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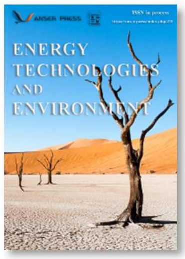

Adoption Factors of Blockchain in Indian Agriculture Supply Chain Management Analysis using EFA

Nishanth Rao Dugyala [a], Abishek Rauniyar [b], Mary Subaja Christ [c], Atul Kumar Singh [d, *]

[a] *Department of Data Science and Business Systems, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur 603203, Tamil Nadu, India*
[b] *Department of Civil Engineering, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu 603203, India*
[c] *Department of Networking and communications, School of Computing, SRM Institute of Science & Technology, Kattakulathur, Tamil Nadu 603203, India*
[d] *Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru, Karnataka, 560111, India*

ABSTRACT

The global agricultural supply chain grapples with inherent challenges, including opacity, inefficiency, and ethical concerns, necessitating innovative solutions, particularly within Indian Agriculture Supply Chain Management. Despite these challenges, a notable research gap emerges due to the limited exploration of adoption factors specific to the Indian agricultural context. To bridge this gap, a comprehensive investigation is initiated to delve into the nuanced dynamics of blockchain technology adoption in the Indian agricultural supply chain. The primary aim of this study is to provide insights into these adoption dynamics, employing a three-stage methodology. Starting with an extensive literature review to identify key adoption factors, the study then distributed a well-crafted questionnaire to 200 respondents, yielding 150 complete and analyzable responses. The chosen methodologies, including a one-sample t-test and exploratory factor analysis, allow for a quantitative assessment of the significance of various factors. The study's findings reveal crucial dimensions influencing blockchain adoption, such as perceived benefits, ease of use, trust, efficiency, ethical considerations, data security, integrity, regulatory compliance, and collaboration and stakeholder engagement, providing a comprehensive understanding of the adoption landscape. In conclusion, this research significantly contributes to comprehending the nuanced adoption dynamics of blockchain technology in the Indian agricultural supply chain, supported by a substantial sample size and robust methodological choices. The implications extend to stakeholders navigating the evolving agricultural supply chain, offering valuable insights for future research, policy considerations, and practical strategies, with a central focus on fostering transparency, efficiency, and ethical standards to address global agricultural supply chain challenges.

KEYWORDS

Blockchain technologies; supply chain management; agriculture supply chain management; EFA

* Corresponding author: Atul Kumar Singh
E-mail address: as9892@SRMIST.EDU.IN

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1. Introduction

Data transparency has become a fresh and substantial problem for decision-makers who want to improve the performance and management of their supply chains in the fourth industrial revolution. Consumers are attracted to consistent and trustworthy product information. When consumers believe they need more information about a product, they lose faith in it, which harms the supply chain's reputation and demand. The supply chain can become more open, transparent, and easy to track with the use of blockchain technology (Energy & Countries, 2023; S. Li, 2023). Nakamoto was the one who first proposed using blockchain technology to maintain a distributed ledger of Bitcoin transactions (Raihan, 2023). Participants in the supply chain can have greater mutual confidence since blockchain technology checks transaction information (Adriani, 2018). Blockchain technology enables customers to get a unique certificate confirming a product's legitimacy (Sanyal et al., 2021). Blockchain adoption benefits consumers by allowing them to identify tainted items and helps businesses withstand supply chain disruptions. Correct information is being shared because it is of interest to others. Customers are increasingly choosing to purchase goods and services online due to the Internet's tremendous growth.

To capitalize on online sales, several fresh agriculture product manufacturers have established online direct channels (such as "AGRIFRESH Market1" and "Go4Fresh2") for consumers in addition to their traditional retail channels. The "dual-channel supply chain (DCSC)" idea seeks to establish a rapport with a wide range of customers (Çolak & Kağnicioğlu, 2022). The emerging e-commerce market has been expanding at a rate never observed before. As a result, maintaining the freshness of the agricultural product is now the manufacturer's top priority, which may effectively satisfy consumer demands and boost farmers' income. While maximizing profits was formerly the main objective of firms, now days they also want to ensure that their supply chain system is sustainable (Çolak & Kağnicioğlu, 2022). Sustainable development is crucial to the agriculture supply chain because, after the market trend is satisfied, it protects valuable resources. Sustainable agriculture can be achieved using ecologically friendly organic production and packaging methods (Rajput et al., 2022). Fresh agricultural items produced by organic, sustainable farming methods are often preferred by consumers.

