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Enerchainability in Agriculture Supply Chain: Examining the adoption of Blockchain and its Energy Efficiency from Farmers' Perspective

Brintha Rajendran, Manivannan Babu*, Veeramani Anandhabalaji

Bharathidasan School of Management, Bharathidasan University, Tamil Nadu, India. *Email: drbabu@bdu.ac.in

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ABSTRACT

This study investigates factors influencing farmers' acceptance of blockchain technology within the concept of "enerchainability," which integrates energy efficiency and blockchain to enhance sustainability in the agriculture supply chain (ASC). It examines how farmers' awareness, social networks, access to technology, and participation in agricultural training shape their behavioral intention to adopt blockchain. Data were collected through a structured survey focusing on demographic factors, social networks, and supply chain challenges. Results show that social networks, technological resources, and education significantly affect blockchain adoption. Younger, educated farmers are more receptive to the technology, while issues like reduced bargaining power and high production costs act as barriers. The study's findings, though focused on one region, have global relevance for similar agricultural and technological contexts, offering insights into how blockchain can drive sustainability and energy efficiency. The research provides recommendations for policymakers and stakeholders, emphasizing the importance of farmer education and external support for blockchain adoption in ASC.

Keywords: Sustainable Agriculture, Enerchainability, Supply Chain Sustainability, Blockchain, Technology, Agricultural Training Programs

JEL Classifications: Q13, Q55, L86

1. INTRODUCTION

Blockchain technology has become essential in promoting sustainability and energy efficiency within the agricultural supply chain (ASC) by improving traceability, transparency, and operational efficiency (Samanta et al., 2023). Its decentralized system allows for tamper-proof data sharing, building trust among stakeholders, from farmers to consumers, and enhancing accountability (Kandeeban and Nivetha, 2019; Dong, 2023). Although this study is based on Tamil Nadu farmers, the challenges of limited transparency, inefficiencies, and exploitation by intermediaries are widespread in developing regions such as Southeast Asia, Africa, and Latin America, making the findings broadly applicable. Blockchain, as a subset of Information and Communication Technology, addresses these challenges by enabling real-time data access, improving coordination, and ensuring secure transactions (Abdul Mumin et al., 2024). Farmers play a key role in sustainability within the ASC, and their adoption of blockchain can drive energy efficiency and accountability (Mukherjee et al., 2022). However, smallholder farmers face common challenges such as limited bargaining power, market unpredictability, and restricted access to credit, which blockchain could help address (Seixas et al., 2019).

To ensure global food security, environmental protection, and economic resilience, the sustainable ASC (SASC) must focus on both energy efficiency and sustainability (Patel et al., 2020; Babu et al., 2022). Blockchain's ability to enhance resource management is evident, but adoption is hindered by obstacles like integrating legacy systems, data governance issues, and the need for operator training (Tetteh-Caesar et al., 2024). "Enerchainability," the combination of energy efficiency, blockchain, and sustainability, provides a framework to overcome these barriers, especially in developing countries (Anandhabalaji et al., 2024). Farmers' adoption of blockchain for SASC relies on factors such as awareness, access to technology, and participation in formal training (Chen and Shang, 2022; Singh et al., 2022; Afghah et al., 2023; Rizzo et al., 2024; Vern et al., 2024). Social influence (SI) from peers, community leaders, and agricultural extension agents is crucial in shaping farmers' attitudes toward new technologies, a trend seen in Tamil Nadu, Africa, and Southeast Asia (Marikyan et al., 2022; Condie et al., 2024; Ding et al., 2023; Moreira-Dantas et al., 2023; Kraft and Kellner, 2022). Additionally, demographic factors like age, education, and farming experience affect farmers' openness to adopting blockchain, with younger, more educated farmers generally more receptive (Chen and Shang, 2022). Although blockchain's potential is widely recognized, there is still a gap in understanding the factors that affect its adoption, particularly in regions facing infrastructure, digital literacy, and socio-economic challenges (Mishra et al., 2024). This study addresses that gap by exploring the factors influencing farmers' behavioral intention (BI) to adopt blockchain technology within the enerchainability framework, using Tamil Nadu as a case study with global implications.

This study directly supports the goals of the United Nations Sustainable Development Agenda, particularly United Nation's Sustainable Development Goals 2 (UN SDG) (Zero Hunger), by improving food security through more efficient and transparent ASCs, and UN SDG 12 (Responsible Consumption and Production), by promoting sustainable agricultural practices through blockchain's traceability features (Vern et al., 2024; Ordoñez et al., 2024). Moreover, the integration of energy efficiency into supply chain management through the concept of enerchainability aligns with UN SDG 7 (Affordable and Clean Energy), as it fosters sustainable energy use in agriculture (Bosona and Gebresenbet, 2023; Mishra et al., 2024).

This research seeks to answer the following key research questions (RQs):

- RQ1: What factors affect farmers' awareness and adoption of enerchainability in SASC, and how do technology access and formal training influence this?
- RQ2: How do social networks and communication patterns affect blockchain adoption for SASC among farmers?
- RQ3: How do demographic factors (age, education, farming experience, farm size) and supply chain challenges influence farmers' BI toward enerchainability?
- RQ4: What are the principal factors affecting farmers' BI to embrace enerchainability, and how do demographic variables, blockchain-related knowledge, SI, and external conditions impact this intention?

The study utilizes the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2016) to examine how performance expectancy (PE), effort expectancy (EE), SI, and facilitating conditions (FC) shape farmers' BI to adopt blockchain in SASC. PE reflects beliefs on how blockchain can enhance sustainability and transparency in ASC (Nayal et al., 2023), while EE captures perceptions of ease of use (He et al., 2023; Duong et al., 2023). Expected Usage Behavior (EUB) is also incorporated to understand long-term adoption patterns, providing insights into farmers' willingness to adopt blockchain for SASC. By investigating these factors, this study adds empirical evidence to the literature on SASC, like ASC drivers of pollution (Zhao et al., 2024), demonstrating the importance of technological access, training, and social networks in shaping farmers' blockchain adoption. It also extends the UTAUT model by exploring the relationships between demographic factors, supply chain challenges, and FC, emphasizing social networks' role in disseminating blockchain knowledge (Mohseni et al., 2022; Tuni and Rentizelas, 2022).

The remaining part of this paper is outlined as follows. The conceptual orientation is described in Section 2. Section 3 describes the methodology. Section 4 presents results of the analysis, while Section 5 discusses the key findings and implications of the study. Finally, Section 6 presents the conclusion and future research.

2. CONCEPTUAL ORIENTATION

2.1. Blockchain Technology and Enerchainability in ASC

Blockchain technology holds vast potential to tackle sustainability challenges within ASC by enhancing traceability, transparency, and energy efficiency (Brintha et al., 2024). These elements are essential for achieving "enerchainability"—a fusion of energy efficiency and sustainability through blockchain (Difrancesco et al., 2023). In the ASC, which involves production, processing, and distribution, blockchain can improve efficiency and fairness by providing tamper-proof transaction records, thus reducing economic inequalities and enhancing product delivery (Esteso et al., 2023; Sahu et al., 2023). Despite these benefits, ASC faces barriers, including poor information dissemination and a lack of sustainable practices like lean and agile approaches (Sahu et al., 2023; Anandhabalaji et al., 2022). Blockchain offers a decentralized and immutable solution that improves ASC transparency and resilience, yet adoption remains limited among farmers due to technology access challenges, lack of formal education, and insufficient exposure to its energy efficiency applications (Tyagi, 2023; Hossain et al., 2022). Most farmers rely on traditional sources of information, including peer networks, community leaders, and agricultural extension services, which rarely cover emerging technologies like blockchain (Hossain et al., 2022). Therefore, increasing farmers' exposure to blockchain's potential for enerchainability is crucial (Hashemi-Tabatabaei et al., 2024).

