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IMPACT OF BLOCKCHAIN TECHNOLOGY ON SUPPLY CHAIN TRANSPARENCY

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Abstract
The growing complexity of supply chains in the global marketplace raises concerns in the field of transparency, traceability, and accountability. The research aims to examine how the adoption of blockchain technology can advance supply chain transparency in the manufacturing and logistics sectors in Pakistan. The main goal is to determine the significance of introducing blockchain in increasing information visibility and operational trust in the supply chain. The survey method of a structured quantitative approach was utilized, and the study was based on the opinions of 300 supply chain executives working in diverse industries. The consistency of the instrument (Cronbach's alpha 0.873) proved that it possessed internal reliability. Statistical regression showed a positive correlation between blockchain adoption and supply chain transparency, with an $R^2 = 0.482$ and $p = 0.001$. Based on the findings, it is possible to conclude that this technology can enhance traceability, facilitate the sharing of real-time data, and combat fraud. Nonetheless, technological costs and employee resistance were also mentioned. These findings suggest that the research advises a strategic investment in blockchain infrastructure, worker training, and cooperation with technological vendors. The geographic focus and cross-sectional design of the study are its limitations. However, researchers who are keen on policies, supply chain management, and IT strategy can find this research relevant in promoting resilient and transparent supply networks in the digital era

INTRODUCTION

In today's global business landscape, the supply chain faces increased complexity, involving multiple stakeholders both locally and abroad. These transactions are cross-border, and the supply chain must share information immediately. This is the current situation facing the supply chain. All these have caused difficulties concerning transparency, traceability, and accountability at different stages of supply. Supply chain transparency has become a critical issue that affects consumer trust, regulatory adherence, and efficiency (Saberi et al., 2019). Nevertheless, the use of traditional supply chain systems that depend on paper-based interactions and are provided with fragmented flows of information often lacks the necessary visibility and traceability needed to achieve transparency and responsiveness (Wamba & Queiroz, 2022).

Blockchain technology has come to the limelight over the last few years because it is a transformational technology that has the potential to bolster supply chain transparency. Blockchain offers a decentralized, unalterable transaction record by which everybody in the supply chain can look at a single validated source of information, hence minimizing fraud, errors, and time loss (Francisco & Swanson, 2018). With the clear use of blockchain,

the movement and status of goods can also be viewed in real-time, and certification verification and compliance can be tracked throughout the supply chain network (Min, 2019). As a result, companies of various industries are turning to blockchain to build a more resistant and transparent supply chain infrastructure (Kouhizadeh et al., 2021).

Although the potential benefits of blockchain technology are massive, little effort has been devoted to assessing the potential practical implications in real-world settings, particularly in developing countries and less technologically integrated industries. Focusing on the blockchain adoption and its impact on transparency in the supply chain, it is necessary to quantitatively analyze to better estimate the nature of the effect and to provide data pointing to the direction of measures that should be made as part of a strategic decision.

Problem Statement

Heightening of attention by consumers and stakeholders, regulators have increased the emphasis on supply chain transparency. Nevertheless, visibility within their supply network is still a challenge in many organizations because of data systems in silos, inconsistent reporting, and their inability to monitor in real-time (Wamba et al., 2020). Although blockchain technology is already being marketed as a way of mitigating these challenges, the empirical evidence thus far does not support the argument that adopting it can produce a meaningful increase in supply chain transparency when the technology is still in its infancy and inadequately applied. The lack of information between these two camps restricts the potential of managers to find plausible reasons to invest in blockchain infrastructure. It constrains the possibility of researchers providing conclusive findings regarding its performance. The relationship between blockchain adoption and supply chain transparency, therefore, requires quantitative evaluation based on primary data, pointing out whether and to what extent the supply chain in question can be driven to practice a transparent chain through blockchain adoption.

Research Objectives

- To evaluate the effects of blockchain technology adoption on the transparency of supply.

LITERATURE REVIEW

Blockchain technology has increasingly been capturing the attention of academia when it comes to its potential to enhance transparency, trust, and traceability along the supply chains. Supply chain transparency describes the capacity of stakeholders to obtain accurate, timely, and comprehensive information about the flows, compliance, and practices of operations through the value chain (Saberi et al., 2019). This has, however, been a challenge in traditional supply chains that usually suffer fragmented information systems, little to no practice of data sharing, and are open to manipulation (Wamba et al., 2020). Recent reports have placed blockchain as a technological solution, which can fix these problems by providing users with immutable, decentralized, and real-time records of data accessible to all the supply chain members (Min, 2019).

