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The role of blockchain technology in advancing supply chain innovation: A descriptive-analytical study

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Abstract

This study aims to explore the role of blockchain technology in enhancing supply chain quality by examining key aspects such as security, transparency, decentralization, and trust within the context of the Egyptian Customs Authority. A descriptive analytical approach was employed, with a sample of 300 employees selected using stratified random sampling to represent various departments, including operations, logistics, and IT. Data was collected through structured surveys and analyzed using Structural Equation Modeling (SEM) and Confirmatory Factor Analysis (CFA). The results indicate that transparency and decentralization are the most influential factors in improving supply chain performance. Security significantly enhances efficiency, while trust positively impacts efficiency and cost reduction. However, security and trust did not show a significant effect on timeliness. Blockchain technology enhances supply chain operations by increasing transparency and decentralization, leading to improved efficiency and cost-effectiveness. These findings underline the potential of blockchain to revolutionize supply chain management. The study provides valuable insights for managers, policymakers, and researchers looking to implement blockchain in supply chains to secure competitive advantages and drive innovation.

Keywords: Blockchain technology, Cost reduction, Decentralization, Efficiency, Innovation, Structural equation modeling, Supply chain management, Transparency.

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1. Introduction

The growing intricacies of worldwide supply networks and the swift progress of technology have underscored the necessity for creative approaches to tackle inefficiencies and improve operational efficiency. In the vast landscape of technological progress, blockchain technology stands out as a groundbreaking force with the potential to fundamentally change supply chain management. The capacity to provide transparency, security, and decentralization presents a strong solution for tackling issues such as fraud, inefficiency, and the absence of trust among stakeholders.

This research is significant due to the essential function that blockchain can serve in updating supply chains to align with the needs of global economies. This research explores the challenge of incorporating blockchain technology into supply chain processes to eliminate conventional obstacles and enhance performance indicators. This study is carried out within the framework of organizational initiatives aimed at adjusting to a swiftly evolving technological environment, where embracing cutting-edge tools such as blockchain is crucial for maintaining a competitive edge. This study highlights how blockchain can improve transparency, lower costs, and optimize operations, adding to the current conversation about technological advancements in supply chain management. This work lays the groundwork for comprehending the systematic application of blockchain in addressing inefficiencies and enhancing trust in intricate logistical networks.

2. Literature Review

Blockchain technology has emerged as an innovative solution to significant issues in supply chain management, garnering considerable interest from both academia and industry. With the rising complexity and interconnectivity of supply chains, it is essential to develop innovative solutions that ensure efficiency, transparency, and trust. The decentralized nature of blockchain, supported by cryptographic techniques, offers a revolutionary method for addressing these challenges, positioning it as a crucial area of focus for current inquiry. Blockchain fundamentally functions as a decentralized ledger mechanism, wherein information is authenticated, documented, and preserved across a network of interconnected nodes. In contrast to conventional centralized databases, blockchain promotes transparency and data integrity by allowing every participant in the network to access an unchangeable and time-stamped version of the ledger [1]. This aspect holds significant importance in supply chains, where strong traceability systems are essential for ensuring authenticity and reducing the risk of fraud. Utilizing blockchain technology in this area has demonstrated a decrease in operational inefficiencies and an improvement in stakeholder trust [2]. The first application of blockchain technology occurred within the financial industry, especially in relation to cryptocurrencies like Bitcoin. Nonetheless, its capacity to tackle inefficiencies in various sectors, such as supply chain management, healthcare, and public administration, soon became evident [3]. In the realm of supply chains, blockchain enhances the precise monitoring and validation of products, leading to increased dependability and management efficiency. Research conducted by D'Atri, et al. [4] and Punga and Dutescu [5] emphasizes the potential of blockchain to combat data manipulation, fraud, and delays, providing a robust framework for validating transactions.

The key aspects of blockchain that pertain to the quality of supply chains encompass security, transparency, decentralization, and trust. Security serves as a fundamental aspect of blockchain technology, safeguarding transaction data from unauthorized access via sophisticated encryption and consensus mechanisms. This holds particular importance in settings such as customs operations, where the secure exchange of data is essential [5]. Transparency, a crucial characteristic, offers all participants a common perspective on supply chain activities, minimizing information asymmetry and facilitating real-time tracking of goods. Increased transparency has been associated with higher compliance rates, lower levels of corruption, and greater confidence among stakeholders [6, 7]. The aspect of decentralization represents a significant transformation brought about by blockchain technology. Distributing data management across a network of nodes, as opposed to relying on a central authority, effectively reduces the risks linked to system failures and bolsters resilience. This decentralized method facilitates smooth cooperation among various parties, such as customs authorities, shipping firms, and regulatory agencies, thus enhancing operational efficiency and minimizing delays [8]. Trust plays a vital role in the efficiency of supply chains, bolstered by the consensus mechanisms of blockchain that guarantee the authenticity and permanence of transactions. Research conducted by Vazquez Melendez, et al. [9] emphasizes the critical role of trust in promoting collaboration among public and private sector participants, showcasing the potential of blockchain to improve operational synergy. The influence of blockchain on essential performance metrics like efficiency, cost, and timeliness has been thoroughly recorded. Through the automation of processes via smart contracts and a decrease in dependence on paperwork, blockchain improves efficiency and speeds up customs clearance operations [10]. One notable benefit is the reduction of costs, accomplished by removing unnecessary processes and enhancing data accuracy, thereby decreasing penalties and expenses related to compliance [11]. Furthermore, the ability of blockchain to track in real-time allows for improved forecasting of delivery times, which in turn boosts customer satisfaction and competitive edge [12]. Research findings offer strong support for the beneficial impact of blockchain on the quality of supply chains. Akhavan and Philsoophian [13] highlight the role of blockchain in promoting flexibility, whereas [14] focus on its impact on sustainability. Chinyanya [15] illustrates the ways in which blockchain technology in trade finance enhances liquidity management and fosters collaboration, thereby improving the overall performance of the supply chain. Even with these advantages, obstacles like technological preparedness, regulatory hurdles, and reluctance to adapt continue to exist [16]. Successful implementation of blockchain necessitates the coordination of stakeholder involvement and the establishment of favorable regulatory environments, in addition to investments in technology and skill development [12]. In summary, the distinctive characteristics of blockchain—security, transparency, decentralization, and trust—present significant opportunities for enhancing the quality of supply chains. Despite ongoing obstacles to adoption, substantial evidence highlights the enduring advantages of integrating blockchain, especially in improving traceability, accountability, and collaboration.

