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Blockchain's Transparency and the Performance of the Small-Scale Agricultural Farms in Kenya

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Abstract: Agriculture remains a fundamental pillar of Kenya's economy, supporting livelihoods and contributing significantly to GDP. However, small-scale agricultural farms face persistent inefficiencies, including poor traceability, inadequate record-keeping, and limited accountability, which constrain productivity and market integration. This study investigates the extent to which blockchain technology's transparency can address these challenges and enhance farm performance. Blockchain's decentralized and tamper-proof ledger system offers the potential to improve transparency, build trust, and streamline agricultural processes. This research specifically explores how blockchain-driven transparency influences trust, decision-making, coordination, and operational efficiency in Kenya's small-scale farming context. The study employed a pragmatic philosophy and a mixed-methods approach, integrating both qualitative and quantitative methodologies. Focus group discussions with selected village champions provided contextual insights into farmers' experiences with blockchain applications, while structured questionnaires collected quantitative data from all 52 blockchain-enabled agricultural firms in the study population, enabling a full census. Data analysis included both descriptive and inferential techniques. Thematic analysis was applied to qualitative responses to identify recurring patterns, while Pearson's and Spearman's Rank correlation tests assessed key relationships. Multiple regression models were used to determine the predictive strength and statistical significance of blockchain-related variables on farm performance. Findings indicate that blockchain transparency significantly enhances traceability, improves operational decision-making, and fosters stronger stakeholder trust. These outcomes collectively contribute to improved market access, reduced post-harvest losses, and greater efficiency. Despite challenges such as low awareness levels and technical skill gaps, the evidence supports blockchain transparency as a valuable enabler of performance improvement in Kenya's small-scale agricultural sector. This study contributes to the growing body of literature on agricultural digitalization, offering empirical evidence on the practical value of blockchain technology in emerging economies.

Keywords: *Blockchain Technology, Performance, Small-Scale Agricultural Farms, Transparency, Kenya, Value Chains.*

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I. INTRODUCTION

A blockchain functions as a peer-to-peer ledger system that facilitates direct transactions between systems without requiring a central authority (Xiong et al., 2020). In a foundational white paper, Nakamoto (2008) introduced blockchain as a method for creating distributed digital currency systems by cryptographically chaining blocks of data. Blockchain technology holds the potential to revolutionize the digital landscape by enabling contracts to be coded and stored in transparent, shared databases, safeguarded against deletion, tampering, or revision (Lakhani and Iansiti, 2017). This technology envisions a world where every agreement, process, task, and payment are recorded with a digital signature that can be identified, validated, stored, and shared.

Blockchains possess technical attributes, including transparency, distributed ledger technology, cryptographic security, and the capacity to integrate smart contract logic. These features enable blockchains to facilitate transparent transactions among multiple users who may not trust one

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another, as smart contracts autonomously execute transactions, eliminating the need for a trusted third party (Su, 2018).

Blockchain technology enhances security, trust, and transparency across organizations by leveraging its decentralized nature to improve data traceability throughout business networks. This feature ensures that every transaction is securely recorded and verifiable, fostering greater accountability and confidence among stakeholders. Additionally, the rise of decentralized applications (DApps) aims to further revolutionize industries by providing more efficient and cost-effective transaction processing, eliminating the need for intermediaries. As blockchain continues to grow, its economic impact is expected to be substantial, with projections estimating an annual business value exceeding $3 trillion by 2030, highlighting its transformative potential across sectors (IBM, 2023; Garg et al., 2023; Davies, 2018).

Blockchain technology is transforming the agricultural supply chain by enhancing transparency, traceability, and efficiency. Its decentralized, tamper-proof systems enable seamless tracking of products from farm to table, ensuring each stage of production and distribution is securely documented. This addresses key challenges such as food safety, fraud prevention, and inefficiency by providing stakeholders with real-time, reliable data (Vignesh et al., 2024).

By storing data immutably, blockchain guarantees the integrity of information, allowing for easy verification of product origin, quality, and condition. This increased transparency fosters consumer trust, as buyers can trace a product's journey and confirm its authenticity (Shew et al., 2021). Additionally, blockchain optimizes supply chain performance by automating record-keeping, reducing transaction costs, and eliminating intermediaries, ultimately fostering accountability and improving outcomes for producers and consumers (Adewusi et al., 2023).

The market for blockchain in agriculture and food supply chains is growing rapidly, valued at $285.34 million in 2022 and projected to reach $7,378.68 million by 2031, with a compound annual growth rate (CAGR) of 43.76% (InsightAce Analytic, 2023).In Kenya, small-scale farms, typically 0.2 to 12 hectares, are vital to food security and economic stability, accounting for 78% of total agricultural production and contributing 23.5% to the nation's GDP (Wahome et al., 2024). As blockchain adoption expands, its potential to revolutionize agricultural operations and build a more sustainable food system becomes increasingly evident.

- *Statement of the Problem*

Small-scale farming is a cornerstone of Kenya's agricultural economy, significantly contributing to food security, rural livelihoods, and national economic resilience (Kufuor, 2021). Despite its importance, this sector continues to face systemic challenges, particularly in the areas of transparency, traceability, and operational efficiency. Traditional paper-based and informal methods of record-keeping and supply chain management introduce vulnerabilities such as data inaccuracies, limited visibility, and susceptibility to fraud. These inefficiencies contribute to post-harvest losses, constrain market access, and ultimately diminish profitability for smallholder farmers.

Blockchain technology, with its decentralized and tamper-proof ledger system, offers a promising solution to these persistent issues (World Food Programme, 2017). Features such as immutable data storage, real-time traceability, and secure transaction validation can enhance transparency across the agricultural value chain. This increased visibility empowers stakeholders from farmers to consumers by providing access to accurate, verifiable, and timely information. Improved traceability not only mitigates fraud and disputes but also fosters accountability and facilitates more efficient market engagement (Chod et al., 2019; Babich and Hilary, 2018).

For Kenyan small-scale farmers, blockchain-enabled transparency can reduce information asymmetry, enhance trust with buyers, and increase negotiation leverage. Traceability systems allow producers to verify the quality and origin of their goods, a factor shown to influence consumer confidence and open opportunities for premium pricing (Xia et al., 2023). As a result, blockchain adoption in agriculture is increasingly being explored as a means to improve supply chain integrity and farmer outcomes.

Nevertheless, several barriers hinder the broader implementation of blockchain technology within Kenya's agricultural sector. These include concerns around scalability, technical complexity, cost, and regulatory uncertainty (Hang et al., 2020; Zhao et al., 2019). While pilot farms have demonstrated the utility of blockchain in addressing transparency-related issues, questions remain about its economic viability and accessibility for smallholders (Mapanje et al., 2023). Innovations such as layer-2 solutions, enhanced interoperability, and supportive policy frameworks are necessary to overcome these limitations.

