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The Role of Blockchain Technology in Reducing the Transaction Cost of Agricultural Supply Chain

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Abstract:
Given the critical importance of the agricultural product supply chain in our country, this study was conducted to examine the role of blockchain technology in reducing transaction costs in this sector. The research is practical in purpose and analytical-correlational in terms of data collection and analysis. First, through a review of existing literature, the advantages and capabilities of blockchain technology were identified. Using comprehensive definitions of transaction costs, the relationship between blockchain and transaction costs was explored. As transaction costs include elements such as contract enforcement and building trust between parties, blockchain offers a suitable platform for addressing these challenges. Although official statistics on the implementation of blockchain in Iranian companies are not yet available, the views of managers and union representatives active in the agricultural supply chain were examined. The findings indicate that, from the perspective of these practitioners, features such as confidentiality, transparency, reduced manual interventions, and consistent monitoring through blockchain platforms contribute to lowering transaction costs in the agricultural supply chain.

Keywords: Blockchain Technology, Transaction Cost, Agriculture, Supply Chain, Marketing.

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INTRODUCTION

Implementing the supply chain yields benefits such as cost reduction, increased market share, and stronger customer relationships (Khosravipour & Shoaibi, 2019). However, a major weakness is the lack of rapid access to information regarding the quantity, location, and price of products. This limits timely communication with various suppliers and impedes effective comparison in terms of cost and supply capabilities. Moreover, there is no systematic forecasting of supply and demand for different products, leading to market imbalances and irregular price fluctuations (Zarei & Azizi, 2025). The blockchain platform can record product status from planting to harvest, inventory, and delivery, allowing for necessary updates. A key advantage of this structure is that the decentralized information recorded on the blockchain can be utilized in warehouse inventory management. The ability to trace products and prevent shipment loss is another benefit of blockchain in the supply chain. By reducing intermediaries and enabling validation, it can significantly lower transaction costs in the agricultural product market. The application of blockchain technology is expanding rapidly. Its integration with the supply chain enhances visibility throughout the value chain, reduces paperwork, ensures transparency among parties, and improves data security. However, implementing blockchain in Iran faces numerous challenges. This study aims to highlight the role of blockchain features such as confidentiality, transparency, consistent monitoring, and reduced manual interventions in lowering transaction costs in the agricultural supply chain, thereby contributing to its improvement in Iran (Azizi, et al. 2010).

Tayeizadeh and Rezaei (2019), in a study titled The Impact of Blockchain on Supply Chain Information, identified key points for utilizing blockchain capacities in the supply chain through a structural analysis of blockchain and the Internet of Things. They emphasized the integration and control of material flow from top to bottom and highlighted the digitization of the supply chain, noting that blockchain implementation enables an adaptable supply chain. Nasser (2019), in Legal Analysis of the Function of Smart Contracts in Digital Transfers of Financial Markets, used a documentary method to examine the mechanism and function of smart contracts. They concluded that implementing smart contracts in Iran's exchange system relies on the blockchain platform. They also emphasized the importance of transparency and database use (e.g., Ora Kol) but noted challenges due to international legal frameworks. Taami and Riahi (2019), in Supply Chain, Blockchain Technology and Its Impact on the Prevention of Commodity Smuggling, proposed a model combining smart contracts and multi-agent systems (MAS) for food tracking. This model promotes a circular economy (make-use-recycle) over the traditional linear value chain (take-make-dispose). It is based on the GS1 standard for global commodity numbering, already in use in countries including Iran. Radfar (2016), in Effective Drivers of the Desire to Use Financial Services in Platforms Based on Blockchain, analyzed customer intentions to use blockchain-based financial services. The study found that blockchain could significantly transform the banking system and has the potential to reshape the broader economy. Jabarzadeh et al. (2016), in Multi-objective Mathematical Model for Managing the Direct and Indirect Integrated Supply Chain of Apple Trees, presented a multi-period, multi-objective integer linear programming model. It addresses both forward and reverse logistics in the apple supply chain, including orchards, distribution centers, composting facilities, and markets (domestic and foreign). Khosravipour and Shoaibi (2019), in Agricultural Supply Chain Management Concepts and Strategies, through a literature review, defined the agricultural supply chain as a combination of related organizations, resources, and processes that deliver agricultural products and services to end users. Sharifzadegan and Aboutalebpour (2008), in Reducing Transaction Costs by Spatial Planning to Optimize Urban Service Centres: Case Study of Fruit and Vegetable Markets in Tehran Region 5, proposed a method to estimate reduced demand based on land use optimization. They demonstrated a decrease in exchange costs by reducing travel demand through better spatial planning.