The purpose of the study is to investigate the role of blockchain technology in enhancing supply chain quality through its core dimensions: security, transparency, decentralization, and trust.

Based on the review of previous studies and relevant literature, a research model was constructed to illustrate the relationships between the research variables as shown in (Figure 1):

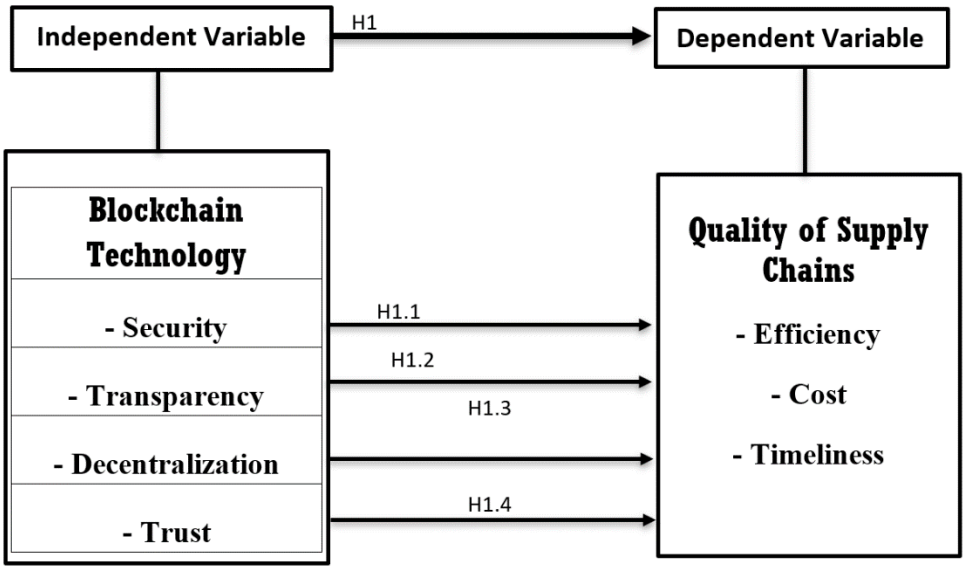

Figure 1.
Research Model.

Based on the research model and its measurements, we can formulate the research hypotheses as follows:

H_1: There is a statistically significant impact of using blockchain technology on improving the quality of supply chains within the Egyptian Customs Authority.

$H_{1.1}$: There is a statistically significant impact of security (as a dimension of blockchain technology) on improving the quality of supply chains in the Egyptian Customs Authority.

$H_{1.2}$: There is a statistically significant impact of transparency (as a dimension of blockchain technology) on improving the quality of supply chains in the Egyptian Customs Authority.

$H_{1.3}$: There is a statistically significant impact of decentralization (as a dimension of blockchain technology) on improving the quality of supply chains in the Egyptian Customs Authority.

$H_{1.4}$: There is a statistically significant impact of trust (as a dimension of blockchain technology) on improving the quality of supply chains in the Egyptian Customs Authority.

3. Methodology

The research utilizes a descriptive-analytical approach, commonly applied in studies that aim to identify and clarify the relationships among variables. This strategy allows for a comprehensive insight into how aspects of blockchain, specifically security, transparency, decentralization, and trust, affect the quality dimensions of supply chains, including efficiency, cost, and timeliness. The research employs a field-based approach, focusing on gathering primary data directly from employees at the Egyptian Customs Authority. This strategy facilitates the gathering of direct insights that capture the genuine experiences and viewpoints of employees engaged in supply chain activities.

The participants in this study are employees of the Egyptian Customs Authority, chosen for their direct involvement with customs procedures and supply chain processes. The authority is expected to have a total of 3,500 employees. To achieve a representative and generalizable sample, a straightforward random sampling approach was utilized. This approach guarantees that each employee in the population has an equal opportunity for selection, thus minimizing the chances of sampling bias.

According to the Krejcie and Morgan [17] table for determining sample size from a finite population, a sample of 300 employees was chosen for the study. This sample size is adequate to reach a 95% confidence level with a 5% margin of error, offering a solid foundation for data analysis and hypothesis testing.

Table 1 presents the characteristics of the sample, illustrating the distribution of respondents based on gender, educational qualification, years of experience, and career level. The demographic distribution offers a detailed insight into the participants involved in the study, confirming that the sample accurately reflects the broader population of the Egyptian Customs Authority.

Table 1.
Characteristics of the Study Sample (n = 300).

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	219	73.00%
	Female	81	27.00%
Educational Qualification	Pre-University	16	5.40%
	University Degree	113	37.80%
	Postgraduate Degree	171	56.80%
Years of Experience	Less than 10 years	24	8.10%
	10 to less than 20 years	130	43.20%
	20 years or more	146	48.60%
Career Level	Director General	121	40.50%
	Director of Department	49	16.20%

The information presented in Table 1 reveals that 73% of the participants are male, whereas 27% are female, emphasizing the gender breakdown within the sample. In terms of educational qualifications, 56.8% of respondents possess postgraduate degrees, 37.8% have university degrees, and 5.4% hold pre-university qualifications. A significant portion of respondents, 48.6%, possess 20 years or more of experience, while 43.2% have between 10 to 20 years. Only a small fraction, 8.1%, have less than 10 years of experience. The sample showcases a range of career levels, including 40.5% in the role of Directors General, 16.2% as Directors of Departments, and 43.2% as Heads of Departments. The variety within this demographic guarantees that insights from employees across various levels of authority are incorporated, thereby strengthening the validity of the findings. The study employed a structured questionnaire as the main tool for gathering data. The questionnaire aimed to gather pertinent information concerning blockchain technology and the quality of supply chains. To guarantee clarity, precision, and suitability of the content, the questionnaire underwent pre-testing with a small pilot sample. The insights gained from the pilot test were utilized to enhance the language, clarity, and organization of the questions. The survey is divided into three primary parts. The initial section collects demographic details of the respondents, such as gender, educational background, years of experience, and career stage. The second section delves into the various aspects of blockchain technology, encompassing elements such as security, transparency, decentralization, and trust. The third section explores the aspects of supply chain quality, emphasizing efficiency, cost, and timeliness. The questionnaire includes statements that are evaluated using a five-point Likert scale, with 1 indicating "strongly disagree" and 5 indicating "strongly agree." This strategy offers a numerical assessment of employees' perceptions, facilitating an in-depth examination of their opinions on blockchain and supply chain quality.

