EXPLORING BLOCK CHAIN TECHNOLOGY IN COMMODITY MARKETS : A MEASUREMENT AND STRUCTURAL MODEL VALIDATION

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Abstract

This study explores the application and validation of blockchain technology in commodity markets, focusing on the effectiveness and potential impact of blockchain-based systems. Using a combination of measurement and structural modeling techniques, the research aims to assess how blockchain can enhance transparency, reduce transaction costs, and improve security in commodity trading. A structural model is developed to identify key factors influencing the adoption and implementation of blockchain technology within commodity markets. The model is tested using data from industry participants and commodity traders, allowing for the evaluation of blockchain's performance in real-world scenarios. Through this empirical validation, the study provides a comprehensive understanding of the technological, economic, and regulatory challenges associated with blockchain integration in commodity markets. The findings highlight the significant potential of blockchain in transforming commodity trading by improving operational efficiencies, reducing fraud, and enhancing trust between market participants. This research contributes to the growing body of knowledge on blockchain's role in financial markets and offers insights for stakeholders considering the adoption of this disruptive technology in commodity sectors.

INTRODUCTION

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].

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. 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. This resulted in enhanced transparency, integrity, and traceability throughout the entire e-bidding process. Dr.Naveen Prasadula [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. Marin *et al.* [17] proposed a blockchain-based traceability framework for textile and clothing industry to address the challenges of information asymmetry and low visibility. Symonds [18] provided a systematic review of new business models developed using blockchain technology from 2012 to 2022.

Study of Objectives

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.

METHODOLOGY

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

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

1.1. 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.

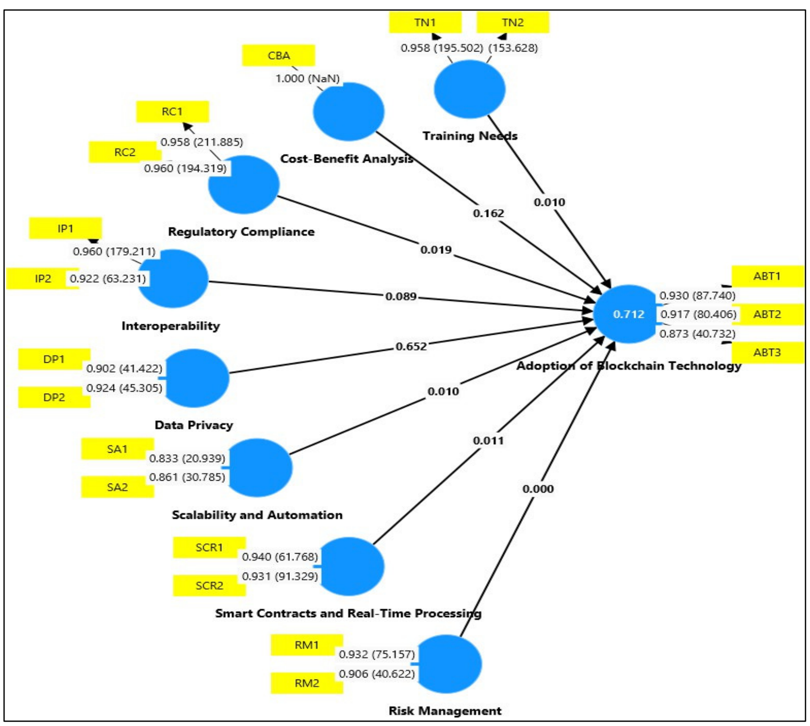


Figure 1. Structural model

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

1.2. 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 ($p = 0.000$).

5. ***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.

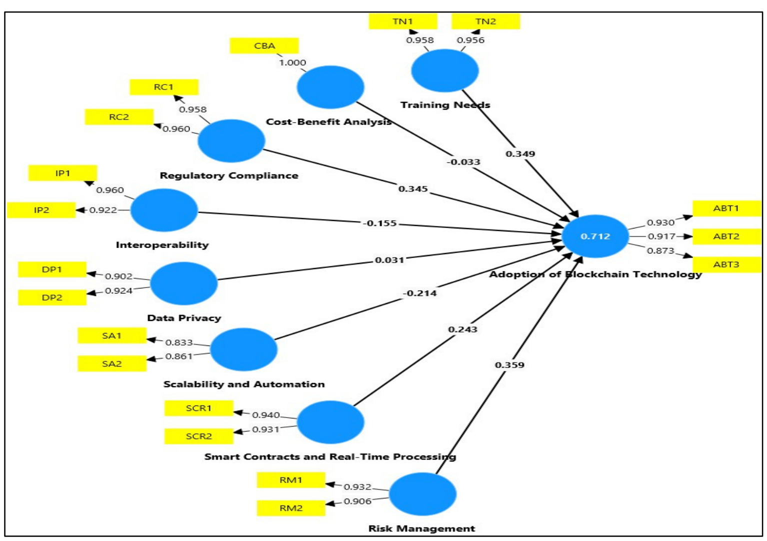


Figure 2. Measurement model

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.

