Journal of Information Systems Engineering and Management
2025, 10(13s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Validating a Blockchain Technology-Based System in Commodity Markets: A Measurement and Structural Model Assessment-Based Approach

Vivian Brian Lobo[1], Dr. Madhuri Rao[2]

[1]*Research Scholar, Department of Information Technology, Thadomal Shahani Engineering College, Bandra, Mumbai—400050, Maharashtra, India*

[2]*Research Guide, Professor and Head, Department of Artificial Intelligence and Data Science, Thadomal Shahani Engineering College, Bandra, Mumbai—400050, Maharashtra, India*

Corresponding Author: Vivian Brian Lobo

ARTICLE INFO	ABSTRACT
Received: 28 Nov 2024 Revised: 10 Jan 2025 Accepted: 31 Jan 2025	In recent years, commodity markets in India and in other parts of the world are receiving a significant amount of recognition because of blockchain. A commodity can be defined as an artifact or a thing that can be merchandized between two regions, states, or nations. In general, commodities can be broadly categorized as agricultural and non-agricultural. There exists several actors in a commodity trading ecosystem that usually get involved when commodity trading between nations needs to be performed, such as exporters, customs, importer, insurance, and importer bank, and each of them are assigned certain roles and responsibilities that need to be carried out such as L/C, BoL, factoring, exporting credit, and insurance. Blockchain is a DLT that can leverage commodity markets on the whole by supporting the actors and their set of associated activities. It has been observed that commodity markets face a lot of issues during the conduct of trade, which ultimately affects its business processes. The identification of pain points or issues w.r.t. commodity market-related business processes and easing them through blockchain, especially via systems approach, shall enable smoother functioning, thereby improving overall cost and efficiency along with enhanced digital security. This study aims to validate a blockchain-based system in commodity markets by means of a measurement and structural model assessment-based approach. **Keywords:** Blockchain, Business Process Modeling, Commodity Markets, Measurement Model, Structural Model,Validation.

INTRODUCTION

1.1. Background Information

Commodity markets, in recent years, have gained a significant extent of recognition and acceptance because of the usage of blockchain technology. A commodity is a tangible item traded in markets, serving as a basic material for manufacturing products. In other words, commodities can be defined as identical goods that are not only purchased but also retailed with certain restrictions [1]. Commodities comprise metals, food, and fundamental items that govern terrestrial marketability [2–4]. In the nineteenth century, commodity markets transpired, concentrating on agricultural products to accelerate trade in a well-ordered and steadfast manner [5].

A blockchain is a decentralized network and a type of distributed ledger technology that organizes transactions into blocks that contain a timestamp and a connection to the previous block. Blockchain ensures that each individual's ledger copy remains coordinated and exclusive. Although data can be added to the blockchain, it cannot be modified, altered, or deleted [6].

As per research, blockchain technology market size worldwide has a valuation of $0.98 billion in 2017, and it is expected to expand significantly, thereby reaching approximately $162.84 billion by 2027 [7].

1.2. Research Problem or Question

To create a secure and unalterable decentralized system that autonomously tracks and monitors commodity trading, offering users relevant information anytime and anywhere. This system leverages blockchain technology to guarantee data security and uses chain codes to remove intermediaries, thereby enhancing the efficiency and transparency of current trading processes.

1.3. Research Significance

The study is conducted for the following reasons:

1. To know the function of blockchain technology in business process and procedure development within commodity markets.

2. To build a strong, resilient, and reliable blockchain technology-enabled system with an intention to create business processes that can withstand commodity trading-related issues or challenges and operate effectively in various conditions.

3. To adopt a holistic perspective (i.e., systems approach) by considering the interconnections and interdependencies of various components within commodity markets.

4. The integration of technological advancements, specifically blockchain, to enhance and optimize business processes within commodity markets.

The rest of the study is structured as follows. Section II explicates on related work w.r.t. blockchain-based models in commodity markets, Section III details the methodology for creating a theoretical model to establish robust blockchain technology-enabled procedures in commodity markets, utilizing a systems approach, which includes research design, hypothesis formulation, data collection methods, category-wise distribution, and data analysis techniques, Section IV presents the results on business process modeling in blockchain-based commodity markets, i.e., structural model and measurement model and their assessments, Section V provides an overview of the discussions based on the acquired results followed by graphical narration and comparison with existing literature w.r.t. several parameters, and lastly, Section VI concludes the study by recapitulating the crucial findings, delineating the contributions to the field, and offering future research recommendations.

LITERATURE REVIEW

A great deal of literature has been reviewed to understand the importance of blockchain technology-enabled business processes in commodity markets and a few of them have been specified below:

Toorajipour *et al.* [8] suggested a technique to discourse the drawbacks of 3rd party reliant agreements. The mechanism was developed according to the standards and recommendations of business process model and notation 2.0. The authors also proposed a blockchain-based letter of credit (L/C) after evaluating blockchain's capabilities. However, the study primarily concentrated on business transactions involving blockchain-based L/C. Greater emphasis could have been placed on other business transactions, particularly in the contexts of artworks and real estate.

Agibalova *et al.* [9] performed an examination of the classic L/Cs composition and content in international transactions and preliminary Russian experience in implementing L/C, a blockchain platform, and smart contract usage.

Samy *et al.* [10] addressed the need for a consensus algorithm to be fault tolerant and offered an unwavering alternative for several commercial use cases by propositioning a revision in IBFT voting-based algorithm that offered 1140 tx/s throughput, which could be used in L/C as it is a part of trade finance (i.e., relationship amongst exporter, importer, and bank institutions).

Belu [11] presented prospective merits of the usage of blockchain in international trade. He believed that blockchain, as a disruptive technology, would revolutionize foreign trade operations.

Chang *et al.* [12] investigated blockchain's pertinency in an international trade process from L/C's payment perspective. The authors conducted a fair analysis and probability study to ascertain and corroborate the perspectives of the proposed blockchain-based international trade process model. Nonetheless, the study only focused on eradicating disintermediation in business processes by means of blockchain technology. Factors such as block size, security and privacy concerns, etc. were not taken into consideration.

Neha and Sedamkar [13] discussed the challenges of the global trade system concerning security and trust, proposing a blockchain solution through the use of letters of credit (L/C). They suggested a smart contract-based blockchain approach to ensure the security and trust of commodity trade.

Kowalski *et al.* [14] carried out in-depth interviews—from research and practice perspective—with experts from industry to inspect how blockchain influenced trust rapports amongst business associates. The authors included only a finite number of industry experts in their study.

Xu and Yang [15] used systems approach and proposed a design path of a blockchain-based e-bidding system that aimed to provide better efficiency, trust, and security of e-trading process. They developed a foundational blockchain platform and integrated e-bidding business processes. This resulted in enhanced transparency, integrity, and traceability throughout the entire e-bidding process.