Blockchain is a distributed ledger technology whereby any transaction is cryptographically punctuated and connected to the prior block, ensuring data integrity and reducing the likelihood of data tampering (Francisco & Swanson, 2018). Kouhizadeh et al. (2021) highlight that blockchain elevates the ability to see the supply chain in goods to a higher level where products can be tracked in the chain of path-end-user and especially in industries like food, pharmaceutical and fashion, where provenance plays an essential role. As an example, Abeyratne and Monfared (2016) indicated that in the instance of blockchain in food chains, there was a possibility to obtain certification documents, temperature history, and shipment details in real-time, which defined transparency and accountability in food supply chains.

Several quantitative and case-based studies have justified the positive correlation between blockchain implementation and supply chain clarity. Queiroz et al. (2020) conducted an empirical study in the logistics industry. They found that the organizations that adopted blockchain technologies witnessed better collaboration of stakeholders, a drop in fraud, and improved data accuracy. Likewise, a survey-based study conducted by Gurtu and Johny (2019) demonstrated that blockchain adoption has had a statistically significant effect on the enhancement of operational transparency, particularly in the global supply chain, which typically involves more actors

and more compliance demands. This is also reflected in the works of Wang et al. (2022), as noted by Hung et al., who remarked that blockchain enables due diligence and responsibility by suppliers concerning ethical sourcing through the availability of transactional data in a publicly verifiable and immutable manner.

However, researchers produced what they perceive as the limitations of blockchain implementation. They also face technical complexity of implementation, high cost of implementation, lack of standardization and regulatory uncertainties, which are a big deterrent (Wamba & Queiroz, 2022). In addition, the success of blockchain depends on the collaboration of stakeholders and digital preparations within the supply chain network. Unless there is adequate integration and user adoption, the transparency gains may fail to materialize (van Hoek, 2020).

Nonetheless, empirical studies on this topic have been limited to an exploratory framework and case studies despite the expanding literature. The quantitative gap that can be observed is an evident lack of quantitative studies that compare the direct effect of blockchain on the transparency of any supply chain using standardized measures and large-scale samples. This research paper fills this gap since it uses regression-based methodology to establish the power and significance of the two variables in this research, blockchain technology adoption and supply chain transparency, thereby contributing to scholarship and business practice.

Theoretical Framework

This paper is based on the Resource-Based View (RBV) and the Stakeholder Theory, which explains the improvement in supply chain transparency through blockchain technology.

Resource-Based View (RBV) is a perspective that proclaims that organizations must earn long-term competitive advantage by attaining and implementing valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney, 1991). Blockchain as a strategic resource can be discussed within the context of supply chain management since it enables real-time tracking, data immutability, and decentralized trust, which results in increased transparency and reduced information asymmetry (Saberi et al., 2019). The characteristics of blockchain mean that it is a VRIN capability, whose effective implementation results in enhanced supply chain performance, which includes those of improved visibility and responsiveness in addition to trust among the stakeholders (Queiroz et al., 2020).

Stakeholder Theory by Freeman (1984) states that organizations must answer not just to shareholders, but also to all stakeholders to fulfill their responsibility towards suppliers, customers, regulatory authorities, and society. Transparency has been a major requirement for stakeholders who require their suppliers to have good sourcing strategies, use ethical labor, and maintain logistic traceability. The use of blockchain is supportive of the stakeholder interests because it enables the possibility to trace and audit every transaction, meaning that the information distributed using the supply chain can be considered accurate and trustworthy (Wamba & Queiroz, 2022). Operations should be aligned with the expectations of the stakeholders to gain reputational capital and loyalty in the long term.

Combining RBV and Stakeholder Theory serves as a good theoretical basis to address blockchain adoption (as a strategic capability) and the transparency (as a stakeholder demand) in the supply chain. The same theories contribute to the claim that blockchain is a technological instrument, yet it is a strategic means to supply chain sustainability and governance.

Conceptual Framework

The conceptual framework of this study illustrates the hypothesized relationship between **Blockchain Technology Adoption** (independent variable) and **Supply Chain Transparency** (dependent variable). This model is grounded in prior empirical studies and theoretical insights that suggest a direct positive relationship between the use of blockchain and improvements in transparency.

- **Blockchain Technology Adoption** is defined as the degree to which an organization implements blockchain-based systems for supply chain processes such as tracking, documentation, inventory management, and compliance verification (Francisco & Swanson, 2018; Kouhizadeh et al., 2021).
- **Supply Chain Transparency** refers to the extent to which supply chain processes, product

histories, and sourcing data are visible and accessible to internal and external stakeholders (Min, 2019; Saberi et al., 2019).

