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Blockchain's Smart Contract Technology on the Performance of the Small-Scale Agricultural Farms in Kenya

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Abstract: In Kenya's small-scale agricultural sector, where productivity is often hindered by limited credit access, delayed payments, and exploitative intermediaries, blockchain-based smart contracts offer a bold new frontier. This study explores how these automated, self-executing agreements built on decentralized blockchain platforms are reshaping the performance landscape for smallholder farms. By enabling secure, transparent, and trustless transactions, smart contracts promise to streamline value chains, enforce agreements without intermediaries, and accelerate financial flows. Guided by a pragmatic philosophy and a mixed-methods design, this research draws on both quantitative and qualitative data. Focus group discussions with village champions provided contextual insight into farmers' lived experiences with smart contract platforms. A census of 52 blockchain-enabled agricultural firms yielded structured survey data, analyzed using descriptive statistics, thematic coding, Pearson and Spearman correlation tests, and regression modeling. Findings show that smart contracts significantly improve farm performance by enhancing payment reliability, reducing transactional friction, and increasing transparency in financial and operational records. The technology also fosters trust and coordination among stakeholders, while facilitating access to financing and new markets. Ultimately, this study underscores the transformative potential of blockchain smart contracts in small-scale farming not only as a technical innovation but as a catalyst for inclusive agricultural development. However, realizing this potential at scale will require sustained investment, policy support, and farmer-centered digital literacy initiatives.

Keywords: *Blockchain Technology, Performance, Small-Scale Agricultural Farms, Smart Contract Technology, Kenya.*

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I. INTRODUCTION

Blockchain has been utilized to address issues across various industries. It has transformed financial services by serving as the foundational framework for cryptocurrencies like Bitcoin and Ethereum. Its decentralized nature allows for peer-to-peer transactions, eliminating the need for intermediaries such as banks or payment processors. This innovation not only reduces transaction costs but also enhances the speed of financial exchanges, making it particularly valuable for cross-border payments and remittances. By fostering a system that is transparent, secure, and efficient, blockchain technology is reshaping how value is exchanged in the digital economy (Hayes, 2024).

Blockchain technology is revolutionizing supply chain management by providing real-time insights that enhance transparency and efficiency. Its decentralized ledger allows for accurate product traceability, enabling companies to track goods at every stage of the supply chain. This capability is instrumental in combating counterfeiting and ensuring authenticity, particularly in industries such as pharmaceuticals and luxury goods. Additionally, blockchain improves quality control by providing an immutable record of transactions and processes, which facilitates compliance and accountability across the supply chain (U.Cumberlands, 2023).

According to Hema and Manickavasagan (2024), blockchain's decentralized and tamper-proof architecture ensures that data related to food production, handling, and distribution remains secure and accessible. A key feature of blockchain that has gained significant attention is the use of smart contracts, self-executing agreements that are written

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into the blockchain and automatically enforce the terms of a contract once predefined conditions are met.

Building on this foundation, smart contracts, a dominant feature of blockchain technology, not only streamline operations but also mitigate risks associated with human error and fraud. Their decentralized execution ensures that transactions are transparent and verifiable, fostering trust in environments where traditional systems often lack accountability. Moreover, the versatility of smart contracts extends their application to emerging areas such as decentralized finance (DeFi) and tokenized assets, paving the way for innovative solutions to longstanding challenges across various industries (Davies, 2018).

The agricultural sector contributes approximately 33% to Kenya's Gross Domestic Product (GDP), employing over 40% of the total population and 70% of the rural populace (USAID, 2023.). Notably, smallholder farmers are responsible for 78% of the country's total agricultural production and 70% of its commercial output (Wahome et al., 2024).

- *Statement of the Problem*

Small-scale farming is a foundational component of Kenya's agricultural sector, contributing significantly to food security, rural employment, and the national economy. According to USAID (2022), over 75% of Kenyans depend on agriculture for their livelihoods, and the sector accounts for more than a quarter of the country's gross domestic product. Similarly, the World Bank (2023) underscores that enhancing agricultural productivity is crucial for reducing rural poverty and achieving sustainable development.

Despite this central role, smallholder farmers in Kenya continue to face persistent operational challenges, including inadequate record-keeping, delayed payments, lack of transparency, and a heavy reliance on intermediaries (Dhillon and Moncur, 2023). These inefficiencies contribute to post-harvest losses, reduce profitability, and restrict market access, ultimately limiting the sector's ability to meet its developmental potential.

Emerging technologies such as blockchain, particularly smart contracts, present promising avenues for addressing these systemic inefficiencies. Smart contracts self-executing agreements encoded on decentralized ledgers enable secure, transparent, and automated transactions that reduce the need for third-party intermediaries (Pranto et al., 2021). In the context of agriculture, these technologies can streamline payment systems, automate data collection, and enhance accountability, thereby improving stakeholder trust and operational efficiency (Xia et al., 2023). Moreover, smart contracts have demonstrated potential in enhancing farmer-buyer coordination, enforcing traceability, and supporting dynamic pricing models.

However, while pilot implementations suggest positive outcomes, the widespread adoption of blockchain in Kenyan agriculture remains constrained by scalability issues, limited technical knowledge, and ambiguous regulatory frameworks (Hang et al., 2020; Zhao et al., 2019). Existing literature also highlights the technology's potential to mitigate information asymmetry and strengthen transparency in agricultural supply chains (El Mane et al., 2022; Akella et al., 2023), but empirical evidence on its effectiveness in small-scale Kenyan farming contexts remains scarce.

This study addressed this gap by investigating how blockchain-based smart contracts influence the performance of small-scale agricultural farms in Kenya. Specifically, it explored the extent to which smart contracts improve productivity, enhance market access, and mitigate risks within smallholder operations. The findings contribute to a growing body of knowledge on digital transformation in agriculture and offer practical insights for stakeholders aiming to leverage blockchain to enhance sustainability and resilience in Kenya's agricultural sector.

- *Objective*

To assess the influence of blockchain's smart contract technology on the performance of the small-scale agricultural farms in Kenya.