There remains a significant gap in research on how blockchain can enhance energy efficiency while supporting sustainable practices in the ASC. Existing research largely focuses on blockchain's ability to improve transparency and traceability but lacks empirical evidence on how blockchain drives energy-efficient practices, particularly in developing regions (Hashemi-Tabatabaei et al., 2024). Additionally, the farmers' perspective is often neglected, though their involvement is key to ensuring a sustainable supply chain (Hossain et al., 2022).

2.2. Social Networks and Information Sources as Catalysts

Social networks and informal communication channels are critical in influencing farmers' adoption of blockchain technology and the concept of enerchainability (Saurabh and Dey, 2021). Farmers depend heavily on peer networks, community leaders, and agricultural officials for information on new technologies (Lien et al., 2023). Studies indicate that when blockchain knowledge is shared through trusted social networks, it can positively influence farmers' decisions to adopt the technology (Asha et al., 2024). These networks also help increase the perceived value of blockchain in improving transparency, resource efficiency, and accountability within the supply chain (Abdulai, 2023). As found by Tay et al. (2024), community supported agriculture not only brings about economic benefits for farmers but also fosters sustainable food production and distribution, enhancing social equity within local communities.

In areas where formal technology education is limited, social networks play a pivotal role in sharing blockchain knowledge. Farmers closely connected to key influencers like leading farmers or extension officers are more likely to adopt innovative practices (Abdulai, 2023; Srinivasan et al., 2022). Younger and more educated farmers are more receptive to blockchain, while older farmers with lower digital literacy may find it complex (Yadav et al., 2023). This generational divide highlights the need for targeted interventions catering to diverse farmer demographics to ensure blockchain supports sustainable, energy-efficient supply chains across varied profiles (Tasic and Cano, 2024). Research often overlooks informal ways farmers acquire and act on new technology information. Addressing this gap will clarify how SIs drive blockchain adoption and enerchainability in ASC (Yadav et al., 2023).

2.3. Demographic and Structural Drivers in Shaping Enerchainability Adoption

Structural factors like access to financial resources, infrastructure, and technical support are crucial for farmers' adoption of blockchain technology. Farmers with access to smartphones, reliable internet, and digital tools are more likely to apply blockchain in the ASC (Sharma et al., 2025). Financial incentives, such as government subsidies or support from cooperatives, also encourage adoption by offsetting high upfront technology costs (Sharma et al., 2023; Elangovan et al., 2024; Anandhabalaji et al., 2023). BI is a key factor determining whether farmers will adopt blockchain technology in the ASC. Research shows that farmers with strong BI are more likely to adopt blockchain if they believe it will enhance supply chain transparency and profitability (Adaryani et al., 2024). Similarly, EUB indicates how frequently and extensively farmers foresee using blockchain once adopted. Farmers anticipating regular use of blockchain are more inclined to integrate it into daily operations, particularly when they understand its long-term benefits, such as reduced operational complexity and improved transparency (Hung, 2024). Agricultural training programs also play a significant role in boosting farmers' readiness to adopt blockchain, as training enhances digital literacy and provides insights into blockchain's ASC applications (Bosona and Gebresenbet, 2023).

Although these factors are critical for blockchain adoption, research on how structural and demographic elements influence farmers' decisions remains limited. Understanding how financial incentives, infrastructure, and training can overcome barriers in rural, developing regions is scarce (Sharma et al., 2023; Hamidoğlu et al., 2024). Furthermore, supply chain inefficiencies, like low bargaining power, high production costs, and market volatility, often prevent farmers from adopting blockchain, even when it offers long-term benefits such as enhanced transparency and trust (Sharma et al., 2023). This study aims to fill these gaps by exploring how blockchain can enhance sustainability and energy efficiency in the ASC, considering farmers' demographic, social, and structural constraints. The study provides insights for policymakers and stakeholders to promote technology-driven sustainability in the supply chain (Casati et al., 2024; Mohamed et al., 2023).

3. MATERIALS AND METHODS

3.1. Participants and Procedures

This study was conducted between March and November 2023 across Tamil Nadu (Figure 1), India, a region facing socio-economic and agricultural challenges similar to those in parts of Africa, Southeast Asia, and Latin America (Campbell et al., 2020). The map delineates study areas, not necessarily representing national boundaries. Tamil Nadu was chosen due to its exemplification of global agricultural issues such as low digital literacy, infrastructure constraints, and economic hardships common in rural agricultural communities worldwide. Purposive sampling was used to recruit farmers from 23 villages in Tamil Nadu, ensuring a diverse and representative sample of agricultural experiences (Campbell et al., 2020). The study's insights aim to contribute to global knowledge on blockchain's potential to address the UN's SDGs, especially regarding sustainability and energy efficiency in ASC. These findings are applicable to other developing regions where smallholder farmers encounter similar challenges in adopting technologies like blockchain.

During data collection, the authors explained the basics of blockchain technology, ensuring that only those who fully understood its purpose participated. Farmers of all ages were included to capture diverse perspectives on blockchain adoption. Ethical practices, including informed consent, were followed. Participants were informed about the study's purpose, data management, and confidentiality. They were made aware that their involvement was voluntary, with no risks or financial incentives. Verbal consent was prioritized, ensuring participants clearly understood the research before proceeding. Emphasis was placed on the importance of their contribution to sustainability in ASC. Face-to-face structured surveys were conducted, with the questionnaire initially developed in English and back-translated into Tamil for accuracy (Zavadska et al., 2017). Technical terms related to blockchain were explained in Tamil to enhance understanding. Researchers built trust by engaging with local leaders and respecting local customs, essential for obtaining accurate responses and ensuring full participation in rural settings where trust is critical for effective data collection.

3.2. Measures

The structured questionnaire employed in this inquiry was developed based on a thorough review of related studies and adapted from established literature in the ASC context (Deepak and Senthil, 2018; Kansana et al., 2011; Seranmadevi et al., 2022; Venkatesh et al., 2016). The following variables were quantified using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree):

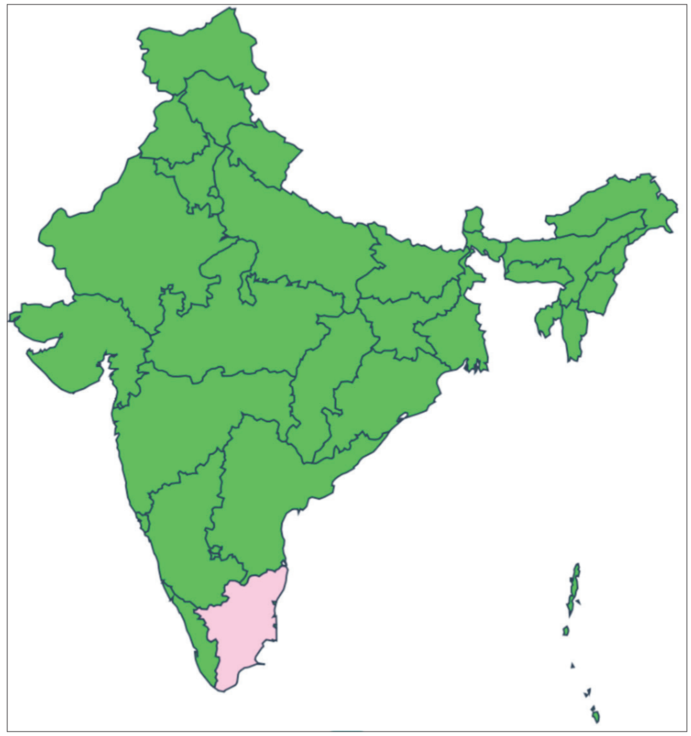
- PE: Perceived utility of blockchain technology in enhancing transparency, traceability, and energy efficiency in ASC (Duong et al., 2023)
- EE: Perception of the simplicity associated with adopting and using blockchain technology in daily farming practices, especially contributing to enerchainability (Duong et al., 2023)
- SI: Influence of contemporaries, agricultural extension officers, and community opinion leaders in facilitating blockchain adoption for a sustainable and energy-efficient supply chain (Condie et al., 2024)
- FC: Accessibility of infrastructure, financial assets, and educational resources to bolster blockchain adoption within the context of enerchainability (Ngongo et al., 2019)
- BI: Farmers' intention and readiness to embrace blockchain technology to enhance both sustainability and energy efficiency in ASC (Adaryani et al., 2024)
- EUB: The projected frequency and extent with which farmers anticipate utilizing blockchain technology post-adoption, focused on improving both transparency and energy efficiency (Hung, 2024)
- Demographic factors: Age, educational attainment, farm size, years of agricultural experience, and household size, which may influence perceptions of blockchain technology for enerchainability
- Supply chain challenges: Issues like diminished bargaining power, limited access to credit, high production costs, and market volatility impacting adoption decisions within the context of a sustainable and energy-efficient supply chain (Akter et al., 2024)
- PT: Engagement in training or educational initiatives related to blockchain technology and enerchainability in ASC (Ordoñez et al., 2024).