Mahak Sharma, Ashwaq Al Khalil, and Tugrul Daim [16] investigated the adoption of BCT in four different countries, i.e., Netherlands, Oregon, Saudi Arabia, and India. Their study aimed to uncover the hierarchy and fundamental relationships among the factors influencing BCT adoption. The findings can be generalized globally. The authors employed an integrated interpretive structural modeling—decision-making trial and evaluation laboratory (ISM-DEMATEL) methodology, heavily reliant on the beliefs of stakeholders such as farmers. Additionally, human bias and inaccuracies during interviews while finalizing factors could not be entirely ruled out.

Tarun Kumar Agrawal *et al.* [17] proposed a blockchain-based traceability framework for textile and clothing industry to address the challenges of information asymmetry and low visibility. Their study aimed to provide transparency and quality assurance to consumers and build technology-based trust amongst supply chain stakeholders. The study, however, did not examine how different blockchain systems interact and integrate when a supply chain partner was involved with multiple buyers or suppliers across various blockchain networks.

Hamed Taherdoost and Mitra Madanchian [18] provided a systematic review of new business models developed using blockchain technology from 2012 to 2022. They analyzed the state of blockchain-based business models, identified open research questions, and suggested promising new directions for investigation. They noted that, since these new business models are still in their early stages, there has been limited research. They emphasized that the role of these networks in the creation of new business models requires further consideration.

Manoshi Turjo *et al.* [19] focused on integrating blockchain and smart contract into traditional supply chain management systems to improve data security, authenticity, time management, and transaction processes. Their goal was to reduce 3rd involvement in the supply chain system and enhance data security to improve openness, efficacy, and rightness throughout the process. The authors focused on a small-scale, highly specific piece of work. However, with a large volume of data, latency could become an issue. Additionally, for large-scale deployment, more tracking devices would be needed. An off-chain architecture should be used to store original data, while proof-of-existence should be maintained on the blockchain itself.

Sumit Rana *et al.* [20] proposed a model to integrate blockchain technology with digital supply chain to improve its performance by maintaining traceability, transparency, and trustworthiness. The proposed model utilized a combination of the Ethereum blockchain and IPFS. It had certain constraints, including Tx no./second, transaction latency, and the volume of data in transactions. Additionally, regular updates could impact the model's functioning in the future.

Edward Sweeney's study [21] described an extension of traditional systems approaches beyond the operations of an individual company to the complete supply chain. This led to the acceptance of a systems approach for enhancing supply chain performance. Implementing this approach required a methodology, an understanding of best practices, and the utilization of appropriate techniques. The process of supply chain analysis was multifaceted, necessitating comprehensive management.

Tsolakis *et al.* [22] explored joint implementation of AI and BCT in supply chain for extending operations performance boundaries and fostering sustainable development and data monetisation. Thailand's tuna fish supply chain was examined to recognize end-to-end operations, observe data handling processes, and envisage AI and BCT implementation. However, the study did not address the trade-off between information loss and privacy protection. Additionally, the proposed framework for integrating AI and BCT was not tested in a practical context.

Rajeev Kumar and Dilip Kumar [23] explored the relationship amongst supply chain management practices, BCT, and supply chain performance in the Indian dairy industry. They proposed a theoretical model illustrating BCT effects between supply chain management practices and performance. The authors primarily focused on the Indian dairy industry in New Delhi and Uttar Pradesh. Future investigations should examine the dairy industry operating in different formats and across various geographic locations.

Joseph Lee and Vere Marie Khan [24] focused on the use of blockchain technology in energy trading, especially in crude oil trade. They believed that blockchain technology and chain codes could facilitate responsible sourcing and reduce information asymmetry. However, a significant challenge with this system was the structure of contractual frameworks and related regulations.

Su *et al.* [25] addressed the problem of expense for storing large files in an Ethereum blockchain by applying IPFS. They proposed using Ethereum blockchain and IPFS to develop a used-car trading and MIS that supports decentralized data storage services. They ensured permanent storage, immutability, and car maintenance traceability data through smart contract operations. The study did not address potential security vulnerabilities and risks associated via smart contracts and IPFS for storing and managing sensitive car information.

Yang *et al.* [26] analyzed the concept of countertrade to illustrate the potential efficiencies over traditional countertrade transactions. They utilized TCCB to facilitate international countertrade, which helped reduce counterparty risk and transaction costs associated with logistics chain management and contract arbitration, particularly in less developed countries.

Wang, Liu, and Ji [27] presented a conceptual framework for blockchain-based trading in the energy internet environment. Their study explored the integration of blockchain technology into the electricity market under the energy internet, characterized by distributed energy, diverse entities, and a flexible market mechanism. A blockchain-based trading framework for multi-agent cooperation and sharing was proposed, integrating power system modeling with transaction consensus strategies. The approach was validated through simulations on a modified IEEE 13-node distribution network using an Ethereum private blockchain. The study did not specify the potential challenges or limitations of implementing the proposed framework in real-world scenarios.

Stopfer and others [28] focused on transparency in forestry and timber supply chain, and the associated certification of sustainable forest management, as well as proof of legality of raw material. Their study combated illegal timber trade at national and international level and improved certification systems. Moreover, supplier–customer relationships was improved through reliable information. The study didn't address standardization and interoperability problems, which could reduce efficiency in implementing blockchain technology in forestry.

Kowalski *et al.* [29] addressed the fundamental question of whether and how blockchain technology contributed to trust-free economic transactions amongst trading partners in trade finance through in-depth interviews with industry experts to examine how blockchain technology influenced trust relationships among trading partners. The authors did not specify about the analysis of the impact of blockchain technology on transactional costs in trade finance.

Bai, Liu, and Yeo [30] provided an initial conceptual framework for understanding the challenges of blockchain adoption in supply chain finance through a case study. Results revealed that, from a technological perspective, the major barriers were framework identification, cross-chain interoperability, and data governance. From a working standpoint, challenges included the new business process and complete supply chain transformation. Additionally, other obstacles such as job elimination and regulatory issues were also significant. A comprehensive analysis of the potential benefits or success factors of blockchain adoption in supply chain finance was neglected.

Kharche, Badholia, and Upadhyay [31] explored the potential of blockchain technology in the context of integrated IoT networks for constructing scalable ITS systems in India. They developed a PoC blockchain-based application, integrated the blockchain solution to the existing infrastructure, and ensured appropriate compatibility. The authors achieved 87% accuracy rate in the integrated blockchain and IoT framework. The authors did not consider expanding the sample size to collect sufficient data and information for more comprehensive analysis. A comprehensive analysis of the potential benefits or success factors of blockchain adoption in supply chain finance was overlooked.