- *Theoretical Framework*

Blockchain's smart contract technology is a novel innovation that automates and enforces contractual agreements without intermediaries. Its adoption by small-scale agricultural farmers in Kenya holds the potential to improve operational efficiency, reduce disputes, and streamline transactions. Understanding the factors that influence farmers' acceptance and use of smart contracts is crucial to realizing these benefits. Theoretical models such as the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM) provide valuable frameworks for exploring the behavioral intentions, perceived usefulness, and facilitating conditions that drive smart contract adoption in this context. These models help clarify how socio-technical factors impact the integration of smart contracts into daily farming operations and subsequently affect farm performance.

- *Unified Theory of Acceptance and use of Technology (UTAUT)*

The Unified Theory of Acceptance and Use of Technology (UTAUT) integrates elements from multiple models, including the Technology Acceptance Model (TAM), to offer a comprehensive framework for understanding technology adoption behavior. UTAUT highlights four primary factors influencing technology use: performance expectancy, effort expectancy, social influence, and facilitating conditions. It also considers moderating variables such as age, gender, and experience, which can affect adoption intentions (Venkatesh et al., 2003).

In the context of blockchain smart contract technology adoption among Kenya's small-scale agricultural farms, UTAUT provides valuable insights. Performance expectancy reflects farmers' beliefs about the extent to which smart contracts can improve farm operations, such as automating agreements and securing transactions to enhance productivity and reduce disputes. Effort expectancy addresses how easily farmers perceive these smart contracts can be used, which is critical given varying levels of digital literacy in rural communities. Social influence, including the encouragement from community leaders or cooperative groups, can significantly shape farmers' willingness to adopt smart contracts. Facilitating conditions, such as access to mobile devices, internet connectivity, and technical support, also play a crucial role in enabling the use of this technology.

However, while UTAUT offers a robust lens for examining adoption, it has been noted that its framework is primarily oriented toward organizational or individual contexts in formal settings. This may limit its direct applicability to smallholder farms in Kenya, where adoption is often influenced by communal norms, resource constraints, and informal practices.

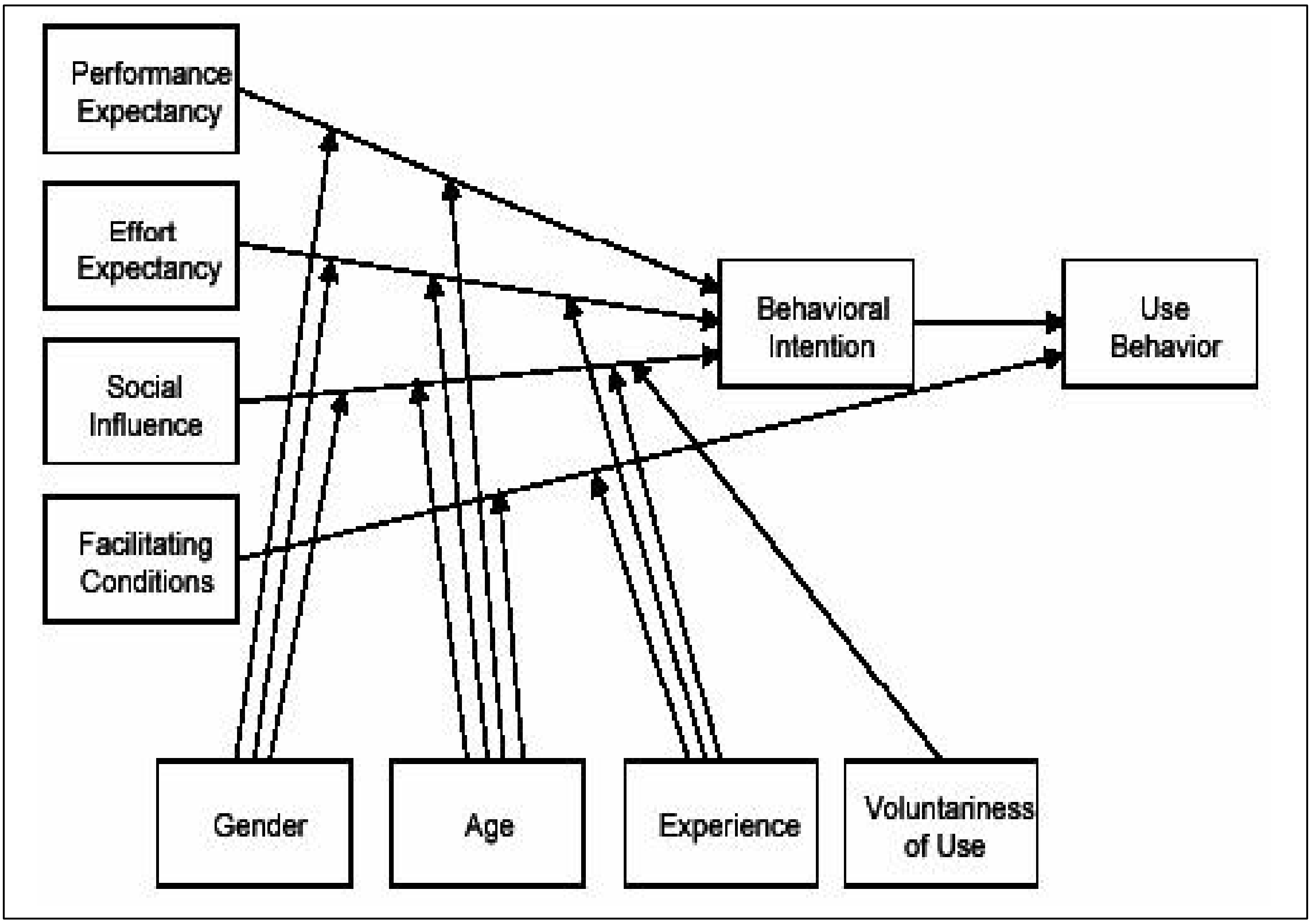

Fig 1 United Theory of Acceptance and use of Technology.
Source: Venkatesh et al. (2003)

➢ *Technology Acceptance Model (TAM)*

The Technology Acceptance Model (TAM) is a foundational framework that explains technology adoption based on users' perceptions of its usefulness and ease of use (Davis, 1989). In the context of blockchain smart contract technology for smallholder farmers in Kenya, perceived usefulness includes benefits such as automating transactions, reducing reliance on intermediaries, and ensuring timely and secure payments key for improving operational efficiency and trust.

Perceived ease of use also plays a central role. If smart contracts can be accessed and executed through simple interfaces that do not require advanced technical skills, farmers are more likely to adopt the technology. In regions where digital literacy is varied, the simplicity of interacting with blockchain systems is a decisive factor.