1.3. 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

1.4. 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

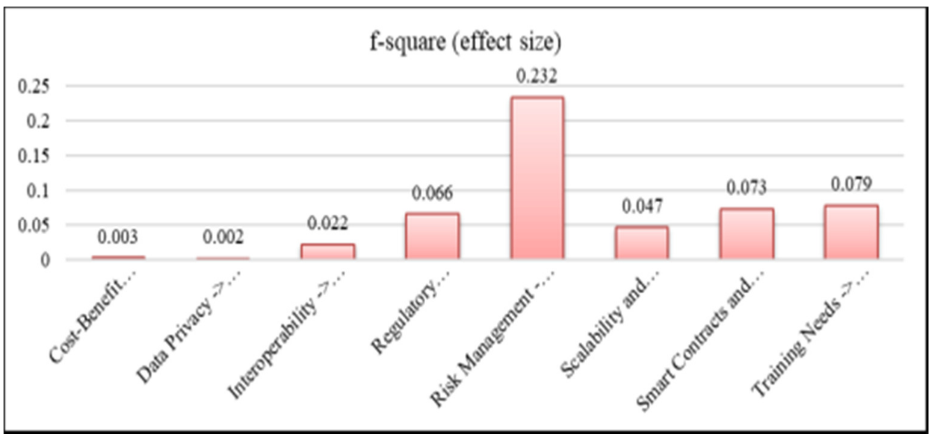
	R-square	R-square adjusted
Adoption of Blockchain Technology	0.712	0.703

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.

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.*

4.

5. 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 $\chi 2$ suggest better fit.
- It is sensitive to sample size; with large sample sizes, the $\chi 2$ 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

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≥0.05*** *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

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. 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.
2. D.S. Jacks, Intra- and International Commodity Markets Integration in the Atlantic Economy, Department of Economy Simon Fraiser University, pp. 1800 1930, 2005.
3. 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
4. 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/)
5. 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.
6. Dr. Naveen Prasadula (2024) Exploring Block Chain Technology In Commodity Markets : A Measurement And Structural Model Validation.
7. 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
8. 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.
9. Belu, Mihaela Gabriela. "Application of blockchain in international trade: An overview." *The Romanian Economic Journal*, 71, no. 22 (2019): 2-16.
10. 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.
11. 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.
12. Kowalski, Michał, Zach WY Lee, and Tommy KH Chan. "Blockchain technology and trust relationships in
13. trade finance." *Technological forecasting and social change* 166 (2021): 120641.
14. 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.
15. Dr.Naveen Prasadula(2024) "Blockchain technology adoption: Multinational analysis of the agriculture supply chain." *IEEE Transactions on Engineering Management* .
16. Taherdoost, Hamed, and Mitra Madanchian. "Blockchain-based new business models: A systematic review." *Electronics* 12, no. 6 (2023): 1479.

17. Manjit Kaur. "Smart supply chain management using the blockchain and smart contract." *Scientific programming* 2021, no. 1 (2021): 6092792.
18. 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-
19. generation digital supply chain." *Sustainability* 13, no. 18 (2021): 10008.
20. Sweeney, Edward. "The Systems Approach to Analysing Supply Chains and Improving their Performance." (1999).
21. 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.
22. 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.
23. 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.
24. 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.
25. 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.
26. Stopfer, Lukas, Alexander Kaulen, and Thomas Purfürst. "Potential of blockchain technology in wood supply chains." *Computers and Electronics in Agriculture* 216 (2024): 108496.
27. Kowalski, Michał, Zach WY Lee, and Tommy KH Chan. "Blockchain technology and trust relationships in
28. 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.
29. Greinidge "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.
30. 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.
31. 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.
32. Liao, Chia-Hung, Hui-En Lin, and Shyan-Ming Yuan. "Blockchain-enabled integrated market platform for contract production." *IEEE Access*, 8 (2020): 211007-211027.
33. 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-
34. 251. 2021.
35. Symonds. "The major issues in development of commodity derivatives market in India." *IOSR J Bus Manag (IOSR-JBM)* (2017): 41-46.
36. Lobo, V.B., Rao, M. (2024). A Conceptual Framework for Building Robust Blockchain Technology-Enabled Business Processes in Commodity Markets: