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ORIGINAL

Factors Influencing Blockchain Adoption in Operations and Supply Chain Management Among Small and Medium Enterprises

Factores que influyen en la adopción de la cadena de bloques en las operaciones y la gestión de la cadena de suministro entre las pequeñas y medianas empresas

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ABSTRACT

Blockchain technology has developed as a revolutionary tool in the area of improving transparency, efficiency, and security of supply chain management (SCM). Nonetheless, its use is low among small and medium enterprises (SMEs). This research investigates the factors influencing blockchain adoption in SMEs and its effect on five independent variables: top management support (TMS) as the central independent variable, technological readiness (TR), cost of implementation (COI), regulatory environment (RE), and supply chain partner pressure (SCPP). The research employs a structured survey sampling of 324 SMEs across various industries, and it applies Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) using IBM SPSS 25 to test the hypotheses. It also helps mitigate perceived cost barriers, though cost remains a notable challenge for many SMEs. Furthermore, while top management support fosters alignment with the regulatory environment, the strength of this relationship is weaker than expected. SCPP emerges as a substantial influence, often reinforced by leadership engagement. The research highlights that top management plays a pivotal role in shaping organizational readiness and external responsiveness to blockchain technologies. The CFA confirmed this with strong results, including a factor loading of 0,91 for TSM. Similarly, the SEM analysis revealed a standardized path coefficient of 0,68 from TMS to BO-SCM-SME, indicating a significant and positive influence. The results offer actionable insights for SMEs and policymakers, emphasizing the need for strong leadership commitment, affordable blockchain solutions, and clearer regulatory frameworks.

Keywords: Blockchain; Small and Medium Enterprises (SMEs); Supply Chain; Adoption; SEM Analysis.

RESUMEN

La tecnología blockchain se ha desarrollado como una herramienta revolucionaria en el ámbito de la mejora de la transparencia, la eficiencia y la seguridad de la gestión de la cadena de suministro (SCM). No obstante, su uso es escaso entre las pequeñas y medianas empresas (pymes). Esta investigación analiza los factores que influyen en la adopción de la cadena de bloques en las pymes y su efecto en cinco variables independientes:

el apoyo de la alta dirección (TMS) como variable independiente central, la preparación tecnológica (TR), el coste de implementación (COI), el entorno normativo (RE) y la presión de los socios de la cadena de suministro (SCPP). La investigación emplea una muestra estructurada de 324 pymes de diversos sectores y aplica el análisis factorial confirmatorio (CFA) y el modelado de ecuaciones estructurales (SEM) utilizando IBM SPSS 25 para comprobar las hipótesis. También ayuda a mitigar las barreras de costes percibidas, aunque el coste sigue siendo un reto importante para muchas pymes. Además, aunque el apoyo de la alta dirección fomenta la alineación con el entorno normativo, la fuerza de esta relación es más débil de lo esperado. La SCPP surge como una influencia sustancial, a menudo reforzada por el compromiso de los líderes. La investigación destaca que la alta dirección desempeña un papel fundamental en la configuración de la preparación de la organización y la capacidad de respuesta externa a las tecnologías blockchain. El CFA lo confirmó con resultados sólidos, incluyendo una carga factorial de 0,91 para TSM. Del mismo modo, el análisis SEM reveló un coeficiente de ruta estandarizado de 0,68 de TMS a BO-SCM-SME, lo que indica una influencia significativa y positiva. Los resultados ofrecen información útil para las pymes y los responsables políticos, y hacen hincapié en la necesidad de un fuerte compromiso por parte de los líderes, soluciones de cadena de bloques asequibles y marcos normativos más claros.

Palabras clave: Cadena de Bloques; Pequeñas y Medianas Empresas (pymes); Cadena de Suministro; Adopción; Análisis SEM.

INTRODUCTION

The blockchain is one of the revolutionary inventions in operations and supply chain management (OSCM) has characteristics that allow decentralization, transparency, traceability, and security. The traits are particularly desirable in improving trust between the supply chain players, decreasing the chances of fraud, and overall increasing cooperation.[1] The backbone of many financial services, SMEs, has not been as quick to adopt blockchain technology as the major companies, which have begun to integrate into their businesses.[2] Following inadequate financing options, insufficient knowledge, poor digital infrastructure, and unclear regulations, SMEs have to struggle considerably to implement blockchain solutions. Since the supply chains of the world are getting integrated, these bottlenecks expose SMEs to the danger of being left out of the broader network.[3] Traditional education of technology adoption has largely been intentional the domain of larger companies or has focused on the technological capability of blockchain instead of considering the real-world reality of SMEs. Moreover, much of the existing research is unidirectional, and it ignores how one aspect connects to another in terms of organizational preparedness, views on technology, and environmental influences to influence adoption behavior.[4,5] Limited to the SMEs, which may lack insights about the large enterprises and fail to show the industry-based or region-based insights, which may be influencing the rate of adoption of the blockchain.[6,7]

This research aims to examine key factors affecting blockchain adoption in operations and SCM among SMEs.