Sonawane and Motwani [32] suggested solutions to problems such as getting new commodities, attracting small participants, fewer commodities of agriculture products, managing a huge set of documentations, inefficiency due to physical marketplace, the collaboration of all stakeholders, etc. by using a blockchain distributed ledger, which helps to create a network of trust and digitize every product connected to the trade and finance industry using Ethereum blockchain and smart contracts in different governing agencies like MCX, NCDEX, NMCE, ICEX, etc. Potential challenges and limitations of implementing blockchain technology in the commodity market and trade finance in India was overlooked.

Wang [33] investigated the way in which blockchain technology was likely to influence future supply chain practices and policies. Their study provided valuable insights for supply chain practitioners on how blockchain technology could disrupt existing supply chain provisions and highlighted numerous challenges to its successful adoption. There was a need for more research on implementation strategies to materialize the expected value of blockchain in supply chain.

Dutta *et al.* [34] identified current trends of research on blockchain in different domains of supply chain operations. They examined various supply chain functions, provided compelling examples across different industrial sectors, suggested decision-making insinuations, emphasized defies, and developed a forthcoming research agenda. The study did not explore the use of blockchain in business process re-engineering within supply chain operations.

Liao, Lin, and Yuan [35] proposed a blockchain-enabled integrated marketing platform (BeIMP) for contract production and transactions. Results demonstrated that the chain code function was sufficiently steady, and the PoA mechanism offered superior throughput, enhancing user experience. However, the authors did not discuss potential scalability issues or the impact of a large number of participants on the BeIMP system's performance.

Sharma and others [36] explored blockchain adoption in the agriculture supply chain while focusing on comparing the trends in developed versus developing economies. Their study utilized ISM and the decision-making trial and evaluation laboratory to rank several factors. While the study highlighted differences in Netherlands, United States, Saudi Arabia, and India, it also identified policies as the most crucial enabler of BCT adoption in agriculture supply chain. However, the study did not address the potential implications of blockchain adoption in the agriculture supply chain.

Chang, Lin, and He [37] proposed options to hedge the risk by the fluctuation of physical settlement cost. Given that listed as well as OTC options would take considerable time to be issued, the authors proposed using blockchain technology to issue physical settlement rights through tokens. The authors did not focus on reducing listed and over-the-counter (OTC) options time.

Raveendarnaik [38] specified that the performance of the Indian commodity derivatives market is analyzed in terms of the number of commodities permitted for trading, volume, and value of the commodity derivatives traded. The author evaluated commodity policies and regulatory frameworks, examining the commodity futures market in India by considering its history, trading mechanisms, segments, and regulatory framework. However, the author could have further focused on enhancing commodity markets in India.

Lobo and Rao [4] presented an empirical study of commodity market-based systems that enable the use of blockchain technology in various business processes. They believed that blockchain technology has radically transformed the concept of centralization. Characteristics such as decentralization, tamperproof nature, transparency, and peer-to-peer (P2P) exchange have helped address issues faced by commodity markets.

Lobo and Rao [39] presented a conceptual framework for building robust blockchain technology-enabled business processes in commodity markets using systems approach wherein the authors addressed existing challenges such as process heterogeneity, information leakage risks, and high costs and attempted to offer solutions through blockchain's decentralized, transparent, traceable, and tamperproof nature to address such challenges. Moreover, the application of a systems approach further strengthened the improvements thereby enhancing overall market efficiency and security.

METHODOLOGY

3.1. Research Design

A quantitative comparative study will be conducted to investigate blockchain technology's influence on efficiencies and security in commodity markets. The research will involve selecting a sample of companies that have adopted blockchain technology and a control group that has not. Key efficiency metrics such as *transaction time*, *operational costs*, and *error rates*, along with security metrics like *incidence of fraud*, *data breaches*, and *dispute resolution time*, will be measured. Statistical tests, including t-tests, will be used to compare these metrics between the two groups. The study aims to determine whether blockchain adoption leads to significant improvements in efficiencies and security, thereby testing the null hypothesis that blockchain technology does not improve these aspects against the alternative hypothesis that it does.

Hypothesis

Null Hypothesis (H_0): Blockchain technology adoption does not improve efficiencies and security (*there is no significant impact on efficiencies and security due to blockchain technology adoption*)

Alternative Hypothesis (H_a): Blockchain technology adoption improves efficiencies and security (*there is a significant positive impact on efficiencies and security due to blockchain technology adoption*)

Data collection methods and sample selection

1. **Data Collection:** Its main goal is to obtain quantitative data on traders' experiences, satisfaction levels, and the challenges they face within the current trading system.
2. **Population:** The target population includes traders, financial professionals, or participants involved in trading activities within the system being studied.
3. **Sampling Technique:** A specific sampling technique such as stratified sampling, random sampling, or convenience sampling was used to select participants.
4. **Survey Questionnaire:** The main tool used for data collection was a structured survey questionnaire.
5. **Data Storage and Management:** The collected data was stored securely, often in digital format within Excel, ensuring confidentiality and data protection.

Table 1. Category-wise distribution

Category	Subcategory	Frequency	Percentage (%)
Gender	Male	156	59.50%
	Female	106	40.50%
Age Group	18–24	50	19.10%
	25–34	98	37.40%
	35–44	64	24.40%
	45–54	36	13.70%
	55 and above	14	5.30%
Education Level	High School/Diploma	30	11.50%
	Bachelor's Degree	132	50.40%
	Master's Degree	86	32.80%
	Doctorate/Ph.D.	14	5.30%
Experience in Trading	Less than 1 year	38	14.50%
	1–3 years	84	32.10%
	4–6 years	72	27.50%
	7–10 years	40	15.30%
	More than 10 years	28	10.70%

3.2. Data Analysis Techniques

The SmartPLS 4 analysis depicted in the image below represents the structural model for assessing the adoption of blockchain technology in the trading system [40, 41].

The model consists of several latent constructs (indicated by blue circles), such as

- **Training Needs (TN):** Identifying and addressing knowledge gaps among stakeholders ensures effective use of blockchain technology in commodity markets. Proper training fosters user confidence and minimizes operational errors.
- **Cost-Benefit Analysis (CBA):** A systematic evaluation of blockchain implementation costs versus potential benefits helps in determining its financial viability. It ensures resources are allocated efficiently for maximum returns.
- **Regulatory Compliance (RC):** Adhering to legal and regulatory standards is crucial for system validation in the commodity market. It reduces risks of penalties and enhances trust among participants.
- **Interoperability (IP):** Seamless integration with existing systems ensures a smooth transition to blockchain-based platforms. It enhances data flow and functionality across multiple stakeholders.
- **Data Privacy (DP):** Robust privacy measures protect sensitive data in a blockchain system, maintaining user trust. Compliance with data protection regulations prevents legal issues.
- **Scalability and Automation (SA):** Ensuring the system can handle increasing data and transaction volumes is essential for long-term success. Automation reduces manual processes, improving efficiency and accuracy.
- **Smart Contracts and Real-Time Processing (SCR):** Smart contracts automate and enforce agreements, enhancing reliability and transparency. Real-time processing accelerates transactions and decision-making in the commodity market.
- **Risk Management (RM):** Blockchain's inherent security features help mitigate risks such as fraud and data tampering. Proactive risk management ensures system reliability and stakeholder confidence.
- **Adoption of Blockchain Technology (AB):** Encouraging stakeholders to embrace blockchain involves addressing resistance to change and demonstrating its benefits. Adoption strategies should focus on awareness, usability, and tangible value.