The questionnaire included socio-demographic characteristics, blockchain perception variables based on the UTAUT model, and classified farmers into low, medium, and high awareness categories using a categorical grouping variable labeled "blockchain perception." The classification was derived from respondents' awareness, voluntariness, and understanding of blockchain technology using weighted scores. Cronbach's alpha was computed as 0.91, signifying strong internal reliability.

3.3. Pilot Testing and Survey Instrument

A pilot test was conducted with 30 farmers (excluded from the final analysis) to evaluate the clarity, thoroughness, and duration needed to finalize the questionnaire. Insights gained from the pilot test were used to refine the questionnaire, ensuring accuracy and ease of understanding, thus improving the survey's reliability and validity. Given the emphasis on enerchainability, additional attention was placed on refining questions related to energy efficiency and sustainability alongside blockchain, ensuring these key areas were clearly communicated to farmers.

Figure 1: Geographical area under study



Source: Authors' own work

3.4. Data Collection and Sample Characteristics

A total of 467 farmers participated in the final survey. The sample was predominantly male (mean gender score = 1.27), with the average respondent falling in the 31-45-year age range (mean = 3.45, SD = 0.87). Most farmers had completed secondary education (mean score = 3.76), and the average farm size was between 2.51 and 5.00 acres (mean = 1.55, SD = 0.716). On average, the farmers had 11-20 years of agricultural experience, with pulses as their primary crop and an annual income between Rs. 31,000 and Rs. 40,000. This demographic mirrors many developing regions, making the study highly relevant beyond the Tamil Nadu region. Technological engagement was limited, with farmers reporting infrequent use of digital tools and occasional contact with agricultural officials or leading farmers. On average, each household owned two smartphones or basic mobile devices. The data also captured farmers' awareness of blockchain and enerchainability, focusing on energy efficiency, transparency, and sustainability in the ASC. The family farm decision-maker displayed moderate proficiency in smartphone usage.

3.5. Data Analysis

The data were analyzed using various statistical techniques to meet the research objectives:

1. Descriptive Statistics: Statistical Package for Social Sciences (SPSS) 23.0 was used for descriptive analysis, summarizing

demographic characteristics through means, standard deviations, and frequency distributions.

2. Multiple discriminant analysis (MDA): SPSS 23.0 was used to assess the impact of various information sources on farmers' awareness of blockchain and enerchainability (Deepak and Senthil, 2018; Huberty, 1975). Farmers were categorized into low, medium, and high awareness groups based on weighted scores derived from their responses. Stepwise selection methods identified significant factors, and canonical correlation and cross-validation authenticated the model's accuracy (Dufrenois et al., 2022).
3. Network Analysis: Gephi was applied to map the dissemination of blockchain- and enerchainability-related information among farmers. Nodes represented farmers, and their information-sharing relationships were depicted as edges. This analysis identified key influencers in the farming community (Wellman, 1983).
4. Multivariate analysis of variance (MANOVA): SPSS 23.0 was used to assess the effects of demographic variables, agricultural training participation, and supply chain challenges on variables such as PE, EE, SI, BI, and EUB in the context of enerchainability for ASC. Pillai's Trace and Wilks' Lambda were used to evaluate the significance of the independent variables (IV) on the dependent variables (DV) (Smith et al., 1962; Alrawashdeh and Radwan, 2017).
5. Hierarchical LINEAR REGRESSION ANALYSIS: JASP software was employed to explore the incremental impact of demographic variables, blockchain awareness, SI, and FC on BI and EUB within the context of enerchainability. The regression models included:
   a) Model M0: Incorporated demographic factors like age, education, farm size, and smartphone proficiency
   b) Model M1: Added variables related to blockchain awareness, comprehension, and PT
   c) Model M2: Included SI and FC, significantly enhancing the explained variance in BI and EUB (Miki et al., 2021).

Key statistical assumptions were verified for all analyses. Normality was assessed using the Kolmogorov-Smirnov test (Drezner et al., 2010), and no multicollinearity issues were identified, with VIF values within acceptable limits. This section provides the groundwork for presenting the results of the study, adhering to ethical and academic standards throughout the data acquisition, analysis, and interpretation processes. The focus on enerchainability principles underscores the integration of blockchain technology with sustainability and energy efficiency objectives.

4. RESULTS

4.1. Sample Characteristics

The demographic characteristics of the 467 farmers surveyed from Tamil Nadu, India, present a detailed profile of the respondents involved in this study. The majority of respondents were male, as indicated by a gender mean of 1.27. The average age of the farmers falls within the 31-45-year range (mean = 3.45, SD = 0.87), signifying a relatively young and mid-career farming population. Educational attainment on average was at the secondary school level (mean = 3.76), indicating moderate formal education, which plays a significant role in influencing the ability to comprehend and adopt innovative technologies like blockchain. The mean farm size of 1.55 suggests that most respondents operated small farms (2.51-5.00 acres), although some variability was observed (SD = 0.716), with a smaller group managing larger or smaller plots of land. Farming experience averaged between 11 and 20 years, implying substantial practical expertise, while the majority of farmers reported cultivating pulses, which is a common crop in the region (mean = 4.39). In terms of income, most respondents earned between Rs. 31,000 and Rs. 40,000 annually from their crops, highlighting modest economic yields that further emphasize the potential financial constraints farmers face in adopting new technologies.

Digital engagement was moderate, with farmers possessing an average of two smartphones per household, but participation in agriculture-related technology initiatives was limited. Interaction with neighboring farmers and agricultural extension services was also low, reflecting the limited access to formal knowledge networks. This digital and social isolation poses a challenge to the adoption of blockchain and related technologies, but it also highlights opportunities to foster increased engagement through targeted programs. Understanding these demographic and operational profiles helps illustrate the barriers and potential opportunities for promoting enerchainability in the ASC.

4.2. MDA

The MDA utilized in this study provides valuable insights into the factors influencing farmers' awareness and adoption of enerchainability within ASC. MDA classifies farmers into distinct groups based on several IVs, allowing patterns in blockchain adoption to emerge within agricultural communities (Dufrenois et al., 2022).

The results, outlined in Table 1, reveal that Wilks' Lambda for Function 1 is 0.492, with a Chi-square value of 325.737 (P = 0.000), indicating that Function 1 effectively distinguishes between farmers' varying levels of awareness regarding blockchain technology. This highlights the role of primary information sources—such as training programs, farm size, and technology access—in determining farmers' blockchain awareness levels (Sarkodie et al., 2023). In contrast, Function 2 has a Wilks' Lambda of 0.948, reflecting a smaller distinction, meaning that while information source variations exist, they don't drastically affect awareness levels (Alrawashdeh and Radwan, 2017; Laskar and Laskar, 2021).