To establish and prioritize the core contributors of the implementation of an SCM solution, given that blockchain technology was presented.[6,8] That experiment was created by a methodology based on the Technology Organization and Environment (TOE) framework with fourteen crucial elements using an Integrative Literature Review (ILR). After applying the Analytical Hierarchy Process (AHP), it was shown that environmental factors are the most significant.[9,10]

The technical, managerial, and external elements impacting the acceptance of digital currency for activities and logistics networks have been identified.[7] Based on an empirical approach using the TOE framework and content analysis of refereed journals from 2013 to 2021, the results show that organizational, technological, and environmental factors, especially in Asia, Europe, and America, have a key influence on blockchain integration in this industry.[11,12]

Through a topical evaluation of data from the agricultural products business and expert comments using the Oxford Agriculture dataset, organizational and behavioral aspects impacting the acceptance of digital currency in SCM were examined.[8] Four major themes were identified, supporting the Diffusion of Innovation (DOI) and the TOE framework by revealing how technological benefits, strategic adoption approaches, and external barriers shape implementation intentions.[13,14]

Variables influencing blockchain adoption in supply chains and operations were examined,[9] along with the moderating role of sustainability-focused supplier development. Research evaluating a TOE framework and DOI theory on 412 Bangladeshi apparel suppliers found that adoption was significantly influenced by organizational, technological, and environmental factors, while regulatory support remains limited. Blockchain adoption in SCM, with emphasis on its antecedents, long-term impacts, and influencing factors across different stages of implementation was examined.[10,15]

Research gap

The use of blockchain technology in SCM has enormous potential to increase efficiency and transparency. However, a number of contributing variables mean that its adoption among SMEs is quite limited. Technological, organizational, and environmental influences are important, and research employing the TOE paradigm reveals that environmental elements are the most important.[6,16] Furthermore, investigation indicates that outside factors, including a lack of governmental backing and supplier preparedness have a huge influence on adoption choices, particularly in developing nations.[9,17] To enable successful blockchain integration among SMEs, these elements still need to be precisely identified and prioritized.

Hypothesis development

H1: TMS has a significant positive influence on blockchain adoption in supply chain management among SMEs (BO-SCM-SME)

H2: TR positively shapes the adoption of BO-SCM-SME

H3: COI negatively correlates with BO-SCM-SME

H4: RE facilitates the adoption of BO-SCM-SME

H5: SCPP has a strong positive impact on BO-SCM-SME

METHOD

This investigation employs quantitative survey data to explore how blockchain adoption in SMEs. Key factors, including TR, COI, RE, SCPP, and TMS, were measured using a standardized questionnaire. Figure 1 illustrates the conceptual framework linking five independent variables to blockchain adoption in SMEs, adapted from investigation hypotheses.

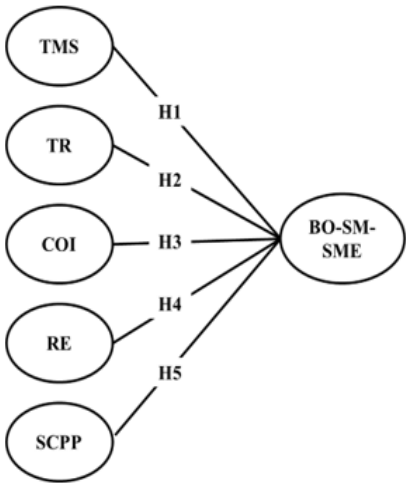

Figure 1. Conceptual Framework

Data collection

A uniform survey is utilized to gather information across SMEs in a number of industries, including manufacturing, logistics, retail, and agriculture. Organizational decision-makers, including company owners, operations managers, and IT directors, were targeted using a purposive sample technique. Over two months, 324 valid replies were gathered. Table 1 displays the demographic background for the participants, showing the distribution across gender, roles, industry sectors, and blockchain familiarity.

Table 1. Demographic Profile of Respondents for Blockchain Adoption in SCM among SMEs

Variable	Category	Frequency (n)	Percentage (%)
Gender of Respondent	Female	210	64,80
	Male	114	35,20
Respondent's Role	Owner/Founder	102	31,50
	Manager/Executive	155	47,80
	IT/Technical Staff	67	20,70
Industry Sector	Manufacturing	94	29,00
	Logistics and Transportation	76	23,50
	Retail and Wholesale	81	25,00

	Services	73	22,50
Number of Employees	Fewer than 50	138	42,60
	50–100	104	32,10
	101–250	82	25,30
Years in Operation	Less than 5 years	77	23,80
	5–10 years	126	38,90
	More than 10 years	121	37,30
Familiarity with Blockchain	Very Low	48	14,80
	Moderate	167	51,50
	High	109	33,60

Inclusion Criteria

- SMEs that are actively involved in operations management or SCM.
- The companies meet national criteria for small and medium-sized business registration.
- The answer is that the respondents have to be the owners or managers or make decisions about the adoption of technology.
- Businesses with basic knowledge or a form of interest in blockchain technology.
- Organizations that are in the chosen scope of geography or industry.