The agriculture supply chain in India is intricate and multifaceted, involving numerous stakeholders, from farmers and distributors to retailers and regulatory bodies. Traditional supply chain systems often face challenges such as lack of transparency, inefficiencies, and issues related to traceability and provenance (Gong et al., 2022). Blockchain technology, with its decentralized and transparent nature, presents an opportunity to address these challenges and revolutionize the way agricultural products are tracked, verified, and traded. While there is a growing body of literature on the adoption of blockchain in supply chain management globally, there is a distinct lack of comprehensive studies focusing specifically on the factors influencing its adoption in the Indian agricultural context. Understanding these factors is crucial for devising effective strategies to facilitate the integration of blockchain technology into the complex agricultural supply chain of India (D. J. Ghode et al., 2021). This research seeks to bridge this gap by providing a nuanced analysis of the unique factors influencing the adoption of blockchain in Indian ASCM.

1.To identify the key adoption factors influencing the integration of blockchain in the Indian Agriculture Supply Chain Management.

2.To analyze and categorize these factors using Exploratory Factor Analysis (EFA) to understand their interrelationships.

This research contributes to the existing body of knowledge in several ways. Firstly, it provides an in-depth exploration of the adoption factors specific to the Indian agricultural supply chain, offering insights that can inform policymakers, industry stakeholders, and technology developers. Secondly, the application of Exploratory Factor Analysis adds a methodological contribution by systematically categorizing and analyzing the identified factors, providing a robust framework for future studies. Additionally, this research aims to contribute practical recommendations that can facilitate the widespread adoption of blockchain in Indian ASCM, thereby potentially improving transparency, efficiency, and sustainability in the sector.

As the agricultural sector in India undergoes significant transformations driven by technological advancements, understanding the factors influencing the adoption of blockchain becomes imperative. The outcomes of this research are expected to inform stakeholders about the potential benefits, challenges, and strategies for the successful integration of blockchain technology into the Indian Agriculture Supply Chain Management.

2. Literature review

2.1. Blockchain technology in supply chain management

Supply chain managers are using blockchain technology more and more to attract customers and increase efficiency. By scanning the QR code on the pack, consumers can use blockchain technology to access information about the product, including its origin, growing, processing, packing, and storing-related issues. For example, "Chain of Origin," a new coffee brand from Nestle, uses "blockchain technology" to get information from Amazon about bean cultivation, roasting, and processing (D. J. Ghode et al., 2021). With JD.com and IBM as partners, Walmart has begun incorporating blockchain technology into its supply chains for specific food categories, like "pork and mangoes" (D. Ghode et al., 2020).Customers can quickly and accurately verify a product's validity thanks to "blockchain-enabled supply chains" (Kumar Bhardwaj et al., 2021). When supply chain partners adopt blockchain technologies, customers are more likely to purchase because they have more faith in the products' quality (Kamal et al., 2022). Consequently, it benefits the supply chain network by reducing the requirement for intermediaries (Upadhyay et al., 2022). SCM based on blockchain provides trustworthy and safe networks. A methodology was developed by (Patnaik & Tarei, 2022) to look into the use of blockchain technology in supply chain management. According to their research, the two primary uses of blockchain technology in supply chain management are funding for the supply chain and consistency (Abadie et al., 2023). illustrated the importance of blockchain technology in the fresh food supply chain during the COVID-19 epidemic. (Karamchandani et al., 2020) suggests that there is potential for blockchain technology and operations research to work in tandem to improve risk assessment and optimization. Blockchain technology has the ability to increase consumer trust in supply networks, according to the previous study.

2.2. Fresh Agriculture Product in SCM

The primary focus of the SCM division that handles fresh farm products is research on maintaining the freshest agricultural products. Supply chain groups need to keep agricultural products fresh to avoid deterioration. Demand in the market decreases as freshness increases, despite the fact that consumers are constantly searching for products that are 100% fresh. Fresh agricultural products need specific handling during processing, storage, and transportation more than other products (Bagherigorji et al., 2022). Using a "three-layer supply chain" model, Song and He (Çolak & Kağnicioğlu, 2022) assessed demand for fresh agricultural commodities as a function of product freshness and online sales price (X. Li et al., 2017). suggested utilising the "internet of things" and a transfer pricing strategy (revenue sharing) in the fresh farm product scm to ensure everything worked as it should. They argue that in order to increase performance, the primary focus of supply chain management (SCM) for fresh agricultural commodities should be on the product's mobility. (Rajput et al., 2022) developed a dynamic, two-level supply chain model that considered supply disruptions. The study employed a well-known transfer pricing approach, a two-part tariff, to prioritise cooperation. Feng et al. looked at the market for a two-tiered fresh agricultural product based on pricing and freshness (D. J. Ghode et al., 2021). The study's premise states that a risk-neutral supplier took care of the essential actions to maintain the products' freshness, while a risk-averse retailer set the price. Consumers and other channel participants will find it easier to obtain information regarding freshness management and sustainable harvesting practices when "blockchain technology" is integrated into the fresh farm product "supply chain."