Casado Vara et al. (2018), in a study titled Blockchain Improves Supply Chain: A Study of Foodstuffs proposed a new model aimed at enhancing supply chain operations. The model integrates blockchain, smart contracts, and a multi-agent system (MAS) to coordinate food tracking in the agricultural supply chain. It enables the application of circular economy principles and ensures that if parties fail to meet agreed terms; predefined penalties are enforced, supported by relevant authorities for legitimacy verification. The model is more efficient than existing ones, allows for validation through established systems, and can be further enhanced through case-based reasoning (CBR) system integration. Saberi et al. (2018), in a study titled Blockchain and its Relationship with Sustainable Supply Chain Management, noted that blockchain is still in its early developmental stages and faces various behavioural, organizational, technological, and policy-related challenges. The study emphasizes that blockchain can highlight and track five essential product attributes: nature (what the product is), quality (how it is), quantity (how much it is), location (where it is), and ownership (who owns it at a given time). The findings suggest that blockchain technology enhances the management of economic and environmental sustainability more effectively than social sustainability within supply chains. Min (2018), in a study titled Blockchain Technology to Increase Supply Chain Flexibility, discusses how blockchain contributes to improving operational speed and reducing risks and security threats in the supply chain. Sadeghi et al. (2018), in a study titled The Role of Blockchain in Achieving the Key Goals of Sustainable Supply Chain Management, highlights the core objectives of supply chains and analyses them through a case study. He emphasizes that the effectiveness of blockchain increases when it operates within a network involving multiple participants. Min, et al. (2019), in their research titled Defining Supply Chain: Past, Present, Future, provide a historical overview of supply chain management and present findings from 28 interviews conducted with executives and academics from the University of Tennessee (UT). The study explores dominant perspectives on the prerequisites and expected outcomes of SCM. Lohmer et al. (2020), in an article titled Analysis of Flexibility Strategies and the Effect of Waves on Blockchain and Supply Chain Coordination: A Factor-Based Simulated Study, argue that blockchain use in supply chains can significantly reduce the number of affected partners during disruptions. The paper models various scenarios for BCT application in SCM and emphasizes flexibility using simulation-based methods. Leng et al. (2018), in a study titled Research on the Supply Chain of Dual-Structure, Blockchain-Based Agricultural Products, conducted a simulation-based analysis in China. It investigates a POS-based weighted consensus algorithm for blockchain and concludes that its implementation enhances public service credibility, system efficiency, and reduces rent-seeking behaviour in agricultural supply chains. Ronaghi (2020), in a study titled Blockchain Maturity Model in the Agricultural Supply Chain, proposes a model to assess blockchain maturity. The research was conducted in three stages: ranking blockchain dimensions using the SWARA method by 13 agricultural faculty members, designing a maturity evaluation model, and validating the model using data from an agricultural food production company. Dutta et al. (2020), in their comprehensive review Blockchain Technology in Supply Chain Operations: Research Programs, Challenges, and Opportunities, analysed 178 articles on blockchain and SCM integration. The study outlines sector-specific opportunities and challenges in adopting blockchain across industries including transportation, manufacturing, finance, healthcare, agriculture, and education, highlighting blockchain's transformative potential.