Exclusion Criteria

- Large companies or international firms.
- Firms without any involvement in supply chain-related functions.
- Respondents who don't participate in decision-making, are temporary employees, or interns.
- Companies that have heard nothing about the blockchain.
- Partial or incoherent answers to the survey.
- Multiple entries or any survey of identical respondents.

Variables

Dependent Variable

BO-SCM-SME: small and medium-sized businesses' use of blockchain technology shows that they are interested in, prepared to use, and want to integrate it into their supply chain operations.

Independent variable

TMS: the level of organizational leadership in the enterprise that facilitates, promotes, and provides resources to the blockchain adoption efforts in the enterprise.

TR: the information about the SME's technical knowledge, software compatibility, and IT infrastructure required to embrace blockchain.

COI: this stands for the perceived financial burden of putting blockchain into practice, which includes setup, training, and maintenance expenses.

RE: it measures the clarity of the legal and regulatory environment in which blockchain can be adopted in the country, including the support of the government and compliance regulations.

SCPP: the push from outsiders, including vendors and clients, to use blockchain technology to improve SME integration and transparency is captured. Table 2 presents the measurement items used to assess each variable related to blockchain adoption among SMEs.

Table 2. Survey Questions for Key Blockchain Adoption Factors

Variable	Question 1	Question 2
TMS	Does your top management actively support blockchain-related initiatives?	Has leadership allocated resources specifically for blockchain implementation?
TR	Does your organization have the IT infrastructure needed to implement blockchain?	Are your current systems compatible with blockchain technology?
COI	Is the cost of adopting blockchain perceived as a barrier in your organization?	Do you believe your company has sufficient financial resources to invest in blockchain?
RE	Are government policies clear and supportive of blockchain adoption?	Does your organization face regulatory uncertainty in implementing blockchain technology?
SCPP	Have any of your supply chain partners encouraged blockchain adoption?	Do external partners influence your decision to adopt blockchain technology?

Statistical Analysis

The data reliability and validity were checked, and the overall model fit was examined through the use of IBM SPSS 25 in statistical analysis. To investigate the associations between variables, the investigation used SEM and CFA. While SEM explored proposed associations among input and outcome variables, CFA evaluated the relevance and stability of measuring items. Because TMS had a significant impact on other features that blockchain implementation, the investigation demonstrated the significance of these elements comprehending the interaction between variables.

RESULTS

Utilizing the components in this section, to assess the Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM).

CFA

By evaluating how well-observed variables reflect underlying constructs, CFA verifies the measurement model. In this research, CFA ensure that **categories** like technological capacity and top management support accurately assess the variables affecting SMEs' adoption of blockchain. Equation 1 is given by:

$$= x_i D_i - x_{1 \ldots} D_{1 \ldots} - x_{\ldots} D_{\ldots} \qquad (2)$$

Where:
x -Vector of signals detected.
Λ_x- Vector of factor loading.
ζ -Terms for measuring error.

For the five constructs, TMS, TR, COI, RE, and SCPP, the CFA findings are shown in table 3. Two items were used to measure each variable, and all factor loadings were more than 0,79, suggesting high item dependability. All constructions had adequate internal consistency, as shown by the αMetrics, which varied from 0,74 to 0,79. That dependability of the constructions is further confirmed by the CR values, which varied from 0,85 to 0,88. With the lowest AVE being 0,73 and the highest being 0,78, all values were over the suggested cutoff of 0,50, indicating strong convergent validity.

Table 3. CFA Results for Key Determinants Influencing Blockchain Adoption in SMEs

Variables	Item Code	Factor Loading	Cronbach's Alpha (α)	Composite Reliability (CR)	Average Variance Extracted (AVE)
TMS	TMS1	0,83	0,77	0,87	0,77
	TMS2	0,91			
TR	TR1	0,88	0,79	0,88	0,78
	TR2	0,88			
COI	COI1	0,79	0,74	0,85	0,73
	COI2	0,91			
RE	RE1	0,85	0,76	0,86	0,75
	RE2	0,88			
SCPP	SP1	0,84	0,75	0,85	0,73
	SP2	0,87			

SEM

The SEM considers the connections between the supposed and seen variables. The SEM will be utilized in testing the influence of TMS on critical determinants like technological preparedness and costs as indicators, which have direct outcomes on blockchain adoption by SMEs (equation 2).