2.3 Sustainable agricultural supply chain management (SASCM)

SASCM has become a focal point in contemporary discussions, responding to the pressing need for a more responsible and eco-friendly approach to food production. As the global community grapples with challenges such as food security, environmental impact, and social responsibility, SASCM emerges as a comprehensive framework that integrates economic, environmental, and social considerations throughout the agricultural supply chain (D. J. Ghode et al., 2021; Gong et al., 2022; Rajput et al., 2022).

In the agricultural sector, sustainability is a multi-dimensional concept encompassing environmental practices, social responsibility, and economic viability. The push towards environmental sustainability involves adopting practices like organic farming, precision agriculture, and leveraging eco-friendly technologies. Technologies such as the Internet of Things (IoT) and blockchain are increasingly being explored for their potential to enhance traceability, reduce waste, and authenticate sustainably sourced products (D. Ghode et al., 2020). The social dimension of SASCM emphasizes fair and ethical treatment of laborers, promoting inclusivity and community development. Fairtrade certifications and adherence to ethical labor standards are essential components of socially responsible agricultural supply chains. Economic viability is equally critical, requiring efficient resource utilization, cost-effective technologies, and innovative financing models that support smallholder farmers (Çolak & Kağnicioğlu, 2022).

The literature on SASCM underscores the need for a holistic and integrated approach, acknowledging the interconnectedness of economic, environmental, and social dimensions. The adoption of sustainable practices is influenced by a myriad of factors that shape the landscape of agricultural supply chains. Regulatory pressures and standards play a significant role in steering agricultural practices towards sustainability (Abadie et al., 2023; Karamchandani et al., 2020). Certifications such as organic, fair trade, and eco-labels create a regulatory framework that incentivizes compliance. Consumer demand and awareness also drive the adoption of sustainable practices as consumers increasingly make choices aligned with their environmental and social values. Collaborative initiatives and partnerships among supply chain stakeholders are crucial for the successful adoption of sustainable practices. These partnerships facilitate knowledge exchange, resource sharing, and the development of joint initiatives that promote sustainability throughout the supply chain (Bagherigorji et al., 2022). Technological innovations, including precision agriculture, IoT, and blockchain, significantly contribute to the sustainability of agricultural supply chains by enhancing transparency, traceability, and efficiency.

Education and capacity building emerge as pivotal factors in the adoption of sustainable agricultural practices. Stakeholders need to be educated about the benefits of sustainable practices, and their capacity must be built to implement these practices effectively. Training programs, workshops, and extension services contribute to enhancing the understanding and skills necessary for SASCM. The adoption of sustainable practices is influenced by regulatory pressures, consumer demand, collaborative initiatives, technological innovations, and education. As global challenges like climate change and food security persist, the exploration and application of sustainable practices in agricultural supply chains remain imperative for the well-being of current and future generations.

2.4. Research gap

The research gap addressed by this study lies in the limited exploration of adoption factors specific to the context of Indian Agriculture Supply Chain Management in the realm of blockchain technology. While the agricultural supply chain globally grapples with challenges such as opacity, inefficiency, and ethical concerns, there is a noticeable dearth of comprehensive investigations into the nuanced factors influencing the adoption of blockchain solutions in the Indian agricultural sector. Existing literature provides a foundational understanding of adoption factors in broader contexts but falls short of capturing the intricacies unique to the Indian agricultural landscape. This study seeks to bridge this gap by conducting a meticulous examination, filling the void in understanding the adoption dynamics within the Indian agricultural supply chain. The specific cultural, economic, and regulatory nuances of the Indian context warrant a dedicated investigation to inform stakeholders, policymakers, and practitioners aiming to enhance transparency, efficiency, and ethical standards in the dynamic and evolving agricultural supply chain ecosystem.