A systematic review by Akella et al. (2023) affirms blockchain's potential in reducing information asymmetry and strengthening trust among agricultural stakeholders. However, realizing these benefits at scale will require coordinated industry efforts, capacity-building programs, and targeted regulatory interventions. For Kenya's smallholder farmers, the successful deployment of blockchain technologies could unlock greater supply chain visibility, improve access to competitive markets, and enhance long-term economic resilience.

This study investigates the role of blockchain transparency in addressing inefficiencies in Kenya's small-scale agriculture. It examines how blockchain-driven traceability systems influence key performance indicators such as productivity, market access, and risk management. By identifying barriers and enablers of adoption, the study aims to inform policy, guide the development of tailored blockchain solutions, and support the training of agricultural stakeholders. In doing so, it contributes to unlocking

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blockchain's transformative potential for smallholder farming, rural development, and food system sustainability in Kenya.

➢ *Objective*

To assess the influence of blockchain's transparency on the performance of the small-scale agricultural farms in Kenya

➢ *Theoretical Framework*

Blockchain technology (BCT), particularly its transparency feature, is rapidly reshaping agricultural value chains by enhancing trust, traceability, and accountability. To understand the adoption and performance implications of blockchain transparency among small-scale farmers in Kenya, this study adopts the Innovation Diffusion Theory (IDT) and the Technology Acceptance Model (TAM) as guiding frameworks. IDT provides insight into how blockchain innovations spread among farmers based on perceived attributes such as relative advantage, compatibility, and observability. TAM complements this by examining how perceived usefulness and ease of use shape the intention to adopt transparency-focused technologies. These two models together offer a comprehensive lens for exploring how blockchain transparency can drive improved performance in Kenya's small-scale agricultural sector.

➢ *Innovation Diffusion Theory (IDT)*

Developed by Everett Rogers, the Innovation Diffusion Theory (IDT) is foundational in understanding how new technologies are adopted over time. Rogers proposes that individuals in a society do not all adopt an innovation simultaneously. Instead, adoption occurs in stages, categorized into five groups based on their willingness to adopt a new technology: innovators, early adopters, early majority, late majority, and laggards. These categories reflect different levels of openness and readiness to embrace change (Rogers, 1995).

For smallholder farmers in Kenya, this theory helps explain how blockchain technology might spread among them. Initially, innovators and early adopters, those who are willing to take risks and are more inclined to adopt new technologies, may experiment with BCT. As the technology proves its value and becomes more visible, the early majority will follow, seeking practical solutions to improve their farm's productivity and sustainability. Eventually, the late majority and laggards may adopt the technology, driven by social pressure, peer influence, or government interventions.

The theory also identifies key characteristics of an innovation that affect its adoption: observability, relative advantage, compatibility, trialability, and complexity. BCT's potential to offer visible improvements in traceability and transparency (observability), enhance farm efficiency (relative advantage), align with existing agricultural practices (compatibility), allow for testing on a small scale (trialability), and be user-friendly (low complexity) are crucial in determining how quickly and widely it may be adopted among Kenyan smallholders.

However, IDT has limitations, such as assuming that all individuals will adopt innovations eventually and not accounting for rejections even after full understanding of the technology. Additionally, the model's focus on individual adoption neglects the role of social structures and collective decision-making.

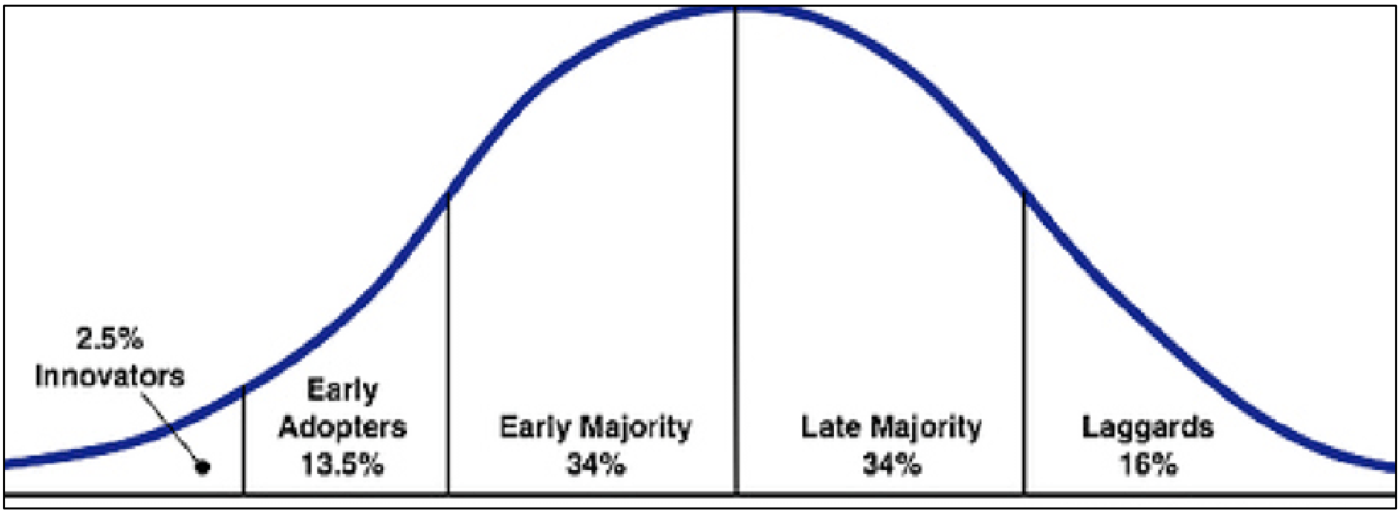

Fig 1 Diffusion of Innovations model (Rogers, 2003). Image by Wesley Fryer

➢ *Technology Acceptance Model (TAM)*

The Technology Acceptance Model (TAM) is another key framework that helps predict how users will adopt technology based on their perceptions of its usefulness and ease of use (Davis, 1989). In the context of smallholder farmers in Kenya, BCT's perceived usefulness (for example improving market access, reducing fraud, increasing transparency) and ease of use (for example minimal technical expertise required) are critical factors that will influence its adoption.

TAM also considers social influence and facilitating conditions. Social influence refers to how external factors, such as peer pressure or extension services, may encourage or discourage the adoption of blockchain, while facilitating conditions look at the availability of resources (for example

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internet access, mobile phones, training). In Kenya, where agricultural extension services play a pivotal role in disseminating information, these factors will significantly affect blockchain adoption.

Despite its strengths, TAM has been criticized for focusing on individual behaviors without considering the wider social and organizational contexts. This limitation may affect its applicability in rural, collective farming settings.