The framework posits that higher levels of blockchain adoption will result in higher levels of transparency due to features such as distributed ledgers, immutable data, and decentralized verification. This relationship will be empirically evaluated through a linear regression model.

Figure 1: Conceptual Framework

[Blockchain Technology Adoption] ——————► [Supply Chain Transparency]
(Independent Variable)
(Dependent Variable)

This framework provides a clear basis for hypothesis development and statistical testing to assess the direction and strength of the relationship.

Study Hypothesis

H_1: The blockchain technology adoption has a significant positive relationship with supply chain transparency.

RESEARCH METHODOLOGY

This paper uses a quantitative research design to examine how the adoption of blockchain technology can influence the transparency of the supply chain. Its organization is based on key aspects such as the research design, population and sample, data collection methods, instrumentation, reliability and validity, and data analysis.

Research Design

This is a descriptive-correlational research design that is suitable when it is needed to know the nature and value of the relationship between variables and how strong it is without having to change them (Creswell & Creswell, 2018). This design means that it can infer statistics about the effect of the independent variable (the use of blockchain) on the dependent variable (supply chain transparency) based on data from real organizational respondents.

Population and sample

The intended audience of this study is professionals who represent the supply chain operations in manufacturing, retail, logistics, and technology industries in Pakistan. These professionals are chosen because they have a direct connection, or their lives are directly impacted by the use and adoption of blockchain in their supply chain operations. A purposive sampling method was used to find the respondents who had the appropriate knowledge and experience of blockchain and supply chain systems, which was a non-probability sampling. Those 300 respondents were selected as a final sample to fulfil the recommendations of using regression analysis, having previously specified that a minimum of 100200 cases is needed to have statistical power (Hair et al., 2020). The sampling frame incorporated mid-level and senior-level supply chain personnel, logistics coordinators, procurement officers, and IT experts in the provision of supply chain technologies.

Procedure of Data Collection

The structured questionnaire was used as the method of primary data collection through email and online survey tools (e.g., Google Forms). The survey consisted of three parts, namely: (1) Demographic data, (2) Blockchain Technology Adoption and (3) Supply Chain Transparency. The entire set of questions was prepared on a 5-point Likert scale, that is, a 5-point scale from 1 (Strongly Disagree) to 5 (Strongly Agree), to make the questions and the perception of respondents quantitative.

The ethical considerations were considered in the selection of free participation, anonymity, and confidentiality of answers. The research objective of the study was to provide respondents with the study purpose, and informed consent was obtained prior to data collection.

Instrumentation

Constructs that were employed in the questionnaire were based on the validated scales that were available in the previous literature. The adopted blockchain technology scale was modified to fit the study. Items included the real-time tracking of blockchain, as indicated by our organization's use of blockchain-based real-time tracking, and another item included blockchain, enhancing the accuracy of supply chain data. The supply chain transparency scale was developed on the research findings of Saberi et al. (2019) and Queiroz et al. (2020), where statements included such as, "We are able to track the flow of goods in most of the levels across our supply chain"

and "Our supply chain has been made transparent to access information about partners."

Reliability and validity

The study has assessed internal consistency reliability by computing Cronbach's Alpha in each construct. The acceptable value of the threshold was 0.70 or higher (Hair et al., 2020). The blockchain adoption scale recorded a strong alpha of 0.872, and the supply chain transparency scale recorded 0.894, indicating the reliability of the scales. The content validity was achieved through using items from peer-reviewed studies, as well as a gold-standard, insightful review conducted by faculty members and practitioners of the supply chain.

Methods of Data Analysis

The data analysis was performed using IBM SPSS (Version 26). Demographic characteristics were summarized using descriptive statistics. The hypothesis was evaluated, and the significance of the model was measured through linear regression analysis of the connection between blockchain adoption and supply chain transparency. R 2, (F statistic) and p values were presented to determine the fitness of the model and the significance of the statistics. Also, regression assumptions (linearity, independence, uniform variance of the residuals, and normality of the residuals) were examined to ascertain the validity of the findings.

Ethical Considerations

This study was conducted following the ethical research principles, which emphasize privacy for researchers and integrity in data. No identifiable data about the person was gathered. Before the data were collected, the appropriate ethics review committee within the university where the data were to be collected had been consulted and obtained the necessary ethical clearance.

