Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

Characteristics of blockchain technology and its impact on improving supply chain performance from an accounting perspective: Evidence from Saudi Arabia

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ARTICLE INFO

Article history:
Received 30 November 2023
Received in revised form
10 July 2024
Accepted 15 July 2024

Keywords:
Blockchain technology
Supply chain performance
Industrial companies
Transparency and privacy
Decentralization

ABSTRACT

This study aimed to clarify the importance of using blockchain in the supply chain sector and examine the impact of blockchain technology characteristics on improving supply chain performance by applying it to industrial companies in Saudi Arabia. To achieve this, the study used an inductive approach to analyze existing accounting literature on four blockchain characteristics and their impact on enhancing supply chain performance. A field study was conducted to gather the perspectives and opinions of faculty members in the Accounting Department of Saudi universities, accountants in Saudi industrial companies, and information and communications technology experts working in blockchain and supply chain fields. The sample size was 150 individuals from 2012 to August 2023, and the analysis was performed using IBM SPSS Version 29. The study concluded that blockchain technology significantly improves supply chain performance in Saudi industrial companies, with the four blockchain characteristics (transparency and privacy, decentralization, traceability, and smart contracts) having a positive impact. The study recommends future research on the relationship between blockchain technology and corporate governance, examining tax issues related to blockchain operations, and training accountants and industrial workers to use blockchain to enhance supply chain performance.

1. Introduction

Blockchain technology has gained the attention of all sectors in the digital transformation era. It represents one of the modern and effective technologies that is applied in various fields such as accounting and auditing, finance, financial markets, banks, supply chains, health care, education, energy, and insurance. It is the backbone of supply chain management (Hamdan, et al., 2022) as it gives a comprehensive view of the company's activities and achieves integration between logistical operations within the supply chain, which contributes to developing the strategy of business organizations and increasing business efficiency, and working to provide products with high quality and at an appropriate price value in the proper time to meet customer needs and increase their satisfaction, and to provide appropriate data in the proper time, eliminating the complexity of procedures, reducing costs, increasing productivity to increase sales and profits, improving inventory management, , increasing levels of safety, transparency, and protection from counterfeit goods and price manipulation, increasing opportunities for innovation in developing processes and products, and improving operational and financial performance, which contributes to creating value and achieving competitive advantages for companies, and resilient in an ever-evolving business landscape as stated by Nasereddin (2024).

The supply chain faces several problems that affect its efficiency, including the difficulty of tracking the supply chain, the difficulty of flowing and sharing data, the asymmetry of information along the supply chain, the problem of real-time delays, the complexity of supply chain financing operations, a lack of trust between partners, theft, and fraud, delays and increased costs of letters of guarantee, increased shipping costs, the problem of risk management with the presence of a negative impact on the complexity of supply chains during COVID-19 (Xiong et al., 2021), not managing inventory efficiently, not managing reverse flows

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efficiently, the presence of a communication gap between supply chain parties, Low quality of products and failure to satisfy customer desires (Ghode et al., 2020). To solve these problems, companies must use blockchain technology to increase the efficiency of the supply chain (Sheel and Nath, 2020).

The importance of using blockchain in improving the performance of the supply chain from an accounting point of view is that it helps in tracking products along the supply chain, reducing errors that occur during the supply process, and providing products with high quality and appropriate price value at the right time to achieve a highly competitive advantage for institutions, improving the reputation and brand of companies, improving their operational and financial performance, increasing productivity, profitability, and value creation, discovering opportunities to reduce costs, accounting in real-time, and increasing the level of disclosure and transparency because of exchanging information between the parties of the chain easily, which leads to reducing information asymmetry, tracking inventory levels. And manage it efficiently, reduce transportation time, and rationalize the use of resources so that companies can ensure that their products are obtained from ethical and sustainable sources (Kamble et al., 2020) to achieve sustainable performance, digitizing and automating supply chain processes and simplifying their procedures using smart contracts. Improving the supervisory role on the performance of all parties within the supply chain, increasing the efficiency of after-sales services such as warranties and maintenance to provide better services to customers and increasing their level of satisfaction, increasing the value of companies through their ability to build new business models and manage risks by Alkhudary et al. (2024), which in turn is reflected in an increase supply chain efficiency. Aramco, Unilever, and Maersk are among the major companies that use blockchain technology and benefit from it in the field of supply chain management and tracking transactions and products (Garanina et al., 2022).

From the above, the importance of the subject of the study is clear, so the researcher to conduct this study because they are one of the Recent topics that are still under research and need further study, this study is considered additional research to testing the relationship between blockchain technology characteristics and the performance of supply chains due to the increasing need for companies in the Saudi market to apply blockchain technology as business solutions specifically designed to serve the supply chain, logistics services, and also the importance of Saudi companies keeping pace with modern developments in digital technologies and benefiting from them, which supports the vision of the Kingdom of Saudi Arabia 2030 and the application of digital transformation in various fields, Communications, Space and Technology Commission stated in the workshop titled "Blockchain Technology and its Effects on Digital Transformation" that the blockchain market is expected to grow to exceed the barrier of 100 billion riyals by 2025.