The analysis of data involved utilizing a blend of descriptive and inferential statistical approaches. A descriptive analysis was performed to outline the demographic features of the sample, encompassing gender, educational qualifications, years of experience, and career level. Calculations were performed for means, standard deviations, and frequencies to provide a comprehensive overview of the characteristics of the respondents. Descriptive statistics were employed to illustrate the levels of agreement with the questionnaire items concerning blockchain technology and supply chain quality. This analysis offers broad insight into how respondents view the constructs being examined. To evaluate the hypotheses and explore the connections between blockchain technology and supply chain quality, inferential statistical analysis was performed utilizing Structural Equation Modeling (SEM) and Confirmatory Factor Analysis (CFA). SEM is a statistical approach that enables researchers to examine intricate relationships among variables and assess the intensity of both direct and indirect influences. This approach was selected due to its thoroughness in examining the causal links between blockchain technology and the quality of supply chains. The research examined four primary hypotheses concerning how various aspects of blockchain influence the quality dimensions of supply chains, specifically focusing on efficiency, cost, and timeliness. Path coefficients, p-values, and Z-statistics were employed to assess the significance of these relationships.

This study's approach is thorough and meticulous, utilizing a strong research framework, a suitable sampling strategy, credible and dependable measurement instruments, and advanced data analysis methods. A structured questionnaire, along with Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM), guarantees the validity and reliability of the findings. The study engages a varied group of employees from the Egyptian Customs Authority, reflecting a range of viewpoints on how blockchain technology can enhance supply chain quality. The careful approach ensures that the study yields reliable, broadly applicable, and practical insights for decision-makers, professionals, and researchers in the areas of blockchain technology, supply chain management, and customs modernization.

4. Results

4.1. Validity and Reliability Coefficients of Study Variables

To guarantee the accuracy and dependability of the questionnaire, various approaches were utilized. Content validity was confirmed through discussions with academic experts and professionals specializing in blockchain technology and supply chain management. Their input enhanced the clarity, relevance, and comprehensiveness of the questionnaire items. Construct validity was confirmed through Confirmatory Factor Analysis (CFA), ensuring that the items effectively assessed the dimensions of blockchain and supply chain quality. The assessment of reliability was conducted using Cronbach's alpha coefficient, which serves as an indicator of internal consistency. The findings demonstrated strong internal consistency across all dimensions, as illustrated in Table 2.

Table 2.
Validity and Reliability Coefficients of Study Variables.

Dimension	Number of Items	Cronbach's Alpha (α)	Composite Reliability
Security	3	0.775	0.88
Transparency	3	0.729	0.854
Decentralization	3	0.825	0.908
Trust	3	0.73	0.854
Efficiency	3	0.814	0.902
Cost	3	0.808	0.899
Timeliness	3	0.778	0.882

The values presented in Table 2 show that Cronbach's alpha coefficients for all variables exceed the recommended threshold of 0.70, indicating a strong level of internal consistency. The composite reliability values surpass the 0.70 threshold, demonstrating robust construct reliability. The findings validate and affirm the dependability of the measurement tool, guaranteeing the precision of the data gathered for this study.

This study presents its results comprehensively, featuring Confirmatory Factor Analysis (CFA), descriptive statistics, and Structural Equation Modeling (SEM) for testing hypotheses. The findings illustrate how the various aspects of blockchain technology—such as security, transparency, decentralization, and trust—contribute to improving the quality of supply chains regarding efficiency, cost, and timeliness.

A Confirmatory Factor Analysis (CFA) was performed to evaluate the measurement model. The Goodness-of-Fit Indices (GFI) were employed to assess the suitability of the proposed model. Table 3 presents the fit indices used to evaluate the CFA model.

Table 3.
Goodness-of-Fit Indices.

Index	Acceptance Condition
Chi-Square (X^2) Test	p-value < 0.05
Goodness of Fit Index (GFI)	GFI > 0.90
Adjusted Goodness of Fit Index (AGFI)	AGFI > 0.90
Normed Fit Index (NFI)	NFI > 0.90
Relative Fit Index (RFI)	RFI > 0.90
Incremental Fit Index (IFI)	IFI > 0.90
Tucker Lewis Index (TLI)	TLI > 0.90
Comparative Fit Index (CFI)	CFI > 0.90
Root Mean Square Error of Approximation (RMSEA)	RMSEA < 0.08

Table 3 shows the conditions that must be met for the model to be considered a good fit. If most of the indices meet their respective thresholds, it indicates that the proposed model is a good fit for the data.

The Confirmatory Factor Analysis for blockchain technology was conducted to assess how well the variables (security, transparency, decentralization, and trust) represent the underlying construct. The results are depicted in Figure 2, which visually represents the relationships between the observed variables and the corresponding latent factors.