RESULTS

4.1. Presentation of Findings

Structural Model: The structural model focuses on the impact of relationships between constructs. Full structural model indicates that each construct's measurement and structural relationships are encompassed in model testing.

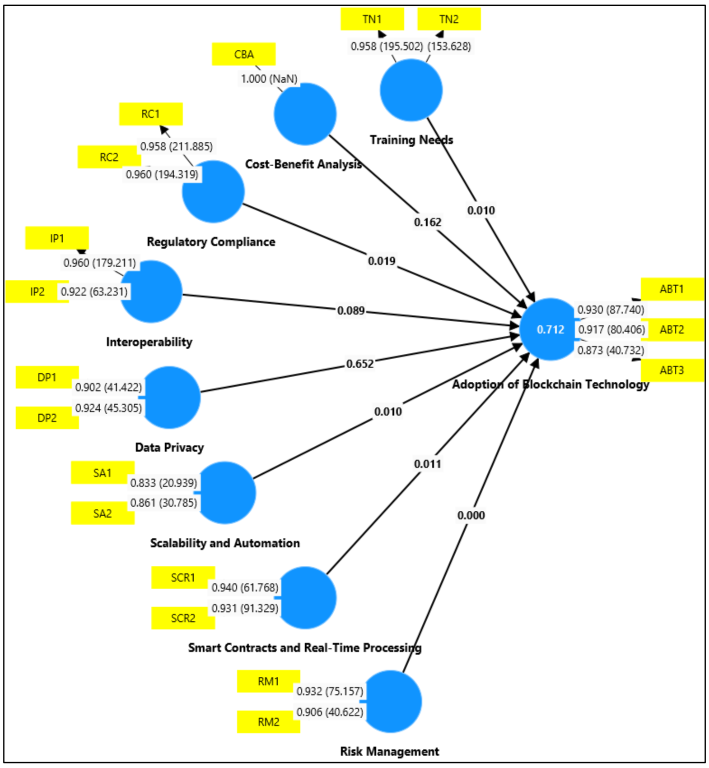

Figure 1. Structural model

Figure 1 represents a structural model assessment of factors influencing the **Adoption of Blockchain Technology (AB)**. The central node (AB) is connected to various influencing constructs such as *Training Needs (TN)*, *Cost-Benefit Analysis (CBA)*, *Regulatory Compliance (RC)*, *Interoperability (IP)*, *Data Privacy (DP)*, *Scalability and Automation (SA)*, *Smart Contracts and Real-Time Processing (SCR)*, and *Risk Management (RM)*. Each construct is measured using specific indicators (e.g., TN1, TN2 for Training Needs) with their corresponding reliability values shown in yellow. Path coefficients (numbers on connecting lines) indicate strength as well as direction of relationships between constructs and AB. The value at the central node (0.712) represents the R^2 value, explaining the variance in AB caused by all predictors. Stronger connections, such as between SCR and AB, indicate a more significant influence on blockchain adoption.

A. Independent Variables

Training Needs (TN)

RQ1: Level of training and support needed to implement blockchain technology in commodity trading.

RQ15: Level of familiarity with blockchain technology in commodity markets.

Cost-Benefit Analysis (CBA)

RQ2: Conduction of cost-benefit analysis for implementing blockchain technology in commodity trading.

Regulatory Compliance (RC)

RQ3: Importance of regulatory compliance in blockchain technology for commodity markets.

RQ5: Management of intellectual property rights in commodity trading.

Interoperability (IP)

RQ4: Level of interoperability do you currently have with other organizations in commodity trading.

RQ8: Level of standardization existing in commodity trading processes.

Data Privacy (DP)

RQ6: Issues w.r.t. data privacy and security in commodity trading.

RQ12: Ensure data integrity and accuracy in your commodity trading operation.

Scalability and Automation (SA)

RQ7: Importance of scalability in blockchain technology for commodity markets to your organization.

RQ11: Level of automation do you currently have in your commodity trading processes.

Smart Contracts and Real-Time Processing (SCR)

RQ9: Explored the use of smart contracts in commodity trading.

RQ10: Importance of real-time settlement and clearance to your organization.

Risk Management (RM)

RQ13: Challenges with counterparty risk in commodity trading.

RQ14: Importance of transparency in commodity trading to your organization.

B. Dependent Variables

Adoption of Blockchain Technology in Commodity Trading

AB1: Likelihood of adopting blockchain technology in commodity trading processes within the next two years

AB2: Blockchain technology will significantly improve the efficiency and security of commodity trading activities

AB3: The benefits of adopting blockchain technology in commodity trading outweigh the potential challenges and costs

4.2. Key Elements of the Model

1. Latent Variables and Indicators: Each latent variable is linked to its indicators, shown in yellow boxes (e.g., RC1, IP1, DP1). These indicators have factor loadings that represent the strength of their relationship with the corresponding latent variable. For example, RC1 has a loading of 0.958 on Regulatory Compliance.

2. Path Coefficients/β Values: The model illustrates the relationships between the latent variables using path coefficients (e.g., 0.019, 0.011). These coefficients show the strength and direction of the relationships between variables. For instance, Regulatory Compliance has a positive path coefficient of 0.019 towards the Adoption of Blockchain Technology.

3. R-squared (R^2) and R-squared Adjusted Values: The R^2 value next to the Adoption of Blockchain Technology construct (0.712) signifies that the model supports 71.2% of variance in blockchain adoption, which signifies a substantial model. Also, R-squared adjusted value is 0.703.

4. Significance Levels: The *p*-values associated with each path coefficient show significant relationships. Lower the *p*-value (nearly 0), more significant the relationship. For example, Risk Management has a highly significant path with Adoption of Blockchain Technology ($p = 0.000$).

Inferences: *The model provides a* ***strong explanation*** *for the adoption of blockchain technology, with over* ***70%*** *of its variance explained by the predictors. The small difference between R-squared (0.712) and Adjusted R-squared (0.703) suggests the model is not overfitting and is well-balanced in terms of complexity.*

Measurement Model: In SEM, the measurement model is used to assess indicators' validity for each construct. Once measurement model's validity is established, a research scholar can move on to the structural model.