2. Literature review

2.1. Theoretical background

Blockchain technology is important in the accounting and auditing field, as Deloitte launched the Chains of Trust program for use in the field of accounting and auditing, with the aim of accelerating the processes of reviewing blockchain transactions, improving the efficiency of the supply chain, and increasing customer satisfaction. Blockchain technology affects the future of the accounting and auditing profession, as stated by Liu et al. (2019). In the accounting field, it works to increase the efficiency of accountants and develop their skills by increasing their ability to understand blockchain technology and how to use it and deal with modern software, which is reflected in the efficiency of the workflow of accounting, and the development of the role of accountants. Rather than performing traditional accounting tasks, they will mainly focus on ensuring the accuracy of information in financial reports and creating new roles for this purpose. These roles will include tasks such as reviewing smart contracts, verifying data and the identities of contract parties, reporting on encrypted assets, and acting as arbitrators to resolve disputes between contract participants (Schmitz and Leoni, 2019).

The importance of using blockchain technology for the accounting and auditing profession is due to increasing the efficiency of accounting by automating accounting transactions, increasing the efficiency of recording accounting operations and ensuring the completion of financial transactions, the inability to modify financial data, which reflects on its protection, and reducing data loss rates. It also works to limit profit management, as blockchain technology provides financial transactions in real-time as they occur, so managers cannot use practices of earning manipulation. The use of blockchain technology affects the speed of financial transactions, reduces the rate of financial errors and fraud in accounting operations, increases audit operations while reducing the costs and fees of accounting and auditing offices because it contains a central ledger that includes all the data and information necessary for accounting and auditing operations (Bonsón and Bednárová, 2019), and reduces The cost and time of accessing financial information to stakeholders, verifying the application of accounting rules, efficient selection of the supply chain, increasing the assurance of the security and privacy of the information, and it also helps in activating the target costing method for products by facilitating cooperation between the parties of the supply chain. It also reduces tax evasion and tax compliance by automatically imposing a tax on all financial transactions. The use of blockchain technology increases the accuracy of

accounting information, which leads to an increase in the quality of the information content of accounting reports and increases the efficiency and effectiveness of digital financial reports, which in turn is reflected in increased confidence of stakeholders, and more disclosure of non-financial information. It also affects the efficiency of the facility's accounting system in terms of providing reliable data. Garanina et al. (2022) confirmed that Blockchain technology works to increase the level of disclosure and transparency of financial information and provide it promptly, as blockchain technology replaces traditional accounting with accounting based on Blockchain technology, which automatically publishes all financial information to stakeholders, which is kept in one central a ledger, so each of them can track the company's transactions and prepare whatever data they need of profitability or financial position.

2.2. Blockchain technology and its characteristics from an accounting point of view

Cryptocurrencies are considered the first application of blockchain technology, as they depend mainly on financial transactions and the transfer of ownership between individuals and institutions without intermediaries. It is defined as a distributed ledger technology or an encrypted information system that relies on a decentralized database that allows all transactions to be recorded as a series of blocks. The new blocks include timestamps and links to previous blocks, so they are a record-keeping system that cannot be changed or hacked and is available to all parties participating in the chain, as defined by Hackius and Peterson (2017) as a peer-to-peer information network, as it involves a decentralized computing system that maintains records of digital transactions through distributed offices to replace traditional databases controlled by governments and banks, as defined by Chod et al. (2020) as an open-source protocol that uses Bitcoin to provide transparency to the supply chain and shows the importance of blockchain technology in achieving integration between logistical operations that take place between parties. To ensure the successful implementation of BCT in supply chains, the Internet of Things (IoT) must be used to track goods and products, accurately record transaction data, standardize data from different sources, and perform predictive and prescriptive analyses. The use of blockchain technology contributes to increasing the efficiency of supply chain performance through its various characteristics.

Researchers differed when presenting blockchain characteristics. Some specified (Chang et al., 2022) the following: anonymity, traceability, autonomy, contract automation, decentralization, immutable, irreversible, open source, ownership, and uniqueness, source, security, intelligent execution, as stated by Lin and Liao (2017) defined it as a decentralized distributed network, open source network, transparency, records cannot be deleted or modified, efficiency and speed, reducing transaction costs, privacy and anonymity, Real-time, and others have defined it as Hackius and Peterson (2017). Security, decentralization, and transparency. Given the many characteristics of blockchain technology, the researcher found that blockchains contain several distinctive characteristics, which can be presented as follows: Transparency and privacy, Decentralization, Traceability, and Smart Contracts. Blockchain technology plays an important role in supply chain management by providing information on demand forecasts, managing resources effectively, reducing inventory management costs, and tracking and monitoring goods along the supply chain. In adverse circumstances, this technology helps in accurately identifying the cause and source and automatically activates payments after validating pre-defined conditions (Yadlapalli et al., 2022). Song et al. (2019) opined that Blockchain technology represents a good system for tracking the supply chain through its various characteristics.