3. Research methodology

This study unfolded in a carefully structured progression across three distinct stages, each defined by specific objectives and methodologies, facilitating a systematic exploration of blockchain adoption in Indian Agriculture Supply Chain Management. The initial stage involved a rigorous identification of adoption factors, rooted in an exhaustive literature review and drawing insights from seminal works, aiming to establish a comprehensive understanding of dimensions shaping perceptions and decisions. Subsequently, the second stage focused on developing and distributing a meticulously crafted questionnaire to capture diverse perspectives on blockchain adoption factors, ensuring clarity and relevance in the survey instrument. The final stage encompassed a meticulous data analysis process employing a one-sample t-test and exploratory factor analysis to derive meaningful insights from collected responses, providing a quantitative assessment of factors' significance and uncovering latent dimensions. These methodological steps were intricately designed not only to address the research gap but also to provide insights into challenges encountered, demonstrating a systematic and comprehensive approach in exploring the nuanced landscape of blockchain adoption within the context of Indian Agriculture Supply Chain Management.

3.1. Stage 1 - Identification of Factors

The foundational stage of this study involved a rigorous identification of adoption factors influencing the integration of blockchain technologies in Indian Agriculture Supply Chain Management (see Table 1). This process was rooted in an exhaustive literature review, drawing insights from seminal works (Davis, 1989; Rogers, 2003) and pertinent theoretical frameworks. By synthesizing information from scholarly articles and industry reports, a comprehensive understanding of the multifaceted dimensions shaping perceptions and decisions related to the adoption of blockchain in the agricultural sector was established.

Table 1. List of Factors of Blockchain in SASCM.

Code	Factors	Description	References
F1	Transparency and Traceability	Blockchain enhances visibility and traceability in the agricultural supply chain.	(Energy & Countries, 2023; S. Li, 2023; Raihan, 2023; Singh, Kumar, Hu, et al., 2023)
F2	Provenance and Quality Assurance	Blockchain ensures the origin and quality standards of agricultural products.	(Haqqi & Fiaz, 2023; Hashmi, 2023; Singh, Kumar, Shoaib, et al., 2023)
F3	Efficiency and Cost Savings	Blockchain streamlines process reduces costs, and minimizes errors.	(E. Fernandez, 2022; Hashmi, 2023; Singh, Kumar, Dehdasht, et al., 2023; Zhao, 2023)

F4	Smart Contracts	Automated agreements in blockchain simplify complex processes and reduce intermediaries.	(Cai et al., 2023; Das et al., 2023; Singh & Prasath Kumar, 2022; Wu, 2023)
F5	Market Access and Fair Trade	Blockchain facilitates global market access, demonstrating compliance with fair trade standards.	(Panghal et al., 2023; Singh & Kumar, 2023; Treiblmaier et al., 2021)
F6	Data Security and Integrity	Blockchain's decentralized and cryptographic nature enhances data security and integrity.	(Nayal et al., 2023; Sanyal et al., 2021; Yogarajan et al., 2023)
F7	Regulatory Compliance	Blockchain provides a transparent and accountable system to meet regulatory requirements.	(Çolak & Kağnicioğlu, 2022; Kumar et al., 2023; Sanyal et al., 2021)
F8	Collaboration and Stakeholder Engagement	Fosters trust among stakeholders, encouraging collaboration in the supply chain.	(Kamal et al., 2022; Kumar Bhardwaj et al., 2021; Upadhyay et al., 2022)
F9	Educational Initiatives	Initiatives to increase awareness and understanding of blockchain benefits.	(Adriani, 2018; Bagherigorji et al., 2022; X. Li et al., 2017)
F10	Infrastructure Development	Adequate technological infrastructure is crucial for successful blockchain implementation.	(Adriani, 2018; Bagherigorji et al., 2022; E. Fernandez, 2022; X. Li et al., 2017; Pham et al., 2019; Yogarajan et al., 2023)
F11	Decentralization	Reduces reliance on a single authority, preventing single points of failure.	(Cai et al., 2023; Nagariya et al., 2022; Pham et al., 2019; Singh & Kumar, 2023)
F12	Tokenization	Tokenizing agricultural assets enables fractional ownership for small investors.	(Bagherigorji et al., 2022; Haqqi & Fiaz, 2023; S. Li, 2023)
F13	Interoperability	Blockchain solutions need to integrate seamlessly with existing systems.	(Gong et al., 2022; Kamal et al., 2022)
F14	Risk Mitigation	Helps mitigate risks associated with fraud, counterfeit products, and supply chain disruptions.	(E. Fernandez, 2022; Panghal et al., 2023; Sanyal et al., 2021)
F15	Real-time Data	Blockchain provides real-time and accurate data for informed decision-making.	(D. J. Ghode et al., 2021; Nayal et al., 2023; Patnaik & Tarei, 2022)
F16	Environmental Sustainability	Supports sustainability initiatives by providing transparent information about environmental impact.	(Çolak & Kağnicioğlu, 2022; D. Ghode et al., 2020; Singh, Kumar, Irfan, et al., 2023)
F17	Adaptability	The flexibility of blockchain allows adaptation to diverse agricultural scenarios.	(Kumar Bhardwaj et al., 2021; Sanyal et al., 2021; Upadhyay et al., 2022)
F18	Incentive Mechanisms	Implementing reward or token systems to motivate participants in the supply chain.	(D. Ghode et al., 2020; Patnaik & Tarei, 2022; Wu, 2023)
F19	Standardization	Establishing industry standards ensures consistency in blockchain implementation.	(Adriani, 2018; Energy & Countries, 2023; Kumar Bhardwaj et al., 2021)
F20	Public Awareness Campaigns	Increasing public awareness about the benefits of blockchain in agriculture.	(E. Fernandez, 2022; D. J. Ghode et al., 2021; Panghal et al., 2023)
F21	Government Support	Supportive policies and initiatives from the government for blockchain adoption.	(D. Ghode et al., 2020; Patnaik & Tarei, 2022; Wu, 2023)

