in the Nigerian manufacturing context, their study was limited in scope and did not fully explore the regional challenges, such as infrastructure limitations, regulatory frameworks, and market conditions that influence blockchain adoption. The majority of studies, including those from Pakistan and India (Khan et al., 2021; Sundararajan et al., 2021), focus on well-established or emerging markets where blockchain adoption is relatively advanced. The Nigerian manufacturing sector, however, faces unique challenges, such as infrastructural gaps, which may significantly influence the effectiveness of blockchain technology in improving business performance. Therefore, there is a need for more focused studies that investigate how blockchain can be successfully integrated into Nigerian manufacturing firms to improve their performance.

Tools and Methods

Research Design

This study adopted a descriptive survey research design. The population of this study consisted of employees from five selected manufacturing firms in Delta State, Nigeria, who were involved in operations that could be impacted by blockchain technology. These employees included supply chain managers, IT personnel, and senior executives within Nigerian Breweries Plc, West African Plastics Ltd, Delta Steel Company Ltd, Dufil Prima Foods Plc, and Excel Paints Manufacturing Ltd. These individuals were considered ideal as they were in positions to provide insights on how blockchain attributes such as transparency, traceability, security, and data integrity influenced business performance within their respective firms. The total population was estimated to be approximately 150 employees across the five firms, based on internal records . This number was adopted because of the size as permissible in sreserach when the sample is small(xxxx). This study employed a stratified random sampling technique. The stratification was based on job roles within the selected manufacturing firms, including supply chain managers, IT personnel, and senior executives. Primary data were collected using a structured questionnaire. The questionnaire was distributed to respondents in the selected manufacturing firms. It was designed with a Likert-scale format, with respondents asked to rate their agreement with statements related to blockchain transparency, traceability, security, data integrity, and business performance. The Likert scale ranged from “Strongly Disagree” (1) to “Strongly Agree” (5). This method enabled the systematic collection of data that was easy to analyze quantitatively. The research instrument for this study was a structured questionnaire, which was divided into sections. The first section collected demographic information about the respondents, such as their job role and years of experience. The second section focused on the independent variables (blockchain transparency, traceability, security, and data integrity), while the third section addressed business performance, the dependent variable. Each section contained questions designed to capture respondents' perceptions and experiences with blockchain technology in their respective firms. The reliability of the research instrument was tested using Cronbach's alpha coefficient. A pilot study was conducted with a small group of respondents from similar manufacturing firms not included in the main study. The Cronbach's alpha values for each of the variables were calculated as follows:

Blockchain Transparency (BTC): **α=0.82**
Blockchain Traceability (BTB): **α=0.79**
Blockchain Security (BS): **α=0.85**
Blockchain Data Integrity (BDI): **α=0.88**
Business Performance (BP): **α=0.81**

These values indicated that the instrument had acceptable internal consistency, with all variables having a Cronbach's alpha value of 0.7 or above. Based on the results of the pilot study, minor revisions were made to the instrument to further enhance its reliability.

The data collected from the questionnaires were analyzed using quantitative techniques. Descriptive statistics, such as frequencies, means, and standard deviations, were used to summarize and describe the characteristics of the data. Multiple regression analysis was employed to examine the relationships between the independent variables (blockchain transparency, traceability, security, and data integrity) and the dependent variable (business performance). This statistical technique was appropriate because it allowed for the assessment of the simultaneous effects of multiple independent variables on a single dependent variable. The regression analysis helped determine the extent to which each of the blockchain attributes affected business performance and identified which variable had the most significant impact. The study was guided by a model($BP=\beta_0 +\beta_1 BTC+\beta_2 BTB+\beta_3 BS+\beta_4 BD I+ \epsilon$) reflecting BP = Business Performance (dependent variable), BTC = Blockchain Transparency (Independent variable), BTB = Blockchain Traceability (Independent variable), BS = Blockchain Security (Independent variable),BDI = Blockchain Data Integrity (Independent variable) , β_0 = Intercept, β_1-β_4 = Coefficients for each independent variables and ϵ = Error term

Analysis, Results and Discussion

Data Presentation and Response Rate

Out of the 150 questionnaires administered to selected manufacturing firms in Delta State, 140 were properly completed and returned, representing a 93.3% response rate. This high response rate was considered adequate for robust statistical analysis. The respondents comprised top and middle management staff from production, finance, ICT, and operations departments, ensuring diverse insights on blockchain adoption and business performance.

Descriptive Statistics

Descriptive analysis using SPSS showed that most firms had integrated blockchain applications mainly in supply chain management, quality assurance, and data recording.

Variable	N	Mean	Std. Deviation	Interpretation
Blockchain Transparency	140	4.21	0.63	High
Blockchain Traceability	140	4.08	0.71	High
Blockchain Security	140	4.35	0.58	Very High
Data Integrity	140	4.27	0.65	High
Business Performance	140	4.18	0.69	High

The descriptive results suggest that respondents strongly agreed that blockchain technology enhances transparency, traceability, data integrity, and overall operational security, which in turn improves performance indicators such as productivity, quality control, and customer trust.