2.3. Supply chain management and measured

The supply chain refers to the process through which materials, money, and information move from suppliers to the final consumer. It is also known as a value chain, as it involves a series of activities that add value across different companies to meet the needs of the final consumer. Supply chain management is the practice of overseeing the flow of goods, information, and funds related to products or services, from the purchase of raw materials to delivering the final product to the consumer. The main goals of supply chain management are to improve long-term performance, reduce costs, increase profitability, provide products and services at the right price, quality, and time, and efficiently manage the flow of raw materials to ensure timely and cost-effective delivery. Additionally, it aims to resolve conflicts of interest among supply chain members, achieve a competitive advantage for companies, and meet customer demands (Kummer et al., 2020). Wang et al. (2023) showed that there are financial consequences caused by supply chain disruptions during COVID-19 and indicate firms' supply chain diversification strategies, including diversified suppliers, customers, and products, moderate the negative effect on shareholder value, operating performance, and firm performance. The supply chain efficiency increases by achieving its goals, so any business with a supply chain must manage all suppliers, manufacturers, consumers, and logistics parties accurately and quickly. Today, supply chains have become more complex and often lack transparency and speed, making it difficult to maintain their efficient performance. As a result, the use of blockchain in supply chain management has become increasingly important (Müßigmann et al. 2020).

Supply chain performance is measured through several criteria, including cost and speed of supply, quality of performance, customer satisfaction,

quality, and appropriate timing of supply (Altay et al., 2024). Supply chain performance refers to the overall measure of how well the supply chain operates, which largely depends on the efficiency of its various stages. Efficiency, in this context, means the ratio of outputs to inputs. To improve efficiency, companies need to maximize performance and reduce costs while recognizing the limitations of achieving a competitive advantage. Efficiency can be enhanced by meeting supply chain objectives, which can be supported by decentralization, transparency, tracking, and automation. Blockchain technology, with these characteristics, helps achieve supply chain goals and, therefore, increases its efficiency (Hald and Kinra, 2019).

2.4. The impact of blockchain technology characteristics on supply chain performance

Most previous studies have focused on different characteristics of blockchain technology; the present study is the first to focus on four characteristics (Transparency and privacy, Decentralization, Traceability, and Smart Contracts) and examine the relationship between them and the performance of supply chains from the point of view of accounting thought in Saudi industrial companies.

2.4.1. Transparency and privacy

This feature improves the level of transparency for all transactions compared to traditional systems, as it is an open-source network that allows all parties in the supply chain to view all data and transactions. Any changes can only be made with the approval of all parties involved. This increases transparency and trust between the participants in the supply chain and consumers while also providing data, identifying the causes of costs, and uncovering opportunities to reduce costs (Ivaninskiy and Ivashkovskaya, 2022). This feature allows information to flow easily between all parties in the supply chain and provides quick access when needed. It helps companies manage risks, sustain their supply chains, and increase customer confidence by improving their awareness of product quality and safety. Additionally, it enhances interaction between all parties in the supply chain, including suppliers, producers, customers, and distributors, improving performance and quality. The feature also enables real-time sharing of resources and information from suppliers to customers while simplifying production processes. It allows accountants to access the network and gather data on activities, customers, suppliers, distributors, wholesalers, and retailers within the supply chain. Privacy also plays a role in improving supply chain performance by building security and trust between participants and reducing risks through maintaining data privacy and protecting user identities. Therefore, the researcher believes that the transparency and privacy features of blockchain technology contribute to a more efficient and transparent supply chain, ultimately improving its performance.

2.4.2. Decentralization

This feature provides a decentralized database that maintains records of digital transactions through distributed offices without the need for an intermediary from the financial market or the bank, which helps accountants verify the accuracy of the data and that it is free from any fraud or error and thus increasing the truthfulness of the information. Decentralization eliminates individual weak points from the use of central systems in terms of monopolizing the storage and management of data (Dhillon et al., 2023). As a result of the lack of central authority to control the system within the network and the availability of a verifiable record of every financial transaction, people within the network can authenticate and verify the transactions. This feature facilitates cooperation between entities. It is effective and verifies the origin of the goods and the conditions of their transfer until they reach the final consumer, which contributes to reducing hacking and loss of data. It also helps accountants in verifying financial transactions and ensuring their authenticity, and that there is a sufficient balance of funds with the sender to complete the transaction, which contributes to increasing confidence in the transactions that take place on the length of the supply chain, so researcher believes that decentralization feature of blockchains lead to improving supply chain performance.