In Table 2, the standardized canonical discriminant function coefficients further detail the influence of these information sources. Function 1 demonstrates that the use of agricultural

Table 1: Wilks' lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Significant
1 through 2	0.492	325.737	20	0.000
2	0.948	24.487	9	0.004

Source: Authors' own work

Table 2: Standardized canonical discriminant function coefficients

Primary information sources in agriculture	Function	
	1	2
Work of family	0.067	−0.081
Years of experience in farming	−0.405	−0.075
Farm size	0.327	−0.384
Application of agricultural information technology	0.671	−0.61
Participation in agricultural training	0.121	0.46
Relationship with neighbour farmers	0.02	0.106
Habit of contact with leading farmers of the village	0.185	0.076
Habit of contact with agricultural extension workers/officials	−0.083	−0.15
Number of smartphones/mobile phones in the household	0.165	0.192
Family farm decision-maker's Knowledge of the use of smartphones/mobile phones	0.332	0.694

Source: Authors' own work

Table 3: Correlation

Information sources in agriculture	Function	
	1	2
Application of agricultural information technology	0.800*	−0.306
PT	0.455*	0.256
Habit of contact with agricultural extension workers/officials	0.434*	0.008
Farm size	0.431*	−0.402
Habit of contact with leading farmers of the village	0.269*	−0.085
Family farm decision-maker's Knowledge of the use of smartphones/mobile phones	0.612	0.620*
Number of smartphones/mobile phones in the household	0.34	0.365*
Work of family	0.033	−0.330*
Years of experience in farming	0.022	−0.190*
Relationship with neighbour farmers	0.025	0.063*

Source: Authors' own work

information technology (0.671) and farm size (0.327) have the most substantial positive effects on blockchain awareness. This suggests that larger farms and those utilizing agricultural technologies are better positioned to comprehend and adopt enerchainability. Blockchain's integration not only improves transparency and traceability but also enhances sustainability by reducing inefficiencies in agricultural processes (Prayoga and Raya, 2019). The knowledge of smartphones by farm decision-makers (0.332) also significantly impacts awareness, underscoring how access to modern technology aids farmers in grasping blockchain's potential for enhancing supply chain sustainability.

The findings also show that farmers with fewer years of farming experience (−0.405) have higher blockchain awareness, likely because younger farmers are more inclined to adopt new technologies (Prayoga and Raya, 2019). Meanwhile, Function 2 in Table 3 highlights PT (0.455) as a key factor, emphasizing the importance of formal educational programs in promoting blockchain adoption for enerchainability. Conversely, larger farm sizes negatively correlate with awareness in this function, which could be due to interaction effects between the variables (Chen and Shang, 2022; Seranmadevi et al., 2022).

4.3. Network Analysis

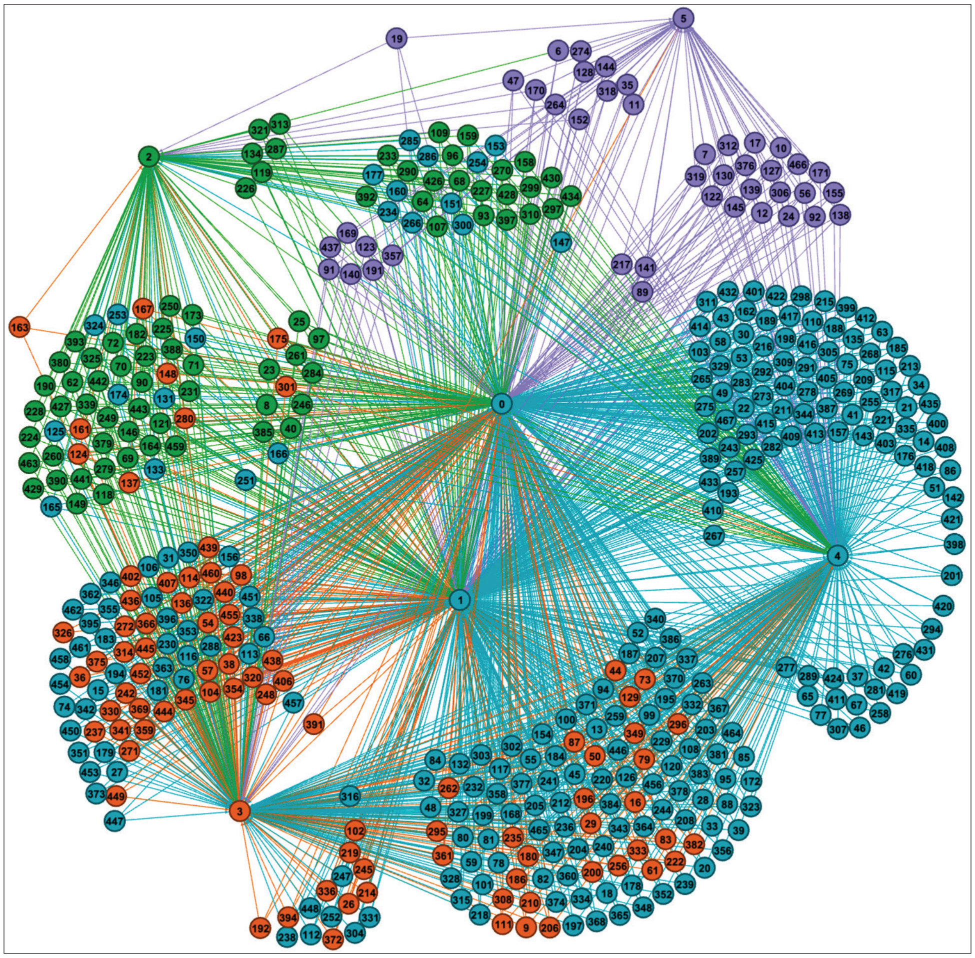
The network analysis in Figure 2 visualizes how blockchain technology information spreads among 467 farmers, depicted as nodes. The analysis is based on assumptions: (A) the frequency of information exchange is not proportional to edge weight due to limited data, (B) local informal exchanges of blockchain-related information are excluded, and (C) the network represents only the sampled farmers, not the entire community. The network reveals a complex structure, with distinct clusters representing different patterns of information sharing. These clusters were identified using a community detection algorithm in Gephi, categorizing farmers based on their communication patterns and challenges related to blockchain adoption in enerchainability. The visualization highlights four distinct clusters, each in a different color, showing specific communication behaviors concerning blockchain knowledge dissemination. The analysis emphasizes the role of community leaders and agricultural extension officers as central nodes. Their connectivity with peripheral farmers, who have less access to blockchain information, underscores their importance in knowledge dissemination. These clusters suggest that focusing interventions on central nodes can greatly expand blockchain awareness in the ASC, promoting broader enerchainability adoption.

1. Cluster 1 (Green): Farmers here rely heavily on key village figures for blockchain information, maintaining neutral relationships with neighbors, which points to a hierarchical flow of knowledge. This dependence on informal networks suggests centralized blockchain expertise, potentially causing uneven adoption within the cluster.
2. Cluster 2 (Purple): This group maintains regular contact with both leading farmers and agricultural extension officers, bridging formal and informal knowledge systems. These farmers are likely to adopt blockchain more quickly due to access to formal information, positioning them as early adopters of blockchain for supply chain management.
3. Cluster 3 (Orange): Farmers in this cluster have minimal contact with extension officers, relying more on informal knowledge networks. This isolation may delay blockchain adoption, as information dissemination is slower and less formalized.
4. Cluster 4 (Blue): Farmers here have strong ties with their neighbors and frequent interactions with leading farmers, suggesting a community-driven approach to blockchain knowledge dissemination. This cluster is likely to see more uniform blockchain adoption due to strong interconnectivity and collective action toward improving supply chain sustainability.

4.4. MANOVA

The MANOVA analysis offers critical insights into the relationships between farmers' demographics, PT, supply chain challenges, and their perceptions and BI towards adopting enerchainability. Table 4 details the impact of IVs like age, education, farm size, and family size on multiple DVs, including awareness, comprehension, PE, EE, SI, BI, and EUB. The multivariate tests—Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root—indicate significant effects of these IVs on the combined DVs, showing how demographic factors and supply chain challenges shape farmers' motivations and intentions to adopt blockchain for enerchainability.

