Blockchain System Applications and Supply Chain Performance in the Retail Sector: Evidence from Carrefour Supermarkets in Nairobi City County, Kenya

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ABSTRACT

Blockchain technology has emerged as a strategic digital innovation with the potential to enhance supply chain transparency, coordination, process automation, and transaction integrity. Although blockchain adoption has accelerated across manufacturing, logistics, and financial services, empirical evidence on the operational value of specific blockchain capabilities within retail supply chains in emerging economies remains limited. This study examined the influence of blockchain system applications-synchronized data, consensus protocols, smart contracts, and data immutability - on supply chain performance using evidence from Carrefour Supermarkets in Nairobi City County, Kenya.

The study was anchored on the Technology-Organization-Environment (TOE) framework and complemented by Diffusion of Innovation Theory, Institutional Theory, and Information Processing Theory. A positivist philosophy and descriptive-explanatory cross-sectional survey design were adopted. Primary data were collected through structured questionnaires administered to 175 employees engaged in supply chain functions and analyzed using descriptive statistics, Pearson correlation, and multiple regression analysis.

The regression model explained 35.2% of the variation in supply chain performance ($R^2 = 0.352$; Adjusted $R^2 = 0.336$). The findings revealed that synchronized data ($\beta = 0.2217$, $p = 0.003$), consensus protocols ($\beta = 0.1860$, $p = 0.009$), and smart contracts ($\beta = 0.3198$, $p < 0.001$) exerted positive and statistically significant effects on supply chain performance, while data immutability ($\beta = 0.1185$, $p = 0.095$) exhibited a positive but statistically insignificant influence. Smart contracts emerged as the strongest predictor, underscoring the strategic importance of blockchain-enabled process automation in enhancing operational efficiency and coordination.

The study advances blockchain scholarship by conceptualizing blockchain as a multidimensional organizational capability rather than a single technological innovation and demonstrates that individual blockchain capabilities contribute differently to organizational performance. The findings extend current theoretical understanding of blockchain adoption in emerging economies and provide practical guidance for retail managers and policymakers seeking to strengthen supply chain resilience, operational efficiency, and digital transformation through targeted blockchain implementation.

Keywords: Blockchain technology; blockchain system applications; supply chain performance; synchronized data; consensus protocols; smart contracts; data immutability; retail supply chains; emerging economies; Kenya.

INTRODUCTION

Digital transformation has fundamentally altered the manner in which organizations coordinate supply chain activities, exchange information, and create value across increasingly interconnected business ecosystems. Contemporary supply chains extend beyond the traditional movement of products and now encompass the continuous exchange of information, financial transactions, contractual obligations, and collaborative decision-making among geographically dispersed stakeholders. As supply chains become more globalized and digitally integrated, organizations face growing pressure to improve operational transparency, traceability, responsiveness, and resilience while simultaneously reducing transaction costs and information asymmetry.

Blockchain technology has emerged as one of the most influential digital innovations capable of addressing these challenges. Unlike conventional centralized information systems, blockchain provides a decentralized digital ledger that enables multiple authorized participants to access synchronized information, validate transactions through consensus mechanisms, execute automated smart contracts, and maintain immutable transaction records. These capabilities have positioned blockchain as a strategic technology for enhancing supply chain visibility, strengthening inter-organizational trust, reducing fraud, and improving operational efficiency.

Despite considerable academic interest in blockchain technology, empirical research examining its contribution to organizational performance remains fragmented. Existing studies have largely concentrated on technological adoption, conceptual frameworks, or applications within financial services, manufacturing, agriculture, and healthcare. Comparatively fewer studies have investigated blockchain-enabled supply chain capabilities within the retail sector, particularly in emerging economies where institutional conditions, technological readiness, and digital infrastructure differ markedly from those in developed countries.

The retail sector presents a particularly important context for blockchain research. Retail supply chains are characterized by extensive supplier networks, complex inventory management systems, high transaction volumes, and increasing customer expectations regarding product availability, authenticity, and transparency. These characteristics require information systems capable of providing real-time visibility, secure transaction validation, and automated coordination across multiple organizational actors. Blockchain technology offers considerable potential to address these operational requirements by integrating information flows across procurement, warehousing, logistics, finance, and retail operations.

In Kenya, the retail industry has undergone rapid modernization, driven by digital commerce, mobile payment technologies, and changing consumer expectations. Multinational retailers such as Carrefour have invested substantially in digital supply chain systems to improve operational efficiency and customer service. Nevertheless, empirical evidence regarding the operational contribution of blockchain system applications within Kenyan retail supply chains remains limited. Consequently, managers lack sufficient empirical guidance regarding which blockchain capabilities contribute most significantly to supply chain performance.

This study addresses this gap by conceptualizing blockchain as a multidimensional organizational capability comprising synchronized data, consensus protocols, smart contracts, and data immutability. Rather than examining blockchain adoption as a binary technological decision, the study investigates how individual blockchain capabilities influence supply chain performance. Such an approach provides a more nuanced understanding of blockchain implementation while extending current theory and practice.