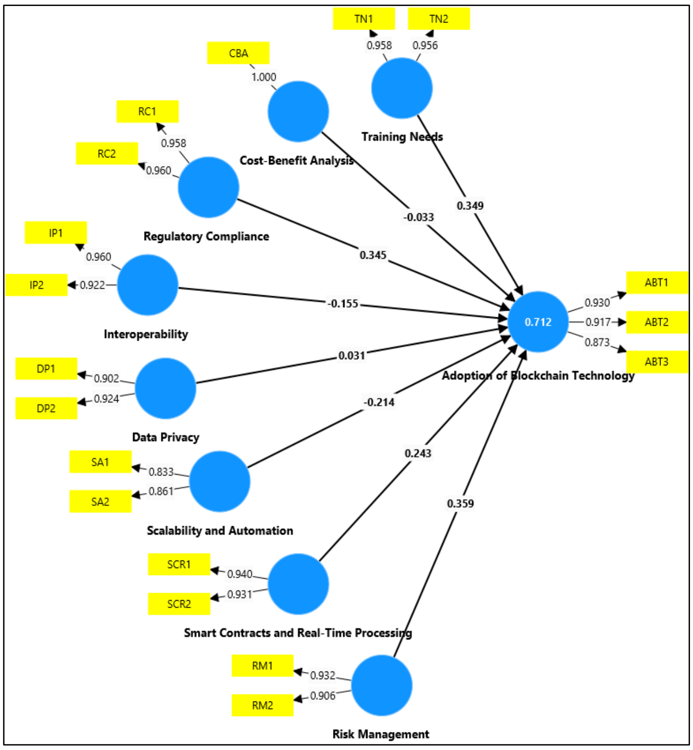

Figure 2. Measurement model

Figure 2 showcases a measurement model evaluating the factors affecting **Adoption of Blockchain Technology (AB)**. The central node (AB) has an R^2 value of 0.712, implying that 71.2% of variance in adoption is elucidated by the connected factors. The constructs include *Training Needs (TN)*, *Cost-Benefit Analysis (CBA)*, *Regulatory Compliance (RC)*, *Interoperability (IP)*, *Data Privacy (DP)*, *Scalability and Automation (SA)*, *Smart Contracts and Real-Time Processing (SCR)*, and *Risk Management (RM)*. Each construct is measured by indicators (e.g., TN1, TN2) with reliability values in yellow. The path coefficients (values on arrows) represent the strength and direction of influence. Positive values (e.g., SCR to AB with 0.359) signify a positive relationship, while negative values (e.g., IP to AB with -0.155) indicate a negative influence. Strong connections highlight key factors driving blockchain adoption.

4.3. Data Analysis and Interpretation

Table 2. Path co-efficient (*β values*)

Variables	Path coefficients
Cost-Benefit Analysis → Adoption of Blockchain Technology	−0.033
Data Privacy → Adoption of Blockchain Technology	0.031
Interoperability → Adoption of Blockchain Technology	−0.155
Regulatory Compliance → Adoption of Blockchain Technology	0.345
Risk Management → Adoption of Blockchain Technology	0.359
Scalability and Automation → Adoption of Blockchain Technology	−0.214
Smart Contracts and Real-Time Processing → Adoption of Blockchain Technology	0.243
Training Needs → Adoption of Blockchain Technology	0.349

4.4. Measurement Model Assessment

Table 3. Correlations amongst variables

	AB	CBA	DP	IP	RC	RM	SA	SCR	TN

AB	1.000	0.111	0.352	0.607	0.755	0.689	0.499	0.520	0.778
CBA	0.111	1.000	−0.084	0.135	0.189	0.018	0.117	0.165	0.232
DP	0.352	−0.084	1.000	0.437	0.400	0.377	0.612	0.352	0.454
IP	0.607	0.135	0.437	1.000	0.791	0.577	0.614	0.681	0.685
RC	0.755	0.189	0.400	0.791	1.000	0.593	0.599	0.561	0.876
RM	0.689	0.018	0.377	0.577	0.593	1.000	0.543	0.412	0.631
SA	0.499	0.117	0.612	0.614	0.599	0.543	1.000	0.719	0.621
SCR	0.520	0.165	0.352	0.681	0.561	0.412	0.719	1.000	0.546
TN	0.778	0.232	0.454	0.685	0.876	0.631	0.621	0.546	1.000

Table 4. Quality criteria

	R-square	**R-square adjusted**
Adoption of Blockchain Technology	0.712	0.703

Table 5. Effect size (f^2)

Variables	***f*-square**
Cost-Benefit Analysis → Adoption of Blockchain Technology	0.003
Data Privacy → Adoption of Blockchain Technology	0.002
Interoperability → Adoption of Blockchain Technology	0.022
Regulatory Compliance → Adoption of Blockchain Technology	0.066
Risk Management → Adoption of Blockchain Technology	0.232
Scalability and Automation → Adoption of Blockchain Technology	0.047
Smart Contracts and Real-Time Processing → Adoption of Blockchain Technology	0.073
Training Needs → Adoption of Blockchain Technology	0.079

Table 5 shows the f^2 (effect size) values for various **independent variables** and their influence on the **Adoption of Blockchain Technology**. The f^2 value measures how much each variable contributes to the explained variance of the dependent variable when removed from the model.

Inferences:

*1. **Risk Management** has the largest effect size (f^2 = 0.232), making it a critical factor in blockchain adoption.*

*2. **Cost-Benefit Analysis** and **Data Privacy** have very small effects, suggesting they may have less immediate impact in this model.*

*3. **Smart Contracts and Real-Time Processing** and **Training Needs** show moderate effects, implying they are important but not dominant factors.*

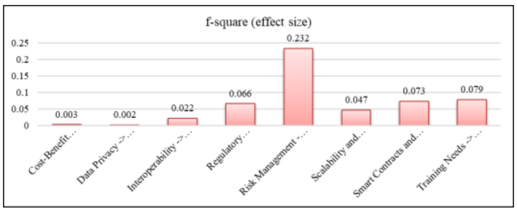

Figure 3. Effect size

Overall, these f^2 values help prioritize factors influencing blockchain adoption based on their relative impact.

Table 6. Construct reliability and validity: Reliability (*alpha and composite reliability* [42])

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
AB	0.892	0.892	0.933	0.822
DP	0.801	0.809	0.909	0.833
IP	0.875	0.944	0.940	0.886
RC	0.913	0.913	0.958	0.920
RM	0.818	0.831	0.916	0.845
SA	0.606	0.608	0.835	0.717
SCR	0.857	0.860	0.933	0.875
TN	0.909	0.909	0.956	0.916

Average Variance Extracted (AVE) is a measure used in structural equation modeling (SEM) to assess the amount of variance captured by a latent construct from its indicators relative to the variance due to measurement error. It is used to evaluate convergent validity, which ensures that indicators effectively measure the same construct.