TAM also acknowledges the role of social influence and facilitating conditions. Farmers may be influenced by peers, cooperatives, or agricultural advisors who promote the use of smart contracts. Facilitating conditions, such as mobile connectivity, access to blockchain-enabled platforms, and training, further support adoption especially in Kenya's rural areas where infrastructure can be limited.

However, TAM's focus on individual behavior may not fully address the communal decision-making structures common in smallholder farming. This limits its explanatory power in capturing broader social or institutional barriers to adoption.

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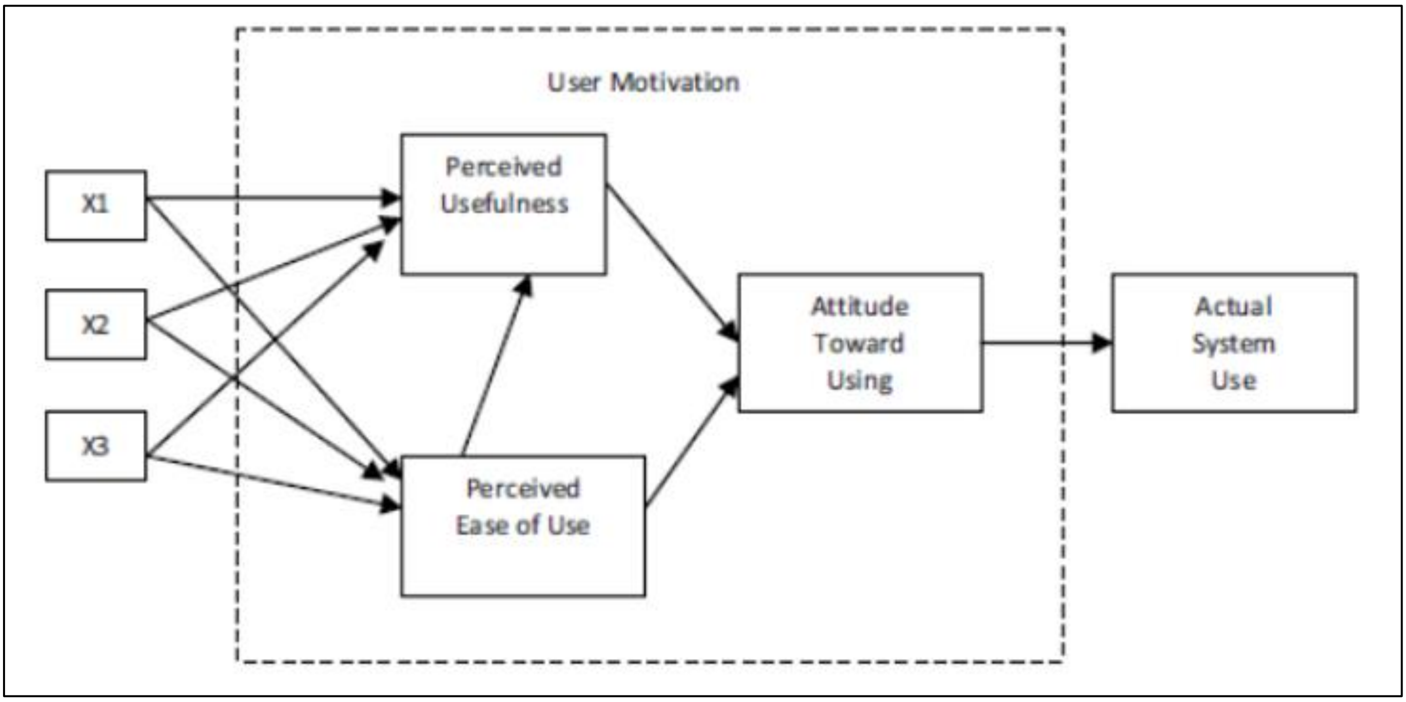

Fig 2 Original Technology Acceptance Model (TAM)
Source: Davis (1986)

The theoretical frameworks of the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM) provide critical insights into the adoption of blockchain smart contract technology among small-scale agricultural farms in Kenya. UTAUT highlights the importance of farmers' expectations regarding the performance benefits and ease of use of smart contracts, while also emphasizing social influence and facilitating conditions such as access to technology and community support. Similarly, TAM focuses on the perceived usefulness and ease of use of smart contract technology, alongside the effects of social influence and available resources.

Together, these models underscore the need to address both individual perceptions and external factors influencing adoption to ensure successful implementation. By applying these frameworks, policymakers, extension services, and technology developers can tailor strategies that enhance acceptance and usage of smart contract technology, ultimately improving farm performance through increased operational efficiency, trust, and transparency in agricultural transactions.

➢ *Conceptual Framework*

The conceptual framework shows the anticipated relationship between blockchain's smart contract technology and small-holder agricultural farms performance.

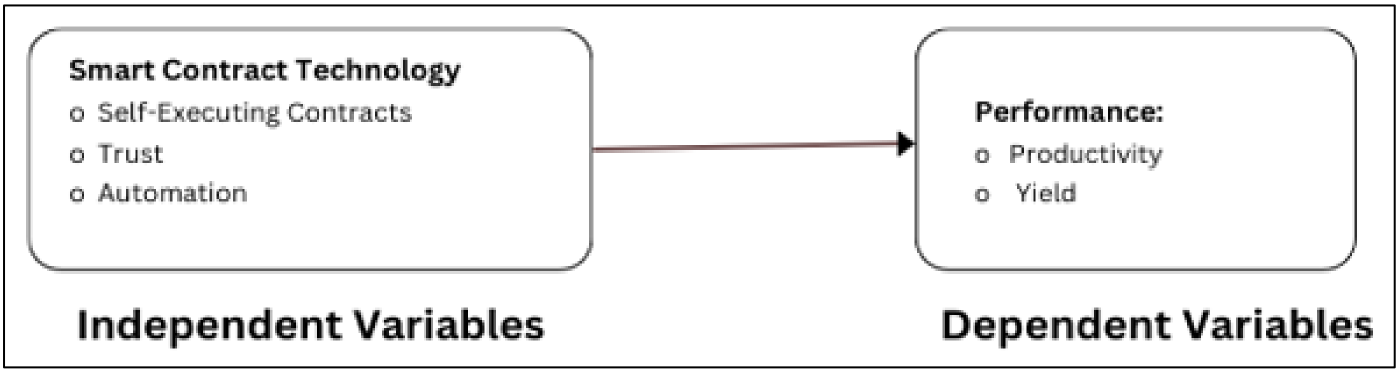

Fig 3 Illustrate the Diagrammatical Presentation of the Relationship between Independent Variable Transparency and Dependent Variable Performance

➢ *Empirical Evidence*

- *Blockchain's Smart Contract Technology and Performance*

Blockchain technology, often envisioned as a distributed ledger, shines brightest when paired with its intelligent counterpart, smart contracts. These self-executing agreements written in code reside on the blockchain, automating specific actions upon predetermined conditions being met (Prause, 2019). In the context of agricultural supply chains, this dynamic duo unveils a world of enhanced trust and efficiency.