The study contributes to the literature in three principal ways. First, it advances the conceptualization of blockchain by operationalizing it through four distinct organizational capabilities. Second, it integrates the Technology–Organization–Environment framework with Diffusion of Innovation Theory, Institutional Theory, and Information Processing Theory to provide a comprehensive explanation of blockchain-enabled organizational performance. Third, it provides empirical evidence from an emerging retail market where blockchain research remains comparatively underdeveloped.

LITERATURE REVIEW

Blockchain System Applications and Supply Chain Performance

Blockchain technology has emerged as one of the most transformative digital innovations shaping modern supply chain management. Initially developed as the underlying architecture for cryptocurrencies, blockchain has evolved into a versatile distributed ledger technology capable of facilitating secure, transparent, decentralized, and tamper-resistant transactions across complex organizational networks. Unlike conventional centralized information systems, blockchain enables multiple stakeholders to maintain synchronized records without relying on a single trusted intermediary, thereby enhancing transparency, accountability, and operational coordination (Babich & Hilary, 2020; Wamba & Queiroz, 2020).

Within supply chain management, blockchain addresses persistent challenges associated with fragmented information systems, limited traceability, poor coordination, information asymmetry, and opportunistic behaviour among supply chain partners. Modern supply chains comprise numerous independent organizations, including manufacturers, suppliers, logistics providers, distributors, retailers, regulators, and customers, that continuously exchange information, products, financial resources, and contractual obligations. The efficiency of these interactions depends largely on the quality, reliability, and timeliness of information shared across organizational boundaries. Blockchain technology offers an integrated digital infrastructure capable of improving these interactions through decentralized governance, synchronized information exchange, automated contractual execution, and immutable transaction records.

Although blockchain adoption has attracted substantial scholarly attention over the past decade, the evidence regarding its organizational benefits remains mixed. Earlier conceptual studies frequently portrayed blockchain as a revolutionary technology capable of transforming virtually every aspect of supply chain management through enhanced transparency and trust (Tapscott & Tapscott, 2016; Kshetri, 2018). Subsequent empirical investigations, however, have revealed a more nuanced reality. Rather than producing universal performance improvements, blockchain appears to create organizational value only when implemented alongside complementary organizational capabilities, managerial commitment, and supportive institutional environments (Kamble et al., 2019; Dutta et al., 2020).

Consequently, contemporary blockchain research has shifted from examining whether organizations adopt blockchain toward understanding how specific blockchain capabilities influence organizational performance. This capability-oriented perspective recognizes that blockchain should not be treated as a single technological innovation but rather as a portfolio of complementary functionalities that collectively enhance organizational processes, governance structures, and information management. The present study adopts this perspective by conceptualizing blockchain system application as a multidimensional construct comprising synchronized data, consensus protocols, smart contracts, and data immutability.

This conceptualization is consistent with organizational capability theory, which argues that sustainable competitive advantage arises not merely from technology ownership but from an organization's ability to integrate technological resources into effective operational routines and strategic processes. Accordingly, blockchain capabilities are expected to influence supply chain performance by improving coordination, reducing transaction costs, enhancing trust among supply chain partners, and facilitating more informed managerial decision-making.

Critical Review of Recent Empirical Literature

Recent empirical research generally supports the proposition that blockchain technologies improve supply chain performance, although the magnitude and mechanisms of these effects vary considerably across organizational contexts. Several systematic reviews have concluded that blockchain enhances supply chain transparency, traceability, information security, and operational efficiency while simultaneously reducing fraud, transaction costs, and information asymmetry (Casino et al., 2019; Pournader et al., 2020). Nevertheless, these reviews also emphasize that many published studies remain conceptual or exploratory, with comparatively limited empirical evidence from real organizational settings.

Babich and Hilary (2020) argue that blockchain creates organizational value primarily by improving information quality and strengthening governance mechanisms across decentralized business networks. Their analysis

suggests that distributed ledgers reduce verification costs while improving coordination among supply chain participants. However, they caution that blockchain implementation should not be viewed as a technological panacea because its effectiveness depends upon organizational readiness, process redesign, and stakeholder collaboration.

Similarly, Kamble et al. (2019) found that blockchain adoption positively influences supply chain integration and organizational performance through enhanced information sharing and collaborative relationships. However, the study also reported that technological readiness, management support, and organizational capabilities significantly moderate these relationships, implying that blockchain adoption alone is insufficient to guarantee superior organizational outcomes.

Ivanov and Dolgui (2020) further extend this argument by suggesting that blockchain contributes most effectively to supply chain resilience when integrated with complementary Industry 4.0 technologies, including artificial intelligence, cloud computing, Internet of Things (IoT), digital twins, and predictive analytics. According to these authors, blockchain functions as one component within a broader digital ecosystem rather than an isolated technological solution. This perspective challenges earlier assumptions that blockchain independently transforms supply chain performance.