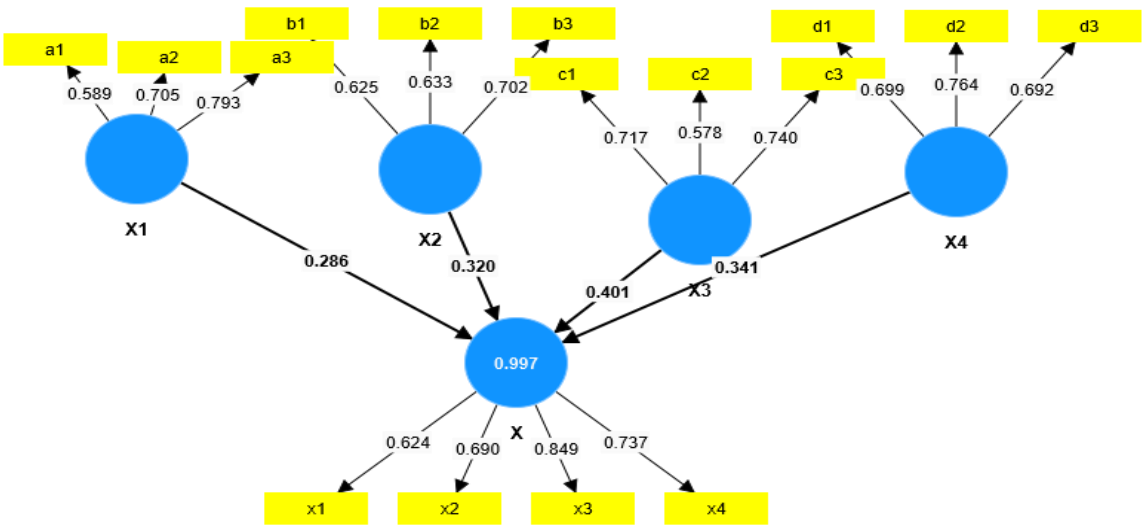

Figure 2.
Confirmatory Factor Analysis (CFA) for Blockchain Technology.

The fit indices for the blockchain technology model are summarized in Table 4, which confirms that the model fits the data appropriately.

Table 4.
Model Fit Indices for Blockchain Technology.

Index	Value
Chi-Square (X^2) Test	349.213
p-value	0.000
GFI	0.977
AGFI	0.925
NFI	0.938
RFI	0.978
IFI	0.945
TLI	0.957
CFI	0.919
RMSEA	0.016

The fit indices shown in Table 4 indicate that all essential indices surpass their respective thresholds, validating the model's goodness of fit. Although the Chi-Square test showed significance because of the large sample size, other indices like GFI (0.977), CFI (0.919), and RMSEA (0.016) fulfilled their acceptance criteria, suggesting a satisfactory model fit. To enhance the understanding of the connections between blockchain technology and its various aspects, Table 5 displays the estimates of the path coefficients, standard errors, and p-values for each path in the model.

Table 5.
CFA Model Estimates for Blockchain Technology.

Paths	Estimate B	S.E.	Z-Test	p-value
Security → Blockchain Technology	0.286	0.032	19.385	***
Transparency → Blockchain Technology	0.32	0.011	24.198	***
Decentralization → Blockchain Technology	0.401	0.029	27.146	***
Trust → Blockchain Technology	0.341	0.051	23.884	***

The estimates in Table 5 show that every aspect of blockchain technology (security, transparency, decentralization, and trust) exhibits significant path coefficients with p-values below 0.05, highlighting their substantial impact on the blockchain technology construct.

The Confirmatory Factor Analysis for supply chain quality was performed to assess the relationship between the dimensions (efficiency, cost, and timeliness) and the construct of "enhancing the quality of supply chains." Figure 3 shows the connections between the observed variables and the underlying factors.

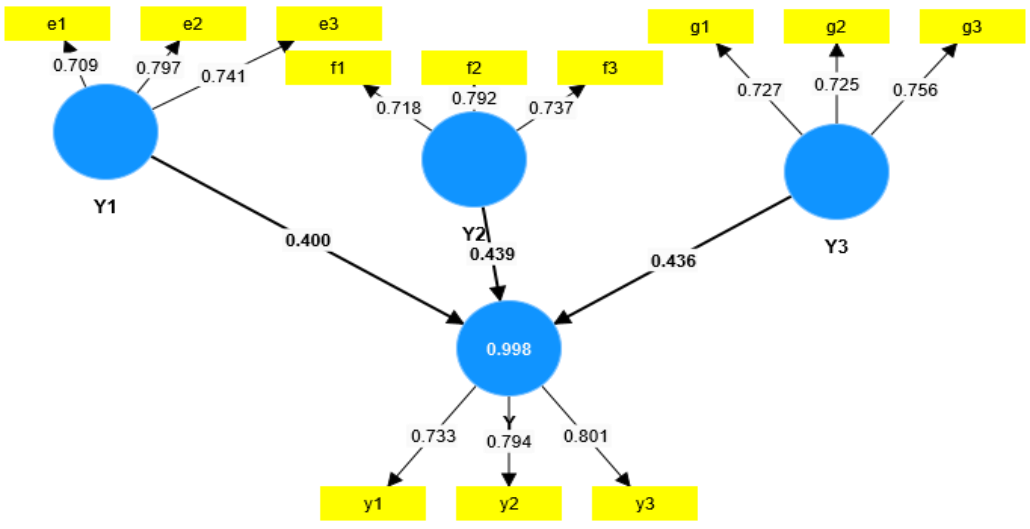

Figure 3.
Confirmatory Factor Analysis (CFA) for Improving the Quality of Supply Chains.

The results for the fit indices of the model are shown in Table 6.

Table 6.
Model Fit Indices for Improving the Quality of Supply Chains.

Index	Value
Chi-Square (X^2) Test	398.771
p-value	0.000
GFI	0.964
AGFI	0.958
NFI	0.965
RFI	0.967
IFI	0.972
TLI	0.982
CFI	0.948
RMSEA	0.044

As shown in Table 6 the framework for enhancing supply chain quality aligns effectively, as demonstrated by the data shown in Table 6. The GFI, AGFI, NFI, and other indices exceed 0.90, while the RMSEA stands at 0.044, indicating that the model is valid.

Table 7.
CFA Model Estimates for Improving the Quality of Supply Chains.

Paths	Estimate B	S.E.	Z-Test	p-value
Efficiency → Supply Chain Quality	0.400	0.033	67.165	***
Cost → Supply Chain Quality	0.439	0.037	74.38	***
Timeliness → Supply Chain Quality	0.436	0.038	71.995	***

The estimates in Table 7 reveal that efficiency, cost, and timeliness are all significantly related to the quality of supply chains, with p-values less than 0.05. These findings highlight the relevance of these dimensions to the supply chain quality construct.

To test the proposed hypotheses, a structural equation modeling (SEM) approach was utilized. The relationships between blockchain technology dimensions (security, transparency, decentralization, and trust) and supply chain quality dimensions (efficiency, cost, and timeliness) were analyzed.