Figure 2: Farmers' network of information flow



Source: Authors' own work created using Gephi

Age is a key factor influencing all DVs, particularly awareness and understanding of blockchain technology. The strong significance in the multivariate tests suggests age plays a central role in shaping perspectives on blockchain adoption in sustainable agriculture. Educational qualification also significantly impacts understanding blockchain and BI, with a Pillai's Trace value of 0.227 ($F = 2.941$, $P < 0.001$), showing that higher education correlates with better comprehension and a stronger willingness to adopt blockchain, essential for integrating enerchainability practices. Farm size, with a Pillai's Trace value of 0.158 ($F = 3.420$, $P < 0.001$), also influences blockchain awareness, as larger farms are more likely to recognize blockchain's potential for improving sustainability and efficiency in the supply chain. PT significantly boosts blockchain adoption, shown by Pillai's Trace = 0.232, $F = 3.796$, $P < 0.001$, underscoring the importance of educational programs in raising adoption rates. Supply chain challenges like limited credit, low bargaining power, and high production costs heavily influence perceptions and BI, acting as both barriers and motivators for considering blockchain as a solution to improve transparency and efficiency in the ASC.

Age remains a significant factor across all DVs, especially in BI, with younger farmers more willing to adopt blockchain for enerchainability. Blockchain awareness scores also highlight age's role, as younger farmers show higher awareness and understanding of blockchain's benefits. Educational qualifications similarly play a crucial role, as more educated farmers are likelier to understand and engage with blockchain. Higher education enhances the willingness to explore and adopt technologies related to enerchainability. PT also strongly impacts EE and BI, showing that trained farmers view blockchain as beneficial for improving farming practices, boosting their confidence in its usability and promoting wider adoption. Supply chain challenges, including low bargaining power and high production costs, shape farmers' BI by emphasizing the transparency and efficiency blockchain can offer. Resistance to new technologies notably affects SI and BI, with peer influence playing a key role in blockchain adoption. In contrast, challenges like labor shortages, transportation issues, and seasonal risks show little direct influence on perceptions of blockchain. Although labor shortages marginally affect BI, these challenges are not seen as areas where blockchain provides substantial solutions. This suggests that while blockchain offers advantages in transparency and decision-making in SASC, operational issues may require other interventions beyond technological adoption.

4.5. Hierarchical Regression

The hierarchical regression analysis explores the determinants of BI in adopting enerchainability in ASC, focusing on demographic variables, knowledge, and supply chain challenges. Additional predictors are integrated across models:

1. Model M0: The preliminary model in Table 5 includes demographics such as age, education, farming experience, farm size, and smartphone knowledge. It explains 43.4% of the variance in BI (R^2 = 0.434). Age and smartphone knowledge have the strongest effects, with age negatively impacting BI and smartphone knowledge increasing it. Older farmers tend to show less inclination towards blockchain adoption, while better smartphone skills enhance BI.
2. Model M1: This model adds variables like blockchain awareness, understanding, PT, and the use of agricultural information technology, increasing R^2 to 0.473. PT and blockchain understanding show significant impacts, highlighting the role of training and knowledge in boosting farmers' intention to adopt blockchain for enerchainability, especially in energy-efficient ASC.
3. Model M2: The final model incorporates SI and FC, raising R^2 to 0.753, showing these factors explain 75.3% of BI variance. FC has the strongest effect (β = 0.548, P < 0.001), indicating that external support, infrastructure, and resources significantly influence blockchain adoption. SI also plays a key

Table 4: Multivariate analysis of variance results

Effect	Pillai's Trace	F	Hypothesis df	Error df	P-value	Key insights
Age	0.287	4.758	28	1724	<0.001	Significant effect on all DVs, especially BI and EE, showing a generational gap in BI.
Educational qualification	0.227	2.941	35	2160	<0.001	Strongly linked to understanding and intention to adopt blockchain; higher education leads to better grasp of blockchain's potential.
Years of farming experience	0.089	1.404	28	1724	0.078	Limited overall effect but significantly impacts blockchain awareness; experienced farmers may be more familiar with blockchain applications.
Farm Size	0.158	3.42	21	1290	<0.001	Larger farms have greater awareness and understanding of blockchain, possibly due to exposure to tech solutions in large-scale operations.
Family Size	0.133	4.355	14	858	<0.001	Modest yet significant influence on blockchain perceptions, especially EUB; larger families may face more complexities that blockchain can address.
Participation in Agricultural Training	0.232	3.796	28	1724	<0.001	Strong effect on multiple outcomes, especially BI, showing the importance of knowledge transfer in blockchain adoption.
No Credit Facility	0.033	2.06	7	428	0.047	Modest but significant effect on BI, highlighting financial barriers to technology adoption.
Low Bargaining Power	0.036	2.264	7	428	0.028	Significant barrier; farmers with low bargaining power may view blockchain as a tool to strengthen negotiation in the supply chain.
High Cost of Production	0.033	2.078	7	428	0.045	Significantly affects BI and EE; cost-conscious farmers are more motivated to adopt cost-saving technologies like blockchain.
Risks Related to Seasonal Variations	0.031	1.957	7	428	0.06	Not highly significant but influences BI; reflects the need for blockchain's predictability in supply chain management.
Transportation Issues	0.024	1.501	7	428	0.165	No significant influence on BI, implying farmers don't see blockchain as a solution for logistical concerns.
Lack of Timely Market Information	0.05	3.252	7	428	0.002	Lack of timely market information significantly affects awareness and SI; blockchain's real-time data potential is crucial for improving market access.
Labor Shortage	0.027	1.67	7	428	0.115	Not a significant predictor, but slightly elevated F-value suggests farmers recognize blockchain's potential to streamline labor processes.
Reluctance to Adopt Technology	0.068	4.455	7	428	<0.001	Significant impact on awareness, PE, and SI; technophobia remains a key barrier to blockchain adoption

Source: Authors' own work

Table 5: Model summary

Model	R	R^2	Adjusted R^2	RMSE	Durbin-Watson	P-value
M0	0.659	0.434	0.428	0.74	1.52	<0.001
M1	0.688	0.473	0.463	0.717	1.543	<0.001
M2	0.868	0.753	0.747	0.492	2.008	0.96

Source: Authors' own work

role, showing that SIs like community leaders impact farmers' BI. The addition of these factors considerably strengthens the model's explanatory power.

4. Key Predictors of BI: Age remains a significant negative predictor, while smartphone knowledge plays a diminishing role as external factors like FC and SI gain importance. FC, the strongest positive predictor, reflects that access to resources and external support drives farmers' willingness to adopt blockchain, improving sustainability and energy efficiency in agriculture. SI further reinforces the importance of SI in promoting blockchain adoption in enerchainability.

The ANOVA findings (Table 6) demonstrate that all three models are significant determinants of BI, with Model M2 exhibiting the most considerable enhancement in model adequacy ($F = 126.197$, $P < 0.001$). The increase in F-statistics across the models signifies the additive significance of blockchain-related knowledge, training, and FC in explaining BI.

The predicted values for BI oscillate between 0.901 and 5.246, with an average of 3.427, indicating that the model forecasts a moderate to high degree of intention to embrace blockchain technology in ASC. Residuals signify the discrepancies in prediction, computed as the variance between actual and forecasted BI scores. The residuals extend from −2.055 to 2.122, with a mean approximating zero (−0.004). This implies that the model's predictions are relatively precise, as the residuals are symmetrically distributed around zero.

5. DISCUSSION

This research explores the determinants of farmers' awareness and adoption of enerchainability in ASC, using MDA, network analysis, MANOVA, and hierarchical regression. The findings provide insights into how technological access, social networks, demographic factors, and supply chain challenges influence the adoption of blockchain for enerchainability. This study contributes to the growing literature on blockchain's role in enhancing sustainability and transparency within ASC and offers broader insights applicable to other regions facing similar challenges.