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According to El Mane et al., (2022), smart contract technology plays a pivotal role in ensuring data integrity and security within the agricultural supply chain. Blockchain technology, underpinned by smart contracts, creates a secure and immutable ledger that records every transaction. This ensures that agricultural data remains tamper-proof and inaccessible to unauthorized parties, fostering a higher level of trust among stakeholders. By automating transaction processes and eliminating the need for intermediaries, smart contracts not only enhance transparency but also reduce the risk of human error and data manipulation, ultimately streamlining agricultural supply chain management.

In supply chain management, smart contracts automate and streamline processes by ensuring that transactions and logistics are executed precisely as stipulated. For instance, Datahash, formerly Entrust, is Australia's first full-service agricultural supply chain platform. It utilizes smart contracts to trace data in a trusted way, aiming to combat the $3 billion-a-year market in fraudulent wine. This application enhances transparency and trust among stakeholders, reducing fraud and improving operational efficiency, (Hedera, 2023).

The insurance industry has also benefited from smart contract integration. A notable example is the French insurance company AXA's introduction of Fizzy, an Ethereum-based flight-delay insurance application. Fizzy utilizes smart contracts to automate compensation processes between providers and claimants by automatically triggering payouts based on predetermined conditions, such as flight delays, without the need for filing claims or human intervention. This automation reduces administrative costs and enhances customer satisfaction by providing timely payouts, (Higgins, 2017)).

Another notable example of smart contracts in parametric insurance is Lemonade's initiative in Kenya. The program utilized blockchain-based smart contracts to provide immediate payouts to farmers affected by drought during the 2023 growing season. By predefining conditions, such as rainfall thresholds, smart contracts automatically triggered compensation without requiring human intervention or the traditional claims adjustment process. This streamlined approach reduced administrative delays, a common issue in conventional insurance systems, and ensured farmers could quickly access fun ds to purchase essential resources like seeds and food, (Business Wire, 2023).

The figure below intricately illustrates the architecture of smart contracts on a blockchain, encompassing key elements such as identity agreement, condition setting, business logic coding, encryption, and blockchain integration, as well as execution and processing mechanisms. Within this visual representation, each component plays a pivotal role in the functioning of smart contracts.

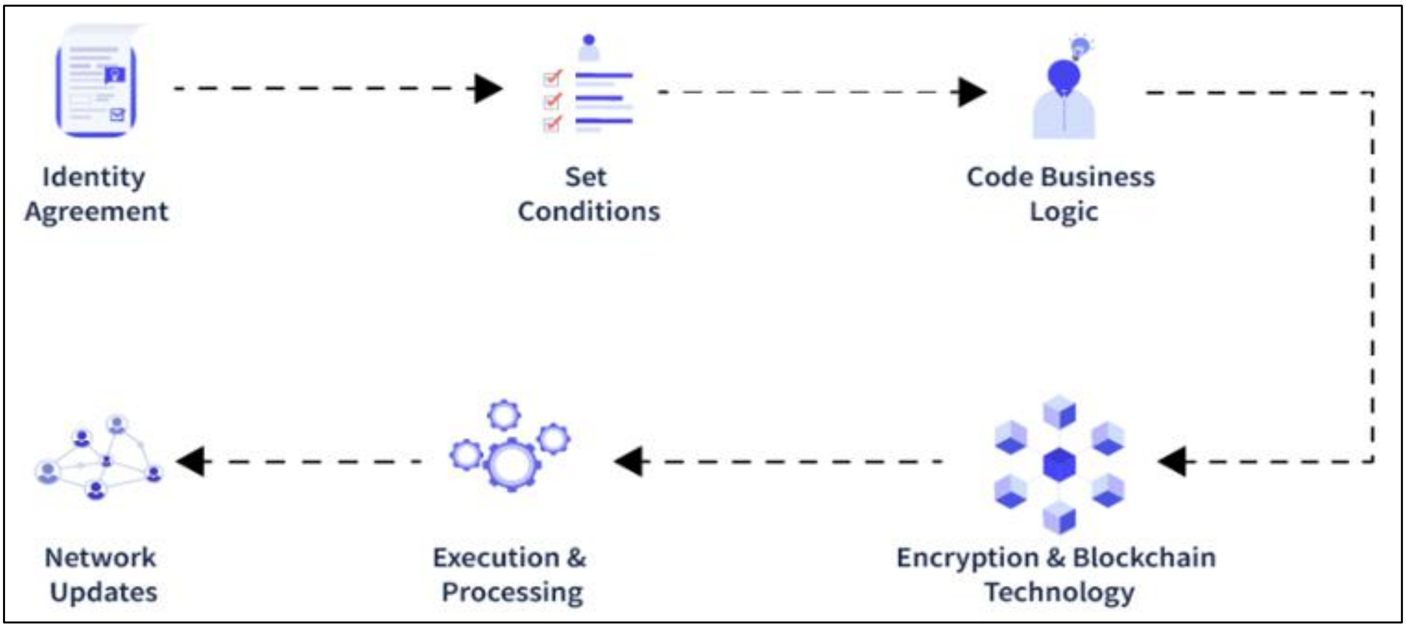

Fig 4 Smart Contracts on Blockchain
(CoinDCX, 2023)

Blockchain technology has a significant impact on yield and productivity in agriculture. It can enhance data-driven decision making, ensure food security, and improve the food supply chain, leading to greater efficiency and transparency in agriculture (Rehman et al., 2023). By utilizing blockchain, stakeholders can create a more transparent, secure, and efficient agricultural system, which is crucial for addressing the challenges of a growing global population and increasing demands on the food system.