2.4.3. Traceability

The importance of the traceability feature appears when applying blockchain technology in supply chain management, as it can ensure the safety of operations by tracking illustrative maps stored on the blockchain network and tracking the product, which contributes to saving resources, scheduling production, tracking the progress of goods as they pass through the supply chain, and delivering the product with high quality in a timely manner to achieve customer satisfaction (Mukherjee et al., 2023), this feature provides participants in the supply chain with accurate and stable financial and non-financial data about the company's activities and how to exploit resources, verifying the safety and quality of the product from its source until it reaches the final consumer, and forecasting demand in the market and supporting production decisions according to Liu (2023), tracking supply chain quality eliminates fraud risks, prevents adulteration of products, and increases operational efficiency, which contributes to creating added value for organizations. Tracking helps accountants support the value chain analysis method between the parties of the chain (Chaouni Benabdellah et al. 2023), activating the target costing method, determining the costs and revenues achieved from the facility's activities, and activating inter-cost management

tools, traceability also eliminates unethical practices of stakeholders, which supports the coordination and integration of the supply chain. Therefore, the researcher believes that the traceability feature of blockchains leads to improving supply chain performance, as stated by Hastig (2019).

2.4.4. Smart contracts

Smart contracts and the use of Bitcoin-encrypted currencies help reduce costs and speed up commercial transactions, including import and export processes, by enabling instant payments. They also reduce errors by automatically executing pre-agreed terms without the need for intermediaries like banks, unlike traditional systems. This eliminates the delays of traditional banking systems, which require manual audits, especially for cash assets, and removes the additional expenses paid to intermediaries. Smart contracts also assist accountants in monitoring costs and verifying that all parties comply with agreed terms, such as purchase costs and penalties for delayed deliveries, leading to higher profits (Ghariani and Boujelbene, 2024). By using smart contracts, supply chain transactions become faster and less expensive, allowing companies to agree on product specifications, prices, delivery times, and related logistical costs while simplifying payment methods and reducing transaction costs. They also reduce the need for letters of guarantee, secure financing conditions, prevent fraud and contract manipulation, and lower the risk of non-payment, as payments are made electronically using digital currencies once the contract is fulfilled. Additionally, smart contracts help accountants reduce costs by managing inventory more efficiently and minimizing non-value-adding activities like promotion, distribution, transportation, handling, and storage. Therefore, the researcher believes that the use of smart contracts through blockchain technology leads to improved supply chain performance. From the part above, it becomes clear to the researcher the importance of blockchain technology in the supply chain sector, as it contributes, through its various characteristics, to increasing the efficiency of supply chain performance, which can be expressed in Fig. 1.

Based on the above literature review, the study's main hypothesis can be formulated as follows:

H1: Blockchain technology characteristics have a positive impact on supply chain performance.

It is divided into four sub-hypotheses as follows:

H1.1: Blockchain technology characteristics (transparency and privacy) have a positive impact on improving supply chain performance in Saudi industrial companies.
H1.2: Blockchain technology characteristics (decentralization) have a positive impact on improving supply chain performance in Saudi industrial companies.
H1.3: Blockchain technology characteristics (traceability) have a positive impact on improving supply chain performance in Saudi industrial companies.
H1.4: Blockchain technology characteristics (smart contracts) have a positive impact on improving supply chain performance in Saudi industrial companies.

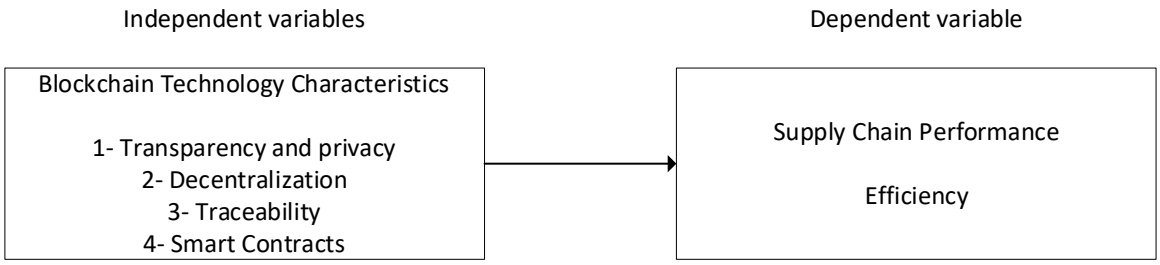

Fig. 1: The relationship between blockchain technology characteristics and supply chain performance

3. Research methodology

3.1. Sample selection and data collection

The study population includes faculty members from Accounting Departments at Saudi universities, accountants from Saudi industrial companies, and experts in information and communications technology who specialize in blockchain and supply chain fields based on their experience and knowledge of the industry. Given the large size of the study population, the researcher selected a sample of 150 individuals from 2012 to August 2023. The field study participants were chosen for their scientific and practical experience, and industrial joint stock companies listed on the Saudi stock market were selected because they are among the most active sectors and key pillars of the Saudi economy, especially following the launch of the "National Industrial Development and Logistics Services Program" within Saudi Vision 2030. Data was collected to test the study hypotheses through a questionnaire, which contained a series of statements to gauge the attitudes of the sample group towards the study variables. To design this model, the researcher reviewed several previous studies and used a five-point Likert scale. Before distributing the questionnaire, it was reviewed by Saudi university professors specializing in this field, and adjustments were made based on their feedback.