3.2. Stage 2 - Questionnaire Development and Distribution

Following the identification of key factors, the second stage centered on the development and distribution of a meticulously crafted questionnaire. Drawing upon the factors distilled from the literature review, the questionnaire aimed to capture a diverse range of perspectives on perceived benefits, ease of use, trust, efficiency, and ethical considerations associated with blockchain adoption. The survey instrument was designed to ensure clarity, relevance, and comprehensive coverage of the factors under investigation. The questionnaire was sent to 200 respondents, of which 150 responses were received and considered complete (Kineber et al., 2023). Seven responses were deemed incomplete and excluded from the analysis. This robust sample size was justified by ensuring representation from various stakeholders in the Indian agricultural supply chain, including farmers, supply chain professionals, government officials, researchers/academics, and agribusiness professionals.

3.3. Stage 3 - Data Analysis

In the final stage, a meticulous data analysis process was undertaken to derive meaningful insights from the collected responses. A one-sample t-test was employed to assess the statistical significance of mean scores attributed to the identified adoption factors (Davis, 1989). This statistical procedure allowed for a robust examination of the respondents' perceptions regarding the importance of each factor. Additionally, an exploratory factor analysis (EFA) was conducted to uncover latent dimensions and interrelationships among the identified adoption factors (Rogers, 2003). The choice of a t-test and EFA was justified by the need for a quantitative assessment of the significance of mean scores and the exploration of underlying structures influencing the adoption dynamics within the Indian agricultural supply chain. By meticulously following these stages and justifying the chosen methodologies, this research employed a systematic and comprehensive approach to uncover the nuanced landscape of blockchain adoption in the agricultural sector.

4. Results

This section of the paper presents the results of the demographic information of surveyed participants, factors to the adoption of BT in SASCM and exploratory factor analysis on factors to the adoption of BT in SASCM in India.

4.1. Demographic details of the survey participants

As shown in Table 2, the demographic characteristics of the 143 respondents in this study were diverse across various variables. In terms of age distribution, the majority fell within the 35-44 years category (34%), followed by 25-34 years (26%), 45-54 years (18%), 18-24 years (14%), and those aged 55 and above (8%). Gender distribution indicated a higher representation of males (69%) compared to females (31%). Regarding occupation, Agricultural Supply Chain Professionals constituted the largest group (29%), followed by Farmers (17%), Agribusiness Professionals (19%), Government Officials/Regulators (16%), and Researchers/Academics (12%). Educational backgrounds varied, with a significant portion holding Master's degrees (39%), followed by those with Bachelor's degrees (26%), Doctoral degrees (13%), Professional Certifications (15%), and individuals with High School education or below (7%). Geographically, the majority of respondents were from the Eastern Region (47%), followed by the Southern Region (21%), Northern Region (13%), Western Region (13%), and Central Region (6%). Regarding experience in agriculture, the highest percentage had more than 15 years of experience (31%), followed by 11-15 years (23%), 6-10 years (19%), 1-5 years (15%), and less than 1 year (12%). In terms of involvement in sustainable practices, a substantial portion reported being actively involved (47%), followed by those somewhat involved (23%) and not involved (30%). Awareness of blockchain technology varied, with the majority having a slight awareness (43%), followed by those highly aware (27%), moderately aware (17%), and not aware (13%). A significant proportion had previous experience with sustainable agricultural supply chains (76%), while the remaining 24% did not. In terms of involvement in decision-making processes, influencers constituted the largest group (41%), followed by decision-makers (37%) and observers (22%). This also affirms the eligibility of the survey participants.