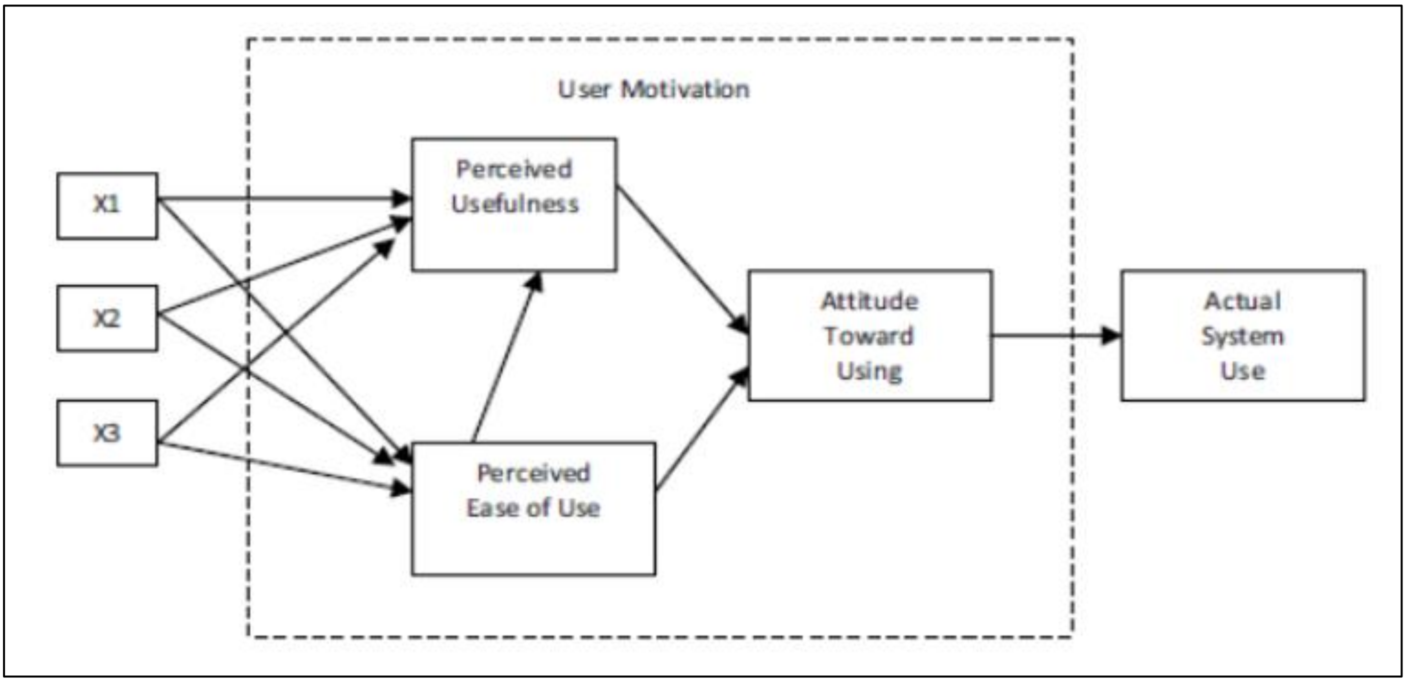

Fig 2 Original Technology Acceptance Model (TAM).
Source: Davis (1986)

➢ *Conclusion*

The theoretical models discussed, Innovation Diffusion Theory (IDT), Technology Acceptance Model (TAM), and Unified Theory of Acceptance and Use of Technology (UTAUT), provide critical insights into the adoption of Blockchain Technology (BCT) in small-scale agricultural farms in Kenya. Each framework highlights different aspects of technology adoption: IDT explains the stages of adoption and key characteristics influencing diffusion, TAM emphasizes perceived usefulness and ease of use, while UTAUT integrates multiple factors, including social influence and facilitating conditions.

For blockchain to enhance transparency and performance in Kenya's smallholder farms, understanding these theoretical perspectives is crucial. Adoption will depend on farmers' willingness to embrace innovation, the perceived benefits of blockchain in reducing fraud and improving market access, and the role of extension services and cooperative networks in facilitating implementation. By addressing these factors, policymakers, agricultural stakeholders, and technology developers can create targeted interventions that accelerate blockchain adoption, leading to greater efficiency, traceability, and trust in the agricultural value chain.

➢ *Conceptual Framework*

The conceptual framework shows the anticipated relationship between blockchain's transparency and Small-holder Agricultural farms Performance.

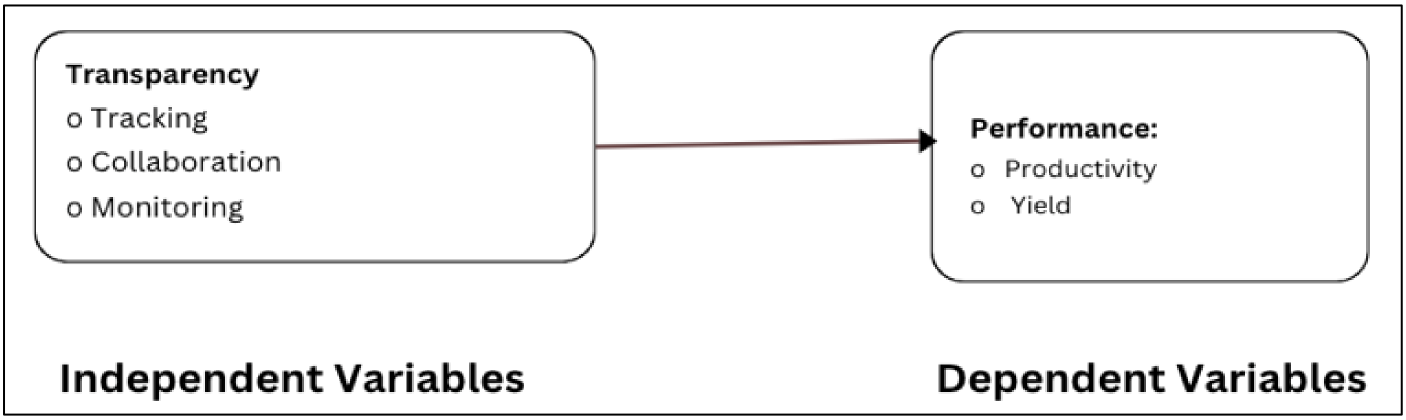

Fig 3 Diagrammatic Presentation of the Relationship between the Independent Variable *Transparency* and the Dependent Variable *Performance*.

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II. EMPIRICAL REVIEW

➢ *Blockchain's Transparency and Performance*

Blockchain technology has revolutionized supply chain management by enhancing transparency and improving performance through streamlined verification processes. Unlike traditional systems that depend on manual documentation and audits, blockchain introduces an automated, immutable ledger that reduces inefficiencies, cuts verification costs, and ensures consistency across supply chain operations.

Imagine a tamper-proof, shared ledger where every step of a product's journey is immutably recorded and transparently accessible to authorized parties. Blockchain achieves this by employing a distributed network, eliminating the need for a central authority and ensuring trust through cryptographic verification (Sharma and Joshi, 2021).

A study highlights the significant influence of blockchain technology adoption on supply chain transparency and ethical sourcing practices within the cocoa and agricultural sectors. Companies leveraging blockchain technology tend to exhibit more transparent supply chains and are more inclined to engage in ethical sourcing compared to those not utilizing blockchain. Furthermore, robust evidence suggests that blockchain adoption serves as a strong predictor of increased transparency, showing positive correlations across various industries. These findings underscore blockchain technology's potential to enhance ethical sourcing methods and supply chain transparency specifically within Ghana's cocoa and agriculture industries (Ibrahim et al., 2024).