Interpretation of AVE [43]

- *Threshold for Acceptable AVE: ≥0.50 AVE value signifies adequate convergent validity.*
- *<0.50 AVE value indicates that the measurement model may need refinement, such as removing low-loading indicators.*

Inferences:

1. *One of the primary measures in PLS-SEM is* **composite reliability (rho_c)** [44]. *Values over 0.70 are normally considered reliable.*

2. ***0.60–0.70*** *reliability are '**acceptable in exploratory research**', whereas **0.70–0.90** are **satisfactory**.*

3. ***0.90–0.95*** *values are problematic since they indicate that the indicators are redundant, thereby reducing construct validity* [45]. ***≥0.95*** *values recommend the likelihood of undesirable response patterns.*

The equation for variance extracted is given by

$$VE = \sum_{i=1}^{n} \frac{\lambda_i^2}{n} \quad \textbf{(1)}$$

$where\ \lambda = standardized\ factor\ loading$ and $n = number\ of\ items$

All AVE values are >0.50 → reliability and validity are established

Table 7. Discriminant validity: Fornell & Larcker criterion [46]

	AB	CBA	DP	IP	RC	RM	SA	SCR	TN
AB	0.907								
CBA	0.111	1.000							
DP	0.352	−0.084	0.913						
IP	0.607	0.135	0.437	0.942					
RC	0.755	0.189	0.400	0.791	0.959				
RM	0.689	0.018	0.377	0.577	0.593	0.919			
SA	0.499	0.117	0.612	0.614	0.599	0.543	0.847		

SCR	0.520	0.165	0.352	0.681	0.561	0.412	0.719	0.935	
TN	0.778	0.232	0.454	0.685	0.876	0.631	0.621	0.546	0.957

Inferences: *It is a traditional metric for establishing discriminant validity wherein each construct's square root of AVE should be compared to the inter-construct correlation of that same construct and all other reflectively measured constructs in the structural model, and so, discriminant validity has been established.*

Table 8. Discriminant validity: Heterotrait–Monotrait (HTMT) ratio

	AB	**CBA**	**DP**	**IP**	**RC**	**RM**	**SA**	**SCR**	**TN**
AB									
CBA	0.117								
DP	0.416	0.094							
IP	0.670	0.143	0.510						
RC	0.836	0.198	0.469	0.872					
RM	0.803	0.027	0.468	0.687	0.687				
SA	0.677	0.147	0.894	0.826	0.808	0.786			
SCR	0.595	0.179	0.425	0.773	0.633	0.490	0.987		
TN	0.863	0.243	0.537	0.764	0.962	0.732	0.842	0.619	

It is a statistical measure that calculates the similarity between latent variables and assesses discriminant validity.

Inferences (HTMT ratio < 0.85): *It represents the average of all correlations between indicators across different constructs, compared to the average of the correlations between indicators measuring the same construct. If HTMT value is >0.85, then it indicates that there is a lack of discriminant validity.*

Table 9. Discriminant validity: Cross loadings

	AB	**CBA**	**DP**	**IP**	**RC**	**RM**	**SA**	**SCR**	**TN**
ABT1	0.930	0.039	0.363	0.543	0.628	0.640	0.453	0.515	0.650
ABT2	0.917	0.106	0.242	0.580	0.673	0.682	0.458	0.433	0.746
ABT3	0.873	0.156	0.354	0.526	0.750	0.552	0.444	0.469	0.716
CBA	0.111	1.000	-0.084	0.135	0.189	0.018	0.117	0.165	0.232
DP1	0.301	−0.078	0.902	0.446	0.386	0.307	0.569	0.286	0.463
DP2	0.340	−0.075	0.924	0.357	0.347	0.377	0.551	0.353	0.372
IP1	0.649	0.136	0.482	0.960	0.806	0.528	0.645	0.704	0.674
IP2	0.467	0.116	0.316	0.922	0.665	0.569	0.490	0.559	0.609
RC1	0.714	0.195	0.353	0.682	0.958	0.561	0.491	0.478	0.848
RC2	0.734	0.167	0.413	0.833	0.960	0.576	0.656	0.596	0.833
RM1	0.679	0.037	0.299	0.534	0.544	0.932	0.443	0.413	0.583
RM2	0.582	-0.008	0.402	0.527	0.547	0.906	0.566	0.339	0.578
SA1	0.404	0.058	0.713	0.499	0.566	0.544	0.833	0.465	0.585
SA2	0.439	0.137	0.340	0.540	0.453	0.383	0.861	0.741	0.471
SCR1	0.502	0.152	0.253	0.635	0.528	0.355	0.711	0.940	0.521
SCR2	0.471	0.158	0.411	0.640	0.521	0.417	0.632	0.931	0.500

TN1	0.752	0.227	0.378	0.579	0.828	0.615	0.493	0.455	0.958
TN2	0.737	0.217	0.493	0.734	0.849	0.593	0.697	0.592	0.956
ABT1	0.930	0.039	0.363	0.543	0.628	0.640	0.453	0.515	0.650

Inferences:

1. An item in a construct shall load considerably well onto its own construct instead of other constructs.

*2. **Loadings on own construct:** Indicators should load highly on the latent variable they are intended to measure (e.g., values > 0.7).*

*3. **Loadings on other constructs:** Indicators should load lower on other constructs compared to their loading on their associated construct.*

DISCUSSION

5.1 Interpretation of Results

1. ***SRMR:*** It calculates the discrepancy between the model's observed and predicted correlations. It is an absolute goodness-of-fit measure.

Thresholds:

SRMR ≤ 0.08: *Acceptable model fit.*

SRMR ≤ 0.10: *Considered marginally acceptable.*

Value *in Table 10 is* ***0.075*** *for both models, indicating that the model has an acceptable fit.*

2. ***d_ULS:*** It compares the inconsistency between observed and model-implied matrices using the Unweighted Least Squares (ULS) method. A lower value indicates better model fit, but there is no strict threshold; it is typically used for comparison between models. ***Value*** *in Table 10 is* ***0.968****, which suggests a good fit based on ULS.*

3. ***d_G:*** It compares the incongruity between the observed and model-implied matrices using a Geodesic distance measure. Similar to d_ULS, smaller values indicate a better fit. ***Value*** in Table 10 is ***1.759***, which also suggests a reasonable model fit.