The concept of transaction costs was first introduced by Ronald Coase in 1937 as part of his effort to establish a framework for determining when an economic activity should be carried out within a firm and when it should be handled through the market (Nikzadi Panah et al. 2021). Following Coase, many researchers explored this concept, the most prominent among them being Oliver Williamson, who expanded on it extensively in his book The Economics of Transaction Costs (Mangla, et al. (2018). Williamson provided detailed arguments for the significance of transaction costs and contributed significantly to developing the theory. Transaction costs refer to the costs incurred in the process of achieving economic equilibrium (Keshetri, 2018). These costs include:

Search and information costs: These involve the effort to locate sources of goods and services and obtain price and quality information. Increased availability of information can reduce other transaction costs.

Contracting costs: These are the expenses associated with negotiating and formalizing agreements between parties.

Monitoring and enforcement costs: These refer to the resources spent to ensure compliance with contractual terms and to resolve disputes when breaches occur. Today, the transaction cost concept is widely used to explain behaviours of individuals and institutions. It extends beyond market exchanges to everyday activities such as commuting or informal agreements, highlighting its relevance in various social and economic contexts.

The introduction of smart contracts into a country's legal system can add a transformative technological layer that helps prevent legal disputes and securely records transactions, thereby contributing to the advancement of the economic system and other sectors (Maikel, 2019) To establish a reliable economic system, all individuals must be identified within a comprehensive legal framework that grants them access to such systems under defined legal conditions. As discussed in relation to transaction costs, one effective approach to reducing contracting costs is the implementation of a blockchain platform. This technology enhances transparency and builds trust in transactions within the agricultural supply chain. Significant international progress has been made to prevent the misuse of virtual currencies, notably through the ratification of the 2017 Convention on the Uniformity of Transactions Based on Virtual Currencies. Smart contracts—due to their speed, accuracy, and cost-efficiency—are increasingly seen as viable alternatives to traditional contracts. The formalities outlined in paragraph 2 of the Convention resemble those used in developed countries to legalize digital signatures. These procedures facilitate the identification of currency holders by governments and reduce the likelihood of money laundering and other criminal activities. Additionally, the use of the internet lowers the cost of searching for market information on the availability and location of goods and services. The integration of blockchain technology into the agricultural supply chain fundamentally alters the structure of the supply chain model. In this model, all members of the supply chain record their transactions on the blockchain, which enhances transaction security. Moreover, the model addresses the shortcomings of the current supply chain by decentralizing data, allowing each participant to access relevant information necessary for their operations. For instance, the producer can view product details from the processor as well as shipping information.

METHODOLOGY

In this study, after distributing and collecting questionnaires, conclusions and suggestions were presented based on the analysis of the data. The sample included 80 managers active in the agricultural supply chain in Mashhad in 1400, all familiar with the blockchain platform. Although official statistics on blockchain implementation in these companies have not yet been published, making cost comparisons impossible, the opinions of active managers and unions were examined.

The research hypotheses are as follows:

The confidentiality of the blockchain platform reduces transaction costs in the agricultural supply chain.

The transparency of the blockchain platform reduces transaction costs in the agricultural supply chain.

The reduction of manual interventions by the blockchain platform reduces transaction costs in the agricultural supply chain.

The consistency in inspection of the blockchain platform reduces transaction costs in the agricultural supply chain.

Confidentiality, Transparency, Reduction of Manual Interventions, and Consistency in Inspection are independent variables. The supply chain and transaction costs of agricultural products are the dependent variables. The questionnaire showed acceptable reliability, with a Cronbach's alpha coefficient above 0.7. Two methods were used to analyse the data (Falahati & Azizi, 2011).

Descriptive statistics: Data in this analysis are classified using descriptive indicators such as mean, median, mode, and presented with statistical tables and graphs.

Inferential statistics: This method uses structural equation modelling (SEM) with the partial least squares (PLS) approach to analyse relationships between variables. SEM is a statistical tool to examine relationships among multiple variables in a model.

