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Revolutionizing Supply Chains: Unveiling the Power of Blockchain Technology for Enhanced Transparency and Performance

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A B S T R A C T

In recent years, the significance and prevalence of distributed ledger technology have grown. However, there is a lack of empirical studies examining the managerial and technological aspects essential for implementing it in the distribution network. The objective of this research is to develop a comprehensive framework for the adoption of blockchain technology in the entire distribution chain. This will be achieved by identifying the factors that facilitate adoption and experimentally evaluating their interdependencies and effects on adoption through empirical evidence collection. A quantitative approach was used to assess the model's main objective. The study focused on the medicine manufacturing industry to gather responses regarding the intention to use blockchain technology and its impact on supply chain performance. The findings revealed a significant positive relationship in the hypothetical model. Additionally, secondary data analysis, which considered previous research and online surveys, was conducted to assess the impact of blockchain technology on supply chain performance and the mediating role of supply chain transparency.

1. INTRODUCTION

The utilization of emerging technologies has opened opportunities to enhance various aspects of the supply chain process, and one such technology is blockchain. Its implementation in the supply chain has proven to be beneficial by increasing transparency and significantly reducing administrative costs (Alabi and Telukdarie, 2021). The adoption of blockchain in the supply chain method enhances the management of participants, including factors such as pricing, location, quality, and certification (Korpela et al., 2017). This improvement in supply chain performance, coupled with the mediation of supply chain transparency, has particularly benefited the supply chain industry in the UAE. It has facilitated better traceability of materials and mitigated losses resulting from counterfeit products or involvement in the gray market.

Additionally, there has been a growing adoption of blockchain technology across various industries, aiming to enhance transparency, security, and efficiency in supply chain management. Specifically, the pharmaceutical industry has recognized the potential advantages of integrating blockchain technology into its intricate and heavily regulated supply chain. By implementing blockchain-based solutions, pharmaceutical companies can enhance visibility and traceability of products throughout the entire supply chain, mitigate counterfeiting and fraudulent activities, and enhance overall supply chain efficiency (Arden et al., 2021). This transformative potential of

blockchain technology holds the promise of revolutionizing the pharmaceutical business, spanning from production to distribution, ultimately leading to improved patient outcomes (Khubrani, 2021). Thus, this research was undertaken to investigate the adoption of blockchain technology and its impact on supply chain performance, while also examining the mediating role of supply chain transparency.

1.1 Medicine Manufacturing Industry in The United Arab Emirates (UAE)

The medicine manufacturing industry in the United Arab Emirates (UAE) is experiencing rapid growth, thanks to several factors such as the strategic location of the country, advanced infrastructure, and favorable business environment. The UAE has successfully positioned itself as a prominent hub for pharmaceutical manufacturing and exports, attracting substantial investments from both local and international companies. To ensure the production of safe and effective drugs, the country has implemented stringent regulatory frameworks and quality standards. Given the rising demand for pharmaceuticals locally and globally, the UAE is poised for further expansion and development of its medicine manufacturing industry in the foreseeable future.

1.2 Research Problem

In recent years, the utilization of blockchain technology in supply chains has garnered significant attention for its potential to improve various aspects of operations. This includes enhancing transparency, enabling traceability, combating fraud, and counterfeiting, and increasing overall efficiency. However, there is still much to be understood about the specific impact of blockchain technology on supply chain performance, particularly in relation to the role of supply chain transparency as a mediator.

While blockchain technology offers a secure and decentralized platform for recording and sharing supply chain data, its benefits may not be fully realized without sufficient transparency throughout the supply chain. Transparency plays a vital role in allowing stakeholders to track the origin and movement of goods, ensure compliance with regulations and standards, and make informed decisions. Therefore, it is crucial to investigate the extent to which blockchain technology can enhance supply chain transparency and how this enhanced transparency can subsequently influence overall supply chain performance.

To address these issues, the research aims to achieve the following objectives:

- Assessing the statistical impact of information integrity on supply chain transparency.
- Identifying the key factors that make risk management essential for maintaining supply chain transparency.
- Examining the interplay between blockchain technology implementation, networking, and risk management as mediators in achieving transparency within the supply network.

By investigating these objectives, the research aims to shed light on the relationship between blockchain technology, supply chain transparency, and overall supply chain performance. This understanding will contribute to the effective adoption and utilization of blockchain in supply chains and pave the way for improved operational efficiency and performance.