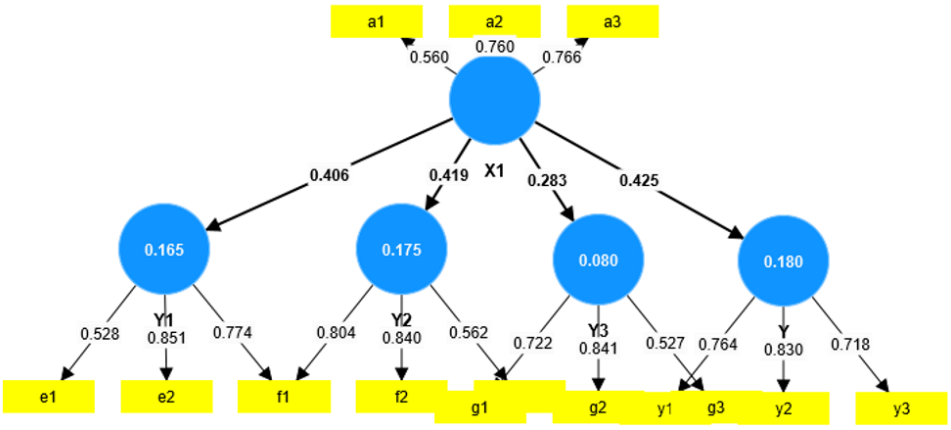

Figure 4.
Structural Model for Blockchain Technology and Supply Chain Quality.

4.2. Test the Hypotheses of the Study

This section deals with testing hypotheses using statistical methods to determine their validity. Structural equation modeling (SEM) will be used as follows:

4.2.1. The First Hypothesis

"There is a statistically significant impact of security on improving the quality of supply chains in the Egyptian Customs Authority".

To verify the quality of the model and determine the validity of the hypothesis, this was tested through a set of criteria for judging the quality of the model shown in Table 8.

Table 8.
Measurement Model Assessment (Security).

Indicator	Value	Acceptance level
Normed Chi-Square	3.019	Between (2,5)
The Goodness-of-Fit statistic (GFI)	0.958	Between (0,1)
Adjusted Goodness of Fit Index (AGFI)	0.940	Between (0, 1) ≥ 0.90.
Normed Fit Index (NFI)	0.974	Between (0,1) ≥ 0.95
The Comparative Fit Index (CFI)	0.937	Between (0,1) ≥ 0.95
RMSEA	0.029	Between (0.01, 0.08)

In this structural model, the values are recorded as X^2/df =3.019, NFI=0.958& CFI = 0.937, and RMSEA = 0.029. Because there is an adequate fit, as indicated by these indices, between the hypothesized model and the data collected. An examination of the path coefficients could proceed for the structural model.

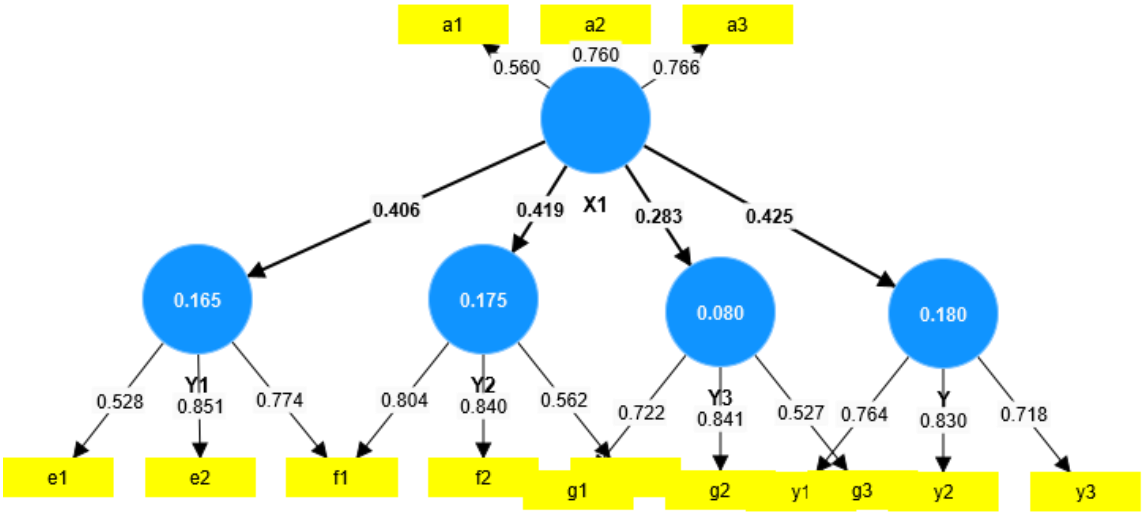

Figure 5.
Structural Model Results H1.

Table 9.
Structural path analysis result (Security).

Exogenous Construct	Path	Endogenous Construct	Estimate B (Path Coefficient)	S. E	Z-Test	R^2	P-Value
Security	⇨⇨	Improve the Quality of Supply Chains	0.425	0.051	3.117	0.180	***
	⇨⇨	Efficiency.	0.406	0.056	3.802	0.165	***
	⇨⇨	Cost.	0.419	0.053	5.249	0.175	***
	⇨⇨	Timeliness.	0.283	0.056	0.143	0.080	0.886

Note: ***p<.001, **p<.01*p<.05.

Table 9 presents the results of the structural path analysis for the dimension of "Security" in the context of the study. Each row corresponds to a specific path from the exogenous construct "Security" to various endogenous constructs, including Improve the Quality of Supply Chains, Efficiency, Cost, and Timeliness. The "Estimate B" column indicates the path coefficient, which represents the strength and direction of the relationship between the constructs. The values of the path coefficients (ranging from 0.283 to 0.419) suggest positive relationships between Security and each of the endogenous constructs. Additionally, the low standard errors and Z-test values indicate the robustness and statistical significance of these relationships. The proportion of variance explained (R^2) values ranging from 0.080 to 0.175 indicate that Security accounts for a small portion of the variability in Improve the Quality of Supply Chains, Efficiency, and Cost. Overall, these results provide evidence supporting the hypothesis that Security significantly predicts and influences various dimensions of Improve the Quality of Supply Chains in the Egyptian customs authority, except that the impact on Timeliness is not significant.

4.2.2. The Second Hypothesis

"There is a statistically significant impact of transparency on improving the quality of supply chains in the Egyptian Customs Authority".