Research has likewise demonstrated considerable variation in the relative contribution of different blockchain functionalities. Dutta et al. (2020) observe that organizations frequently realize greater operational benefits from blockchain-enabled process automation than from immutable ledger functionality alone. Similarly, Wamba and Queiroz (2020) argue that organizations derive maximum value from blockchain when automation, information visibility, governance mechanisms, and inter-organizational collaboration operate simultaneously. These findings suggest that blockchain capabilities should be examined individually rather than aggregated into a single technological construct.

Despite growing empirical evidence, several important limitations remain within existing blockchain scholarship. First, much of the available literature focuses on manufacturing, logistics, healthcare, and financial services, while comparatively little attention has been directed toward retail supply chains. Retail organizations possess unique operational characteristics - including high inventory turnover, complex supplier networks, extensive customer interactions, and decentralized distribution systems - that may influence blockchain implementation differently from manufacturing environments.

Second, existing research remains geographically concentrated within developed economies characterized by relatively advanced digital infrastructure and supportive regulatory environments. Comparatively fewer studies have examined blockchain-enabled organizational performance within developing countries where technological readiness, institutional quality, regulatory frameworks, and digital maturity differ substantially. Consequently, the transferability of findings across institutional contexts remains uncertain.

Third, previous studies frequently operationalize blockchain adoption as a binary technological decision rather than examining the distinct organizational capabilities through which blockchain generates value. Such an approach obscures the possibility that individual blockchain dimensions contribute differently to organizational performance.

These limitations justify the present study, which investigates blockchain system applications as multidimensional organizational capabilities within the context of a multinational retailer operating in an emerging African economy.

Theoretical Perspective

The study is anchored primarily on the Technology-Organization-Environment (TOE) Framework, which explains organizational technology adoption as a function of technological characteristics, organizational readiness, and environmental conditions (Tornatzky & Fleischer, 1990). The framework provides an appropriate

foundation because blockchain implementation requires not only technological infrastructure but also managerial support, organizational capability, and institutional alignment.

However, the TOE framework alone provides only a partial explanation of blockchain-enabled organizational performance. Consequently, the study integrates three complementary theories to explain how blockchain capabilities influence supply chain outcomes.

Diffusion of Innovation Theory (Rogers, 2003) explains how organizations adopt and implement technological innovations based on perceived relative advantage, compatibility, complexity, trialability, and observability. Within blockchain-enabled supply chains, innovations such as smart contracts and decentralized transaction validation become attractive when managers perceive clear operational benefits relative to traditional information systems.

Institutional Theory (DiMaggio & Powell, 1983; Scott, 2014) further explains how organizational behaviour is shaped by regulatory pressures, industry norms, and stakeholder expectations. Blockchain capabilities strengthen organizational legitimacy by promoting transparency, accountability, traceability, and compliance, thereby enhancing trust among supply chain partners and regulatory authorities.

Information Processing Theory (Daft & Lengel, 1986) complements these perspectives by arguing that organizational performance improves when firms develop mechanisms capable of processing increasingly complex information efficiently. Contemporary supply chains generate large volumes of operational information requiring rapid verification, dissemination, and interpretation. Blockchain capabilities - including synchronized data, consensus protocols, and immutable records - enhance organizational information-processing capacity by reducing uncertainty, improving information quality, and facilitating timely managerial decision-making.

The integration of these four theoretical perspectives provides a more comprehensive explanation of blockchain-enabled organizational performance than any individual theory could provide independently. Together, they explain why organizations adopt blockchain technologies, how blockchain innovations diffuse throughout organizations, how governance mechanisms strengthen inter-organizational trust, and how improved information processing enhances operational performance.

Research Gap

Although blockchain research has expanded considerably over the past decade, several important gaps remain. Existing empirical studies have largely focused on technological adoption rather than the organizational capabilities through which blockchain influences operational performance. Moreover, previous investigations have concentrated predominantly on manufacturing industries and developed economies, leaving retail supply chains in emerging markets comparatively underexplored.

Additionally, few studies have simultaneously examined synchronized data, consensus protocols, smart contracts, and data immutability as distinct dimensions of blockchain capability. As a result, limited evidence exists regarding the relative contribution of each capability to supply chain performance.

The present study addresses these gaps by conceptualizing blockchain system applications as multidimensional organizational capabilities and empirically examining their influence on supply chain performance within Carrefour Supermarkets in Nairobi City County, Kenya. By integrating multiple theoretical perspectives and providing evidence from an emerging retail market, the study contributes to both blockchain scholarship and supply chain management literature while offering practical guidance for organizations pursuing digital transformation initiatives.

Research Method

Research Design

This study adopted a positivist research philosophy because it sought to examine objectively measurable relationships between blockchain system applications and supply chain performance. Positivism assumes that organizational phenomena can be quantified and statistically analyzed to establish causal relationships among variables. This philosophical orientation was appropriate because the study investigated the influence of synchronized data, consensus protocols, smart contracts, and data immutability on supply chain performance using structured quantitative data.