1.3 Operational Definitions

1.3.1 Blockchain technology:

Blockchain technology refers to a public and tamper-proof ledger that governs the recording of transactions and tracks assets within a secure business network. Its key components include distributed ledger technology, immutable records, and smart contracts.

1.3.2 Supply chain performance

The evaluation of supply chain performance is essential in assessing the effectiveness of the overall supply chain system. It encompasses both qualitative and quantitative measures to gauge the system's efficiency and effectiveness.

1.3.3 Supply chain transparency

Supply chain transparency is a process wherein organizations strive to gain visibility into upstream activities within the supply chain and facilitate the transfer of information both internally and externally within the organization (Frederico et al., 2021).

By incorporating blockchain technology, organizations can enhance the transparency and

security of their supply chain operations. This technology provides a decentralized and tamper-proof system for recording transactions and tracking assets. It improves trust and accountability within the supply chain network (Marinagi et al., 2015). Evaluating supply chain performance allows organizations to identify areas of improvement and optimize their operations for better efficiency. Furthermore, fostering supply chain transparency enables organizations to gain insights into upstream activities, facilitating informed decision-making and enabling collaboration throughout the supply chain network.

2. LITERATURE REVIEW

2.1 Blockchain Technology

Blockchain technology utilizes a distributed ledger system to record transactions securely and transparently. It operates in a decentralized manner, employing encryption to safeguard data stored within the network, verify, and secure transactions, and ensure their validity (Lu, 2018). While blockchain's association with cryptocurrencies is widely recognized, its potential extends beyond that, encompassing various applications like voting processes, supply chain management, and identity verification (Othman et al., 2020). The immutability of blockchain, which safeguards transactions from alterations or removal once recorded, stands as a significant feature of this technology. As a result, it serves as a crucial tool in ensuring accountability and transparency across diverse industries (Kramer et al., 2021).

2.2 Supply Chain Performance

In logistics development, the supply chain plays a vital role, and its evaluation involves various metrics. These metrics include order planning (i.e., access method direction, order lead time, customer order route), supply link assessment, dealings and production-level key performance indicators (KPIs), calculation of delivery connections (i.e., performance actions for delivery, overall supply cost), measurement of client facility and fulfillment (i.e., flexibility, customer inquiry response time, post-transaction procedures for customer service), supply chain and logistics costs (i.e., price related to assets and return on investment (ROI), and data dispensation rate). These metrics collectively form a comprehensive framework for assessing and improving the efficiency of the supply chain within logistics operations.

2.3 Supply Chain Transparency

Supply chain transparency is a multi-step process that extends beyond mere visibility within the supply chain. It involves an organization's response to insights gained through broader visibility to mitigate risks more effectively. The framework for achieving supply chain transparency comprises the following four steps.

The first step is identification and prioritization of risks. It is to understand the potential risks inherent in the industry is crucial to address them in accordance with their level of severity. Step two is visualization of the risks. Once the risks are identified, the immediate next step is to assess them and determine the necessary measures to prevent their occurrence in the future. Step three is utilization of transparency levers to bridge information gaps. After prioritizing the areas of risk, the subsequent step involves employing transparency levers to close any existing information gaps. The last step is managing and monitoring. Closing an existing gap through transparency lays the foundation for a sustainable transparency program that not only supports the organization but also gathers insights from up-to-date information. Once the new system is established, the subsequent step is to effectively manage and monitor the resulting information. By following this comprehensive four-step process, organizations can enhance their supply chain transparency, thereby mitigating risks and improving overall performance.

2.4 Impact of Blockchain Technology on Supply Chain Performance

A distribution system typically consists of multiple independent companies that actively engage in the movement of goods, services, money, and/or information from the source to the end consumer. To effectively operate such a distribution chain, participants must collaborate and share data. Distributed ledger technology holds significant potential in enhancing supply chain operations and achieving supply chain management goals. It provides a framework for direct communication among supply chain participants, enabling the exchange of reliable and tamper-proof information.