The final form of the questionnaire was created after incorporating the opinions of these experts. According to Table 1, 112 valid questionnaires were received, yielding a response rate of 74.7%, which is acceptable for statistical analysis.

When reviewing the first section of the survey, lists Table 2, it was found that the academic qualification of the respondents was the largest percentage of PhD holders, 40.2%. I also found that the highest percentage of years of experience was for those with more than 15 years of experience, representing 42.9%, which gives reassurance to the level of experience of the interviewee. It was also found that 42.0% of accountants and experts relate their companies' interest in the topic of Blockchain to the reality of work and its relationship to supply chains, and 100% of academics relate to it from the reality of scientific interest and scientific research, which covers the various aspects of research and gives reassurance of the realism of the data.

Table 1: Collecting questionnaire forms for the study

Percentage	Total number of forms			Categories
	Distributed	Received	Feedback	
80%	50	40	10	Faculty members in Saudi universities
76%	50	38	12	Accountants in Saudi industrial companies
68%	50	34	16	ICT experts
74.7%	150	112	38	Total

Table 2: Study sample distribution by academic qualification, experience, and company use of blockchain technology

Category	1	2	3	4	5	6	7	8	9	Total
Faculty members (no.)	7	11	20	6	24	8	6	11	21	100%
Faculty members (%)	18.4%	28.9%	52.6%	15.8%	63.2%	21.1%	15.8%	28.9%	55.3%	100%
Accountants (no.)	9	17	8	15	11	8	5	8	21	100%
Accountants (%)	26.5%	50.5%	23.5%	44.1%	32.4%	23.5%	14.7%	23.5%	61.8%	100%
ICT experts (no.)	45	36	31	48	45	19	11	19	82	100%
ICT experts (%)	40.2%	32.1%	27.7%	42.9%	40.2%	17.0%	9.8%	17.0%	73.2%	100%

1: PhD; 2 Master; 3: Bachelor's degree; 4: More than 15 years; 5: 10-15 years; 6: Less than 5 years; 7: No knowledge of blockchain; 8: Aware nut not used blockchain; 9: Uses blockchain in supply chain

3.2. Study variables and measurement

- Independent Variable (X): Four characteristics of blockchain technology (Transparency and Privacy, Decentralization, Traceability, Smart Contracts).
- Dependent Variable (Y): The efficiency of supply chains. The questionnaire was structured around two main questions, with the researcher using 31 sub-questions to measure the variables. These variables are summarized as follows (abbreviations are explained in Appendix A):
  - Question 1 (Z1): Examines the impact of blockchain characteristics on supply chain performance and includes questions X1 to X22.
  - Question 2 (Z2): Assesses supply chain performance and includes questions Y1 to Y9.

4. Discussion of the results

4.1. Reliability and validity coefficients

By reviewing Table 3, the value of Cronbach's alpha coefficient was high for all variables of the survey form by sample and greater than 70%, and the value of self-reliability for all variables was greater than 90%, so it can be relied upon in generalizing the results to society.

Table 3: Reliability and validity coefficients for survey questionnaire questions

Statement	No. of items	Reliability coefficient (Cronbach's alpha)			Honesty coefficient		
		Academics	Accountants	Experts	Academics	Accountants	Experts
The impact of blockchain characteristics on supply chain performance	22	0.818	0.839	0.844	0.904	0.916	0.919
Factors that lead to improved supply chain performance	9	0.765	0.718	0.715	0.875	0.847	0.846
Questionnaire form variables	31	0.823	0.904	0.903	0.907	0.951	0.950

4.2. Smironoff-kilmogrove test

Table 4 shows the Smironoff-Kilmogrove test, which is considered one of the statistical tests that are used to examine the collected data to see whether it is normally distributed or not. It is a necessary test in the case of testing hypotheses because most laboratory tests require that the distribution of data be normal, and the researcher obtained the following results.

Table 4 shows that the significance levels of Z1 and Z2 are less than the significance level (α>0.05), indicating that the data follows a normal distribution.

Table 4: Results of the Smironoff-Kilmogrove test for one sample

Variables		Z1	Z2
N		112	112
Normal parameters	Mean	4.316	4.313
	Std. deviation	0.429	0.427
Kolmogorov-Smirnov Z		0.150	0.128
Asymp. Sig. (2-tailed)		0.001	0.001

4.3. The results of the hypothesis

Descriptive tests of the variables and simple linear regression analysis were performed using SPSS version 29 to test the hypothesis.

Table 5 shows that most respondents rated the impact of blockchain technology characteristics on

improving supply chain performance in Saudi companies as important to very important. The arithmetic mean of responses ranged from 3.76 to 4.97, while the standard deviation ranged from 0.171 to 0.944. Each sub-hypothesis was tested individually using simple linear regression analysis.