Furthermore, blockchain technology can track the provenance of food, create trustworthy food supply chains, and improve supply chain management, thus contributing to increased productivity in agriculture (Kamilaris et al., 2019). In addition, blockchain technology eliminates duplication of effort, reduces the need for intermediaries, and enables faster transaction settlement, ultimately improving labor productivity in companies.

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Mukherjee et al., 2022, explore the multifaceted landscape of smart agriculture, focusing on how blockchain technology contributes to its effective implementation. The review highlights the challenges and opportunities associated with integrating blockchain into agricultural systems. By leveraging blockchain, the agricultural sector gains a secure platform for storing critical data, which is essential for optimizing processes in smart agriculture. The empirical evidence presented underscores blockchain's potential not only to address security and privacy concerns in data handling but also to significantly improve yield and productivity in the evolving agricultural landscape.

Overall, the use of blockchain technology in agriculture has the potential to significantly increase yield and productivity by enhancing transparency, security, and efficiency in the food supply chain and agricultural systems.

II. METHODOLOGY

➢ *Research Philosophy*

This study was guided by a pragmatic research philosophy, which prioritizes selecting methods based on the specific research questions and objectives rather than committing to a single methodological approach. Dewey (1938) emphasized the importance of research that responds to real-world problems, using methods suited to the practical demands of the inquiry. Similarly, Creswell (2014) supports this adaptable approach, encouraging the use of tools that align with the research context. The study explored the impact of blockchain smart contract technology on the performance of small-scale agricultural farms in Kenya, involving both blockchain-enabled firms and smallholder farmers. A mixed-methods design was adopted, integrating quantitative methods to assess the effects of smart contracts on farm operations and outcomes, alongside qualitative methods to capture the experiences and perspectives of farmers. Quantitative data were gathered using structured questionnaires, while qualitative information was obtained through focus group discussions with village champions. This combination of methods embodied the pragmatic philosophy, enabling a comprehensive and balanced analysis of smart contract implementation in agriculture.

➢ *Research Design*

The study employed a mixed methods research design, integrating both quantitative and qualitative strategies (Creswell, 2009; Creswell and Plano Clark, 2007). This design is well-suited for investigating complex topics that require both empirical evidence and contextual understanding. The quantitative component focused on evaluating how the adoption of blockchain smart contract technology influenced key performance indicators among small-scale farms in Kenya, such as efficiency, automation, and transaction reliability. Complementarily, qualitative data were gathered through focus group discussions with village champions farmer representatives familiar with blockchain systems. These discussions explored farmers' perceptions, benefits, and challenges in using smart contracts in agricultural practices. Structured questionnaires were used to collect numerical data for statistical analysis, while the qualitative data provided depth and nuance. The integration of both methods allowed the study to produce comprehensive insights into both the technical and experiential dimensions of smart contract usage in farming.

➢ *Target Population*

Creswell (2014) emphasizes the importance of identifying a target population that accurately represents the focus of the research. In this study, the target population comprised 52 blockchain-enabled firms actively involved in deploying blockchain technology integrated with smart contract solutions within the agricultural sector. The research aimed to assess how smart contracts influence small-scale farming performance in Kenya, focusing on elements like automation of transactions, reduction of intermediary costs, and increased trust and transparency. To complement the firm-level data, four focus group discussions were held with smallholder farmers who had adopted blockchain smart contracts in their farming practices. This dual-level approach provided both technical insights from the solution providers and practical experiences from the end users, offering a holistic view of smart contracts' role in agricultural performance.

➢ *Data and Data Collection*

Data collection is the process of obtaining information for a specific study (Kumar, 2014). This study used a mixed research design, combining both qualitative and quantitative methods. Quantitative research provides objective data applicable to broader populations, while qualitative research captures detailed, authentic process data from participants (Steckler et al., 1992). Data were gathered through focus group discussions with farmers representatives (village champions) and blockchain firm executives. Quantitative data on blockchain's influence on small-scale farms were collected via closed-ended questionnaires, which facilitated quicker response recording, comparison, and statistical analysis. These questionnaires included Likert scales to capture degrees of opinion. Primary data, as defined by Kothari (2014), refers to information freshly collected for the study. It was gathered from focus groups and structured questionnaires. Focus groups offer rich, detailed data and diverse perspectives through interactive discussions (SIS International Research, 2023), while questionnaires effectively capture participants' sentiments, experiences, and attitudes (Mugenda and Mugenda, 2003; Zikmund, 2003). This data collection method is particularly useful for large-scale studies (Kothari and Garg, 2014).

➢ *Pilot Study*

The research instruments were initially pilot tested with eight blockchain-enabled startup firms engaged in smallholder agricultural activities, selected through the snowball sampling method. The collected data underwent multiple tests to assess both the reliability and validity of the instruments, and the findings contributed to the final study results. The pilot phase uncovered that although smallholder farmers were involved in blockchain-based products, many were unfamiliar with the technology itself, leading to limited and less informed participation. This unexpected discovery prompted a shift in focus toward the technology implementers

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to better understand how blockchain was being introduced and applied in agriculture. To capture the farmers' perspectives, the study identified village champions to serve as persona representatives. These individuals acted as intermediaries between farmers and technology implementers, offering valuable insights into the user experience. Each representative was actively involved in small-scale farming for at least three years and had experience with various agricultural technologies. Despite having only a basic formal education, they possessed critical practical knowledge and adaptability, making them well-suited to interpret and respond to innovations. Their role was instrumental in analyzing blockchain features from the perspective of the end user.

➢ *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 Instruments*

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

III. 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.

➢ *Smart Contract Technology and Farm Performance*

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.