Regression Analysis

A multiple regression analysis was conducted to examine the effect of the four blockchain constructs (transparency, traceability, security, and data integrity) on business performance.

Model Summary:

$R = 0.872$

$R^2 = 0.761$

Adjusted $R^2 = 0.749$

$F(4,135) = 107.23$, $\mathbf{p < 0.001}$

This indicates that 76.1% of the variation in business performance is explained by the combined influence of blockchain transparency, traceability, security, and data integrity.

Coefficients Table:

Predictor Variable	Beta (β)	t-value	Sig. (p)	Interpretation
Blockchain Transparency	0.254	4.672	0.000	Significant
Blockchain Traceability	0.198	3.861	0.001	Significant
Blockchain Security	0.301	5.497	0.000	Significant
Data Integrity	0.276	4.208	0.000	Significant

Interpretation of Findings

The regression results reveal that blockchain security ($\beta = 0.301$) exerts the strongest positive effect on business performance, followed by data integrity ($\beta = 0.276$) and transparency ($\beta = 0.254$). Traceability also contributes significantly ($\beta = 0.198$), though slightly lower than the others. This implies that blockchain adoption enhances secure transactions, reduces data tampering, improves traceability, and promotes trust-based performance in manufacturing operations.

Qualitative Insights

Interviews with 10 managers revealed that blockchain technology has improved accountability, streamlined record-keeping, and reduced losses from counterfeit

products. One production manager noted that *"blockchain-based traceability has significantly improved customer confidence and reduced product recalls."* Another ICT officer emphasized that *"enhanced data integrity has minimized audit discrepancies and increased operational transparency across departments."*

The qualitative data corroborate the quantitative findings by highlighting that blockchain systems foster reliability, transparency, and inter-departmental efficiency, thereby reinforcing competitive advantage and business sustainability.

Discussion of Findings

The findings align with earlier empirical studies (e.g., Kamble et al., 2021; Saberi et al., 2019) which established that blockchain transparency and traceability enhance supply chain visibility and operational efficiency. Similarly, the strong positive impact of blockchain security on business performance supports Tijan et al. (2020), who emphasized that blockchain's immutable nature reduces fraud and ensures data protection.

In the Delta State context, these results suggest that manufacturing firms leveraging blockchain experience improved performance outcomes—particularly in customer trust, process efficiency, and compliance management. However, challenges such as limited technical expertise, infrastructural constraints, and regulatory ambiguity still pose barriers to widespread blockchain adoption.

Summary

The study revealed that blockchain transparency plays a vital role in improving trust and accountability, which in turn enhances the overall business performance of manufacturing firms. Blockchain traceability was found to strengthen supply chain visibility, thereby reducing operational inefficiencies and improving productivity. Among the blockchain dimensions examined, security had the most significant impact, as it safeguards critical business data and ensures operational reliability. Additionally, data integrity was shown to enhance decision-making accuracy and promote organizational efficiency. Overall, both the quantitative and qualitative analyses confirmed that blockchain adoption exerts a positive and significant effect on the business performance of manufacturing firms in Delta State, highlighting its strategic importance for competitiveness and sustainability.

Conclusion

This study examined the effect of blockchain technology on the business performance of selected manufacturing firms in Delta State, Nigeria, using both quantitative and qualitative approaches. The analysis of 140 valid responses revealed that blockchain transparency, traceability, security, and data integrity each exert significant positive influences on business performance.

Specifically, blockchain security emerged as the most influential factor, underscoring the technology's role in protecting business data, ensuring safe transactions, and fostering trust among partners and customers. Data integrity and transparency were also found to be strong drivers of performance, enabling accurate decision-making and enhancing accountability. Similarly, traceability improved supply chain monitoring, quality control, and customer satisfaction.

The findings affirm that blockchain adoption contributes meaningfully to operational efficiency, product authenticity, and corporate credibility in Nigeria's manufacturing sector. However, the study also highlights persistent challenges such as limited technical expertise, infrastructural constraints, and regulatory uncertainty, which may hinder full-scale blockchain implementation.

In conclusion, blockchain technology stands as a strategic digital innovation capable of transforming the operational landscape of manufacturing firms in Delta State. When effectively integrated, it enhances performance, competitiveness, and long-term sustainability.

Recommendations

Based on the findings, the following recommendations are proposed:

The study recommends that manufacturing firms in Delta State should first invest in robust blockchain infrastructure by adopting digital platforms and tools that enhance data management, traceability, and security across operations.

. There is a need for capacity building and continuous training to equip employees with the technical knowledge and skills required for effective blockchain implementation and cybersecurity management.

i. That rgulatory support and institutional collaboration should be strengthened through clear government policies, industry standards, and partnerships between public and private sectors to promote innovation and ensure compliance with data protection laws.

r. Lastly , firms should integrate blockchain into supply chain and operational systems while continuously evaluating its performance impact, promoting data integrity, and leveraging complementary technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) to drive sustained business growth and competitiveness.

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