Table 5: Results of descriptive tests for the variables

Experts				Accountants				Academics				Variables
Ranking	Std. error	Std. deviation	Mean	Ranking	Std. error	Std. deviation	Mean	Ranking	Std. error	Std. deviation	Mean	
3	.041	.239	4.94	2	.064	.393	4.18	1	.076	.480	4.23	X1
4	.056	.327	4.88	6	.093	.574	3.68	4	.050	.316	4.05	X2
1	.029	.171	4.97	1	.064	.393	4.18	2	.086	.545	4.10	X3
5	.070	.409	4.88	5	.122	.754	3.84	6	.067	.423	3.98	X4
6	.075	.436	4.85	3	.069	.428	4.08	3	.070	.441	4.10	X5
2	.041	.239	4.94	4	.094	.578	3.87	5	.062	.392	4.00	X6
2	.041	.239	4.94	2	.053	.324	4.05	2	.064	.404	4.13	X7
5	.041	.239	4.94	5	.079	.490	3.76	5	.130	.822	3.88	X8
4	.041	.239	4.94	3	.059	.367	4.03	4	.078	.496	3.90	X9
1	.029	.171	4.97	4	.118	.727	3.89	3	.062	.392	4.00	X0
3	.041	.239	4.94	1	.074	.457	4.18	1	.082	.516	4.20	X11
3	.041	.239	4.94	5	.103	.634	3.76	2	.084	.533	4.35	X12
1	.029	.171	4.97	2	.056	.343	4.13	1	.094	.594	4.43	X13
5	.086	.500	4.59	4	.122	.749	3.92	4	.104	.660	4.23	X14
2	.041	.239	4.94	3	.065	.399	4.05	5	.109	.687	4.20	X15
4	.065	.379	4.91	1	.130	.801	4.18	3	.104	.656	4.32	X16
5	.082	.479	4.79	2	.073	.453	4.11	3	.078	.494	4.25	X17
1	.059	.343	4.94	4	.108	.665	3.87	2	.093	.586	4.37	X18
2	.065	.379	4.91	1	.067	.414	4.13	5	.094	.594	4.17	X19
4	.079	.459	4.82	5	.101	.622	3.79	4	.123	.781	4.17	X20
3	.086	.500	4.85	3	.079	.487	3.92	6	.149	.944	3.93	X21
6	.086	.500	4.59	6	.106	.654	3.71	1	.079	.501	4.58	X22
8	.086	.500	4.59	6	.122	.749	3.92	5	.104	.660	4.23	Y1
5	.082	.479	4.79	4	.065	.399	4.05	6	.109	.687	4.20	Y2
4	.066	.387	4.82	1	.130	.801	4.18	3	.104	.656	4.32	Y3
6	.082	.479	4.79	3	.073	.453	4.11	4	.078	.494	4.25	Y4
1	.029	.171	4.97	7	.108	.665	3.87	2	.093	.586	4.37	Y5
3	.099	.576	4.82	2	.067	.414	4.13	8	.094	.594	4.17	Y6
7	.082	.479	4.79	8	.101	.622	3.79	7	.123	.781	4.17	Y7
2	.075	.436	4.85	5	.079	.487	3.92	9	.149	.944	3.93	Y8
9	.086	.504	4.56	9	.106	.654	3.71	1	.079	.501	4.58	Y9

Table 6 shows the results of the simple linear regression analysis for the first sub-hypothesis, H1.1, where we find that the correlation coefficient value is R=761. This indicates the existence of a high direct relationship between the transparency and privacy characteristic of blockchains (XC1) and the performance of the supply chain (Y) in the Saudi industrial sector, and this characteristic can explain a percentage of 58% of the change in supply chain performance, where the value of the coefficient of determination R = 0.575, and the value of sig. It is 0.000, which is less than 0.01, and this indicates that there is a statistically significant effect of the transparency and privacy of blockchains on improving the performance of the supply chain. Therefore, we accept the hypothesis: "Blockchain technology characteristics (transparency and privacy) have a positive impact on improving supply chain performance in Saudi industrial companies."

Table 6: Results of simple linear regression analysis for the data

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.	F	Sig.	Collinearity statistics		Results
		B	Std. error	Beta					Tolerance	VIF	
H1.1	Constant	1.399	.238		5.866	.001	151.114	.000			
	XC1	.678	.055	.761	12.293	.000			1.000	1.000	Accept
			R = .761		R Square = .579				Adjusted R Square = .575		
H1.2	Constant	1.557	.251		6.193	.001	121.673	.000			
	XC2	.642	.058	.725	11.031	.000			1.000	1.000	Accept
			R = .725		R Square = .525				Adjusted R Square = .521		
H1.3	Constant	.602	.185		3.248	.002	404.606	.000			
	XC3	.848	.042	.887	20.115	.000			1.000	1.000	Accept
			R = .887		R Square = .786				Adjusted R Square = .784		
H1.4	Constant	.488	.114		4.287	.001	1139.218	.000			
	XC4	.887	.026	.955	33.752	.000			1.000	1.000	Accept
			R = .955		R Square = .912				Adjusted R Square = .911		

VIF: variance inflation factor

Regarding the second sub-hypothesis, H1.2, we find that the value of the correlation coefficient is .725 = R. This indicates the existence of a high direct relationship between the decentralization characteristic of blockchains (XC2) and the performance of the supply chain (Y) in the Saudi sector, and the decentralization characteristic of blockchains can explain 78% of the change the outcome in supply chain performance, where the value of the coefficient of determination R =.784, and the value of sig. It is 0.000, which is less than 0.01, and this indicates that there is a statistically significant effect of the decentralization of blockchains on improving the performance of the supply chain. Therefore, we accept the hypothesis: "Blockchain technology characteristics

(decentralization) have a positive impact on improving supply chain performance in Saudi industrial companies."