In this research, SmartPLS software based on PLS was used. SEM evaluation includes three steps: Evaluation of

the measurement model (external), vvalidity assessment of the measurement model, evaluation of the structural model (internal).
After examining descriptive statistics (central tendency and dispersion indicators such as mean, standard deviation, and variance), the research variables show that the average of all components is above the theoretical mean of 3, indicating an appropriate status of the variables. Next, the Kolmogorov-Smirnov test was used to assess data normality; all variables had significance levels greater than 0.05. The structural equation modelling method with the partial least squares (PLS) approach was employed. In inferential statistics, since SmartPLS results are more reliable, assumptions related to PLS should be examined. Model analysis in SEM with PLS involves two steps: Checking model fit, ttesting research hypotheses, mmodel fit assessment includes three steps (mmeasurement model fit, sstructural model fit and Overall model fit (measurement and structural). After confirming the fit of measurement, structural, and overall models, the researcher can proceed to review and test the hypotheses based on the proposed model.

RESULTS

By examining concepts and definitions, reviewing the research literature, and studying previous works, the dimensions related to each research variable were identified, leading to the development of a conceptual model.
To test the research hypotheses, the path coefficients for each hypothesis must first be calculated. In the sub-output diagram, the path coefficients of the structural equation model are presented for hypothesis testing.
Since the significance of these coefficients cannot be assessed solely based on the magnitude of the standard estimation model coefficients, the t-value model is used to determine the significance of the path coefficients. If the t-values exceed the absolute value of 1.96, the relationships are considered significant at the 95% confidence level. The following diagram illustrates the t-value model for each of the paths.
Therefore, the graphs can be interpreted as a summary of the results of the research hypotheses as follows.

Table 1. The Result for Coefficients Model.

Test result	t-value	Path coefficients	Path
Confirmation	4.027	0.382	Confidentiality of the blockchain platform and reduction of exchange costs in the agricultural supply chain
Confirmation	5.207	0.526	Transparency of the blockchain platform and reduction of transaction costs in the agricultural supply chain
Confirmation	5.718	0.584	Reduce manual interventions of the blockchain platform and reduce transaction costs in the agricultural supply chain
Confirmation	4.234	0.412	Continuity in blockchain platform inspection and reduction of transaction costs in the agricultural supply chain

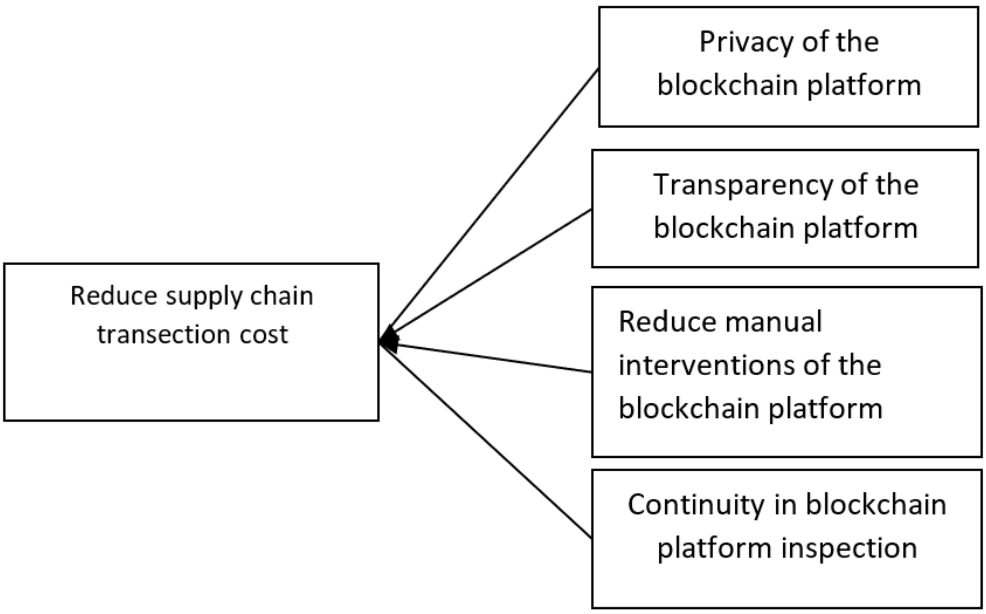

Figure 1. Conceptual Model of Research.