5.1. RQ1. Factors Influencing Farmers' Awareness and Adoption of Blockchain for Enerchainability

MDA results reveal that access to agricultural technology and farm size are key factors in raising blockchain awareness among farmers. Those using digital tools like smartphones have significantly higher awareness, highlighting the role of digital literacy in promoting enerchainability. Larger farms, needing efficient supply chain operations, also show greater awareness of blockchain's potential to enhance transparency and sustainability.

Table 6: ANOVA results

Model	Sum of squares (Regression)	df	Mean square	F	P-value
M0	193.254	5	38.651	70.626	<0.001
M1	210.802	9	23.422	45.6	<0.001
M2	335.555	11	30.505	126.197	<0.001

Source: Authors own work

Younger farmers, with fewer years of experience, are more open to blockchain, viewing it as a solution to supply chain inefficiencies, consistent with global trends where younger farmers adopt digital tools more readily (Rogers et al., 2014). The role of smartphone knowledge further emphasizes how modern technology access influences blockchain perceptions in sustainable farming (Mishra et al., 2024). Formal training programs also significantly boost blockchain awareness, underscoring the need for educational interventions that integrate blockchain into existing agricultural training. This indicates that improving both digital literacy and training access is crucial, especially for smaller farm operators, to streamline farming processes and enhance sustainability through better resource management.

5.2. RQ2. Social Networks and Blockchain Adoption

Network analysis shows that social networks significantly influence blockchain dissemination within ASC. Farmers form distinct clusters based on communication patterns, with some clusters relying on a few key figures for information, while others share information more horizontally through community ties (Colussi et al., 2024). Horizontal communication allows for more uniform blockchain adoption, promoting sustainable practices across the network. SI is crucial in blockchain adoption, as influential farmers serve as central nodes for spreading knowledge (Venkatesh et al., 2016). Farmers who regularly interact with extension officers have better access to blockchain, suggesting that enhancing the role of formal knowledge providers can bridge informal and formal networks and speed up adoption (Akella et al., 2023). Isolated clusters with minimal access to formal information require targeted interventions to ensure equitable blockchain adoption (Song et al., 2022). This underscores the need to improve knowledge access across all farming communities to promote sustainability within the supply chain.

5.3. RQ3. Demographic Factors, Training, and Supply Chain Challenges

MANOVA results indicate that age is a key predictor of BI, with older farmers less likely to adopt blockchain. EE influences their resistance to adoption, as older farmers view blockchain as complex (Venkatesh et al., 2016). Education positively affects both understanding and BI, suggesting that educated farmers better grasp blockchain's potential to improve supply chain sustainability (Singh et al., 2022). PT strongly impacts EE and BI, indicating that formal training reduces blockchain's perceived complexity and increases its utility in addressing supply chain inefficiencies (Ordoñez et al., 2024). Supply chain challenges, such as low bargaining power and high production costs, also significantly shape BI, with farmers seeing blockchain as a solution to improve their standing within the supply chain (Song et al., 2022). By increasing traceability and offering real-time data, blockchain can address information asymmetry and foster equity within ASC.

5.4. RQ4. Key Predictors of BI to Adopt Blockchain for Enerchainability

Hierarchical regression identifies FC and SI as the most important determinants of BI to adopt blockchain. FC, including access to infrastructure, financial assets, and support, highlights the importance of creating an environment conducive to blockchain adoption. Farmers who perceive that external resources and support are available are more likely to adopt blockchain, aligning with the PE dimension of the UTAUT model (Venkatesh et al., 2016). SI also plays a strong role, showing that community leaders and peers significantly shape farmers' perceptions of blockchain adoption (Dilleen et al., 2023). While demographic factors like age and smartphone knowledge are notable early predictors, their influence diminishes when SI and FC are considered. This suggests that favorable external conditions reduce the importance of personal factors in adoption. The findings stress the need for strategies that address both technological readiness and social dynamics, highlighting the importance of infrastructure development and engaging key influencers to promote blockchain adoption.

By integrating MDA, network analysis, MANOVA, and hierarchical regression, this study provides a comprehensive understanding of blockchain adoption in enerchainability, addressing research gaps on the social and technological determinants of adoption. The study emphasizes the importance of technology access, social networks, and formal training in advancing blockchain for sustainable and energy-efficient supply chains. These findings offer actionable insights for researchers, policymakers, and practitioners focused on fostering blockchain adoption in agricultural communities.

6. CONCLUSION

This research makes a significant contribution to understanding how blockchain, sustainability, and energy efficiency can transform the ASC through the concept of enerchainability. It fills a critical gap by examining the comprehensive technological, social, and demographic factors influencing farmers' BI to adopt blockchain, extending its relevance beyond Tamil Nadu to other developing regions facing similar agricultural challenges. Access to agricultural information technology, such as smartphones, and farm scale are critical to increasing blockchain awareness. These findings offer scalable solutions to global agricultural inefficiencies, resource mismanagement, and market volatility. The study emphasizes the importance of social networks and FC, such as infrastructure and financial support, in promoting blockchain adoption. Younger, educated farmers are more open to adopting blockchain, revealing a generational shift. SI from community leaders and peers plays a key role in accelerating blockchain adoption in rural communities worldwide. The findings address major agricultural challenges such as low bargaining power, high production costs, and limited access to credit, demonstrating blockchain's potential to enhance transparency, resource management, and market access. These challenges are prevalent in many developing regions, making the insights broadly applicable.

By addressing inefficiencies and fostering transparency, this study contributes to achieving UNSDG 2 (Zero Hunger), which aims to improve food security and sustainable agriculture. Additionally, the promotion of blockchain for traceability in the ASC directly aligns with UNSDG 12 (Responsible Consumption and Production), ensuring that agricultural practices are sustainable and environmentally responsible (Patel et al., 2020; Ordoñez et al., 2024). The study's focus on enerchainability also supports UNSDG 7 (Affordable and Clean Energy), promoting energy efficiency in agricultural practices and supply chains, which is crucial for sustainable development (Singh et al., 2022; Wu et al., 2023).

Future research should explore blockchain's application in specific agricultural sub-sectors like livestock, horticulture, and organic farming, as well as conduct comparative studies across regions with different technological infrastructures and regulations. Collaborative opportunities with emerging technologies such as IoT, AI (Chaudhary and Kumar 2022), and big data should also be investigated to enhance real-time decision-making and supply chain efficiency. Blockchain's potential to reduce socio-economic inequalities by improving market access and transparency is another critical area for exploration. The research also highlights the need for stakeholder collaboration, involving farmers, distributors, retailers, policymakers, and consumers, to harness blockchain's full potential. Policymakers could drive adoption through regulatory incentives, while consumer demand for ethical, transparent food production could further integrate blockchain into global supply chains. Ethical issues, such as data confidentiality, ownership rights, and equitable access, also require attention to ensure blockchain's broader societal impact. In conclusion, this study offers actionable insights for researchers, practitioners, and policymakers on how blockchain can promote sustainability, transparency, and energy efficiency in ASC. Its implications extend far beyond Tamil Nadu, contributing to global efforts to address agricultural challenges through blockchain's transformative potential.

7. DECLARATION OF INTEREST

None.

REFERENCES

Abdul Mumin, M., Adam, I.O., Alhassan, M.D. (2024), The impact of ICT capabilities on supply chain fraud and sustainability-a dynamic capability perspective. Technological Sustainability, 3(2), 123-146.

Abdulai, A. (2023), Information acquisition and the adoption of improved crop varieties. American Journal of Agricultural Economics, 105(4), 1049-1062.

Adaryani, R.L., Palouj, M., Karbasioun, M., Asadi, A., Gholami, H., Kianirad, A., Damirchi, M.J. (2024), Antecedents of blockchain adoption in the poultry supply chain: An extended UTAUT model. Technological Forecasting and Social Change, 202, 123309.

Afghah, M., Sajadi, S.M., Razavi, S.M., Taghizadeh□Yazdi, M. (2023), Hard dimensions evaluation in sustainable supply chain management for environmentally adaptive and mitigated adverse eco□effect environmental policies. Business Strategy and the Environment, 32(7), 5044-5067.