4. ***Chi-Square:*** *It assesses the discrepancy between the observed covariance matrix and the one predicted by the model.*

- *Lower values of χ2 suggest better fit.*
- *It is sensitive to sample size; with large sample sizes, the χ2 test often becomes significant even for well-fitting models.*

Value *in Table 10 is* ***2339.760****, which reflects the overall fit. Its high value might indicate a large sample size or minor misfit.*

5. ***NFI:*** *It compares the model's Chi-Square value with a baseline model. It evaluates incremental fit.*

NFI ≥ 0.90: *Indicates good fit*

NFI < 0.90: *Indicates poor fit*

Value *in Table 10 is* ***0.560****, which is below the acceptable threshold. This suggests that the model's fit is suboptimal and could be improved.*

Table 10. Summary of model fit for measurement model assessment

Parameters	Estimated model
Standardized Root Mean Square Residual (SRMR)	0.075
Squared Euclidean Distance (d_ULS)	0.968
Geodesic Distance (d_G)	1.759
Chi-square	2339.760
Normed Fit Index (NFI)	0.560

Inferences:

*1. **SRMR (≤0.08)**, **d_ULS**, and **d_G values** suggest acceptable model fit.*

*2. **χ2** is **high**, likely due to sample size.*

*3. **NFI (≥0.90)** is below the acceptable threshold, indicating potential issues with incremental fit and suggesting the model could be improved.*

Table 11. Summary of path coefficients for structural model assessment

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	*t*-statistics (|O/STDEV|)	*p*-values
AB	−0.033	−0.033	0.023	1.398	0.162
DP	0.031	0.036	0.068	0.451	0.652
IP	−0.155	−0.163	0.091	1.701	0.089
RC	0.345	0.353	0.147	2.342	0.019
RM	0.359	0.351	0.075	4.802	0.000
SA	−0.214	−0.213	0.083	2.584	0.010
SCR	0.243	0.250	0.095	2.559	0.011
TN	0.349	0.350	0.135	2.587	0.010

Inferences:

*1. **$p<0.05$** indicates a statistically significant relationship and **$p\geq0.05$** means the relationship is **not statistically significant**.*

*2. **$t>1.96$** (critical value) (two tailed) and **$p<0.05$** mean significant results and **H_a is substantiated***

5.2 Implications and Limitations of the Study

The adoption of blockchain technology in commodity markets, using a systems approach, has significant implications. It can enhance transparency, efficiency, and trust among trading partners by providing a decentralized and tamper-proof system. This can lead to reduced transaction costs and improved supply chain traceability. However, there are limitations, such as the high initial implementation costs, scalability issues, and the need for regulatory compliance. Additionally, the integration of blockchain with existing systems can be multifaceted and may necessitate significant modifications in business processes.

CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

This study aimed to validate a blockchain-based system in commodity markets by means of a measurement and structural model assessment-based approach wherein the structural model provides a strong explanation for the adoption of blockchain technology, with over 70% of its variance explained by the predictors. In addition, the small difference between R-squared and Adjusted R-squared suggests the model is not overfitting and is well-balanced in terms of complexity. The adoption of blockchain technology in commodity markets has shown promising results in enhancing transparency, efficiency, and security. By providing a decentralized and tamper-proof system, blockchain can significantly reduce transaction costs, improve supply chain traceability, and build trust among trading partners. However, the high initial implementation costs, scalability issues, and regulatory compliance challenges remain significant barriers. Future research should focus on developing scalable blockchain solutions that can integrate seamlessly with existing systems. Additionally, exploring the regulatory landscape and creating standardized frameworks for blockchain adoption will be crucial. Empirical studies on the long-term impact of blockchain on commodity market's sustainability and market dynamics will provide deeper insights. Collaborative efforts among academia, industry, and regulators will be fundamental to harness blockchain technology's complete potential in metamorphosing commodity markets.

REFERENCES

[1] What is a Commodity? Business Dictionary, [Online], *Available:* http://www.businessdictionary.com/definition/commodity.html (*accessed on* January 01, 2025)

[2] Commodity Definition | What Does Commodity Mean, [Online], *Available:* https://www.ig.com/en/glossary-trading-terms/commodity-definition (*accessed on* January 24, 2025).

[3] What is Commodity Trading - Definition, Advantages & History, [Online], *Avaialble:* https://www.samco.in/what-is-commodity-trading (*accessed on* January 27, 2025).

[4] V. B. Lobo and M. Rao, "An Empirical Study on Blockchain Technology-Enabled Systems in Commodity Markets," 2022 *International Conference on Emerging Trends in Engineering and Medical Sciences (ICETEMS)*, Nagpur, India, 2022, pp. 232-237, DOI: 10.1109/ICETEMS56252.2022.10093567.

[5] D.S. Jacks, Intra- and International Commodity Markets Integration in the Atlantic Economy, Department of Economy Simon Fraiser University, pp. 1800 1930, 2005.

[6] Vivian Brian Lobo, *et al.* (2023). Modelling the Process of Building Digital Security in Commodity Markets using Blockchain. *International Journal on Recent and Innovation Trends in Computing and Communication*, 11(11), 254–263. https://doi.org/10.17762/ijritcc.v11i11.9389

[7] Blockchain technology market size worldwide in 2017 and 2018, with forecasts from 2019 to 2027 (https://www.statista.com/statistics/1015362/worldwide-blockchain-technology-market-size/)

[8] Toorajipour, Reza, Pejvak Oghazi, Vahid Sohrabpour, Pankaj C. Patel, and Rana Mostaghel. "Block by block: A blockchain-based peer-to-peer business transaction for international trade." *Technological Forecasting and Social Change*, 180 (2022): 121714.

[9] Agibalova, E.N., Ilovaysky, I.B., Kayl, Y.Y., Usanova, V.A. (2020). Use of Letter of Credit Form of Payment in the Implementation of Smart Contracts and Blockchain Technology. *In: Popkova, E., Sergi, B. (eds) Scientific and Technical Revolution: Yesterday, Today and Tomorrow. ISC 2019. Lecture Notes in Networks and Systems*, vol 129. Springer, Cham. https://doi.org/10.1007/978-3-030-47945-9_18

[10] Samy, Hossam, Ashraf Tammam, Ahmed Fahmy, and Bahaa Hasan. "Enhancing the performance of the blockchain consensus algorithm using multithreading technology." *Ain Shams Engineering Journal*, 12, no. 3 (2021): 2709-2716.

[11] Belu, Mihaela Gabriela. "Application of blockchain in international trade: An overview." *The Romanian Economic Journal*, 71, no. 22 (2019): 2-16.

[12] Chang, Shuchih Ernest, Yi-Chian Chen, and Tzu-Ching Wu. "Exploring blockchain technology in international trade: Business process re-engineering for letter of credit." *Industrial Management & Data Systems*, 119, no. 8 (2019): 1712-1733.

[13] Jain, Neha, and R. R. Sedamkar. "A blockchain technology approach for the security and trust in trade finance." *In 2020 14th International Conference on Innovations in Information Technology (IIT)*, pp. 192-197. IEEE, 2020.

[14] Kowalski, Michał, Zach WY Lee, and Tommy KH Chan. "Blockchain technology and trust relationships in trade finance." *Technological forecasting and social change* 166 (2021): 120641.

[15] Xu, De, and Qing Yang. "The systems approach and design path of electronic bidding systems based on blockchain technology." *Electronics*, 11, no. 21 (2022): 3501.

[16] Sharma, Mahak, Ashwaq Al Khalil, and Tugrul Daim. "Blockchain technology adoption: Multinational analysis of the agriculture supply chain." *IEEE Transactions on Engineering Management* (2022).