To verify the quality of the model and determine the validity of the hypothesis, this was tested through a set of criteria for judging the quality of the model shown in Table 10.

Table 10.
Measurement Model Assessment (Transparency).

Indicator	Value	Acceptance level
Normed Chi-Square	3.555	Between (2,5)
The Goodness-of-Fit statistic (GFI)	0.968	Between (0,1)
Adjusted Goodness of Fit Index (AGFI)	0.949	Between (0,1) ≥ 0.90
Normed Fit Index (NFI)	0.980	Between (0,1) ≥ 0.95
The Comparative Fit Index (CFI)	0.977	Between (0,1) ≥ 0.95
RMSEA	0.029	Between (0.01,0.08)

In Figure 6 the structural model, the values are recorded as X^2/df = 3.601, NFI=0.980& CFI = 0.977, and RMSEA = 0.029. Because there is an adequate fit, as indicated by these indices, between the hypothesized model and the data collected. An examination of the path coefficients could proceed for the structural model.

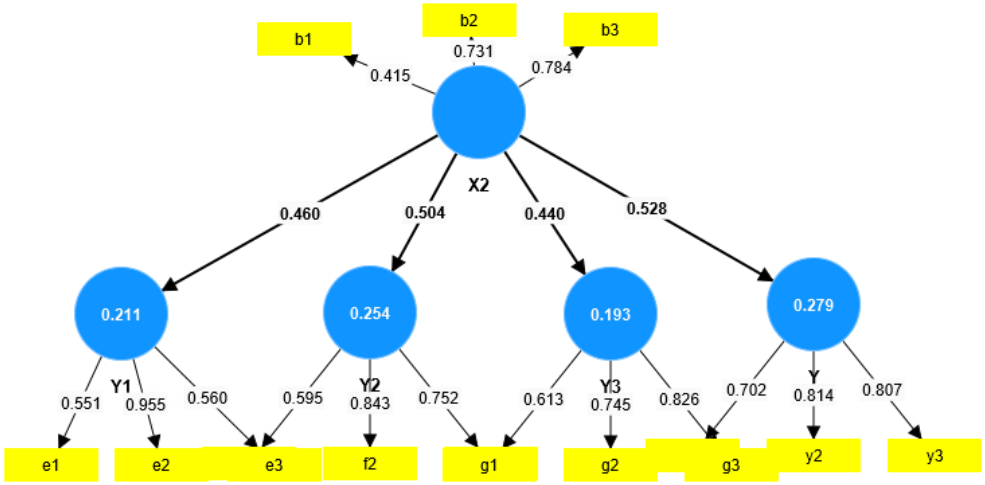

Figure 6.
Structural Model Results H2

Table 11.
Structural path analysis result (Transparency).

exogenous construct	Path	endogenous construct	Estimate B (path coefficient)	S. E	Z-Test	R^2	p-value
Transparency	⇨⇨	Improve the Quality of Supply Chains	0.528	0.032	6.147	0.279	***
	⇨⇨	Efficiency.	0.460	0.049	3.29	0.211	***
	⇨⇨	Cost.	0.504	0.046	4.79	0.254	***
	⇨⇨	Timeliness.	0.440	0.049	3.650	0.193	***

Note: ***p<.001, **p<.01*p<.05.

Table 11 outlines the outcomes of the structural path analysis for the "Transparency" dimension. All path coefficients exhibit substantial positive values, ranging from 0.440 to 0.528, implying strong positive associations between Transparency and the endogenous constructs. Moreover, the low standard errors and high Z-test values further affirm the robustness and statistical significance of these relationships. The proportion of variance explained (R2) values, ranging from 0.193 to 0.254, signify that Transparency accounts for a considerable portion of the variability in improving the quality of supply chains, efficiency, cost, and timeliness. Additionally, the p-values indicate high significance levels (***p<.001), endorsing the strength of these relationships. In essence, these results underscore the significant and positive impact of Transparency on various dimensions of improving the quality of supply chains within university libraries, as inferred from the structural path analysis.

4.2.3. The Third Hypothesis

" There is a statistically significant impact of decentralization on improving the quality of supply chains in the Egyptian Customs Authority.".

To verify the quality of the model and determine the validity of the hypothesis, this was tested through a set of criteria for judging the quality of the model shown in the following table.

Table 12.
Measurement Model Assessment (Decentralization).

Indicator	Value	Acceptance level
Normed Chi-Square	4.121	Between (2,5)
The Goodness-of-Fit statistic (GFI)	0.948	Between (0,1)
Adjusted Goodness of Fit Index (AGFI)	0.961	Between (0,1) ≥ 0.90
Normed Fit Index (NFI)	0.958	Between (0,1) ≥ 0.95
The Comparative Fit Index (CFI)	0.960	Between (0,1) ≥ 0.95
RMSEA	0.019	Between (0.01,0.08)

In Figure 7 the structural model, the values are recorded as $X^2/df = 4.121$, NFI=0.958& CFI = 0.960, and RMSEA = 0.019. Because there is an adequate fit, as indicated by these indices, between the hypothesized model and the data collected. An examination of the path coefficients could proceed for the structural model.

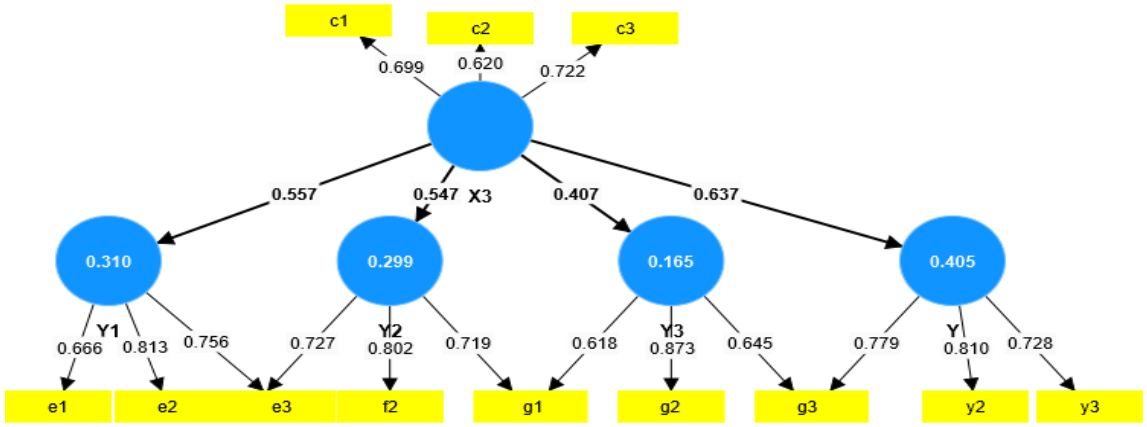

Figure 7.
Structural Model Results H3.