Akella, G.K., Wibowo, S., Grandhi, S., Mubarak, S. (2023), A systematic review of blockchain technology adoption barriers and enablers for smart and sustainable agriculture. Big Data and Cognitive Computing, 7(2), 86.

Akter, M., Kummer, T.F., Yigitbasioglu, O. (2024), Looking beyond the hype: The challenges of blockchain adoption in accounting. International Journal of Accounting Information Systems, 53, 100681.

Alrawashdeh, M.J., Radwan, T. (2017), Wilk's Lambda Based on Robust Method. In: AIP Conference Proceedings. Vol. 1842. AIP Publishing.

Anandhabalaji, V., Babu, M., Anandhi, E. (2022), Cryptocurrency: The Good, the Bad and the Ugly. In: 2022 International Conference on Computer, Power and Communications (ICCPC). Vol. 64. p656-663.

Anandhabalaji, V., Babu, M., Brintha, R. (2024), Energy consumption by cryptocurrency: A bibliometric analysis revealing research trends and insights. Energy Nexus, 13, 100274.

Anandhabalaji, V., Babu, M., Gayathri, J., Sathya, J., Indhumathi, G., Brintha, R., Michael, J.N. (2023), Examining the volatility of conventional cryptocurrencies and sustainable cryptocurrency during Covid-19: Based on energy consumption. International Journal of Energy Economics and Policy, 13(6), 344-352.

Asha, L.N., Aragon, L.G., Dey, A., Yodo, N. (2024), Location optimization strategies for corn production and distribution towards sustainable green supply chain. Logistics, 8(3), 78.

Babu, M., Lourdesraj, A.A., Hariharan, C., Jayapal, G., Indhumathi, G., Sathya, J., Kathiravan, C. (2022), Dynamics of volatility spillover between energy and environmental, social and sustainable indices. International Journal of Energy Economics and Policy, 12(6), 50-55.

Bosona, T., Gebresenbet, G. (2023), The role of blockchain technology in promoting traceability systems in agri-food production and supply chains. Sensors, 23(11), 5342.

Brintha, R., Babu, M., Tripathy, N., Anandhabalaji, V. (2024), A Bibliometric exploration of environmental sustainability in supply chain research. Supply Chain Analytics, 8, 100086.

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., & Walker, K. (2020), Purposive sampling: Complex or simple? Research case examples. Journal of Research in Nursing, 25(8), 652-661.

Casati, M., Soregaroli, C., Frizzi, G.L., Stranieri, S. (2024), Impacts of blockchain technology in agrifood: Exploring the interplay between transactions and firms' strategic resources. Supply Chain Management: An International Journal, 29(7), 51-70.

Chaudhary, B., Kumar, V. (2022), Emerging technological frameworks for the sustainable agriculture and environmental management. Sustainable Horizons, 3, 100026.

Chen, X., Shang, J. (2022), Analysis of farmers' willingness to use blockchain and influencing factors based on the binary logit model. Wireless Communications and Mobile Computing, 2022(1), 7412261.

Colussi, J., Sonka, S., Schnitkey, G. D., Morgan, E.L., Padula, A.D. (2024), A comparative study of the influence of communication on the adoption of digital agriculture in the United States and Brazil. Agriculture, 14(7), 1027.

Condie, C.M., Fulton, E.A., Alexander, K.A., Vince, J., Haward, M., Condie, S.A. (2024), Social influence modelling demonstrates that strategic communication and depoliticization reduces conflict in aquaculture. Marine Policy, 165, 106211.

Deepak, K.S., Senthil, D. (2018), Challenges in organic farming and marketing the organic products in Tamil Nadu. International Journal of Management Studies, 2(1), 136-140.

Difrancesco, R.M., Meena, P., Kumar, G. (2023), How blockchain technology improves sustainable supply chain processes: A practical guide. Operations Management Research, 16(2), 620-641.

Dilleen, G., Claffey, E., Foley, A., Doolin, K. (2023), Investigating knowledge dissemination and social media use in the farming network to build trust in smart farming technology adoption. Journal of Business and Industrial Marketing, 38(8), 1754-1765.

Dong, Z. (2023), Challenges faced by agricultural supply chain finance under Blockchain Application. Highlights in Business, Economics and Management, 11, 144-148.

Drezner, Z., Turel, O., Zerom, D. (2010), A modified Kolmogorov-Smirnov test for normality. Communications in Statistics-Simulation and Computation, 39(4), 693-704.

Duong, C.D., Bui, D.T., Pham, H.T., Vu, A.T. (2023), How effort expectancy and performance expectancy interact to trigger higher education students' uses of ChatGPT for learning. Interactive Technology and Smart Education, 21(3), 356-380.

Elangovan, A., Babu, M., Gayathri, J., Sathya, J., Indhumathi, G. (2024), Determinants of intention to purchase energy-efficient appliances: Extended technology acceptance model. International Journal of Energy Economics and Policy, 14(3), 518-523.

Esteso, A., Alemany, M.M.E., Ortiz, A. (2023), Sustainable agri-food supply chain planning through multi-objective optimisation. Journal of Decision Systems, 33(4), 808-832.

Hamidoğlu, A., Gül, Ö.M., Kadry, S.N. (2024), A game-theoretical approach for the adoption of government-supported blockchain application in the IoT-enabled agricultural supply chain. Internet of Things, 26, 101163.

Hashemi-Tabatabaei, M., Amiri, M., Keshavarz-Ghorabaee, M. (2024), Gresilient supplier evaluation and selection under uncertainty using a novel streamlined full consistency method. Logistics, 8(3), 90.

He, Y., Yu, Y., Guo, X., Li, D. (2023), Government subsidy and firm's cost sharing in sustainable agriculture supply chain. International Journal of Food Science and Technology, 58(10), 5530-5548.

Hossain, M.R., Uddin, M.D., Khatun, S., Nizami, M.R., Karim, M.R., Sheikh, M.E. (2022), Information requirements for farmers and search behavior: A case study in Manda Upazila, Naogaon. British Journal of Arts and Humanities, 4(3), 63-71.

Huberty, C.J. (1975), Discriminant analysis. Review of Educational Research, 45(4), 543-598.

Hung, A.H.C. (2024), The curious case of blockchain in rural China: Unravelling power, profit, and surveillance. Big Data and Society, 11(2), 20539517241259674.

Kandeeban, M., Nivetha, T. (2019), Blockchain: A tool for a secure, safe and transparent way of food and agricultural supply chain. International Journal of Farm Sciences, 9(1), 97-100.

Kansana, V.K., Singh, V.B., Parik, A.K., Swarnkar, V.K. (2011), Adoption of watershed management technology by the farmers of Morena district. Bhartiya Krishi Anusandhan Patrika, 26(3and4), 100-102.

Kraft, S.K., Kellner, F. (2022), Can blockchain be a basis to ensure transparency in an agricultural supply chain? Sustainability, 14(13), 8044.

Laskar, M.A., Laskar, R.H. (2021), HiLAM-aligned kernel discriminant analysis for text-dependent speaker verification. Expert Systems with Applications, 182, 115281.

Lien, H.H., de Mey, Y., Meuwissen, M.P., Bush, S.R. (2023), Information practices for improved sustainability assurance in Vietnamese shrimp aquaculture. Journal of Rural Studies, 100, 103015.

Marikyan, D., Papagiannidis, S., Rana, O.F., Ranjan, R. (2022), Blockchain adoption: A study of cognitive factors underpinning decision making. Computers in Human Behavior, 131, 107207.

Miki, T., Higuchi, D., Takebayashi, T., Samukawa, M. (2021), Factors associating with disability of non-specific low back pain in different subgroups: A hierarchical linear regression analysis. Scientific Reports, 11(1), 18278.

Mishra, N., Bhandari, N., Maraseni, T., Devkota, N., Khanal, G., Bhusal, B., & Danuwar, R.K. (2024), Technology in farming: Unleashing farmers' behavioral intention for the adoption of agriculture 5.0. PLoS One, 19(8), e0308883.