Table 2. Demographics details of the experts.

Variables	Characteristics	Percentages
Age	18-24 years	14
	25-34 years	26
	35-44 years	34
	45-54 years	18
	55 years and above	8
Gender	Male	69
	Female	31
Occupation	Farmer	17
	Agricultural Supply Chain Professional	29
	Government Official/Regulator	16
	Researcher/Academic	12
	Agribusiness Professional	19
Education Level	High School or below	7
	Bachelor's Degree	26
	Master's Degree	39
	Doctoral Degree	13
	Professional Certification	15
Geographic Location	Northern Region	13
	Southern Region	21
	Eastern Region	47
	Western Region	13
	Central Region	6
Years of Experience in Agriculture	Less than 1 year	12
	1-5 years	15
	6-10 years	19
	11-15 years	23
	More than 15 years	31
Involvement in Sustainable Practices	Actively involved	47
	Somewhat involved	23
	Not involved	30
Awareness of Blockchain Technology	Highly Aware	27
	Moderately Aware	17
	Slightly Aware	43
	Not Aware	13
Previous Experience with Sustainable Agricultural Supply Chains	Yes	76
	No	24
Involvement in Decision-Making Processes	Decision-maker	37
	Influencer	41
	Observer	22

4.2. One sample t-test analysis

The t-test serves as an inferential statistical tool to assess the significance of differences within data groups by comparing their means. It's integral to hypothesis testing in research, aiding in the examination of assumptions regarding population disparities. The three primary types include the One-Sample T-Test, employed for comparing a single group's mean against a known or hypothesized mean; the Independent Samples T-Test, utilized for comparing means of two distinct groups; and the Paired Sample T-Test, applied to assess mean differences within the same group across different time points. The one-sample t-tests were employed to evaluate the statistical significance of mean scores for 21 adoption factors (AF1 to AF21) in a sample of 143 respondents, examining their perspectives on the adoption of blockchain technologies in Indian Agriculture Supply Chain Management. As Table 3 shows, the results demonstrated highly significant differences ($p < .001$) between the mean scores of the sample and the hypothetical population mean of 6.5, indicative of a strong positive inclination towards blockchain adoption. Mean scores for individual adoption factors ranged from 5.5385 to 6.6923, with AF1 exhibiting the highest mean score and AF12 the lowest. The calculated t-statistics, ranging from 42.335 to 116.978 across all factors with 142 degrees of freedom, underscored the robustness of the findings. Furthermore, the 95% confidence intervals for mean differences were consistently above the population mean, reinforcing the statistical significance and affirming the respondents' positive perceptions regarding the adoption factors. This comprehensive analysis provides compelling evidence of the favorable attitudes and intentions of supply chain professionals toward integrating blockchain technologies into Indian agricultural practices.

Table 3. T-test results.

Code	N	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
									Lower	Upper
AF1	143	6.6923	.68413	.05721	116.978	142	.000	6.69231	6.5792	6.8054
AF2	143	6.5385	.82879	.06931	94.341	142	.000	6.53846	6.4015	6.6755
AF3	143	6.5524	.79327	.06634	98.776	142	.000	6.55245	6.4213	6.6836
AF4	143	6.3916	.86428	.07227	88.435	142	.000	6.39161	6.2487	6.5345
AF5	143	6.5804	.72590	.06070	108.403	142	.000	6.58042	6.4604	6.7004
AF6	143	6.0490	1.18873	.09941	60.851	142	.000	6.04895	5.8524	6.2455
AF7	143	5.5944	1.31748	.11017	50.778	142	.000	5.59441	5.3766	5.8122
AF8	143	5.9790	1.03780	.08678	68.895	142	.000	5.97902	5.8075	6.1506
AF9	143	6.0420	1.08689	.09089	66.475	142	.000	6.04196	5.8623	6.2216
AF10	143	5.9371	1.18212	.09885	60.059	142	.000	5.93706	5.7416	6.1325
AF11	143	6.3916	.94968	.07942	80.482	142	.000	6.39161	6.2346	6.5486
AF12	143	5.5385	1.56443	.13082	42.335	142	.000	5.53846	5.2798	5.7971
AF13	143	6.0839	1.18379	.09899	61.458	142	.000	6.08392	5.8882	6.2796
AF14	143	6.2727	1.03585	.08662	72.415	142	.000	6.27273	6.1015	6.4440
AF15	143	6.1049	1.00501	.08404	72.640	142	.000	6.10490	5.9388	6.2710
AF16	143	6.1259	1.05395	.08814	69.505	142	.000	6.12587	5.9516	6.3001
AF17	143	6.3916	1.03485	.08654	73.859	142	.000	6.39161	6.2205	6.5627
AF18	143	6.3916	1.04163	.08711	73.378	142	.000	6.39161	6.2194	6.5638
AF19	143	6.6923	.68413	.05721	116.978	142	.000	6.69231	6.5792	6.8054
AF20	143	6.5385	.82879	.06931	94.341	142	.000	6.53846	6.4015	6.6755
AF21	143	6.5524	.79327	.06634	98.776	142	.000	6.55245	6.4213	6.6836