A descriptive-explanatory cross-sectional survey design was employed. The descriptive component enabled the study to characterize the extent to which blockchain capabilities were implemented within Carrefour Supermarkets, while the explanatory component examined the predictive influence of these capabilities on supply chain performance. A cross-sectional approach was considered appropriate because the study examined organizational perceptions at a single point in time.

Study Context

The empirical investigation was conducted at Carrefour Supermarkets operating within Nairobi City County, Kenya. Carrefour represents one of the largest multinational retail chains operating in East Africa and manages an extensive supply chain involving suppliers, distribution centres, warehouses, logistics providers, and retail outlets. These operational characteristics provide an appropriate context for examining blockchain-enabled supply chain capabilities because they require extensive coordination, real-time information exchange, transaction verification, and inventory visibility.

Population, Sampling and Data Collection

The study targeted employees directly involved in supply chain-related activities, including procurement, logistics, warehousing, inventory management, finance, and operations. Given the relatively small and accessible population, a census approach was adopted to maximize representativeness and eliminate sampling error.

A structured questionnaire was developed from validated measurement scales reported in previous blockchain and supply chain studies and refined to fit the retail context. All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire contained measures for synchronized data, consensus protocols, smart contracts, data immutability, and supply chain performance. Of the 180 questionnaires distributed, 175 were returned fully completed, representing a response rate of 97.2%. Such a response rate exceeds commonly accepted thresholds for organizational survey research and substantially reduces concerns regarding non-response bias.

Measurement of Variables

Blockchain system application was operationalized as a multidimensional construct consisting of four first-order dimensions. Synchronized data measured the extent to which blockchain enables real-time information sharing, data consistency, visibility, and information accessibility across supply chain participants. Consensus protocols assessed decentralized transaction validation, trust mechanisms, transaction authenticity, and verification processes. Smart contracts captured automated execution of contractual obligations, process automation, compliance, operational efficiency, and reduction of manual intervention. Data immutability measured permanence of transaction records, traceability, auditability, integrity, and protection against unauthorized modification. Supply chain performance constituted the dependent variable and was measured through indicators reflecting operational efficiency, information flow, responsiveness, inventory coordination, delivery reliability, and overall supply chain effectiveness.

Reliability and Validity

Internal consistency reliability was assessed using Cronbach's alpha coefficients. All study constructs exceeded the recommended threshold of 0.70, indicating satisfactory internal consistency. Content validity was established through expert evaluation involving academic supervisors and specialists in supply chain management.

Construct validity was enhanced by operationalizing each construct using multiple indicators derived from established literature, thereby ensuring adequate coverage of the conceptual domains investigated.

Data Analysis

The study employed both descriptive and inferential statistical techniques. Descriptive statistics summarized respondent characteristics and perceptions regarding blockchain system applications. Pearson correlation analysis examined the relationships among the study variables. Multiple regression analysis was employed to determine the relative contribution of synchronized data, consensus protocols, smart contracts, and data immutability to supply chain performance.

Prior to regression analysis, diagnostic tests were undertaken to examine normality, multicollinearity, linearity, and homoscedasticity. The diagnostic results indicated that the assumptions underlying multiple linear regression were satisfactorily met.

RESULTS

Respondent Profile

A total of 175 usable questionnaires were analyzed. The high response rate reflects strong organizational participation and provides confidence regarding the robustness of the empirical findings. The respondent profile indicates that the workforce was predominantly male, with operational departments accounting for the largest proportion of respondents. Most participants had between six and ten years of organizational experience, suggesting that respondents possessed sufficient operational knowledge to evaluate blockchain-related practices within Carrefour's supply chain.

The demographic distribution therefore supports the credibility of the responses because the majority of participants occupied positions directly associated with procurement, inventory management, logistics, and operational coordination.

Descriptive Statistics

Descriptive statistics were computed to assess respondents' perceptions regarding blockchain system applications and supply chain performance. Across all blockchain dimensions, mean scores indicated that blockchain implementation within Carrefour remained at a moderate stage of development. Consensus protocols recorded the highest mean score, followed by data immutability, synchronized data, and smart contracts. Although respondents generally acknowledged the presence of blockchain-related practices, the findings suggest that implementation remains incomplete and that considerable opportunities exist for expanding blockchain-enabled operational capabilities.

The relatively moderate standard deviations further indicate substantial agreement among respondents regarding organizational blockchain practices, suggesting consistency in employee perceptions across functional departments. Overall, the descriptive findings imply that Carrefour has initiated digital transformation initiatives incorporating blockchain-related capabilities, although implementation remains in an evolutionary rather than fully mature stage.

Correlation Analysis

Pearson correlation analysis examined the strength and direction of relationships among the study variables.

The results demonstrate positive associations between all blockchain dimensions and supply chain performance. Smart contracts exhibited the strongest positive relationship with supply chain performance, followed by synchronized data, consensus protocols, and data immutability.

The strongest association between smart contracts and supply chain performance suggests that process automation may represent the most operationally valuable blockchain capability within retail supply chains. Automated execution of procurement activities, supplier payments, inventory replenishment, and compliance verification appears to contribute substantially to operational effectiveness.