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Table 1 Smart Contract Technology

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Div
Smart contract technology has streamlined contract execution in our agricultural farms.	2.4%	7.3%	7.3%	51.2%	31.7%	4.02	0.961
The implementation of smart contracts has improved transaction efficiency within our agricultural farms.	4.9%	7.3%	2.4%	63.4%	22.0%	3.90	0.995
Since adopting smart contract technology, we have experienced reduced transaction costs in our agricultural farms.	9.8%	19.5%	26.8%	34.1%	9.8%	3.15	1.152
Since adopting blockchain, we have observed a reduction in fraud or errors in our supply chain processes.	4.9%	12.2%	4.9%	58.5%	19.5%	3.76	1.067
The use of smart contracts has enhanced trust and reliability in contractual processes within our agricultural farms.	4.9%	17.1%	2.4%	46.3%	31.7%	3.83	1.202
Smart contract technology has facilitated faster dispute resolution in our agricultural farms.	2.4%	9.8%	9.8%	46.3%	31.7%	3.95	1.024
The experience with smart contract technology in our small-scale agricultural farms in Kenya has been positive.	7.3%	9.8%	7.3%	56.1%	19.5%	3.71	1.123
We have faced significant challenges in implementing smart contract technology in our small-scale agricultural farms in Kenya.	12.2%	36.6%	34.1%	12.2%	4.9%	2.61	1.022

The findings are based on responses to a structured questionnaire, providing a comprehensive view of stakeholders' experiences and perceptions. The implementation of smart contract technology has significantly streamlined contract execution within agricultural farms. A majority of respondents (51.2%) agreed with this statement, and 31.7% strongly agreed, resulting in a high mean score of 4.02 with a standard deviation of 0.961. This indicates a strong consensus on the effectiveness of smart contracts in simplifying contractual processes. These results are in line with Bore et al. (2020), who found that blockchain-based platforms enhance efficiency by automating contract enforcement, thus minimizing manual interventions in small-scale farms.

Similarly, smart contracts have been perceived to enhance transaction efficiency. The data shows that 63.4% of respondents agreed, and 22.0% strongly agreed that transaction efficiency has improved since the implementation of smart contracts. This is reflected in a mean score of 3.90 and a standard deviation of 0.995, suggesting substantial improvements in transactional operations. Bore et al. (2020) observed similar results in their study on blockchain-enabled digitization, where farmers reported faster and more accurate transaction recording processes through smart contract mechanisms.

Regarding the reduction of transaction costs, responses were more varied. While 34.1% of respondents agreed and 9.8% strongly agreed that transaction costs had decreased, a significant portion (26.8%) remained neutral, and 19.5% disagreed. The mean score for this statement was 3.15 with a standard deviation of 1.152, indicating a moderate impact on transaction cost reduction. This mixed perception may relate to challenges identified by Parra-Moyano and Ross (2017), who argue that while smart contracts reduce intermediary costs, implementation and maintenance expenses can offset these savings in some environments.

The adoption of blockchain technology, in general, has also contributed to a reduction in fraud and errors within supply chain processes. A majority of respondents (58.5%) agreed, and 19.5% strongly agreed with this statement. The mean score was 3.76 with a standard deviation of 1.067, highlighting a perceived decrease in fraudulent activities and errors. These findings align with Kamilaris et al. (2019), who documented that blockchain increases traceability and tamper-resistance across food supply chains, leading to reduced fraud and data manipulation.

Trust and reliability in contractual processes have been enhanced through the use of smart contracts. This is supported by 46.3% of respondents who agreed and 31.7% who strongly agreed. However, 17.1% of respondents disagreed, resulting in a mean score of 3.83 and a standard deviation of 1.202. The trust-enhancing role of smart contracts is further supported by Casino et al. (2019), who found that the decentralized and immutable nature of blockchain systems enhances stakeholder confidence in agricultural value chains.

Smart contract technology has also facilitated faster dispute resolution within agricultural farms. The data shows that 46.3% of respondents agreed, and 31.7% strongly agreed that dispute resolution processes have become quicker. The mean score was 3.95 with a standard deviation of 1.024, underscoring the efficiency gains in resolving disputes. Bore et al. (2020) noted that automation of contract clauses reduces human error and delays, leading to quicker enforcement and fewer conflicts.

The overall experience with smart contract technology in small-scale agricultural farms has been positive. A majority of respondents (56.1%) agreed, and 19.5% strongly agreed with this statement, though 9.8% disagreed. The mean score was 3.71 with a standard deviation of 1.123, reflecting a generally favorable experience. Kamilaris et al. (2019)

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support this view, emphasizing that blockchain systems contribute to farmer empowerment by providing transparent access to market data and verified contract terms.

Despite these benefits, significant challenges in implementing smart contract technology were reported. While 36.6% of respondents disagreed with facing significant challenges, 34.1% remained neutral, and 12.2% agreed that they encountered substantial difficulties. The mean score for this statement was 2.61 with a standard deviation of 1.022, indicating mixed experiences regarding implementation challenges. These concerns are echoed in Parra-Moyano and Ross (2017), who highlighted regulatory, infrastructural, and technological constraints as key hurdles in deploying blockchain systems at scale, particularly in rural agricultural settings.

The data revealed a generally positive perception of smart contract technology among small-scale farmers in Kenya. The technology is credited with streamlining contract execution, improving transaction efficiency, and enhancing trust in contractual processes. However, challenges in implementation and a moderate impact on reducing transaction costs suggest areas for improvement. These findings highlight the potential of smart contracts to transform the agricultural sector while emphasizing the need for strategies to address implementation hurdles and fully realize their benefits (Bore et al., 2020; Kamilaris et al., 2019; Casino et al., 2019; Parra-Moyano and Ross, 2017).

➢ *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.

Table 2 Small-Scale Agricultural Farm Performance

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Div
Blockchain technology 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 has enhanced price visibility for small-scale agricultural products.	0.0%	4.9%	7.3%	63.4%	24.4%	3.95	0.999
The use of blockchain technology has impacted the revenue growth of small-scale agricultural farms.	4.9%	4.9%	19.5%	63.4%	7.3%	3.63	0.888
Blockchain technology has increased the productivity of small-scale agricultural farms.	0%	0%	9.8%	63.4%	26.8%	4.17	0.587
Blockchain technology has enhanced the ability to mitigate agricultural risks. (i.e. Insurance Claims)	0%	2.4%	4.9%	78.0%	14.6%	4.05	0.545
Blockchain technology 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 project performance.	0%	0%	7.3%	65.9%	26.8%	4.20	0.558

A majority of respondents (68.3% agreeing and 26.8% strongly agreeing) believe that blockchain technology has significantly increased trust among stakeholders in small-scale agricultural farms. This is reflected in a high mean score of 4.22 and a standard deviation of 0.525, indicating a strong consensus. This finding aligns with Bore et al. (2020), who observed that blockchain's decentralized and transparent nature fosters trust among stakeholders, particularly in contract management and traceability across the agricultural value chain. Similarly, Lee et al. (2022) emphasize that blockchain can substitute traditional trust mechanisms with digital trust systems, thereby improving confidence and cooperation between farmers, buyers, and intermediaries.