Walmart, in collaboration with IBM, implemented a blockchain-based system to enhance food traceability within its supply chain, leveraging IBM's Food Trust blockchain platform. This technology digitally records and tracks the journey of food products from farm to store shelves, fundamentally transforming the company's supply chain operations by significantly improving transparency and efficiency. Traditional systems required up to seven days to trace the origin of a food product, a process that has been drastically reduced to just 2.2 seconds with the blockchain system (Smith, 2021).

Additionally, Walmart has streamlined its supply chain operations by reducing paperwork and manual tracking. Suppliers now upload information directly to the blockchain, which eliminates redundancies and enhances record-keeping accuracy (Francisco and Swanson, 2018). This digital transformation has also resulted in notable cost savings. Automation and digitization of processes have reduced labor costs associated with traditional tracking systems and minimized product loss by enabling quicker issue resolution. The Deloitte (2022) report emphasizes broad supply chain digital transformation, while McKinsey (2023) provides detailed insights into automation's efficiency gains, making their findings complementary. The Walmart initiative demonstrates how blockchain technology can deliver measurable improvements in traceability, operational efficiency, and cost management, while simultaneously addressing critical food safety challenges.

Provenance, a company dedicated to improving supply chain transparency, leverages blockchain technology to verify the authenticity of products and ensure adherence to ethical sourcing practices. This approach has transformed the way businesses and consumers interact with supply chain information, creating a more transparent and reliable system. Through blockchain, Provenance offers tamper-proof, traceable records that provide consumers with detailed insights into the origin and journey of the products they purchase. Alsdorf and Berkun (2024) explore the potential of blockchain technology for insurance companies, emphasizing its ability to enhance consumer trust, a benefit also demonstrated by Provenance's blockchain-based system. By ensuring the authenticity of claims related to ethical sourcing, Provenance has enhanced consumer confidence in verified products. Studies show that this increased transparency directly influences consumer behavior, with many customers willing to pay a premium for products verified through Provenance's system.

Kemp (2017) highlighted how blockchain platforms like Everledger enhance real-time visibility into product movement and sourcing practices. In the diamond industry, Everledger has played a pivotal role by tracking the origin and journey of diamonds to ensure they are conflict-free. This level of transparency promotes collaboration among stakeholders, builds consumer trust, and empowers ethical purchasing decisions. The blockchain system also improves supply chain performance by streamlining verification processes. Unlike traditional methods, which often rely on manual documentation and audits, blockchain provides an automated and immutable record of transactions. This reduces inefficiencies, cuts verification costs, and ensures that information is consistent across the supply chain.

Enhanced Traceability, which is noted from raw materials to finished goods, blockchain provides granular tracking, pinpointing the location and provenance of each item (Gunasekaran, 2019; Cheng and Li, 2021). This empowers businesses to identify bottlenecks, optimize logistics, and combat counterfeiting (Kshetriwal et al., 2018). Greater Transparency is achieved where stakeholders across the supply chain gain real-time insights into product movement, ethical sourcing practices, and environmental impact (Li et al., 2021b). This fosters collaboration, builds trust, and empowers consumers to make informed choices (Akter et al., 2022). Improved Accountability is achieved with every action recorded on the blockchain, participants become accountable for their contributions. This incentivizes responsible behavior, minimizes fraud, and simplifies dispute resolution (Li et al., 2021).

While the potential of blockchain is undeniable, challenges remain. Integrating this technology into existing systems requires collaboration and standardization (Gunasekaran, 2019). Additionally, human trust, though enhanced, cannot be entirely replaced by technology (Sharma and Joshi, 2021).

Nevertheless, blockchain's ability to illuminate the black box of supply chains is truly revolutionary. By fostering transparency, traceability, and accountability, it paves the way for a more efficient, ethical, and sustainable future for businesses and consumers alike. See figure to Chinaka (2016), emphasizes the transformative potential of blockchain in providing a secure and transparent platform for financial transactions. By utilizing smart contracts and decentralized ledgers, blockchain enables a streamlined and traceable process, reducing the risks associated with lending to farmers. This increased transparency not only fosters trust among stakeholders but also assists financial institutions in assessing the creditworthiness of farmers more accurately.

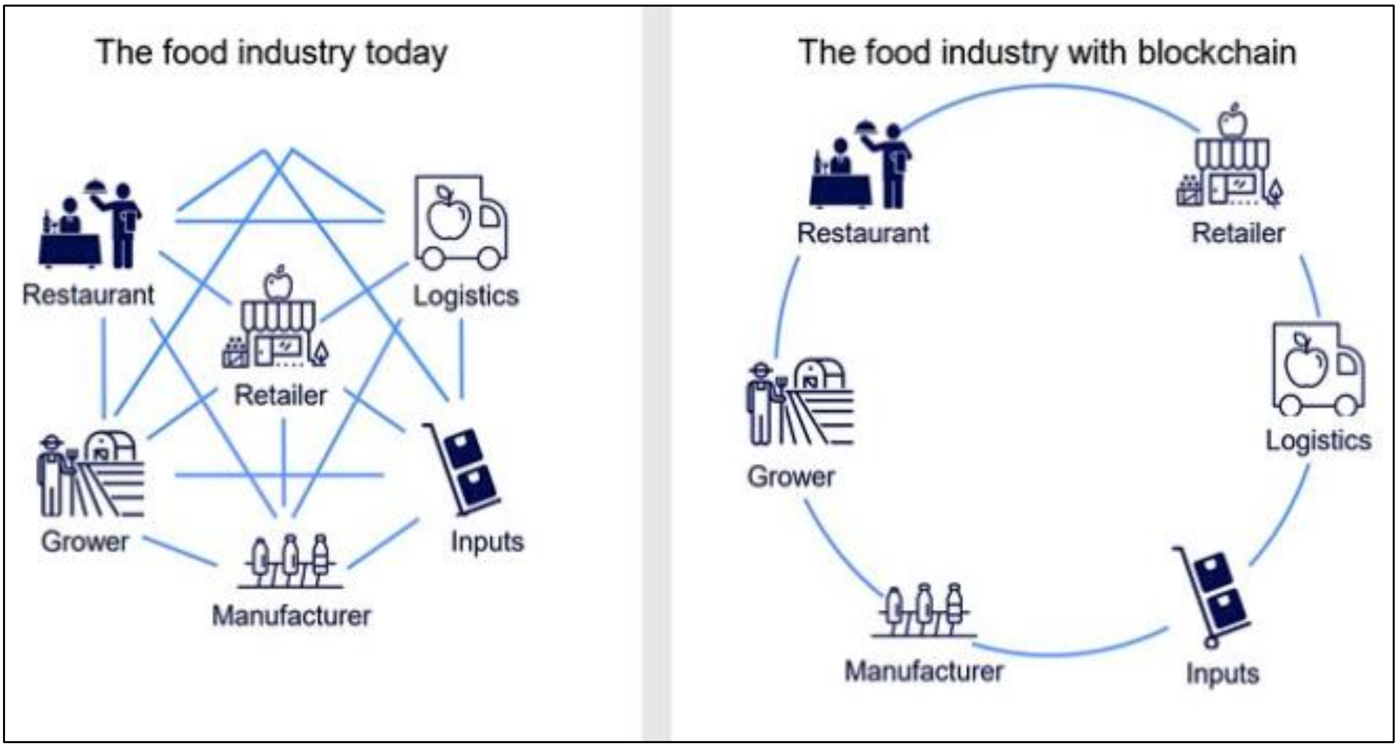

Fig 4 How Blockchain Technology Improves Food Supply Chain Transparency and Efficiency.
Source: Maras (2019).

One of the biggest challenges facing farmers is access to credit. Traditional lenders often view farmers as high-risk borrowers, due to the fact that agriculture is a sector that is subject to a number of risks, such as weather and disease. As a result, many farmers struggle to obtain the financing they need to invest in their businesses and grow their operations. Rijanto (2020) delves into the application of blockchain in agricultural finance. The study highlights how blockchain-based systems enhance the efficiency of credit assessment and disbursement processes, leading to quicker and more accessible financial resources for farmers.

Blockchain can help to address this challenge by providing lenders with a more secure and transparent way to track the movement of goods and funds. By using blockchain, lenders can be more confident that the loans they issue will be repaid, which can make them more willing to lend to farmers. In addition, blockchain can also be used to create new forms of financial products, such as crop insurance and weather derivatives, which can help to reduce the risks faced by farmers. The integration of blockchain in financial systems, as discussed by Mattern (2018) contributes to the creation of a more inclusive financial environment for farmers, overcoming traditional barriers and ensuring timely access to credit.

Lin, W., et al. (2020), discusses the role of blockchain in mitigating credit risks for farmers. By leveraging blockchain's immutability and transparency, the technology minimizes fraudulent activities, making it a reliable tool for financial institutions to extend credit to farmers with confidence. The combination of secure transactions and decentralized record-keeping, as highlighted in various academic sources, including (Kumarathunga et al., 2022; Patel et al., 2021; Zhang, 2020), collectively underscores the positive impact of blockchain on farmers' financial inclusion within the agricultural supply chain.

III. METHODOLOGY

➢ *Research Philosophy*

This study adopted a pragmatic research philosophy, which supports the selection of research methods based on the nature of the research questions and objectives rather than strictly following a single methodological tradition. Dewey (1938) advocated for problem-solving approaches in research, emphasizing that methods should be chosen to effectively address practical challenges. Creswell (2014) reinforces this flexibility by encouraging method selection tailored to the research context. In this study, both smallholder farmers and blockchain-enabled firms in Kenya were engaged to examine how blockchain's transparency

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feature influences the performance of small-scale agricultural farms. A combination of qualitative and quantitative methods was employed to ensure a well-rounded understanding. Quantitative data gathered through structured questionnaires offered statistical insights into the effects of blockchain transparency, while qualitative focus group discussions with village champions provided deeper perspectives into farmers' experiences with transparent blockchain systems. This mixed-methods approach is consistent with the pragmatic philosophy, facilitating a balanced and context-sensitive investigation of the topic.

- *Research Design*

This research adopted a mixed methods design, integrating both quantitative and qualitative approaches (Creswell, 2009; Creswell and Plano Clark, 2007). This design is well-regarded for its ability to systematically and comprehensively address complex research questions across various fields. In this study, quantitative methods were employed to evaluate the influence of blockchain transparency on the performance of small-scale agricultural farms in Kenya, focusing on key transparency-related attributes such as traceability, data accessibility, and accountability. Complementing this, qualitative data was collected through focus group discussions with village champions who represented farmers using blockchain-based systems. These discussions provided rich insights into how transparency within blockchain platforms shaped their experiences, decision-making, and outcomes in farming. Structured questionnaires helped generate numerical data to support statistical analysis aligned with the study's objectives. The integration of both methods enabled the research to capture both measurable outcomes and contextual understanding, offering a comprehensive view of blockchain transparency's role in enhancing farm performance.

- *Target Population*

Creswell (2014) highlights the significance of selecting a target population that accurately reflects the core elements of the research question. In this study, 52 blockchain-enabled firms were purposefully chosen to investigate the technical dimension of blockchain transparency. The research focused on how transparency, one of blockchain's core features affects the performance of small-scale agricultural farms in Kenya, particularly in terms of information accuracy, traceability, and accountability. To complement these insights, four focus group discussions were conducted with farmers who had adopted blockchain technology, allowing for a deeper understanding of how transparency influenced their farming operations and outcomes. This dual approach enabled the study to capture both strategic perspectives from technology providers and the lived experiences of farmers, resulting in a well-rounded analysis of blockchain transparency's influence on small-scale agricultural farms in Kenya.

- *Data and Data Collection*

Data collection refers to the systematic gathering of information for analysis (Kumar, 2014). This study employed a mixed-methods approach, integrating both quantitative and qualitative tools. Quantitative data was collected through structured questionnaires, which included Likert-scale items designed to assess the perceived and actual impact of smart contracts on various aspects of farm performance such productivity and yield. These tools allowed for efficient data recording and statistical comparison. Qualitative data was gathered through focus group discussions with village champions, offering deeper insights into how farmers interact with and benefit from smart contract technologies. According to SIS International Research (2023), focus groups allow for dynamic interaction and exploration of diverse viewpoints, while questionnaires provide structured, quantifiable data (Mugenda and Mugenda, 2003; Zikmund, 2003). All data collected was primary, meaning it was gathered firsthand specifically for this study (Kothari, 2014), enabling a comprehensive and context-rich investigation into the role of blockchain's transparency in small-scale farming.

- *Pilot Study*

The research instruments were pilot tested on 8 blockchain enabled startup firms involved in smallholder agriculture activities. They were selected using snowball technique. The data obtained was then subjected to various tests to check for instrument reliability and instrument validity. The results formed part of the final study results. The pilot study revealed that while smallholder farmers participated in blockchain-based products, most lacked familiarity with the underlying technology, resulting in less enthusiastic and knowledgeable engagement. This unexpected finding shifted the study's focus to the implementers of the technology to understand its introduction and utilization in agriculture. To gain insights into the farmers' experiences, the study selected village champions as persona representatives. These individuals represented the farmers' perspectives during the research, bridging the gap between farmers and technology implementers. The persona representative was a key member in the small-scale agriculture with at least three years of farming experience, familiar with various agricultural technologies. Despite having only basic education, they possessed essential knowledge and skills, facilitating adaptation to new ideas and innovations. Their role was crucial in understanding the the blockchain features from an end user implementation perspective.

- *Validity of Data Collection Instrument*

Validity was assessed through face and content validity. Face validity ensured the questions measured the intended constructs, while content validity confirmed the comprehensive coverage of the behavioral domain. Expert consultation was also used to validate the instruments.

- *Reliability of Data Collection Instrument*

Reliability entails proving that the processes of a study, including data collection methods, can be replicated with consistent results. The reliability of the instruments was assessed using Cronbach's Alpha. According to Kothari (2009), reliability pertains to the consistency of measurement; the more reliable an instrument, the more consistent its measurements will be. In this study, the data collection instrument was tested on 15% of the population instead of the 10% because of the diversity of the applications of the

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technology to ensure its relevance and effectiveness. 8 questionnaires were piloted and these responses were not included in the final study sample. The responses from these 8 questionnaires were coded and entered into SPSS to generate the reliability coefficient. The pilot questionnaire assessed the role of blockchain technology on the performance of the small-scale agricultural sector in Kenya. To determine its reliability, raw data was entered as it appears in the questionnaire and the Cronbach's Alpha scores was as presented. The reliability coefficient was computed as:

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N} \sigma_i^2}{\sigma_T^2}\right)$$

Where:

- N = number of items
- σ_i^2 = variance of each individual item
- σ_T^2 = total variance of the sum of all items

➢ *Model Specification*

Inferential statistics primarily involved testing the correlation among various variables. For nominal data, Pearson's correlation and the correlation coefficient were calculated, while for ordinal data, Spearman's Rank correlation coefficient was used. In both instances, a relationship was considered significant if the associated p-value was less than 0.05. Multiple regression analysis was conducted at a 95% confidence level and a 5% significance level to determine the contribution of predictor variables to the dependent variable. Additionally, ANOVA was performed to assess the model's goodness of fit. Finally, beta coefficients were calculated to determine the impact of a unit change in the predictor variables.

Every value of the independent variable x is associated with a value of the dependent variable *y*.

- *The Panel Regression model is as Follows:*

$$Y = \beta 0 + \beta_1 X_1 + \epsilon$$

Where:

Y = performance of small-scale agricultural farms

β_0 = Constant

β_1 = Slope; how the unit change in the independent variable influences the dependent variable.

X_1= Blockchain's Transparency

ϵ =Error term which captures the unexplained variations in the model.

IV. FINDINGS

The questions were measured on a scale of 1-5, with 1 indicating strongly disagree, 2- Disagree, 3-not sure, 4-Agree and 5 indicating strongly agree to the question that was asked.

➢ *Descriptive Statistics*

In this section, questions were rated on a scale from 1 to 5, where 1 represents "strongly disagree," 2 represents "disagree," 3 represents "neutral," 4 represents "agree," and 5 represents "strongly agree" with the question posed. A mean score of 1 indicates that respondents strongly disagreed with the question, a mean of 2 indicates disagreement, a mean of 3 indicates uncertainty, a mean of 4 indicates agreement, and a mean of 5 indicates strong agreement. Standard deviation reflects the variation of responses around the mean. A smaller standard deviation indicates responses were closer to the mean, implying more consistent results.

➢ *Blockchain's Transparency and Performance*

The questions were measured on a scale of 1-5, with 1 indicating strongly disagree, 2- Disagree, 3- neutral, 4-Agree and 5 indicating strongly agree to the question that was asked.

Table 1 Blockchain's Transparency

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Div
Blockchain technology has significantly improved the transparency of our agricultural supply chain operations.	2.4%	9.8%	7.3%	63.4%	17.1%	3.83	0.919
Blockchain technology has enhanced the visibility of transactions for small-scale farmers in Kenya.	2.4%	2.4%	9.8%	65.9%	19.5%	3.98	0.790
Blockchain technology has enhanced traceability and accountability in our agricultural supply chain.	4.9%	9.8%	9.8%	56.1%	19.5%	3.76	1.044
Since adopting blockchain, we have observed a reduction in fraud or errors in our supply chain processes.	2.4%	9.8%	7.3%	61.0%	19.5%	3.85	0.937
The enhanced supply chain transparency through blockchain has positively influenced decision-making in our agricultural farms.	2.4%	4.9%	4.9%	73.2%	14.6%	3.93	0.787

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Our experience with implementing blockchain for supply chain transparency in our small-scale agricultural farms in Kenya has been positive.	4.9%	9.8%	36.6%	36.6%	12.2%	3.41	0.999
We have faced significant challenges in implementing blockchain for supply chain transparency in our small-scale agricultural farms in Kenya.	19.5%	31.7%	7.3%	26.8%	14.6%	2.85	1.406
To what extent do you agree with the effectiveness of blockchain technology in enhancing supply chain transparency in your small-scale agricultural farms in Kenya?	2.4%	14.6%	4.9%	61.0%	17.1%	3.76	0.994

The findings reveal a generally positive outlook, with notable variations across dimensions such as transparency, visibility, traceability, fraud reduction, decision-making, and implementation experiences. A significant 63.4% of respondents agreed and 17.1% strongly agreed that blockchain enhances transparency in supply chain operations, yielding a mean of 3.83 and a standard deviation of 0.919. This aligns with Kamble et al. (2020), who argue that blockchain's immutable ledger provides real-time data access, fostering trust among stakeholders. In Kenya's context, where informal value chains often obscure processes, this suggests blockchain's potential to address transparency issues.

Similarly, 65.9% of respondents agreed and 19.5% strongly agreed that blockchain improves transaction visibility for small-scale farmers, with a mean of 3.98 and a low standard deviation of 0.790, indicating consistent acknowledgment. This visibility is crucial for farmers balancing work and studies amid distrust in traditional systems, offering a practical advantage in Kenya's agricultural landscape. On traceability and accountability, 56.1% agreed and 19.5% strongly agreed that enhancements are evident, with a mean of 3.76 and a standard deviation of 1.044. The higher variability may reflect uneven adoption, yet Casino et al. (2019) affirm blockchain's role in ensuring "end-to-end traceability," improving accountability, a benefit pertinent to Kenya's poorly documented supply chains.

The reduction of fraud and errors also garnered strong support, with 61.0% agreeing and 19.5% strongly agreeing, resulting in a mean of 3.85 and a standard deviation of 0.937. Raj, Saini, and Surianarayanan (2020) corroborate this, highlighting blockchain's cryptographic security as a safeguard against fraud and errors, a pressing need for Kenyan farmers vulnerable to intermediary exploitation. Furthermore, 73.2% of respondents agreed and 14.6% strongly agreed that enhanced transparency influences decision-making positively, with a mean of 3.93 and a low standard deviation of 0.787. For Kenya's dual-role farmers, this could optimize resource use, underscoring blockchain's transformative potential.

However, responses on overall implementation experience were more mixed, with 36.6% agreeing and 12.2% strongly agreeing it was positive, while 36.6% remained neutral, producing a mean of 3.41 and a standard deviation of 0.999. Challenges were further evident, with 26.8% agreeing and 14.6% strongly agreeing that significant obstacles exist, contrasted by 31.7% disagreeing, yielding a mean of 2.85 and a high standard deviation of 1.406. Similarly, Yadlapalli et al. (2022) found varied stakeholder perspectives on blockchain adoption in supply chains, with some highlighting its potential for efficiency while others emphasized significant barriers like technological complexity and organizational readiness, requiring substantial effort to overcome. Agnew et al. (2022) identify high setup costs and limited digital infrastructure as barriers in sub-Saharan Africa, including Kenya, reflecting the diverse experiences and substantial hurdles some farmers face.