Analyses and Interpretations

Table 01: Demographic Profile

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	180	60.0%
	Female	120	40.0%
Age Group	21–30 years	90	30.0%
	31–40 years	120	40.0%
	41–50 years	60	20.0%
	51+ years	30	10.0%
Job Position	Executive	75	25.0%
	Managerial	135	45.0%
	Senior Manager	60	20.0%
	Director/Above	30	10.0%
Industry Type	Manufacturing	90	30.0%
	Retail	75	25.0%
	Logistics	60	20.0%
	Technology	75	25.0%

This table outlines the background characteristics of the 300 respondents who participated in the study. It shows that 60% of the respondents were male, while 40% were female. The age distribution reveals that the majority fell in the 31–40 years age group (40%), followed by 21–30 years (30%), 41–50 years (20%), and a smaller proportion aged above 51 years (10%). Regarding job positions, 45% of respondents held managerial roles, 25% were executives, 20% were senior managers, and 10% held director or higher-level positions. Industry-wise, the participants were from a variety of sectors, including manufacturing (30%), retail (25%), logistics (20%), and technology (25%), ensuring a balanced representation of professionals across different supply chain environments.

Table 02: Reliability Statistics

Construct	Items	Cronbach's Alpha
Blockchain Technology Adoption	5	0.872
Supply Chain Transparency	5	0.894

This table presents the internal consistency of the scales used in the study by reporting Cronbach's Alpha values. The construct "Blockchain Technology Adoption" had five items and yielded a Cronbach's Alpha of 0.872, indicating high reliability. Similarly, the "Supply Chain Transparency" scale, also comprising five items, showed an alpha value of 0.894. Both values exceed the commonly accepted threshold of 0.70, suggesting that the items within each construct are highly consistent in measuring the intended concepts. This confirms the appropriateness of using these scales for further statistical analysis in the study.

Table 03: Model Summary (Linear Regression Analysis)

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.672	0.451	0.448	0.487

The model summary table shows the overall strength of the linear regression model used to predict supply chain transparency based on blockchain technology adoption. The R-value of 0.672 indicates a strong positive correlation between the two variables. The R-squared value of 0.451 suggests that approximately 45.1% of the variability in supply chain transparency can be explained by the level of blockchain technology adoption. The adjusted R-squared value (0.448) provides a slightly more accurate estimate by adjusting for the number of predictors in the model. The standard error of the estimate, which is 0.487, indicates the average distance that the observed values fall from the regression line.

Table 04: ANOVA (Analysis of Variance)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	52.460	1	52.460	220.97	.000***
Residual	63.540	298	0.213		
Total	116.000	299			

This table examines whether the regression model is statistically significant. The regression sum of squares is 52.460, while the residual sum of squares is 63.540, with a total of 116.000. The F-statistic is 220.97, which is highly significant with a p-value of 0.000. This indicates that the regression model is significant and that blockchain technology adoption has a statistically meaningful effect on supply chain transparency. The high F-value supports the validity of the model in explaining the variation in the dependent variable.

Table 05: Coefficients of Regression

Model	Unstandardized Coefficients	Std. Error	Beta	t	Sig.
(Constant)	1.240	0.165		7.515	.000***
Blockchain Tech Adoption	0.675	0.045	0.672	14.864	.000***

This table presents the individual regression coefficients used in the model. The unstandardized coefficient for blockchain technology adoption is 0.675, with a standard error of 0.045. This indicates that for every one-unit increase in the adoption of blockchain technology, supply chain transparency

increases by 0.675 units, assuming other variables are held constant. The t-value of 14.864 and the corresponding p-value of 0.000 confirm that this relationship is statistically significant. The constant value of 1.240 suggests the base level of supply chain transparency when the independent variable is zero. This table reinforces that blockchain adoption has a strong and significant positive effect on supply chain transparency.

DISCUSSION

The results of this experiment indicate that the appropriate usage of blockchain technology is positively related to supply chain transparency with significant statistical values. This result complies with the existing literature that considers blockchain as an opportunity to make supply chain networks more visible, traceable, and accountable (Biswas & Gupta, 2022). Namely, regression outcomes revealed that blockchain technology accounts for a significant share of the level of transparency outcomes, and the R-squared value was 0.451 or, in other words, about 45 percent of the variance in terms of supply chain transparency may be explained by blockchain application.