One of the key advantages of this technology is its ability to ensure complete product traceability and enhance visibility throughout different phases of the supply chain. For example, a UK-based blockchain technology company has developed systems that enable product monitoring and the collection of specific product data to verify authenticity, provenance, and consistency. Start-up Everledger is another example, utilizing blockchain to generate and maintain unique identifying information for individual units of items across various industries. These technologies offer quality assurance, help the jewelry industry comply with gem industry regulations, and are also employed in monitoring and certifying liquor bottles. Through blockchain technology, supply chain members can share data regarding demand, inventory, and capacity, facilitating improved coordination and efficiency within the supply chain.

2.5 Impact of Blockchain Technology on Supply Chain Transparency

The logistics sector is highly vulnerable to cyber-attacks due to its interconnected nature and reliance on data and software for tracking the movement of goods (Farouk and Darwish, 2020). Understanding the intricate processes involved in logistics can be challenging. Effective planning for optimal efficiency requires careful selection of suppliers, establishing distribution networks, managing inventory, and scheduling workers. Logistic chain management plays a crucial role in ensuring the smooth functioning of these elements (Khai Loon et al., 2018). Given the potential to enhance supply chain operations, the advanced features of blockchain technology and the factors influencing its adoption in a distribution network environment have garnered significant interest (Sillanpää, 2010). A recent study highlighted the challenges faced in implementing distributed ledger technology in international supply chains, particularly related to interoperability among different blockchain platforms and the complexity of contractual regulations across national borders (Chowdhury et al., 2022). A notable example of utilizing distributed ledger technology is its application in tracing the authenticity of fish from the source, such as a fisherman in Indonesia, and providing robust verification of compliance with international standards throughout the network, using smart labeling (Chowdhury et al., 2022). This demonstrates the potential of distributed ledger technology to enhance transparency and traceability in supply chains.

2.6 Impact of Supply Chain Transparency on Blockchain Technology

Blockchain enables end-to-end tracking of distribution networks, offering enhanced openness and precision. By digitizing physical assets, businesses can monitor their journey from production to distribution or end-user use, creating an immutable and distributed record of all interactions. This secure method of data storage makes it difficult to alter or manipulate the network, ensuring transparency in all activities (Arden et al., 2021). Supply chain management plays a crucial role in building trust among businesses, suppliers, and customers, as it signals a company's commitment to transparency and integrity in its operations. With blockchain, businesses can conduct transactions directly, improving the efficiency of global value chains without the need for intermediaries (Meidute-Kavaliauskiene et al., 2021). Furthermore, blockchain facilitates the integration of financial and logistical services, enhancing the sharing of information among stakeholders. By leveraging blockchain technology, companies can enhance trust, streamline operations, and foster collaboration in the supply chain ecosystem.

2.7 Impact of Blockchain Technology on Supply Chain Performance with The Mediating Role of Supply Chain Transparency

According to a study conducted by (Erceg and Sekuloska, 2019) blockchain technology has the potential to enhance transparency and traceability in the supply chain, thereby improving production quality (Min, 2019). The study highlights that real-time tracking of goods through blockchain can aid in early detection of quality issues and enable quicker resolution (Alazab et al., 2021). Furthermore, blockchain can contribute to better coordination among supply chain stakeholders by providing a shared ledger accessible to all, reducing the chances of miscommunication and errors. Similarly, another study by (Sobb et al., 2020) emphasizes the role of blockchain in improving time efficiency within the supply chain. By streamlining processes and minimizing delays, blockchain's real-time tracking capability can

reduce lead times and facilitate faster delivery. The study also suggests that blockchain can automate manual tasks like documentation, saving time and effort.

As explained by (Mondol, 2021), blockchain technology has the potential to significantly enhance supply chains in several ways. It can enable faster and more cost-effective product delivery, strengthen coordination among partners, ensure product provenance, and provide easier access to funding. By facilitating seamless and integrated communications across complex distribution networks, blockchain enhances confidence, speed, and safety. Additionally, it can be utilized to create online platforms where logistics service providers advertise available space on vehicles or containers in real-time (Wu et al., 2006). This further improves efficiency, safety, and confidence in supply chain operations. Overall, blockchain technology holds promise for transforming supply chains by enhancing various aspects of operations and promoting collaboration among stakeholders.