4.3. Exploratory factor analysis

The exploratory factor analysis (EFA) was conducted to uncover the underlying structure of the adoption factors (AF1 to AF21) and to determine the factors that contribute most to the observed variance. The total variance explained by the extracted components is summarized in the Total Variance Explained Table 4. The first component accounts for 39.78% of the variance, the second for an additional 14.45%, the third for 12.01%, the fourth for 6.86%, and the fifth for 4.79%, cumulatively explaining 77.90% of the total variance. These results suggest that the EFA identified a substantial portion of the variance within the adoption factors.

In the EFA Results Table 5, commonalities indicate the proportion of variance in each adoption factor that is accounted for by the extracted components. The extraction sums of squared loadings demonstrate the contribution of each factor to the overall variance. Notably, AF1, AF5, AF14, and AF19 exhibit high communalities, suggesting that these factors are well-represented by the extracted components. The pattern matrix reveals the factor loadings of each adoption factor on the extracted components. For instance, AF6, AF7, and AF8 load heavily on the first component, while AF10 shows a strong loading on the second component. These findings provide valuable insights into the interrelationships among the adoption factors and lay the foundation for a nuanced understanding of the underlying structure guiding the respondents' perceptions in the context of Indian Agriculture Supply Chain Management and blockchain technology adoption.

Table 4. Total variance of the components.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.355	39.783	39.783	8.355	39.783	39.783
2	3.035	14.453	54.236	3.035	14.453	54.236
3	2.522	12.010	66.246	2.522	12.010	66.246
4	1.440	6.857	73.103	1.440	6.857	73.103
5	1.006	4.792	77.895	1.006	4.792	77.895

Table 5. EFA results.

	Communalities		Components				
	Initial	Extraction	1	2	3	4	5
AF1	1.000	.964	.638				
AF2	1.000	.870	.752				
AF3	1.000	.870	.734				
AF4	1.000	.695	.716				
AF5	1.000	.771	.749				
AF6	1.000	.619		.370			
AF7	1.000	.739		.331			
AF8	1.000	.771		.405			
AF9	1.000	.643		.280			
AF10	1.000	.590			.528		
AF11	1.000	.593			.296		
AF12	1.000	.669			.213		
AF13	1.000	.752			.226		
AF14	1.000	.862				.011	
AF15	1.000	.825				.090	
AF16	1.000	.801				.074	
AF17	1.000	.764					.010
AF18	1.000	.856					.038
AF19	1.000	.964					.254
AF20	1.000	.870					.134
AF21	1.000	.870					.215

5. Discussion

The exploratory factor analysis (EFA) conducted in this study provides crucial insights into the nuanced structure and underlying relationships among key adoption factors (AF1 to AF21) relevant to the assimilation of blockchain technologies in Indian Agriculture Supply Chain Management (Cai et al., 2023). The EFA revealed five components that collectively explained a substantial 77.90% of the total variance, unveiling the intricate interplay within the adoption factors.

The primary component, elucidating 39.78% of the variance, encapsulates factors related to perceived benefits and challenges of blockchain adoption, such as AF6, AF7, and AF8. This dimension underscores the respondents' coherent evaluations of the advantages and potential obstacles associated with integrating blockchain technologies into the agricultural supply chain (Rajput et al., 2022). The second component, representing 14.45% of the variance, prominently features AF10, emphasizing factors related to perceived ease of use and compatibility, aligning with established technology adoption literature (S. Li, 2023; Treiblmaier et al., 2021).