Mohamed, S.K., Haddad, S., Barakat, M., Rosi, B. (2023), Blockchain technology adoption for improved environmental supply chain performance: The mediation effect of supply chain resilience, customer integration, and green customer information sharing. Sustainability, 15(10), 7909.

Mohseni, S., Baghizadeh, K., Pahl, J. (2022), Evaluating barriers and drivers to sustainable food supply chains. Mathematical Problems in Engineering, 2022(1), 4486132.

Moreira-Dantas, I.R., Martínez-Zarzoso, I., Torres-Munguía, J.A. (2023), Sustainable food chains to achieve SDG-12 in Europe: Perspectives from multi-stakeholders initiatives. In: SDGs in the European Region. Cham: Springer International Publishing. p1-26.

Mukherjee, A.A., Singh, R.K., Mishra, R., Bag, S. (2022), Application of blockchain technology for sustainability development in agricultural supply chain: Justification framework. Operations Management Research, 15(1), 46-61.

Nayak, S. K., & Rai, D. P. (2014), Farmers preferences of communication sources in perception of farm technology. Hind Agri-Horticultural Society, 5(1/2), 22-25.

Nayal, K., Raut, R.D., Narkhede, B.E., Priyadarshinee, P., Panchal, G.B., Gedam, V.V. (2023), Antecedents for blockchain technology-enabled sustainable agriculture supply chain. Annals of Operations Research, 327(1), 293-337.

Ngongo, B.P., Ochola, P., Ndegwa, J., Katuse, P. (2019), The technological, organizational and environmental determinants of adoption of mobile health applications (m-health) by hospitals in Kenya. PLoS One, 14(12), e0225167.

Ordoñez, C.C., Gonzales, G.R., Corrales, J.C. (2024), Blockchain and agricultural sustainability in South America: A systematic review. Frontiers in Sustainable Food Systems, 8, 1347116.

Patel, S.K., Sharma, A., Singh, G.S. (2020), Traditional agricultural practices in India: An approach for environmental sustainability and food security. Energy, Ecology and Environment, 5(4), 253-271.

Prayoga, K., Raya, A.B. (2019), Young farmers and digitalization: From price taker to price maker. KnE Social Sciences, 3(20), 181-188.

Rizzo, G., Migliore, G., Schifani, G., Vecchio, R. (2024), Key factors influencing farmers' adoption of sustainable innovations: A systematic literature review and research agenda. Organic Agriculture, 14(1), 57-84.

Rogers, E.M., Singhal, A., Quinlan, M.M. (2014), Diffusion of Innovations. An Integrated Approach to Communication Theory and Research. London: Routledge. p432-448.

Sahu, A.K., Raut, R.D., Gedam, V.V., Cheikhrouhou, N., Sahu, A.K. (2023), Lean-agile-resilience-green practices adoption challenges in sustainable agri□food supply chains. Business Strategy and the Environment, 32(6), 3272-3291.

Samanta, D.P.S., Patnaik, B.C.M., Satpathy, I., Khang, A. (2023), Revolutionizing agriculture through blockchain: A bibliometric analysis of emerging trends and applications. In: Handbook of Research on AI-Equipped IoT Applications in High-Tech Agriculture. United States: IGI Global. p295-312.

Sarkodie, K., Fergusson-Rees, A., Abdulkadir, M., Asiedu, N.Y. (2023), Gas-liquid flow regime identification via a non-intrusive optical sensor combined with polynomial regression and linear discriminant analysis. Annals of Nuclear Energy, 180, 109424.

Saurabh, S., Dey, K. (2021), Blockchain technology adoption, architecture, and sustainable agri-food supply chains. Journal of Cleaner Production, 284, 124731.

Seixas, M., Contini, E., Soares, C.O. (2019), Índia: o despertar de um gigante do agronegócio. Revista de Política Agrícola, 27(3), 95-113.

Seranmadevi, R., Kumar, A.S., Hariharan, R. (2022), Enabling agricultural sector through blockchain technology-farmers perspective. Universal Journal of Agricultural Research, 10(3), 213-227.

Sharma, A., Sharma, A., Singh, R.K., Bhatia, T. (2023), Blockchain adoption in agri-food supply chain management: an empirical study of the main drivers using extended UTAUT. Business Process Management Journal, 29(3), 737-756.

Sharma, R., Samad, T.A., Jabbour, C.J.C., de Queiroz, M.J. (2025), Leveraging blockchain technology for circularity in agricultural supply chains: Evidence from a fast-growing economy. Journal of Enterprise Information Management, 38(1), 32-67.

Singh, C., Wojewska, A.N., Persson, U.M., Bager, S.L. (2022), Coffee producers' perspectives of blockchain technology in the context of sustainable global value chains. Frontiers in Blockchain, 5, 955463.

Smith, H., Gnanadesikan, R., Hughes, J.B. (1962), Multivariate analysis of variance (MANOVA). Biometrics, 18(1), 22.

Song, L., Luo, Y., Chang, Z., Jin, C., Nicolas, M. (2022), Blockchain adoption in agricultural supply chain for better sustainability: A game theory perspective. Sustainability, 14(3), 1470.

Srinivasan, S., Babu, M., Shimny, P.S., Hariharan, C., Gayathri, J., Indhumathi, G. (2022), Dataset on farmers' perception of commodity futures market. Data in Brief, 43, 108429.

Tasic, I., Cano, M.D. (2024), An orchestrated IoT□based blockchain system to foster innovation in agritech. IET Collaborative Intelligent Manufacturing, 6(2), e12109.

Tay, M.J., Ng, T.H., Lim, Y.S. (2024), Fostering sustainable agriculture: An exploration of localised food systems through community supported agriculture. Environmental and Sustainability Indicators, 22, 100385.

Tetteh-Caesar, M.G., Gupta, S., Salonitis, K., Jagtap, S. (2024), Implementing Lean 4.0: A review of case studies in pharmaceutical industry transformation. Technological Sustainability, 3, 354-372.

Tuni, A., Rentizelas, A. (2022), Improving environmental sustainability in agri-food supply chains: Evidence from an eco-intensity-based method application. Cleaner Logistics and Supply Chain, 5, 100081.

Tyagi, K. (2023), A global blockchain-based agro-food value chain to facilitate trade and sustainable blocks of healthy lives and food for all. Humanities and Social Sciences Communications, 10(1), 196.

Venkatesh, V., Thong, J.Y., Xu, X. (2016), Unified theory of acceptance and use of technology: A synthesis and the road ahead. Journal of the Association for Information Systems, 17(5), 328-376.

Vern, P., Panghal, A., Mor, R.S., Kumar, V., Sarwar, D. (2024), Unlocking the potential: Leveraging blockchain technology for agri-food supply chain performance and sustainability. The International Journal of Logistics Management, 36(2), 474-500.

Wellman, B. (1983), Network analysis: Some basic principles. Sociological Theory, 1, 155-200.

Wolfert, S., Ge, L., Verdouw, C., Bogaardt, M.J. (2017), Big data in smart farming-a review. Agricultural Systems, 153, 69-80.

Wu, S., Ming, M., Li, W. (2023), Structure innovation of agricultural supply chain in china: From farmers' perspective. Applied Mathematics and Nonlinear Sciences, 8(2), 1313-1324.

Yadav, V.S., Singh, A.R., Raut, R.D., Cheikhrouhou, N. (2023), Blockchain drivers to achieve sustainable food security in the Indian context. Annals of Operations Research, 327, 211-249.

Zavadska, M., Morales, L., Coughlan, J. (2017), The Importance of Integrating Quantitative Research Methods to Understand Commodity Business Finance. In: ECRM 2017 16th European Conference on Research Methods in Business and Management. Academic Conferences and Publishing Limited. p468.

Zhao, C., Wang, Y., Lian, Z., Zhang, Z., Ma, S., Matsubae, K. (2024), Agricultural plastic pollution in China: Sources, supply chain drivers, and mitigation strategies. Sustainable Horizons, 11, 100102.