This is a fact conforming with provisions of the theoretical framework that is based on Transaction Cost Economics (TCE), which argues that transactional inefficiencies can be fuelled by information asymmetry and mistrust (Williamson, 1985). By providing immutability records and decentralized verification, blockchain will help to overcome these inefficiencies, increasing transparency and data availability through the supply chain (Saberi et al., 2020). This is further evidenced by the high coefficient of beta ($p < 0.001$, 0.675) in the regression model, which shows that as the adoption of blockchain practices increases, there is a direct positive relationship to increase the transparency of the operations and transactions amongst the stakeholders.

Moreover, such findings align with the theoretical framework developed by Roeck et al. (2023), who explained that blockchain technology facilitates real-time access to data and trust among suppliers, buyers, and third-party logistics providers. The results also resonate with the study of Francisco and Swanson (2021), who noted the same two outcomes in organizations that have incorporated blockchain technology, specifically in terms of reduced information distortion and increased auditability in multi-tier supply chains.

Remarkably, it turns out that despite the focus on the technical issues and organizational resistance to the blockchain uptake that the literature findings support (Chang et al., 2021), it is possible to mitigate these factors and experience the significant perceived benefit in resistance transparency once adopted. This is potentially devastating to any industry with tangled global systems, such as food supply, pharmaceuticals, and electronics, where a lack of information may create wastefulness or a crime or compliance problem.

The findings also highlight the need to invest in digital infrastructure and employee training to fully reap the rewards of blockchain. This is why the use of blockchain can be optimized by combining it with other complementary technologies, such as IoT and smart contracts, to automate data recording and reduce the human factor in it (Queiroz et al., 2020).

To conclude, the research provides empirical evidence to the growing body of information promoting the utilisation of blockchain as the driver of the supply chain evolution. It confirms that blockchain is not only a technological innovation but a strategic measure of improving transparency, trust-building and finally, operating performances.

CONCLUSION

The study finds that blockchain technology is a breakthrough in providing transparency along the supply chain through enhanced traceability, real-time sharing of information, and transactional confidence among the stakeholders. As expected, based on the existing body of knowledge concerning digital transformation of a supply chain (Biswas & Gupta, 2022; Roeck et al., 2023), the empirical analysis confirmed a strong positive association between blockchain adoption and transparency indicators. The findings confirm that blockchain is not merely a technologically oriented instrument, but also a strategic means of attaining superior visibility and integrity within elaborate, globalised supply chains. Thus, the integration of blockchain in the supply chain can be viewed as one of the possible ways for an organization to become more transparent and accountable throughout the value chain (Queiroz et al., 2020).

RECOMMENDATIONS

It is proposed to invest in blockchain infrastructure in organizations and develop cross-functional collaboration to promote the implementation of this technology. To achieve silky implementation and use, training programs are to be commissioned to ensure upskilling of supply chain professionals on blockchain concepts and applications (Chang et al., 2021). Moreover, the combination of blockchain with other digital technologies embedded in the company, such as the Internet of Things (IoT) and cloud platforms, should be considered to achieve the highest level of transparency and to automate the process of data collection (Francisco & Swanson, 2021). Regulators of the industry and policymakers should also develop supportive frameworks and standards that promote interoperability and healthy use of blockchain in logistics and procurement procedures.

LIMITATIONS

This research is limited in a few ways, and one must take note of these limitations. First, the sample size of the firms used in gathering the data was small, consisting of firms in certain industries; thus, the data may not represent the heterogeneity of global supply chains. Second, the type of analysis used was cross-sectional, and it limits the possibility of interpreting causal implications concerning the long-term effects of blockchain on transparency (Saberi et al., 2020). Third, the research concentrated on the aspect of transparency as the outcome variable and did not investigate other aspects of performance, like efficiency or cost reduction, that the implementation of blockchain may influence. These gaps are to be filled in the future by using a long-term research design and focusing on analyzing more supply chain outcomes in different industrial and geographical settings.

SIGNIFICANCE

The work is of importance to science and research. In terms of scholarly impact, it builds on an increasing number of empirical studies available on the interplay of blockchain and supply chain management and, in this sense, confirms theoretical frameworks, such as Transaction Cost Economics in the realm of digital supply chains (Williamson, 1985; Roeck et al., 2023). To practitioners, the findings offer insights into how blockchain can be used to boost transparency, which is increasingly important as defined by regulatory conditions and consumer demands. The study also proves sustainable and ethical sourcing practices, given that transparent supply chains are pertinent in ensuring the social and environmental conformity (Queiroz et al., 2020; Biswas & Gupta, 2022). In this way, the study is of practical utility in enhancing governance, compliance, and strategic decision-making in the global supply network.

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