2.8 Conceptual Framework

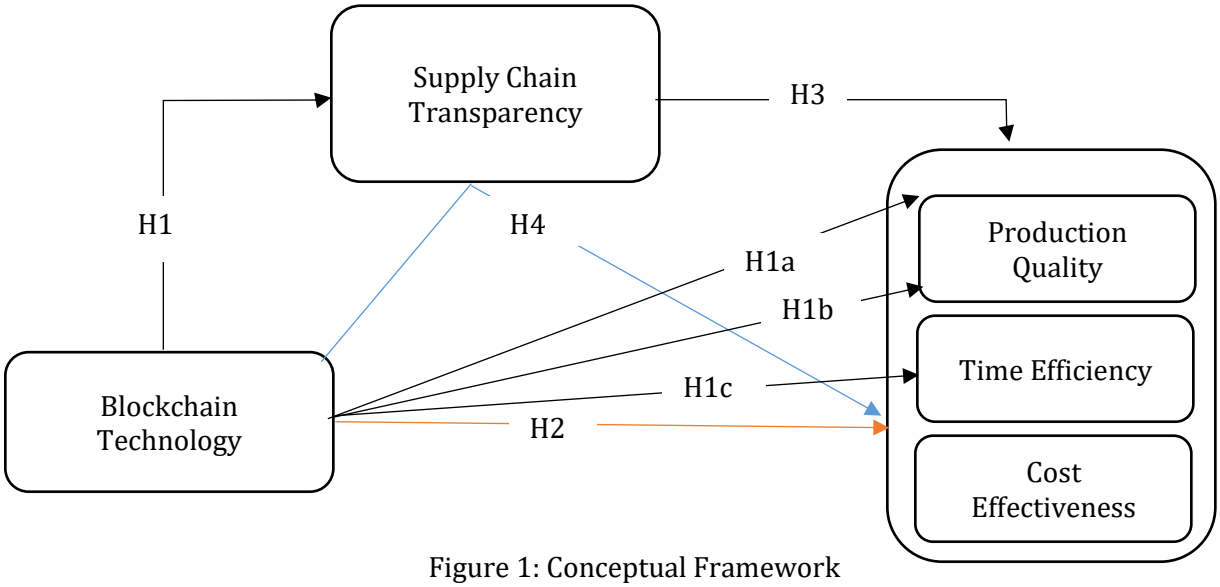


Figure 1: Conceptual Framework

2.9 Research Hypotheses

H1: Block Chain technology has positive impact on Supply Chain Performance.

- **H1a**: Blockchain Technology has positive impact on Quality Production.
- **H1b**: Blockchain Technology has positive impact on Time Efficiency.
- **H1c:** Blockchain Technology has positive impact on Cost Effectiveness.

H2: Blockchain Technology has positive impact on Supply Chain Performance.

H3: Supply Chain Transparency has positive impact on Supply Chain Performance.

H4: Blockchain Technology has positive impact on Supply Chain Performance with the mediation of Supply Chain Transparency.

3. METHODOLOGY

A quantitative research methodology was employed to gather data from participants involved in the pharmaceutical sector. Although 17 pharmaceutical manufacturers were contacted via email, obtaining confidential responses proved to be challenging. However, managers, operations managers, supply chain managers, and logistics officers received a set of 300 questions each via email. After screening, a total of 156 responses were deemed eligible for data analysis. A simple random sample was selected for this study. The questionnaire, consisting of 22 items, was developed by the author. It covered various aspects, including the implementation of blockchain technology (6 questions), supply chain transparency (5 questions), and supply chain

performance (4 questions). Additionally, there were 7 items relating to the cost, time efficiency, and quality output of supply chain performance. The collected data were analyzed using SmartPLS 4.0 software, employing the structured equation modeling technique for hypothesis testing.