Overall, blockchain's effectiveness in enhancing supply chain transparency was affirmed by 61.0% agreeing and 17.1% strongly agreeing, with a mean of 3.76 and a standard deviation of 0.994. Cai et al. (2020) support this, arguing that blockchain improves efficiency in fragmented systems like agriculture, a finding resonant with Kenya's opaque supply chains.

In conclusion, the data reveal a predominantly positive perception among Kenyan small-scale farmers, crediting blockchain with enhancing transparency, visibility, traceability, and decision-making while reducing fraud. Yet, mixed implementation experiences and reported challenges, such as infrastructure and access gaps, highlight areas for further research and development. These insights underscore blockchain's transformative potential in Kenya's agricultural sector, advocating for strategies to mitigate adoption barriers and maximize benefits for smallholders.

- *Performance of Small-scale Agricultural Farms*

The respondents were requested to indicate their level of agreement on various statements relating to performance of small-scale agricultural farms in Kenya. A 5-point Likert scale was used where 1 symbolized strongly disagree, 2 symbolized disagree, 3 symbolized neutral, 4 symbolized agree and 5 symbolized strongly agree. The results were as presented in the table below.

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Table 2 Small-Scale Agricultural Farm Performance

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Div
Blockchain technology's transparency has increased trust among stakeholders in small-scale agricultural farms.	0.0 %	0.0%	4.9%	68.3%	26.8%	4.22	0.525
Blockchain technology's transparency has enhanced price visibility for small-scale agricultural products.	0.0%	4.9%	7.3%	63.4%	24.4%	3.95	0.999
Blockchain technology's transparency has positively affected community engagement and participation in small-scale agricultural farms.	0%	0%	9.85%	78.0%	12.2%	4.02	0.474
I am satisfied with the impact of blockchain technology on small-scale agricultural farms performance.	0%	0%	7.3%	65.9%	26.8%	4.20	0.558

The findings reveal that blockchain technology's transparency has had a notable impact on enhancing the performance of small-scale agricultural farms. The majority of respondents in this study reported that blockchain transparency has significantly increased trust among stakeholders (95.1%), enhanced price visibility for agricultural products (87.8%), and improved community engagement (90.2%). Furthermore, 92.7% of participants expressed overall satisfaction with the role of blockchain transparency in driving better performance outcomes. This aligns with findings by Adewusi et al. (2023), who reported that blockchain's decentralized ledger enhances trust, pricing transparency, and stakeholder collaboration in agricultural supply chains, particularly benefiting small-scale farmers by improving market access and operational efficiency.

Mwewa et al. (2025) reinforce this by asserting that blockchain's transparent data-sharing mechanisms significantly enhance the credibility of agricultural records, thus increasing stakeholder confidence. Their study found that transparent blockchain systems helped eliminate intermediary manipulation and improved accountability across farm-to-market chains.

Moreover, transparency plays a crucial role in price visibility. As Lakhan (2025) explains, the open ledger of blockchain allows all stakeholders to access real-time pricing data, ensuring that farmers receive fair compensation and buyers understand value chains better. This increased visibility helps correct market distortions and supports more equitable trade practices consistent with the 87.8% of respondents in this study who agreed that transparency enhanced price visibility.

Ukidve et al. (2024) further illustrate how transparent blockchain platforms can deepen community engagement by making farming processes visible and participatory. When stakeholders including village champions, cooperatives, and consumers can track agricultural inputs and outputs transparently, it builds collective ownership and involvement. The respondents in this study echoed this sentiment, with 90.2% indicating that transparency positively affected community engagement.

Overall, the results of this research validate the central role of blockchain's transparency in boosting trust, ensuring fair market practices, and fostering participatory agricultural ecosystems. These outcomes suggest that transparency is not just a technical feature but a catalyst for systemic improvements in small-scale agriculture.

➢ *Correlation Analysis*

The correlation analysis examines the relationships between blockchain transparency and the performance of small-scale agricultural farms. The results reveal several significant correlations.

Table 3 Correlation Coefficients

		Performance of Small-Scale Farms	Blockchain's Transparency
Performance of Small-Scale Farms	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	41	
Blockchain's Transparency Mean	Pearson Correlation	.886**	1
	Sig. (2-tailed)	.001	
	N	41	41

Table 3 presents the correlation coefficients between blockchain transparency and the performance of small-scale farms. As expected, the performance variable shows a perfect correlation with itself, with a Pearson correlation coefficient of 1.000. This is a standard statistical result, reflecting that any variable is perfectly correlated with itself. Consequently, the significance value for this correlation is not applicable. The sample size for this observation is 41, indicating that data from 41 farms were used in the analysis.

More importantly, the second part of the table reveals the correlation between blockchain transparency and farm

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performance. The Pearson correlation coefficient is 0.886, indicating a very strong positive linear relationship between the two variables. This suggests that improvements in blockchain transparency are strongly associated with enhanced performance among small-scale farms. The correlation is statistically significant, with a p-value of 0.001, which is well below the commonly accepted threshold of 0.05. This implies that the observed relationship is unlikely to be due to random chance. The sample size for this correlation is also 41, confirming that the analysis was conducted using a consistent dataset.

This strong positive association aligns with previous studies emphasizing the transformative role of blockchain technology in agriculture. For instance, Nangpiire (2024) reported that blockchain adoption led to an 85.3% increase in supply chain transparency within Ghana's cocoa and agricultural sectors, with results statistically significant at $p < 0.001$. Similarly, Falade (2023) found that smallholder nutmeg farmers in Indonesia experienced a 3% increase in revenue and improved output volumes after implementing blockchain-based traceability systems. Although these studies differ in methodology and performance indicators, they collectively support the notion that blockchain-driven transparency mechanisms enhance agricultural efficiency, accountability, and profitability.

In summary, the findings in Table 3 provide compelling empirical evidence that blockchain transparency has a strong and statistically significant positive impact on the performance of small-scale farms. The high correlation coefficient (0.886) and low p-value (0.001) reinforce the conclusion that increased blockchain transparency can play a critical role in improving outcomes in smallholder agricultural operations.

➢ *Test for Hypothesis*

The specific objective of the study was to examine the role of blockchain's transparency on performance of small-scale agricultural farms in Kenya. The associated null hypothesis was that Blockchain's transparency does not positively influence the performance of small-scale agricultural farms in Kenya. A univariate analysis was conducted in which performance of small-scale agricultural farms in Kenya was regressed on blockchain's transparency.

Table 4 Model Summary for Blockchain's Transparency

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.413[a]	.369	.321	.7473

a. Predictors: (Constant), Blockchain's Transparency

The model summary illustrated the statistical relationship between Blockchain's Transparency and the performance of small-scale agricultural farms. The R value, denoted as 0.413, represented the correlation coefficient, which measured the linear association between these variables. This suggested a moderate positive relationship, indicating that increases in Blockchain's Transparency corresponded to improvements in the performance of small-scale farms.