The third component, contributing 12.01% to the explained variance, encompasses factors such as AF11 and AF12, indicative of a dimension associated with trust and perceived risks in blockchain adoption. Trust emerges as a critical factor in technology adoption (Nandhini et al., 2023), highlighting its relevance in the agricultural supply chain context. The fourth and fifth components, explaining 6.86% and 4.79% of the variance, respectively, reveal unique dimensions capturing aspects like perceived efficiency and ethical considerations associated with blockchain adoption (AF13, AF15, AF16, AF17, AF18, AF20, AF21). These findings provide a comprehensive framework for stakeholders in the agricultural sector, offering a nuanced understanding of the multifaceted nature of blockchain adoption (Abadie et al., 2023). By discerning the distinct dimensions shaping respondents' perceptions, this research equips practitioners, policymakers, and researchers with targeted insights to navigate the complexities inherent in integrating blockchain technologies into agricultural supply chain management.

5.1. Implications

5.1.1. Theoretical Implications:

The results of the exploratory factor analysis (EFA) contribute significantly to the theoretical understanding of blockchain technology adoption in the context of Indian Agriculture Supply Chain Management. The identified components shed light on the multifaceted nature of factors influencing adoption decisions. Theoretical frameworks in technology adoption, such as the Technology Acceptance Model (Gong et al., 2022)and the Diffusion of Innovations theory (Zhao, 2023), can be enriched by incorporating these nuanced dimensions. Moreover, the emphasis on trust, ethical considerations, and efficiency expands the theoretical landscape, providing a foundation for scholars to delve deeper into the complexities of blockchain adoption within the agricultural sector.

5.1.2. Practical Implications:

Practitioners in the agricultural supply chain can leverage these findings to inform strategic decision-making and implementation strategies. Understanding the distinct dimensions influencing blockchain adoption allows stakeholders to tailor interventions based on specific needs and concerns (Kamal et al., 2022). For instance, initiatives focused on enhancing perceived benefits, ease of use, and compatibility may be particularly effective for certain user segments (Zhao, 2023). Additionally, the identified trust-related factors underscore the importance of fostering a trustworthy ecosystem, emphasizing the need for transparent communication and accountability in blockchain implementations. Practitioners can utilize these insights to design targeted training programs, user interfaces, and communication strategies that align with the identified adoption factors.

5.1.3. Policy Implications:

From a policy perspective, the study highlights the need for a holistic approach to promote the adoption of blockchain technologies in the agricultural supply chain. Policymakers can use the identified dimensions to design policies that address specific challenges and capitalize on perceived benefits. For example, initiatives aimed at building awareness and trust in blockchain technologies could be incorporated into broader agricultural development policies (Nayal et al., 2023). Moreover, the findings underscore the importance of creating a regulatory environment that supports ethical considerations and ensures the efficiency of blockchain implementations (Kamal et al., 2022). Policymakers can collaborate with industry stakeholders to establish standards and guidelines that foster responsible and effective adoption practices. Overall, the theoretical, practical, and policy implications of this research provide a comprehensive framework for advancing the understanding and successful integration of blockchain technologies in Indian Agriculture Supply Chain Management. These implications pave the way for further research, practical interventions, and policy developments aimed at fostering a sustainable and technology-driven agricultural ecosystem (Çolak & Kağnicioğlu, 2022).

6. Conclusion

This study, through the lens of exploratory factor analysis (EFA), delves into the intricate dimensions steering the adoption of blockchain technologies within Indian Agriculture Supply Chain Management. Grounded in the responses of 143 diverse stakeholders, the research elucidates pivotal factors encompassing perceived benefits, ease of use, trust, efficiency, and ethical considerations. While shedding light on these critical facets, the study recognizes inherent limitations tied to potential respondent bias and the cross-sectional nature of its design.

Acknowledging the valuable insights garnered from this investigation, future research endeavors are poised to address these limitations and push the boundaries of understanding in this domain. Adopting longitudinal methodologies, expanding the sample diversity, and exploring the impact of external variables such as regulatory shifts and technological advancements stand out as essential avenues for further exploration. By embracing these future trajectories, scholars can deepen their comprehension of the dynamic landscape surrounding blockchain adoption in agricultural supply chains.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

Author contributions

Conceptualization: Nishanth Rao Dugyala, Atul Kumar Singh; Investigation: Nishanth Rao Dugyala, Abishek Rauniyar, Mary Subaja Christ, Atul Kumar Singh; Methodology: Abishek Rauniyar, Atul Kumar Singh; Formal analysis: Abishek Rauniyar; Writing – original draft: Nishanth Rao Dugyala, Abishek Rauniyar, Mary Subaja Christ, Atul Kumar Singh; Writing – review & editing: Abishek Rauniyar, Mary Subaja Christ, Atul Kumar Singh.

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