Regarding the third sub-hypothesis, H1.3, we find that the value of the correlation coefficient is .887 =R. This indicates the existence of a highly direct relationship between traceability blockchains (XC3) and supply chain performance (Y) in the Saudi industrial sector. The feature of tracking blockchains can explain 78% of the change that occurred in supply chain performance, the value of the coefficient of determination R = .784, and the value of sig. It is 0.000, which is less than 0.01, and this indicates that there is a statistically significant effect of traceability blockchains on improving the performance of the supply chain. Therefore, we accept the hypothesis: "Blockchain technology characteristics (traceability) have a positive impact on improving supply chain performance in Saudi industrial companies." For the third sub-hypothesis, H1.4, the correlation coefficient (R) is .955, indicating a very strong positive relationship between blockchain smart contracts (XC4) and supply chain performance (Y) in the Saudi industrial sector. Smart contracts account for 91% of the variation in supply chain performance, with the coefficient of determination (R^2) equal to .911. The sig. is less than 0.01, showing a statistically significant effect of smart contracts on improving supply chain performance. Therefore, we accept the hypothesis: "Blockchain technology characteristics (smart contracts) have a positive impact on improving supply chain performance in Saudi industrial companies."

Using multiple regression to test the main hypothesis with the aim of measuring the relationship between the independent variables (characteristics of the four blockchains) XC1, XC2, XC3, XC4 and the dependent variable Y (supply chain performance represented by efficiency), Table 7 shows the following results.

Table 7: Results of the multiple regression analysis to test the significance of the model

Model	Unstandardized coefficients		Standardized coefficients	T	Sig.	Collinearity statistics	
	B	Std. error	Beta			Tolerance	VIF
Constant	.203	.091		2.229	.028		
XC1	-.090	.042	-.101	-2.138	.035	.351	2.849
XC2	-.007	.038	-.008	-.182	.021	.231	4.336
XC3	.370	.039	.387	9.393	.000	.255	3.929
XC4	.674	.035	.725	19.222	.000	.304	3.289
			R = .977				
	R Square = .954			Adjusted R Square = .952			
	F = 550.86			Sig. = .000			

VIF Less than 5, it means there is no problem of multicollinearity between the variables and the results are reliable; Level of statistical significance 5%

Table 7 presents the results of the multiple linear regression analysis for the main hypothesis. It shows a strong correlation between the dependent variable (supply chain performance) and the independent variables (blockchain characteristics XC1, XC2, XC3, XC4). The correlation coefficient (R) is 0.977, and the coefficient of determination (R^2) is 0.925, indicating that 95% of the variation in supply chain performance is explained by the independent variables, which is a very high percentage.

The VIF values range between 1 and 5, showing no multicollinearity between the independent variables. According to Maddala and Lahiri (1992), VIF values should be less than 5 and greater than 1.

The ANOVA test for the regression model shows a sig. of 0.000, which is less than 0.01, indicating that the model is statistically significant. Therefore, blockchain characteristics have a significant effect on improving supply chain performance.

As a result, we accept the hypothesis: "Blockchain technology characteristics have a positive impact on improving supply chain performance in Saudi industrial companies."

5. Conclusions, limitations, and future studies

This study aims to analyze the impact of blockchain technology characteristics on supply chain performance in Saudi industrial companies. The results highlight the importance of blockchain technology in improving supply chain performance and show that key blockchain features—transparency and privacy, decentralization, traceability, and smart contracts—have a positive effect on supply chain performance in these companies. The study encourages companies to adopt blockchain technology in their supply chains to create a reliable, transparent, and secure system that adds value to products, improves response times to customer demands, and helps monitor costs associated with suppliers.

The findings have practical implications for emerging Saudi companies, especially in enhancing supply chain efficiency in a changing business environment. However, this study was limited to examining the impact of blockchain characteristics on supply chains in the Saudi industrial sector.

The study recommends further research into the relationship between blockchain technology and corporate governance, exploring other sectors, analyzing tax issues related to blockchain operations, and training accountants and employees on how to use blockchain effectively to improve supply chain performance and strengthen the competitive position of businesses.

Appendix A. Variables abbreviations

The abbreviations of variables are explained in Table A1.