The R Square value of 0.369 reflected the proportion of variance in the dependent variable explained by the independent variable. This signified that Blockchain's Transparency accounted for 36.9% of the variability in the performance of small-scale farms, highlighting its role as a notable factor influencing farm performance.

The Adjusted R Square value, reported at 0.321, provided an adjusted measure of the explanatory power of the model, accounting for the number of predictors. This adjustment ensured that the explained variance was not overstated due to the inclusion of unnecessary predictors.

The Standard Error of the Estimate, calculated at 0.7473, represented the average distance that the observed values fell from the regression line. This measure evaluated the model's predictive accuracy, with lower values indicating better model fit. Overall, these findings underscored Blockchain's Transparency as a significant predictor of the performance of small-scale agricultural farms, while acknowledging that other factors contributed to the unexplained variance in the model.

This moderate positive association aligns with previous studies emphasizing the transformative role of blockchain technology in agriculture. For example, Bore et al. (2020) developed a blockchain-enabled digitization framework that significantly improved transparency and traceability in small-scale farms across East Africa, highlighting enhanced decision-making and accountability. Similarly, Kamilaris, Cole, and Prenafeta-Boldú (2021) noted that blockchain applications in agricultural systems led to improved logistics coordination, data immutability, and trust in supply chains, particularly benefiting smallholder operations.

Although the performance indicators used in those studies differ from the regression metrics applied here, they collectively support the notion that blockchain-driven transparency mechanisms can explain significant variations in farm performance. This is further reinforced by Haider (2018), who documented case examples where smallholder farmers adopting blockchain platforms saw enhanced market access and fairer pricing due to improved information flow and traceability. Together, these findings confirm that blockchain transparency is not just a theoretical innovation but a statistically and operationally relevant predictor of small-scale agricultural success.

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Table 5 Beta Coefficients for Blockchain's Transparency

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.235	0.049		2.234	.001
	Blockchain's Transparency	0.362	0.072	0.345	3.107	.002
a. Dependent Variable: Performance of Small-Scale Agricultural Farms						

The regression model presented in Table 5 outlined the relationship between blockchain's transparency and the performance of small-scale agricultural farms, as well as the statistical significance of the findings. The dependent variable in this model is the performance of small-scale agricultural farms, with blockchain's transparency as the independent variable.

The constant term has an unstandardized coefficient of 0.235, indicating the baseline level of farm performance when blockchain's transparency is zero. The standard error of 0.049 reflects the precision of this estimate, with a relatively small value suggesting that the coefficient is estimated with good accuracy. The t-value of 2.234 and the p-value of 0.001 indicate that the constant term is statistically significant. This means that the constant value of 0.235 is unlikely to be due to random chance and contributes meaningfully to the regression model.

The coefficient for blockchain's transparency is 0.362, with a standard error of 0.072. This suggests that, for every unit increase in blockchain's transparency, farm performance is expected to increase by 0.362 units, assuming all other factors remain constant. The standardized coefficient, represented by a beta value of 0.345, highlights the relative importance of blockchain's transparency in explaining farm performance. The t-value for this variable is 3.107, and the p-value is 0.002, both of which indicate that blockchain's transparency has a statistically significant positive impact on farm performance. The significance level of 0.002 is well below the standard threshold of 0.05, confirming that blockchain's transparency is a meaningful predictor of farm performance in this model.

These findings are consistent with existing literature emphasizing the role of blockchain in enhancing transparency and efficiency in agricultural supply chains. For instance, Kamilaris et al. (2021) discuss how blockchain technology can improve traceability and trust among stakeholders in the agri-food sector. Similarly, Juneja (2024) presents a case study demonstrating the effectiveness of blockchain in increasing transparency within agricultural supply chains. Additionally, Bore et al. (2020) highlight the benefits of blockchain-enabled digitization for small-scale farms, leading to improved performance and accountability. These studies collectively support the notion that blockchain's transparency feature is crucial for the efficient functioning of agri-food value chains, thereby corroborating the statistical significance observed in the regression model.

From the results in table 5, the following regression model was fitted.

$$Y = 0.235 + 0.3.62\ X_4$$

(X_1 is Blockchains Transparency)

V. SUMMARY

The study conducted an in-depth analysis of the influence of blockchain transparency on the performance of small-scale agricultural farms in Kenya. The findings revealed several significant contributions of blockchain technology to the agricultural supply chain, with particular emphasis on transparency, traceability, and decision-making processes. Notably, blockchain transparency was found to significantly improve agricultural supply chain operations, with respondents generally agreeing that transparency had been enhanced. This aligns with observations by Bore et al. (2020), who noted that blockchain-enabled digitization enhances transparency and accountability in small-scale farming operations. Similarly, Mwewa et al. (2025) highlight that blockchain's immutable nature ensures credibility in supply chain data, fostering consumer trust and facilitating compliance with international quality standards.

The results indicated a positive perception of blockchain's role in improving visibility and accountability. Respondents agreed that blockchain enhanced transaction visibility for small-scale farmers, with a strong acknowledgment of this benefit across the participants. Traceability and accountability were also positively impacted, with respondents agreeing that blockchain improved these aspects. Additionally, blockchain's role in reducing fraud and errors in supply chain processes was evident, with respondents recognizing its effectiveness in this area. The enhanced transparency facilitated by blockchain further influenced decision-making, with respondents agreeing that it significantly improved the decision-making capabilities of small-scale farmers. This positive impact on decision-making was widely acknowledged, corroborating the assertions of Cuellar and Johnson (2022), who discuss how blockchain and IoT technologies can improve traceability, efficiency, and safety in food supply chains.

However, experiences with blockchain implementation were more varied, with some respondents reporting neutral experiences, while a minority encountered challenges in adopting the technology. These challenges are consistent with those identified by Cuellar and Johnson (2022), who note barriers such as a lack of infrastructure and education to support blockchain adoption in agriculture. Overall, blockchain's effectiveness in enhancing supply chain transparency was supported by a general consensus of its positive influence. However, challenges in implementation remain, highlighting the need for further research and targeted interventions to optimize its benefits and address adoption hurdles in the agricultural sector.

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VI. CONCLUSION

In conclusion, the ability of blockchain to offer clear, verifiable, and auditable records plays a pivotal role in enhancing transparency within agricultural transactions. This transparency not only fosters trust among stakeholders but also improves operational efficiency by reducing fraud, errors, and inefficiencies. The real-time access to crucial data along the agricultural supply chain allows stakeholders to ensure that products meet agreed-upon standards, thereby promoting higher levels of accountability and contributing to more sustainable agricultural practices. Blockchain's transparent nature extends to various aspects of small-scale farming, including product traceability, market access, and regulatory compliance. This transparency improves food safety, quality assurance, and ethical sourcing, which are vital in global supply chains. Moreover, it facilitates better decision-making by providing clear, accessible data that helps in informed choices regarding productivity, resource allocation, and profitability.

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