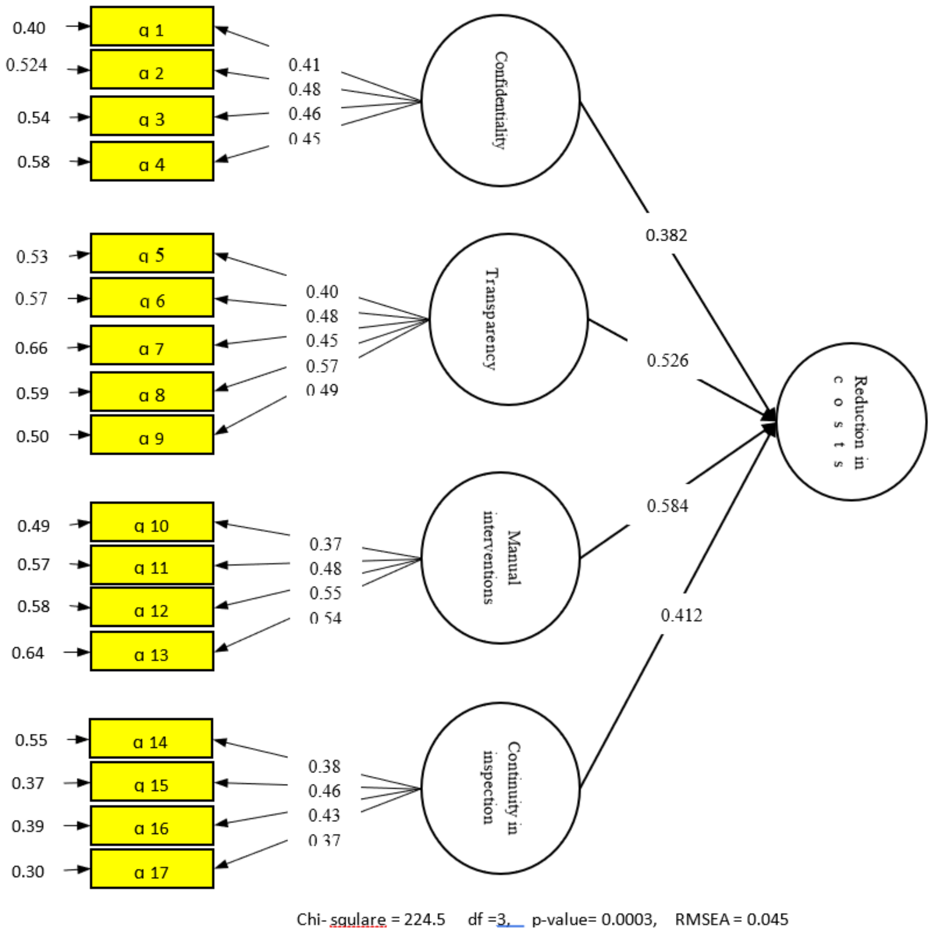

Figure 2. Model Path Coefficients.