Meanwhile, synchronized data demonstrated a moderately strong positive relationship with supply chain performance, highlighting the importance of real-time information visibility and coordination among supply chain participants. Consensus protocols similarly displayed a positive association, reinforcing the proposition that decentralized transaction validation strengthens organizational trust and operational reliability.

Although data immutability exhibited the weakest correlation among the blockchain dimensions, the relationship remained positive, indicating that transparent and tamper-resistant records contribute to organizational performance, albeit to a lesser degree than process automation and synchronized information sharing. Importantly, correlations among the independent variables remained below conventional multicollinearity thresholds, indicating that each blockchain capability represents a distinct organizational construct contributing unique explanatory power.

Regression Analysis

Multiple regression analysis was undertaken to determine the relative contribution of each blockchain capability to supply chain performance.

Table 1: Summary of multivariate regression analysis

Variables	Coefficient(β)	Std error	p-value	Confidence Interval	
				0.025	0.975
Synchronized Data score (ind. Variable)	0.2217	0.073	0.003**	0.078	0.366
Consensus protocol score (ind. Variable)	0.1860	0.070	0.009 **	0.048	0.324
Smart Contracts Score (ind. Variable)	0.3198	0.070	0.000 ***	0.181	0.458
Immutability Score (ind. Variable)	0.1185	0.071	0.095	-0.021	0.258
Constant	0.4620	0.283	0.104	-0.096	1.020
Asterik (**) = p< 0.05; (***) = p<0.0001; R-squared = 0.352, Adjusted R-squared=0.336					

Multiple Regression Analysis

Multiple regression analysis was conducted to determine the influence of the four blockchain system application dimensions-synchronized data, consensus protocols, smart contracts, and data immutability-on supply chain performance. The overall regression model demonstrated satisfactory explanatory power, with an R^2 of 0.352 and an adjusted R^2 of 0.336**,** indicating that approximately 35.2% of the variation in supply chain performance was explained by the four blockchain capability dimensions. This suggests that blockchain system applications constitute important predictors of supply chain performance, although the remaining 64.8% of the variation may be attributable to other organizational, technological, or environmental factors not included in the model.

The regression results indicate that synchronized data exerted a positive and statistically significant influence on supply chain performance **(**β = 0.2217, SE = 0.073, p = 0.003, 95% CI [0.078, 0.366]**).** This finding implies that improvements in real-time information sharing, data consistency, and visibility across supply chain partners significantly enhance operational performance. Specifically, holding all other variables constant, a one-unit increase in synchronized data capability is associated with an estimated 0.222-unit increase in supply chain performance.

Similarly, consensus protocols demonstrated a positive and statistically significant effect on supply chain performance **(**β = 0.1860, SE = 0.070, p = 0.009, 95% CI [0.048, 0.324]**).** The positive regression coefficient suggests that decentralized transaction validation and verification mechanisms contribute significantly to

improved supply chain coordination, trust, and operational reliability. The confidence interval excludes zero, further confirming the robustness of this relationship.

Among all the predictor variables, smart contracts emerged as the strongest determinant of supply chain performance **(**$\beta = 0.3198$, SE = 0.070, $p < 0.001$, 95% CI [0.181, 0.458]**).** The magnitude and statistical significance of this coefficient indicate that blockchain-enabled process automation has the greatest influence on supply chain effectiveness. The findings suggest that increased automation of contractual obligations, procurement processes, supplier payments, and compliance monitoring substantially improves operational efficiency, responsiveness, and coordination within retail supply chains.

Conversely, although data immutability exhibited a positive regression coefficient **(**$\beta = 0.1185$, SE = 0.071**),** its effect on supply chain performance was not statistically significant **(**$p = 0.095$, 95% CI [-0.021, 0.258]**).** Since the confidence interval includes zero, the study does not provide sufficient evidence to conclude that immutable transaction records independently improve supply chain performance after controlling for the effects of synchronized data, consensus protocols, and smart contracts. This finding suggests that while immutable records strengthen transparency, traceability, and governance, these benefits may be indirect and are likely to materialize when combined with complementary blockchain capabilities rather than functioning independently.

The regression constant **(**$\beta = 0.4620$, $p = 0.104$**)** was not statistically significant, indicating that the baseline level of supply chain performance in the absence of the explanatory variables is not significantly different from zero.

Overall, the regression analysis demonstrates that blockchain system applications contribute positively to supply chain performance, although the magnitude of their effects varies considerably. Smart contracts exerted the strongest influence**,** followed by synchronized data and consensus protocols, while data immutability did not demonstrate an independent statistically significant effect within the multivariate model. These findings support the argument that blockchain should be viewed as a multidimensional organizational capability, with process automation and real-time information synchronization serving as the primary mechanisms through which blockchain enhances retail supply chain performance.

Hypothesis Testing

The empirical findings provide substantial support for the proposed theoretical model. The first hypothesis predicted that synchronized data positively influences supply chain performance. This hypothesis was supported because synchronized information demonstrated a positive and statistically significant regression coefficient. The second hypothesis proposed that consensus protocols positively influence supply chain performance. The regression results likewise supported this hypothesis, indicating that transaction validation mechanisms improve organizational performance. The third hypothesis predicted a positive relationship between smart contracts and supply chain performance. The findings strongly supported this hypothesis, with smart contracts emerging as the most influential predictor within the regression model.

The fourth hypothesis proposed that data immutability positively influences supply chain performance. Although the estimated regression coefficient was positive, the relationship was not statistically significant within the multivariate model. Consequently, this hypothesis was not supported.

Collectively, these findings demonstrate that blockchain system applications contribute meaningfully to supply chain performance, although individual blockchain capabilities differ considerably in their relative operational importance. Process automation and synchronized information sharing appear to generate the greatest performance improvements, whereas immutable record management contributes primarily through governance and transparency rather than direct operational efficiency.

SUMMARY OF RESULTS

The empirical analysis demonstrates that blockchain technology should not be viewed as a single technological innovation but rather as a portfolio of complementary organizational capabilities.

The findings indicate that synchronized data enhances information visibility and operational coordination; consensus protocols strengthen trust and transaction reliability; smart contracts substantially improve operational efficiency through automation; and data immutability reinforces transparency and governance. However, the relative contribution of these capabilities differs considerably.

The dominance of smart contracts within the regression model suggests that automation represents the principal mechanism through which blockchain improves retail supply chain performance. Information synchronization follows closely, emphasizing the importance of real-time visibility within complex retail supply networks. Consensus protocols provide the governance infrastructure necessary to support decentralized coordination, whereas data immutability contributes indirectly by strengthening information integrity and accountability.

Taken together, the findings provide robust empirical support for conceptualizing blockchain as a multidimensional organizational capability that enhances supply chain performance through complementary technological mechanisms rather than isolated technological features.

DISCUSSION

Unlike synchronized data, consensus protocols and smart contracts, data immutability did not retain statistical significance within the multivariate model despite exhibiting a positive coefficient. This finding suggests that immutable records alone may not generate immediate operational efficiencies in retail supply chains. Rather, immutability appears to function primarily as an enabling governance capability whose value is realised through complementary blockchain functionalities.

One plausible explanation is that immutable records strengthen auditability, regulatory compliance and transaction integrity, yet these benefits are largely indirect. Employees engaged in procurement, inventory management and logistics are more likely to experience tangible improvements arising from automated workflows and real-time information sharing than from permanent record preservation. Consequently, once the effects of synchronized data and smart contracts are controlled for, the unique explanatory contribution of immutability diminishes.

From an Information Processing Theory perspective, immutability enhances information credibility rather than information processing speed. Likewise, within the TOE framework, immutable ledgers constitute foundational digital infrastructure whose strategic value depends on complementary organizational capabilities and managerial processes. This finding therefore reinforces the argument that blockchain capabilities operate synergistically rather than independently.

The insignificant coefficient should therefore not be interpreted as evidence that immutability lacks strategic importance. Instead, it suggests that organizations should prioritise automation and information synchronization during the early stages of blockchain implementation while progressively integrating immutable record management as blockchain maturity develops.

Synchronized Data and Supply Chain Performance

The significant positive influence of synchronized data indicates that real-time information sharing remains one of the most important determinants of supply chain effectiveness. Retail supply chains depend upon continuous coordination among procurement units, suppliers, warehouses, logistics providers, and retail outlets. Fragmented information systems often result in inventory inaccuracies, delayed replenishment, duplicated activities, and poor customer responsiveness. Blockchain-enabled synchronized data addresses these challenges by creating a common operational picture that is simultaneously accessible to authorized participants.

The findings suggest that synchronized information improves organizational decision-making primarily by reducing information asymmetry and enhancing visibility across the supply chain. When inventory levels, procurement activities, shipment status, and supplier information are updated in real time, managers can respond more rapidly to operational disruptions while optimizing inventory allocation and replenishment decisions.

These findings are consistent with Information Processing Theory, which argues that organizational performance improves when firms develop mechanisms capable of processing increasingly complex information efficiently. Blockchain enables such processing by reducing uncertainty while simultaneously improving the speed, accuracy, and reliability of operational information.

The results also support the Technology–Organization–Environment framework. Although blockchain provides the technological capability for synchronized information sharing, its performance benefits materialize only when organizations possess sufficient technological readiness, managerial commitment, and organizational processes capable of utilizing the information effectively.

The findings further align with previous empirical studies reporting that blockchain-enabled information synchronization improves supply chain visibility, coordination, and resilience. Nevertheless, the present study extends existing knowledge by demonstrating that these benefits are equally relevant within retail supply chains operating in an emerging economy, where empirical evidence has remained comparatively limited.

Consensus Protocols and Supply Chain Performance

Consensus protocols also demonstrated a statistically significant positive influence on supply chain performance. This finding highlights the importance of transaction validation mechanisms in strengthening organizational trust and governance within decentralized supply chain environments. Retail supply chains involve numerous independent actors whose operational objectives are not always perfectly aligned. Under such conditions, decentralized verification mechanisms reduce uncertainty by ensuring that transactions are validated before being permanently recorded. Consequently, organizations experience greater confidence in transaction authenticity while minimizing disputes associated with inaccurate or inconsistent operational records.