[17] Agrawal, Tarun Kumar, Vijay Kumar, Rudrajeet Pal, Lichuan Wang, and Yan Chen. "Blockchain-based framework for supply chain traceability: A case example of textile and clothing industry." *Computers & industrial engineering* 154 (2021): 107130.

[18] Taherdoost, Hamed, and Mitra Madanchian. "Blockchain-based new business models: A systematic review." *Electronics* 12, no. 6 (2023): 1479.

[19] Turjo, Manoshi Das, Mohammad Monirujjaman Khan, Manjit Kaur, and Atef Zaguia. "Smart supply chain management using the blockchain and smart contract." *Scientific programming* 2021, no. 1 (2021): 6092792.

[20] Rana, Sumit Kumar, Hee-Cheol Kim, Subhendu Kumar Pani, Sanjeev Kumar Rana, Moon-Il Joo, Arun Kumar Rana, and Satyabrata Aich. "Blockchain-based model to improve the performance of the next-

generation digital supply chain." *Sustainability* 13, no. 18 (2021): 10008.

[21] Sweeney, Edward. "The Systems Approach to Analysing Supply Chains and Improving their Performance." (1999).

[22] Tsolakis, Naoum, Roman Schumacher, Manoj Dora, and Mukesh Kumar. "Artificial intelligence and blockchain implementation in supply chains: a pathway to sustainability and data monetisation?." *Annals of Operations Research* 327, no. 1 (2023): 157-210.

[23] Kumar, Rajeev, and Dilip Kumar. "Blockchain-based smart dairy supply chain: Catching the momentum for digital transformation." *Journal of Agribusiness in Developing and Emerging Economies* (2023).

[24] Lee, Joseph, and Vere Marie Khan. "Blockchain and energy commodity markets: legal issues and impact on sustainability." *The Journal of World Energy Law & Business*, 15, no. 6 (2022): 462-484.

[25] Su, Yi-Jen, Chao-Ho Chen, Tsong-Yi Chen, and Chun-Wei Yeah. "Applying Ethereum blockchain and IPFS to construct a multi-party used-car trading and management system." *ICT Express*, 10, no. 2 (2024): 306-311.

[26] Yang, Fan, Hai Yu, Craig Wilson, Gady Jacoby, and Zhenyu Wu. "Blockchain technology and international countertrade." *Journal of International Financial Markets, Institutions and Money*, 91 (2024): 101933.

[27] Wang, Xiaohui, Peng Liu, and Zhixiang Ji. "Trading platform for cooperation and sharing based on blockchain within multi-agent energy internet." *Global Energy Interconnection*, 4, no. 4 (2021): 384-393.

[28] Stopfer, Lukas, Alexander Kaulen, and Thomas Purfürst. "Potential of blockchain technology in wood supply chains." *Computers and Electronics in Agriculture* 216 (2024): 108496.

[29] Kowalski, Michał, Zach WY Lee, and Tommy KH Chan. "Blockchain technology and trust relationships in trade finance." *Technological forecasting and social change* 166 (2021): 120641.

[30] Bai, Yutong, Yang Liu, and Wee Meng Yeo. "Supply chain finance: What are the challenges in the adoption of blockchain technology?." *Journal of Digital Economy* 1, no. 3 (2022): 153-165.

[31] Kharche, Arya, Sanskar Badholia, and Ram Krishna Upadhyay. "Implementation of blockchain technology in integrated IoT networks for constructing scalable ITS systems in India." *Blockchain: Research and Applications* (2024): 100188.

[32] Sonawane, Swapnil, and Dilip Motwani. "Issues of commodity market and trade finance in India and its solutions using blockchain technology." *In Emerging Technologies in Data Mining and Information Security: Proceedings of IEMIS 2022*, Volume 1, pp. 451-459. Singapore: Springer Nature Singapore, 2022.

[33] Wang, Yingli, Jeong Hugh Han, and Paul Beynon-Davies. "Understanding blockchain technology for future supply chains: a systematic literature review and research agenda." *Supply Chain Management: An International Journal* 24, no. 1 (2019): 62-84.

[34] Dutta, Pankaj, Tsan-Ming Choi, Surabhi Somani, and Richa Butala. "Blockchain technology in supply chain operations: Applications, challenges and research opportunities." *Transportation research part e: Logistics and transportation review*, 142 (2020): 102067.

[35] Liao, Chia-Hung, Hui-En Lin, and Shyan-Ming Yuan. "Blockchain-enabled integrated market platform for contract production." *IEEE Access*, 8 (2020): 211007-211027.

[36] Sharma, Mahak, Ashwaq Al Khalil, and Tugrul Daim. "Blockchain technology adoption: Multinational analysis of the agriculture supply chain." *IEEE Transactions on Engineering Management* (2022).

[37] Chang, Yali, Jianwu Lin, and Chengying He. "Blockchain-based Options for Physical Settlement of Commodity Futures." *In The CME Vulnerability: The Impact of Negative Oil Futures Trading*, pp. 223-251. 2021.

[38] Raveendarnaik, A. "The major issues in development of commodity derivatives market in India." *IOSR J Bus Manag (IOSR-JBM)* (2017): 41-46.

[39] Lobo, V.B., Rao, M. (2024). A Conceptual Framework for Building Robust Blockchain Technology-Enabled Business Processes in Commodity Markets: A Systems Approach. In: Senjyu, T., So–In, C., Joshi, A. (eds) Smart Trends in Computing and Communications. *SmartCom 2024 2024. Lecture Notes in Networks and*

Systems, vol 945. Springer, Singapore. https://doi.org/10.1007/978-981-97-1320-2_14

[40] Ringle, C. M., Wende, S., and Becker, J.-M. 2024. "SmartPLS 4." *Bönningstedt: SmartPLS*, https://www.smartpls.com.

[41] Hair Jr, J.F., Hult, G.T.M., Ringle, C.M., Sarstedt, M., Danks, N.P. and Ray, S., 2021. Partial least squares structural equation modeling (PLS-SEM) using R: A workbook (p. 197). *Springer Nature*.

[42] Dijkstra, T.K. and Henseler, J., 2015. Consistent partial least squares path modeling. *MIS quarterly*, 39(2), pp.297-316.

[43] Hair, J. F., Jr., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2016). A primer on partial least squares structural equation modeling (PLS-SEM). London: *Sage Publications*.

[44] Jöreskog, K.G., 1971. Statistical analysis of sets of congeneric tests. *Psychometrika*, 36(2), pp.109-133.

[45] Diamantopoulos, A., Sarstedt, M., Fuchs, C., Wilczynski, P. and Kaiser, S., 2012. Guidelines for choosing between multi-item and single-item scales for construct measurement: A predictive validity perspective. *Journal of the Academy of Marketing Science*, 40, pp.434-449.

[46] Fornell, C. and Larcker, D.F., 1981. Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, 18(1), pp.39-50.