Table 13.
Structural path analysis result (Decentralization).

exogenous construct	Path	endogenous construct	Estimate B (path coefficient)	S. E	Z-Test	R^2	p-value
Decentralization	⇨⇨	Improve the Quality of Supply Chains	0.637	0.051	6.556	0.405	***
	⇨⇨	Efficiency.	0.557	0.045	7.722	0.310	***
	⇨⇨	Cost.	0.547	0.044	7.683	0.299	***
	⇨⇨	Timeliness.	0.407	0.049	5.49	0.165	***

Note: ***p<.001, **p<.01*p<.05

Table 13 presents the outcomes of the structural path analysis for the exogenous construction "Decentralization" and its associations with various endogenous constructions including Improve the Quality of Supply Chains, Efficiency, Cost, and Timeliness. The path coefficients reflect the strength and direction of these relationships. The results indicate significant positive relationships between Decentralization and each of the endogenous constructs, with high path coefficients ranging from 0.407 to 0.557. This suggests that higher levels of Decentralization correspond to increased levels of Improve the Quality of Supply Chains, Efficiency, Cost, and Timeliness. Additionally, the low standard errors and high Z-test values reinforce the robustness and statistical significance of these relationships. Overall, these findings underscore the importance of Decentralization in enhancing various dimensions of Improve the Quality of Supply Chains within university libraries.

4.3.4. The Fourth Hypothesis

"There is a statistically significant impact of trust on improving the quality of supply chains in the Egyptian Customs Authority".

To verify the quality of the model and determine the validity of the hypothesis, this was tested through a set of criteria for judging the quality of the model shown in Table 14.

Table 14.
Measurement Model Assessment (Trust).

Indicator	Value	Acceptance level
Normed Chi-Square	4.015	Between (2,5)
The Goodness-of-Fit statistic (GFI)	0.944	Between (0,1)
Adjusted Goodness of Fit Index (AGFI)	0.984	Between (0,1) ≥ 0.90
Normed Fit Index (NFI)	0.980	Between (0,1) ≥ 0.95
The Comparative Fit Index (CFI)	0.974	Between (0,1) ≥ 0.95
RMSEA	0.069	Between (0.01,0.08)

In Figure 8 the structural model, the values are recorded as $X^2/df = 3.601$, NFI=0.980& CFI = 0.974, and RMSEA = 0.069. Because there is an adequate fit, as indicated by these indices, between the hypothesized model and the data collected. An examination of the path coefficients could proceed for the structural model.

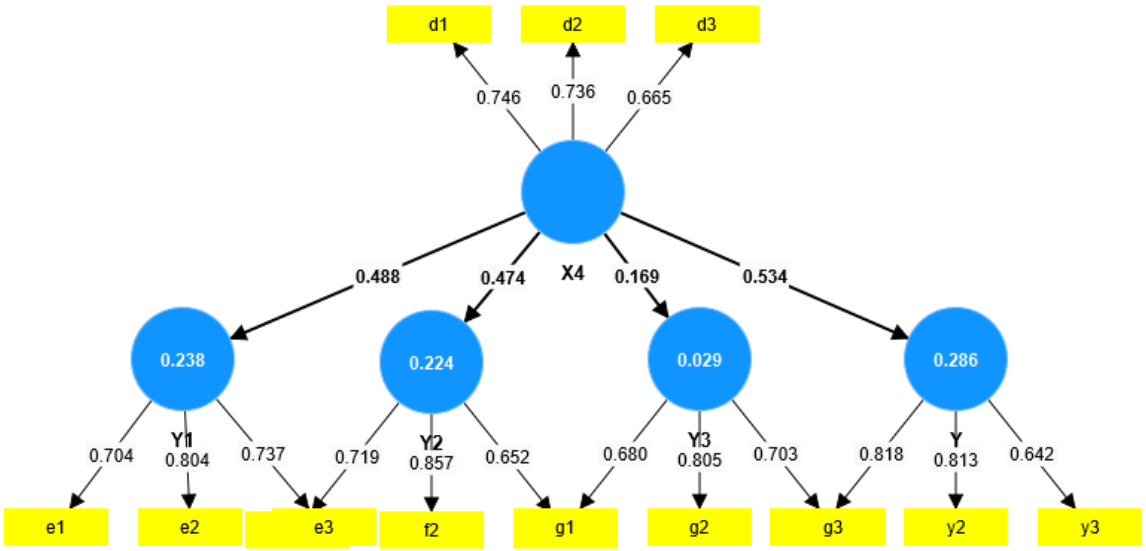

Figure 8.
Structural Model Results H4.

Table 15.
Structural path analysis result (Trust).

exogenous construct	Path	endogenous construct	Estimate B (path coefficient)	S. E	Z-Test	R^2	p-value
Transparency	⇨⇨	Improve the Quality of Supply Chains	0.534	0.044	7.719	0.286	***
	⇨⇨	Efficiency.	0.488	0.049	7.618	0.238	***
	⇨⇨	Cost.	0.474	0.046	6.740	0.224	***
	⇨⇨	Timeliness.	0.169	0.049	1.967	0.029	0.113

Note: ***p<.001, **p<.01*p<.05.

Table 15 shows the impact of "Trust" on Improve the Quality of Supply Chains, Efficiency, Cost, and Timeliness. Path coefficients range from 0.169 to 0.534, indicating strong positive associations. Low standard errors and Z-test values confirm the relationships' robustness. The R2 values (0.029 to 0.238) suggest Trust explains much variability in the constructions. High significance levels (***p<.001) underline the strength of these relationships. Overall, Trust significantly influences Improve the Quality of Supply Chains in university libraries, except that (timeliness) its impact is not significant on Transparency.