The significance of consensus protocols supports Institutional Theory, which argues that organizational performance depends partly upon governance structures capable of promoting legitimacy, accountability, and trust. Blockchain consensus mechanisms contribute directly to these institutional requirements by establishing transparent verification procedures that reduce opportunistic behaviour and improve organizational coordination.

The findings additionally support Information Processing Theory by demonstrating that validated information contributes to more reliable organizational decision-making. Managers are better positioned to coordinate procurement, inventory management, financial reconciliation, and supplier collaboration when transaction records are verified and trusted across the supply chain network.

Compared with synchronized data, consensus protocols exhibited a smaller regression coefficient, suggesting that governance mechanisms complement, but do not substitute for, effective information sharing. Together, these capabilities create an integrated digital infrastructure supporting improved supply chain performance.

Smart Contracts and Supply Chain Performance

Among all blockchain dimensions, smart contracts exerted the strongest positive influence on supply chain performance. This finding represents one of the study's most important contributions because it identifies automation as the principal mechanism through which blockchain enhances operational effectiveness within retail supply chains.

Smart contracts eliminate many routine administrative activities by automatically executing contractual obligations once predetermined conditions have been satisfied. Procurement approvals, supplier payments, inventory replenishment, delivery confirmations, and compliance monitoring can therefore occur with substantially reduced manual intervention.

The dominance of smart contracts within the regression model suggests that organizations derive greater operational value from blockchain-enabled automation than from governance or record-keeping capabilities alone. Process automation reduces transaction costs, shortens processing times, minimizes human error, and

improves consistency across organizational operations. Consequently, employees devote greater attention to strategic decision-making rather than repetitive administrative activities.

These findings strongly support Diffusion of Innovation Theory. Smart contracts appear to offer a highly visible relative advantage compared with traditional contractual procedures, thereby increasing their organizational value and adoption potential. Their observable operational benefits, including reduced delays, improved compliance, and enhanced efficiency, make them particularly attractive innovations within retail supply chains.

The findings are likewise consistent with previous empirical research demonstrating that blockchain-enabled automation substantially improves supply chain efficiency. However, the present study contributes new evidence from a retail context in an emerging economy, where smart contract adoption remains comparatively underexplored.

Data Immutability and Supply Chain Performance

Unlike the other blockchain capabilities, data immutability exhibited a positive but statistically insignificant influence on supply chain performance after controlling for synchronized data, consensus protocols, and smart contracts. This finding should not be interpreted as evidence that immutable records lack organizational value. Rather, it suggests that immutability contributes indirectly through governance, accountability, and transparency rather than generating immediate operational improvements.

Immutable records provide reliable audit trails, strengthen traceability, and reduce opportunities for unauthorized modification of historical transactions. These characteristics are particularly valuable for regulatory compliance, product authentication, and organizational accountability. Nevertheless, employees may perceive these governance benefits less directly than improvements associated with real-time information sharing or process automation.

The results indicate that immutable information becomes strategically valuable when integrated with complementary blockchain capabilities. In isolation, permanent records do not necessarily accelerate procurement, improve inventory coordination, or reduce operational delays. Their value emerges through interaction with synchronized information, automated contractual execution, and reliable transaction validation.

This finding contributes to blockchain scholarship by suggesting that organizations should avoid treating blockchain capabilities as independent technological investments. Instead, blockchain implementation should emphasize integrated capability development where information synchronization, governance mechanisms, automation, and record integrity collectively reinforce organizational performance.

Theoretical Contributions

Beyond confirming existing theoretical propositions, this study extends blockchain scholarship in several important respects. First, it demonstrates that blockchain should be conceptualized as a multidimensional organizational capability rather than a homogeneous technological innovation. By disaggregating blockchain into synchronized data, consensus protocols, smart contracts, and data immutability, the study shows that individual blockchain capabilities contribute differently to organizational performance.

Second, the study advances the Technology-Organization-Environment framework by demonstrating that technological capabilities generate organizational value through complementary operational mechanisms rather than through technological adoption alone. This finding refines the explanatory power of TOE by highlighting the importance of capability configuration in explaining organizational outcomes.

Third, the study enriches Information Processing Theory by demonstrating that blockchain capabilities reduce information asymmetry through multiple complementary mechanisms, including information synchronization, decentralized validation, and automated contractual execution. Rather than treating blockchain as merely an

information repository, the findings position blockchain as an integrated organizational information-processing infrastructure.

Finally, the study contributes context-specific evidence from an emerging African economy, thereby expanding the geographical scope of blockchain scholarship that has traditionally focused on developed economies.