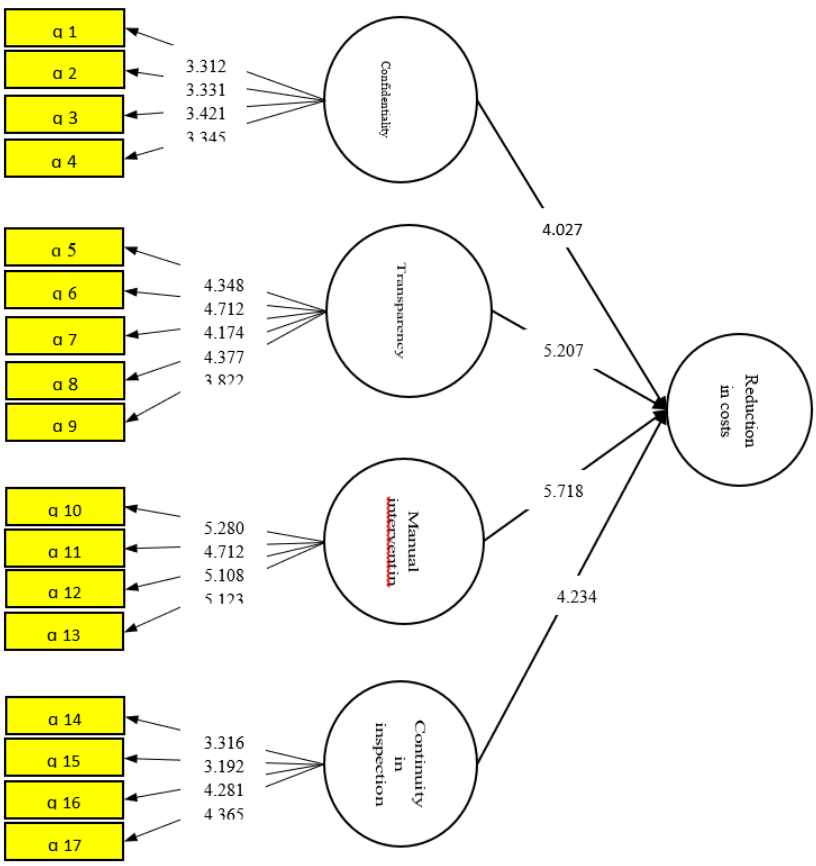

Figure 3. Significance Coefficients of the Model.

DISSCUSION AND CONCLUSION

Blockchain technology offers considerable potential to revolutionize the agricultural supply chain by significantly lowering transaction costs, boosting transparency, and enhancing overall efficiency. Conventional agricultural supply chains frequently face obstacles like disjointed communication, uneven access to information, and steep intermediary fees, all of which drive up transaction costs. By utilizing decentralized ledgers, smart contracts, and real-time traceability, blockchain effectively tackles these issues, fostering trust and optimizing operations among all stakeholders involved. Blockchain technology enhances transaction integrity by providing secure and tamper-resistant records. This reduces reliance on intermediaries, curtails fraud, and speeds up payment processes. As a result, financial and administrative expenses are lowered, while small-scale farmers benefit from fairer pricing and improved market opportunities. Additionally, the use of smart contracts to automate contractual operations minimizes negotiation and enforcement costs, leading to better coordination and increased reliability in supply chain activities.

According to the analysis of the questionnaires and the research findings, blockchain can reduce transaction costs through its distinctive features such as confidentiality, transparency, continuity, and reduced manual interventions. Similar studies also indicate that the limitations faced by supply chains can potentially be addressed by the capabilities of blockchain technology. From the perspective of managers, blockchain reduces the costs of contract formulation, prevents fraud and impersonation, and accelerates exchanges by lowering information acquisition costs. Its decentralized nature allows for public oversight, contributing to the development of a secure economic and social environment. However, blockchain is not a one-size-fits-all solution. Legal frameworks must support the implementation of smart contracts, which is recommended as a direction for future research. Further studies are also suggested on the challenges of implementing blockchain in Iran, such as the need for robust internet infrastructure and computing systems, managerial readiness, system compatibility, and data management.

The adoption of blockchain technology in agriculture comes with its share of challenges. Factors such as limited digital literacy, infrastructural constraints, and unclear regulations need to be resolved to enable broader usage. Despite these obstacles, pilot programs and case studies around the world have showcased the significant potential of blockchain to reduce transaction costs and improve value distribution across the supply chain.

In summary, although still an evolving technology, blockchain holds the promise to transform agricultural supply chains by cutting down transaction costs and fostering a system that is more transparent, fair, and efficient. To fully realize its potential and ensure equitable advantages for all participants in the agricultural sector, ongoing research, supportive policies, and investment in technology will be crucial.

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CONFLICT OF INTERESTS

The Authors declare that there is no conflict of interest.

AUTHORS CONTRIBUTIONS

Conceptualization — SMK, R., J.A.; Methodology — SMK, R.,F, S. and J.A.; Validation — SMK, R., J.A.; Investigation — SMK, R.,F, S. and J.A.; Resources — SMK, R., J.A.; Data Curation — SMK, R.,F, S. and J.A.; Writing — Original Draft — SMK, R.,F, S. and J.A.; Writing — Review & Editing — SMK, R., J.A.; Visualization — SMK, R.,F, S. and J.A.; Supervision — J.A.

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