5. Discussion

This study's findings highlight how blockchain technology can significantly improve the quality of supply chains, especially regarding the Egyptian Customs Authority. The research examined how four fundamental aspects of blockchain—security, transparency, decentralization, and trust—affect the essential performance metrics of supply chain quality: efficiency, cost, and timeliness. This investigation presents strong empirical evidence that highlights the role of blockchain technology in enhancing operational efficiency within customs operations. Additionally, it plays a significant role in the wider conversation about cutting-edge technologies in supply chain management, closely aligning with the journal's emphasis on innovative marketing and operational tools. The analysis showed that security greatly enhances efficiency and cost; however, it does not have a major impact on timeliness. The connection between security and efficiency aligns with the insights from Bornader, et al. [18], who emphasized how blockchain can minimize fraud and errors through its provision of

tamper-proof and verifiable transaction records. This feature holds significant importance for customs operations, as any inaccuracies may result in expensive delays and conflicts. Nonetheless, the minimal effect of security on timeliness indicates that although blockchain improves data accuracy and integrity, its security features—such as encryption and multi-layered authentication—do not inherently speed up supply chain operations. This is consistent with earlier research highlighting the safeguarding function of blockchain instead of its capacity to enhance operational speed [3].

It was observed that transparency significantly and positively impacts all three aspects of supply chain quality. The capacity of blockchain to establish shared, real-time records enhances proactive decision-making, minimizes operational errors, and allows stakeholders to respond to disruptions swiftly. The findings align with the research conducted by Zhang, et al. [7] which showed that transparency improves operational visibility, reduces delays, and fosters trust among participants in the supply chain. The notable impact of transparency on timeliness highlights its importance in facilitating on-time deliveries by offering customs officials and supply chain managers comprehensive visibility of shipment movements. This capability is particularly relevant for tackling logistical challenges in intricate global supply chains. The study emphasizes that decentralization plays a crucial role in improving the quality of supply chains through blockchain technology. The effects of decentralization on efficiency, cost, and timeliness are noteworthy, as its distributed architecture allows for real-time decision-making and lessens dependence on centralized authorities. The findings are consistent with Bulk [8] observations regarding how decentralized systems improve supply chain flexibility and resilience by reducing single points of failure. The positive effect of decentralization on timeliness indicates that distributed networks help minimize delays by promoting smooth coordination among stakeholders and allowing for quicker approvals. This capability in customs operations leads to more efficient processes, lighter administrative loads, and a better ability to respond to trade needs.
The influence of blockchain on trust was shown to significantly affect efficiency and cost, although its effect on timeliness was more limited. The immutable and verifiable transaction records of blockchain foster a sense of confidence among participants in the supply chain. This finding supports the work of Vazquez Melendez, et al. [9] highlighting that trust plays a crucial role in minimizing disputes, lowering transaction costs, and promoting collaborative environments. Nonetheless, the restricted influence of trust on timeliness indicates that although trust fosters enduring collaboration, it does not directly tackle the issue of operational speed. Rather, elements like transparency and real-time tracking seem to significantly influence delivery schedules. The findings of this study align well with the current body of work on blockchain and supply chain management. Numerous empirical studies, including those conducted by Difrancesco, et al. [10] and Hasan, et al. [12] have emphasized the potential of blockchain to enhance efficiency and lower costs within supply chains. However, this study broadens the conversation by offering a detailed analysis of blockchain's dimensions and their unique effects on supply chain performance. The notable impact of decentralization and transparency on timeliness, for example, enriches the current understanding, highlighting the importance of distributed control and real-time visibility in reaching operational excellence.

The results carry important implications for both theory and practice. The study enhances our understanding of how blockchain influences supply chain quality by clearly outlining the roles of security, transparency, decentralization, and trust. This work offers a methodological contribution by employing structural equation modeling (SEM) and confirmatory factor analysis (CFA), presenting a robust framework for examining intricate causal relationships in supply chain research. The findings provide valuable guidance for those involved in policymaking and supply chain management, particularly within the Egyptian Customs Authority and other relevant sectors. The significant influence of openness and distributed authority underscores the necessity for systems powered by blockchain that prioritize clarity and shared governance. Implementing these systems allows customs authorities to minimize delays, boost operational efficiency, and foster better collaboration among stakeholders. Furthermore, it is essential to incorporate security measures alongside automated processes to tackle inefficiencies while ensuring that data integrity remains intact. The findings indicate that mechanisms for building trust, such as shared blockchain platforms, can foster cooperation among supply chain participants, leading to better cost efficiency and overall performance.

Future research should tackle the limitations of this study by examining blockchain's influence in various sectors and different geographic contexts. Longitudinal studies may offer valuable perspectives on the lasting impacts of blockchain adoption on supply chain quality. Additionally, exploring the influences of organizational culture, technological readiness, and regulatory frameworks may provide a deeper insight into the effectiveness of blockchain. These directions would assist in addressing current research gaps and facilitate the creation of thorough strategies for utilizing blockchain in the supply chain.
management.

6. Conclusion

This study aimed to explore how blockchain technology influences the enhancement of supply chain quality within the Egyptian Customs Authority, with an emphasis on security, transparency, decentralization, and trust. The study sought to assess the impact of these dimensions on efficiency, cost, and timeliness, which serve as essential indicators of supply chain performance.

The findings indicated that blockchain technology significantly enhances the quality of supply chains. The emergence of transparency and decentralization has proven to be highly impactful, leading to notable enhancements across all three indicators of supply chain performance. Improved operational visibility and proactive decision-making were achieved through transparency, while decentralization contributed to greater flexibility, responsiveness, and a reduction in bottlenecks. The role of security and trust was pivotal in enhancing efficiency and reducing costs, highlighting their significance in maintaining data integrity and promoting collaboration among stakeholders. Nonetheless, the effect on timeliness appeared to be minimal.

The findings highlight the significant impact that blockchain technology can have in tackling shortcomings in supply chains. Integrating blockchain systems presents a significant opportunity for the Egyptian Customs Authority to enhance customs operations, minimize delays, and foster better collaboration among supply chain participants. The study indicates that focusing on transparency and decentralization, alongside strong security and trust mechanisms, is crucial for enhancing supply chain performance. It is advisable to pursue additional studies to investigate the enduring effects of blockchain implementation and its relevance across various industries and situations.

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