Managerial Implications

The findings suggest that managers should avoid implementing blockchain as a stand-alone technological investment. Instead, blockchain implementation should be approached as a strategic organizational transformation initiative that simultaneously redesigns business processes, strengthens inter-organizational collaboration, develops employee digital competencies, and integrates complementary digital technologies. The superior performance associated with smart contracts indicates that organizations should prioritize automation of procurement, supplier management, inventory replenishment, and payment processes before expanding into more sophisticated blockchain applications. This staged implementation strategy is likely to produce faster operational benefits while minimizing implementation risks.

First, organizations should prioritize investments in smart contract capabilities because automation produced the strongest operational benefits. Automating procurement approvals, supplier payments, inventory replenishment, and compliance verification can substantially improve efficiency while reducing administrative costs. Secondly, managers should strengthen synchronized information systems that enable real-time visibility across procurement, warehousing, logistics, and retail operations. Enhanced information synchronization improves organizational responsiveness while supporting evidence-based decision-making. Organizations should also implement robust consensus mechanisms capable of strengthening transaction reliability and stakeholder trust. Such mechanisms become increasingly important as retail supply chains involve larger numbers of suppliers and distribution partners. Finally, managers should recognize that immutable records primarily strengthen governance and compliance rather than producing immediate operational gains. Consequently, investments in data immutability should be integrated with broader digital transformation initiatives rather than implemented independently.

Policy Implications

Governments seeking to promote digital transformation should establish regulatory frameworks supporting blockchain interoperability, cybersecurity, data governance, and digital identity management. Regulatory certainty will encourage greater organizational investment in blockchain-enabled supply chain systems.

Industry associations should similarly promote standardized blockchain implementation frameworks capable of facilitating secure information exchange among suppliers, logistics providers, retailers, and regulatory agencies. Such collaboration would enhance transparency while reducing duplication of digital infrastructure investments.

Limitations and Future Research

First, the study focused on a single multinational retailer operating within Nairobi City County. Although Carrefour provides an appropriate organizational context, future research should examine multiple retailers across different geographical regions to improve generalizability. Second, the cross-sectional research design captures organizational perceptions at one point in time. Longitudinal studies would provide greater insight into how blockchain capabilities influence supply chain performance as implementation matures. The study also relied upon perceptual survey data. Future research should combine survey responses with objective organizational performance indicators, including inventory turnover, order fulfilment rates, lead times, logistics costs, and customer service metrics. Finally, future studies should examine moderating variables such as digital capability, organizational culture, leadership support, regulatory readiness, cybersecurity capability, and supplier digital maturity to explain additional variation in blockchain-enabled organizational performance.

Although perceptual measures are widely accepted in organizational research because they capture managerial assessments of operational effectiveness, they remain susceptible to common method bias and respondent subjectivity. The present study did not incorporate objective operational indicators such as order fulfilment cycle time, inventory turnover, logistics costs, stock-out frequency, supplier lead time, perfect order rate, or customer service levels. Consequently, the findings primarily reflect employees' perceptions of organizational performance rather than independently verified operational outcomes. Future research should integrate perceptual and archival performance measures to enhance construct validity and provide stronger causal evidence regarding the operational benefits of blockchain-enabled supply chains.

Although perceptual measures are widely accepted within organizational research, future investigations should triangulate employee perceptions with enterprise resource planning (ERP) records and objectively verified operational indicators including inventory turnover, order fulfilment cycle time, stock-out frequency, procurement lead time, logistics costs and perfect order rates. Integrating subjective and objective performance metrics would substantially strengthen causal inference while reducing common method bias.

Future Research

Future studies should employ mixed-method research designs combining large-scale quantitative surveys with qualitative interviews involving procurement managers, logistics directors, technology vendors and policy makers. Such triangulation would provide richer insights into the organizational mechanisms through which blockchain capabilities generate performance improvements.

Researchers should further integrate perceptual measures with audited operational data extracted from enterprise resource planning systems. Longitudinal studies spanning several years would also enable researchers to capture the evolution of blockchain maturity and its dynamic effects on organizational performance.

CONCLUSION

Blockchain technology continues to reshape supply chain management by improving organizational coordination, transaction reliability, process automation, and information transparency. This study demonstrates that blockchain system applications significantly improve retail supply chain performance, although the relative contribution of individual blockchain capabilities differs considerably.

Among the four dimensions investigated, smart contracts emerged as the strongest predictor of supply chain performance, followed by synchronized data and consensus protocols. Data immutability contributed positively but did not demonstrate a statistically significant independent influence within the multivariate model, suggesting that governance-oriented blockchain capabilities generate their greatest value when integrated with broader organizational processes.

The study therefore concludes that blockchain implementation should be approached as an integrated organizational transformation rather than a purely technological initiative. Organizations capable of combining information synchronization, decentralized governance, process automation, and secure record management are more likely to achieve meaningful improvements in supply chain performance.

Beyond its practical implications, the study contributes to the growing body of blockchain scholarship by demonstrating that blockchain-enabled organizational capabilities provide an effective framework for understanding digital supply chain transformation within emerging retail markets. As blockchain technologies continue to mature, their strategic importance is likely to increase, making integrated capability development an essential priority for organizations seeking sustained competitive advantage.

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