Blockchain technology is also perceived to have enhanced price visibility for small-scale agricultural products, with 63.4% of respondents agreeing and 24.4% strongly agreeing. The mean score for this indicator is 3.95, with a standard deviation of 0.999, suggesting some variability in responses, though the overall sentiment remains positive. These findings are consistent with research indicating that blockchain enables transparent, real-time pricing data accessible to farmers and stakeholders, thereby improving decision-making and market access (Lee et al., 2022).

When considering the impact on revenue growth, 63.4% of respondents agreed and 7.3% strongly agreed that blockchain technology has had a positive effect. However, 19.5% were neutral, and a small percentage disagreed (4.9%) or strongly disagreed (4.9%). The mean score is 3.63 with a standard deviation of 0.888, indicating mixed perceptions among respondents. This could reflect what Lee et al. (2022) describe as a lag in measurable financial returns due to infrastructural and educational barriers, which hinder full-scale adoption of blockchain in smallholder farming.

Regarding productivity, a large majority of respondents (63.4% agreeing and 26.8% strongly agreeing) reported that blockchain technology has increased productivity in small-scale agricultural farms. The mean score is 4.17, with a standard deviation of 0.587, reflecting strong positive

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sentiment and consensus. Bore et al. (2020) reported similar outcomes in their blockchain pilot in Kenyan farms, where automating data collection and improving supply chain logistics reduced delays and allowed farmers to focus more on core farming activities, thereby enhancing productivity.

In terms of risk management,particularly in the context of insurance claims,78.0% of respondents agreed and 14.6% strongly agreed that blockchain technology has enhanced the ability to mitigate agricultural risks. This high level of agreement is reflected in a mean score of 4.05 and a standard deviation of 0.545. As noted by Lee et al. (2022), blockchain's immutable and timestamped recordkeeping enables transparent claim histories, reducing fraud and disputes, and increasing access to microinsurance for smallholder farmers.

The impact of blockchain technology on community engagement and participation in agricultural farms was also viewed positively, with 78.0% agreeing and 12.2% strongly agreeing. The mean score for this indicator is 4.02, and the standard deviation is 0.474, indicating widespread approval. These findings align with prior literature, which emphasizes that digital platforms powered by blockchain can support decentralized decision-making and enhance community coordination (Lee et al., 2022).

Finally, the overall satisfaction with the impact of blockchain technology on small-scale agricultural project performance is high. A total of 65.9% of respondents agreed and 26.8% strongly agreed. The mean score is 4.20, with a standard deviation of 0.558, underscoring strong overall satisfaction. These results support the findings that blockchain is seen not only as a technical innovation but as a strategic enabler of performance, governance, and sustainability in small-scale farming contexts (Bore et al., 2020; Lee et al., 2022).

The results from Table 2 suggest that blockchain technology is perceived to have a beneficial impact on various aspects of small-scale agricultural farms, including trust, price visibility, revenue growth, productivity, risk management, community engagement, and overall project performance. These findings indicate a strong consensus on the positive role of blockchain technology in enhancing the performance of small-scale agricultural farms in Kenya, while also highlighting the areas where improvements are still needed for broader adoption.

- *Correlation Analysis*

The correlation analysis examines the relationships between blockchain smart contract technology 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 Smart Contract**
Performance of Small-Scale Farms	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	41	
Blockchain's Smart Contract Mean	Pearson Correlation	.795**	1
	Sig. (2-tailed)	.001	
	N	41	41

The results of this analysis indicated a strong and statistically significant positive correlation between the performance of small-scale farms and the use of blockchain-based smart contract technology. Specifically, the Pearson correlation coefficient was 0.795, with a significance value of 0.001,well below the conventional threshold of 0.05,demonstrating a robust association. This suggests that as the use of smart contracts increases within small-scale farming contexts, there is a corresponding improvement in farm performance.

The strength of this correlation implies that smart contracts, which automate and enforce the terms of agreements without the need for intermediaries, may substantially contribute to more efficient farm operations and improved outcomes. As highlighted by Casino, Dasaklis, and Patsakis (2019), smart contracts enhance trust, transparency, and operational speed across the agricultural value chain by reducing administrative complexity and mitigating risks of fraud or contract disputes. Similarly, Zheng et al. (2019) emphasize that blockchain technology, including smart contracts, can optimize supply chain management and improve transaction efficiency, thereby supporting better economic outcomes for farmers. Moreover, Kim and Laskowski (2018) demonstrate that smart contracts can facilitate transparent and automated agreements, which improve accountability and reduce operational risks in agricultural systems. The high degree of statistical significance further reinforces the reliability of this relationship, indicating that smart contracts are not merely associated with improved farm performance but are likely a pivotal mechanism through which efficiency, cost-effectiveness, and stakeholder accountability are achieved. These benefits align with recent empirical studies that highlight blockchain’s potential to improve productivity and coordination in agricultural ecosystems (Casino et al., 2019; Zheng et al., 2019; Kim and Laskowski, 2018).

- *Test for Hypothesis*

The specific objective of the study was to examine the role of blockchain’s smart contract technology 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 smart contract technology.

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Table 4 Model Summary for Blockchain's Smart Contract Technology

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.364[a]	.201	.199	.67231

a. Predictors: (Constant), Blockchain's Smart Contract Technology

The model summary assessed the statistical relationship between blockchain-based smart contract technology and the performance of small-scale agricultural farms. The correlation coefficient (R) was found to be 0.364, indicating a moderate positive linear relationship between the use of smart contracts and farm performance. This suggests that improvements in blockchain's smart contract technology are associated with enhancements in farm productivity.

The coefficient of determination (R^2) was 0.201, implying that approximately 20.1% of the variance in small-scale farm performance could be explained by the implementation of smart contract technology. While this demonstrates a meaningful contribution of the predictor, a significant portion of variability remains influenced by other factors not included in the model.

The Adjusted R^2 value of 0.199 accounts for the number of predictors, providing a more conservative estimate of the explanatory power and reducing the risk of overestimating the effect of smart contract technology.

The Standard Error of the Estimate was 0.67231, representing the average distance between the observed values and the predicted regression line. Lower values suggest greater predictive accuracy, indicating moderate precision in the model's estimates.