Table A1: Abbreviations of variables

Variables	Symbol		Explanation of the abbreviations
Z1	XC1	X1	Transparency enables participants in the supply chain to see all data and transactions and cannot be changed except after the approval of all parties, which raises the level of transparency and trust in the data, identifies cost causes, and discovers cost opportunities
		X2	Transparency allows accountants to identify the of activities number necessary to carry out a job, ensure that procedures are implemented correctly, and collect the required data on all transactions and activities of suppliers, distributors, and customers across the supply chain
		X3	Enhancing transparency, which in turn increases the level of trust between entities participating in supply chains and consumers, and access to information related to activities and their flow from the source to the final consumer in real-time, while simplifying the procedures for production activities
		X4	Transparency enhances levels of performance and quality by supporting the facility's interaction with all parties of the supply chain, including suppliers, producers, and customers
		X5	Transparency helps manage risks, increases flexibility degree in the use of information technology, and sustains supply chains in the long term
		X6	Privacy builds security and trust between supply chain parties by maintaining privacy and not revealing the user's identity
	XC2	X7	Decentralization increases the speed of access to information, which helps in verifying the accuracy of data and information, which in turn reduces information asymmetry
		X8	Decentralization eliminates individual weaknesses from using centralized systems in terms of monopolizing data storage and management
		X9	Decentralization facilitates cooperation between actors and ensures the origin of goods and the conditions of their transformation until they reach the final consumer, which contributes to reducing hacking, data loss, and conditions of uncertainty facing supply chain parties
		X10	Decentralization enhances the verifiability of every financial transaction and ensures that the sender has sufficient funds to complete the transaction to ensure that no fraud occurs and increases confidence in the transactions that take place along the supply chain
		X11	Decentralization helps accountants review, retrieve, and verify all data and transactions stored on the network, which contributes to increasing confidence in transactions that take place along the supply chain
	XC3	X12	Traceability can ensure operations safety by tracking illustrative maps stored on the Blockchain network and tracking the product, which contributes to saving resources, scheduling production, tracking the progress of goods as they pass through the supply chain, and delivering the product with high quality and at the right time to achieve customer satisfaction
		X13	Traceability provides participants in the supply chain with accurate and consistent financial and non-financial data about the company's activities, and how resources are exploited, verifying the safety and quality of the product from its source until it reaches the final consumer, forecasting market demand, and supporting production decisions
		X14	Tracking supply chain quality eliminates fraud risks, prevents product adulteration, identifies, and addresses production defects, and increases operational efficiency, which contributes to creating added value for organizations
		X15	Tracking helps management accountants support the value chain analysis method between supply chain parties, activating the target costing method, and determining the costs and revenues achieved from the facility's activities
		X16	Traceability eliminates unethical practices of stakeholders, which supports the coordination and integration of the supply chain
	XC4	X17	Smart contracts reduce costs and increase the speed of transactions which are executed automatically when pre-specified agreement conditions are met without intermediaries compared to traditional systems
		X18	Smart contracts eliminate the slowness of traditional banking systems when settling financial transactions, which require manual auditing, and eliminate the additional expenses paid to intermediaries to complete transactions
		X19	Smart contracts help accountants verify the commitment of all parties to costs and constantly monitor them, such as purchasing costs and costs of delay in delivery, which results in increased profits and thus supply chain transactions become convenient and at a lower cost
		X20	Smart contracts enable companies to contract product specifications, price, delivery times, and related logistics costs while simplifying payment methods, lowering transaction costs, reducing letters of guarantee, and securing financing conditions
		X11	Smart contracts eliminate fraud and manipulation of contracts and reduce the risk of non-payment, as payment is made electronically using digital currencies as soon as the contracting process is completed, and the goods are transferred with the required specifications and quality
		X22	Smart contracts help accountants reduce costs by managing inventory and reducing non-value-adding activities such as merchandising, distribution, transportation, handling, and storage
Z2		Y1	Achieving the highest possible performance while reducing transaction costs and producing products with the required quality
		Y2	Speeding the product flow and information and improving response to customer requests and suggestions to achieve added value to companies' products
		Y3	Providing high-quality products at an appropriate price, which contributes to achieving competitive advantages for companies
		Y4	Performing operations in a correct manner while activating the oversight role over the performance of all parties within the supply chain
		Y5	Increasing transparency for all parties of the supply chain and sharing information, so there is no delaying the delivery of products and thus reducing delay costs
		Y6	Providing accurate and timely information to all parties of the supply chain, while unifying this information to improve the relationship with suppliers and customers by sharing and exchanging financial and non-financial information, ideas, and experiences among them
		Y7	Relying on information increases trust and transparency among all parties in the supply chain
		Y8	Successfully managing the risks facing the supply chain in periods of uncertainty
		Y9	Reducing the product life cycle time and improving inventory management, which is reflected in a decrease in the cost of products and an increase in the market share of companies

Acknowledgment

This work was funded by the University of Jeddah, Jeddah, Saudi Arabia, under grant No. (UJ-22-DR-98). The author, therefore, acknowledges with thanks the University of Jeddah for its technical and financial support.

Compliance with ethical standards

Ethical considerations

Informed consent was obtained from all participants, and their anonymity was ensured. The research adhered to the ethical guidelines set by the University of Jeddah and complied with the Declaration of Helsinki.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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