4. DATA ANALYSIS

4.1. Demographic Analysis

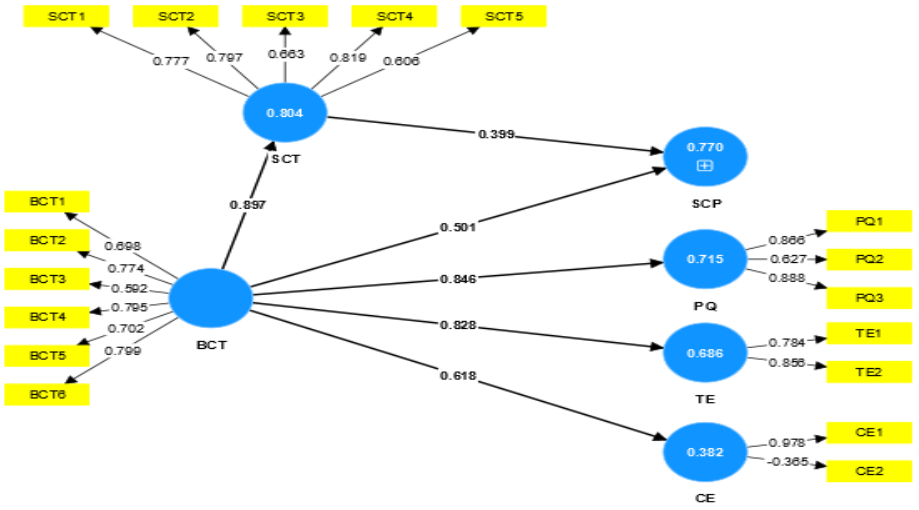
To conduct a demographic analysis, various demographic factors such as age, gender, qualifications, and experience were taken into account to gain insights into the background of the respondents. The demographic data was collected by including questions about gender, age, and qualifications. The results revealed that 87 respondents (56.5%) were male, while 67 respondents (43.5%) were female. The majority of respondents fell within the age range of 18 to 25 years, accounting for 63 respondents (40.9%). In terms of experience, the largest group consisted of 55 respondents (35.7%) with 5 to 10 years of experience. Table 1 provides a comprehensive breakdown of the age groups, qualifications, and experience levels of the respondents.

Table 1: Demographic Analysis

	Description	**Frequency**	**Percentage**
Gender			
	Male	87	56.5
	Female	67	43.5
Age			
	Below 18 years	26	16.9
	Between 18-25 years	63	40.9
	Between 25-33 years	39	25.3
	Above 33 years	26	16.9
Qualification			
	High school degree	38	24.7
	Graduate	55	35.7
	Diploma	41	26.6
	Post graduate degree	20	13.0
Total		154	100

4.2. Assessment of Measurement Model

The Partial Least Squares Structural Equation Modeling (PLS-SEM) was utilized to analyze the model construct, which included three variables and three dimensions of supply chain performance. Figure 2 illustrates the path coefficients of the model, indicating the relationships between the variables and their respective dimensions.



4.3. Assessment of Structural Model

In this study, the bootstrap confidence intervals method was employed, with 5,000 iterations. The purpose was to investigate and provide empirical evidence of the mediating roles of Supply Chain Transparency in the relationship between Blockchain Technology and the three dimensions of Supply Chain Performance (H1a, H1b, H1c). This method was used to determine the size and statistical significance of the indirect effects, as shown in Table 2. Regarding the direct effects, H1, which examines the direct impact of blockchain technology on supply chain performance, was found to be significant (β=0.501, t=3.10), providing support for this hypothesis. H2 explores the impact of blockchain technology on SC transparency, and it was found to have a significant relationship (β=0.897, t=36.5), supporting H2. Furthermore, the impact of SC transparency on supply chain performance was also found to be significant (β=0.399, t=2.49), supporting H3. These results indicate that supply chain transparency acts as a mediating variable between blockchain technology and supply chain performance, positively influencing their relationship.

The direct impacts of blockchain technology on supply chain performance, as shown in Table 2, were found to be significant within the confidence intervals range (β=0.358, t=2.38). The statistical summaries are provided in Table 2 to further elucidate these findings.

Table 2: Hypothesis Testing Direct, and Indirect effect

		Direct Effects		**Indirect Effects**		
Paths	Effects	B	t	B	t	Conclusion
BCT->SCP	H1+	0.501***	3.10			Supported
BCT-> QP	H1a+	0.846***	28.30			Supported
BCT->TE	H1b+	0.832***	12.60			Supported
BCT->CE	H1c+	0.618***	11.80			Supported
BCT->SCT	H2+	0.897***	36.50			Supported
SCT->SCP	H3+	0.399***	2.49			Supported
BCT->SCT->SCP	H4+	0.358***	2.38	0.453***	3.63	Supported
BCI LL		0.132		0.115		
BCI UL		0.720		0.670		

*BCT=Blockchain Technology, SCP=Supply Chain Performance, SCT=Supply chain Transparency, QP=Quality Production, TE=Time Efficiency, CE=Cost Effectiveness, BCI LL=Bootstrapped Confidence Interval Lower level; BCI UL=Bootstrapped Confidence Interval Upper level; ***p< 0.001; **p< 0.01; NS= Not Supported*

The performance measurement of blockchain technology adoption in the pharmaceutical manufacturing sector is illustrated in Figure 3. The statistical analysis conducted in this research revealed significant improvements in production

quality, timeliness, and cost-effectiveness as a result of adopting blockchain technology.