Overall, these findings highlight blockchain-based smart contract technology as a significant, though partial, contributor to the performance improvements observed in small-scale agricultural farms, suggesting that further research should consider additional variables to explain the remaining variance. This aligns with the findings of Casino et al. (2019), who emphasize blockchain's potential to improve trust, transparency, and operational efficiency across supply chains, and Kamilaris et al. (2019), who document the rising impact of blockchain technology on agricultural productivity and food supply chains.

Table 5 Beta Coefficients for Blockchain's Smart Contract Technology

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.235	0.049		3.906	.000
	Blockchain's Smart Contract Technology	0.299	0.084	0.275	2.049	.001

a. Dependent Variable: Performance of Small-Scale Agricultural Farms

The table 5 presented the beta coefficients for Blockchain's Smart Contract Technology in relation to the performance of small-scale agricultural farms. The table illustrated the unstandardized coefficient (B), standardized coefficient (Beta), t-value, and significance level (p-value), along with the constant term. The unstandardized coefficient (B) for Blockchain's Smart Contract Technology was 0.299, indicating that a one-unit increase in Blockchain's Smart Contract Technology was associated with a 0.299-unit improvement in the performance of small-scale farms, assuming other variables were held constant. The standardized coefficient (Beta) was 0.275, which represented the effect of Blockchain's Smart Contract Technology in terms of standard deviations, showing a moderate positive relationship with the dependent variable.

The t-value for Blockchain's Smart Contract Technology was 2.049, with a corresponding significance level ($p = .001$). These statistics demonstrated that the relationship between Blockchain's Smart Contract Technology and farm performance was statistically significant at the 0.05 level, confirming that the variable had a meaningful influence on the dependent variable. The constant value of 0.235, with a t-value of 2.234 and a p-value of .001, represented the expected performance level of small-scale farms when Blockchain's Smart Contract Technology was at zero.

Overall, the findings highlighted the importance of Blockchain's Smart Contract Technology in enhancing the performance of small-scale agricultural farms, consistent with prior research identifying blockchain and smart contracts as key drivers of efficiency and productivity in agricultural supply chains (Casino et al., 2019; Kamilaris et al., 2019).

From the results in table 4.17, the following regression model was fitted:

$Y = 0.235 + 0.299 X_2$

(X_2 is Blockchain's Smart Contract Technology)

IV. SUMMARY

The study explored the influence of blockchain smart contracts on the performance of small-scale agricultural farms in Kenya, offering valuable insights into stakeholders' experiences and perceptions. The findings indicated that the implementation of smart contract technology significantly streamlined contract execution within agricultural farms, a result that aligns with prior research showing that blockchain can enhance contractual processes and reduce inefficiencies in agricultural operations (Kamilaris et al., 2019; Mwewa et al., 2025).

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A strong consensus emerged regarding the effectiveness of smart contracts in simplifying contractual processes, with participants widely acknowledging this improvement. This supports previous studies that highlight the role of blockchain in improving trust, reliability, and traceability within agricultural supply chains (Bore et al., 2020). Smart contracts were also perceived to enhance transaction efficiency, with a substantial number of respondents noting improvements in transactional operations since their adoption, reflecting similar findings in the literature regarding efficiency gains through blockchain integration (Pothula, 2023).

The impact of smart contracts on reducing transaction costs, however, showed more variation. While a portion of respondents agreed that transaction costs had decreased, a significant group remained neutral, and some disagreed, indicating a moderate impact in this area,echoing ongoing debates about cost-related outcomes in blockchain-based implementations (Mwewa et al., 2025).

In terms of reducing fraud and errors, respondents generally agreed that blockchain technology contributed to decreasing fraudulent activities and errors within supply chain processes. This positive trend was supported by a broad consensus on the role of smart contracts in enhancing trust and reliability in contractual processes (Kamilaris et al., 2019), although perceptions varied somewhat among participants. Smart contracts were also credited with facilitating faster dispute resolution, with many respondents agreeing that the technology contributed to quicker resolutions of conflicts in agricultural farms, consistent with the benefits outlined by Bore et al. (2020).

The overall experience with smart contract technology was generally positive, with most respondents reporting favorable experiences, although a few expressed dissatisfaction. Despite these benefits, challenges in implementing smart contracts were reported, with some participants indicating mixed experiences regarding the ease of adoption and execution,an issue highlighted in the literature as a barrier to widespread adoption in low-resource farming contexts (Pothula, 2023; Mwewa et al., 2025).

The findings revealed that smart contract technology has been instrumental in streamlining contract execution, improving transaction efficiency, and enhancing trust in the agricultural sector's contractual processes. However, challenges in implementation and the moderate impact on reducing transaction costs suggest areas for improvement. These results underscore the transformative potential of smart contracts for small-scale agriculture, emphasizing the need for further research and strategies to address implementation obstacles and maximize the benefits of smart contract technology.

V. CONCLUSION

The study revealed that the implementation of blockchain smart contracts has significantly enhanced the performance of small-scale agricultural farms in Kenya by streamlining contract execution and improving transaction efficiency. This is consistent with Mwewa et al. (2025), who emphasize blockchain's role in automating agricultural supply chain operations and improving traceability and performance outcomes. The technology was also widely recognized for simplifying contractual processes, enhancing trust, and reducing fraud and errors in transactions, which aligns with Ehsan et al. (2022) findings on smart contracts promoting data integrity and transparency in agricultural systems. Furthermore, the faster dispute resolution enabled by smart contracts contributed to more efficient farm operations and strengthened relationships among stakeholders, reinforcing Kamilaris et al. (2019) determination on blockchain's ability to improve trust and accountability in food supply chains. While the overall experience with smart contracts was positive, the study also highlighted several challenges, especially regarding the moderate impact on reducing transaction costs and the obstacles associated with implementation. These challenges echo those identified by Mwewa et al. (2025), who point to high costs, technical limitations, and lack of infrastructure as persistent barriers to blockchain adoption in small-scale agricultural contexts across Sub-Saharan Africa. These findings suggest that while blockchain-based smart contracts have significant transformative potential in agriculture, further research and targeted strategies are needed to address implementation challenges. By overcoming these barriers, smart contracts could play a central role in increasing the efficiency, transparency, and reliability of agricultural operations, ultimately driving growth and sustainability in the sector.

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