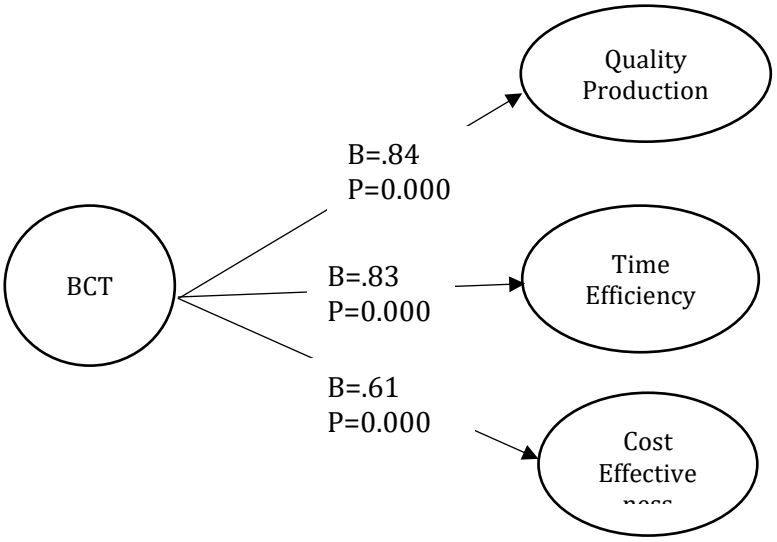


Figure 3: Supply Chain Performance Measurement Statistics

5. RESULTS AND DISCUSSION

The findings of statistical studies paint an intriguing picture of the relationships and synergies between data analytics. Blockchain technology has emerged as a promising solution to address various challenges in supply chain management, including issues of transparency, counterfeiting, and inefficiencies. By providing a decentralized and secure platform for recording transactions and storing data in an immutable ledger, blockchain technology offers companies the potential to enhance supply chain performance in several ways. These include improving transparency and accountability, reducing fraud and errors, enhancing traceability, and enabling real-time tracking of goods and assets.

One of the key advantages of blockchain technology in the supply chain is its ability to enhance transparency. Through the use of distributed ledgers, every transaction and record can be accessed and verified by all parties involved, fostering trust and credibility. This shared transparency mitigates the risks of fraud and errors, as all stakeholders have access to consistent and reliable information.

To fully understand the impact of blockchain technology on supply chain performance, it is important to consider the mediating role of supply chain transparency. Transparency in the supply chain refers to the ability to track and monitor the flow of products and services from raw material sourcing to final delivery. Blockchain technology facilitates supply chain transparency by providing a secure and tamper-proof platform for storing and exchanging data.

Research indicates a positive correlation between supply chain success and supply chain transparency. For example, when supply chain partners have real-time access to information regarding the movement and condition of goods, they can make informed decisions to reduce lead times, improve operational efficiency, and enhance customer satisfaction. Transparency also enables the identification of supply chain inefficiencies and bottlenecks, allowing businesses to take corrective measures and improve overall performance.

However, the research findings suggest that the level of blockchain technology adoption, the complexity of the supply chain, and the availability of supporting technologies can influence the effectiveness of blockchain in improving supply chain performance. The benefits of transparency may be limited, for instance, if only a few participants in the supply chain embrace blockchain technology. Similarly, in highly complex supply chains, blockchain technology alone may not be sufficient to address all challenges and optimize performance.

6. CONCLUSION

The primary focus of this research was to examine the influence of blockchain technology on supply chain performance, considering the mediating role played by supply chain transparency. The findings demonstrate that by enhancing transparency, blockchain technology has the potential to positively impact supply chain performance, leading to decreased inefficiencies and increased customer satisfaction. However, it is important to acknowledge that the effectiveness of blockchain in the supply chain context can be influenced by several factors, such as the extent of adoption, the complexity of the supply chain, and the presence of complementary technologies.

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