$$y) = \frac{}{S}\sum_{s=1} p_s \ (y) \qquad (3)$$

Where:
η-endogenous latent variables
ξ-exogenous latent variables
B -coefficient matrix for endogenous relationships

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The findings of the SEM used to investigate the proposed connections between important components and BO-SCM-SME are shown in table 4 and figure 2. The table displays the path correlations, standardized coefficients (ß), t-values, and significance levels (p-values) for the five hypotheses (H1 through H5). Strong support for each hypothesis was indicated by the fact that all routes were statistically significant at p < 0,001. The greatest impact was shown in H1, where TMS significantly increased the adoption of blockchain (ß = 0,68). SCPP in H5 (ß = 0,63) and TR in H2 (ß = 0,52) came next, demonstrating the need for both internal preparedness and outside support. Significant impacts were also demonstrated by COI and RE, demonstrating that SMEs' decisions to use blockchain are influenced by both financial and policy-related variables.

Table 4. SEM Results for Factors Influencing Blockchain Adoption in SMEs

Hypothesis	Path	Standardized Coefficient (ß)	t-value	p-value
H1	TMS → BO-SCM-SME	0,68	8,45	< 0,001
H2	TR → BO-SCM-SME	0,52	6,12	< 0,001
H3	COI → BO-SCM-SME	0,41	4,87	< 0,001
H4	RE → BO-SCM-SME	0,55	7,03	< 0,001
H5	SCPP → BO-SCM-SME	0,63	9,02	< 0,001

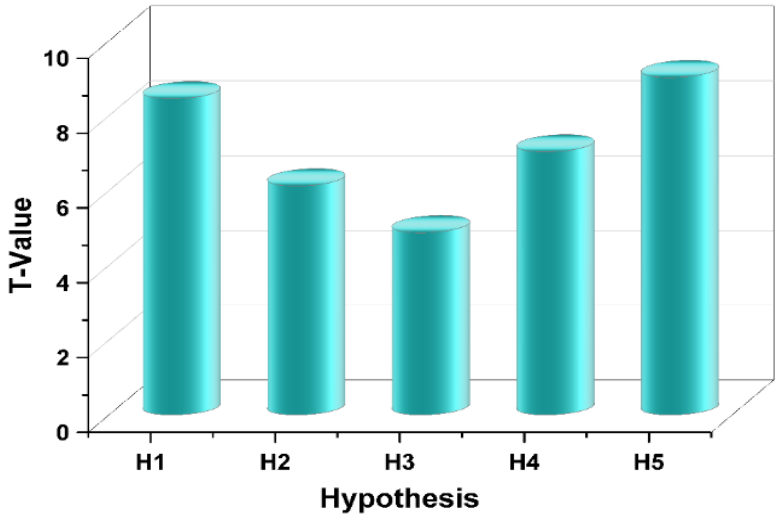

Figure 2. T-Values for Hypothesis Testing on Factors Influencing Blockchain Adoption in SMEs

DISCUSSION

This accomplishment contributes towards achieving the goal because it shows that TMS was the key to propagating the use of blockchain among SME in operations as well as in SCM.[18,19,20] It has a positive influence on internal preparation, partner involvement, and purpose that customizes them.[1,21] The outcomes are in line with other past investigation findings that emphasized leadership commitment as an important consideration in the effective adoption of technology by small businesses.[2,22] The results demonstrate that SMEs' adoption of blockchain is significantly influenced by BO-SCM-SME. With item loadings of 0,88 and AVE of 0,78 for TR, a maximum loading of 0,91 and AVE of 0,77 for TMS, and item loads of 0,85 and AVE of 0,75 for RE, the CFA validated good reliability and validity across all domains. High internal consistency and precise measurement are indicated by these values.[23,24] BO-SCM-SME to TMS (ß = 0,68, t = 8,45), SCPP to BO-SCM-SME (ß = 0,63, t = 9,02), and RE to BO-SCM-SME (ß = 0,55, t = 7,03) had the strongest routes in the SCM data, and they were all significant at p < 0,001. According to this, the active involvement of SME leadership enhances technological preparedness, fortifies partner engagement, and raises the intention to use blockchain. As a result, leadership support is a crucial facilitator in removing adoption hurdles.[25,26]

CONCLUSIONS

This crucial role in facilitating successful technology transformation and integration is confirmed by the fact that strong top management support improves preparedness, lowers obstacles, and promotes the use of blockchain in SME operations and supply chains. According to this investigation, TMS plays a major factor in SMEs' effective use of blockchain technology in operations and SCM. With TMS obtaining the greatest factor loading

of 0,91 and an AVE of 0,77, suggesting excellent internal consistency, the CFA demonstrated high measurement reliability. With substantial correlations between TMS →BO-SCM-SME (β = 0,68, t = 8,45) and SCPP (β = 0,63, t = 9,02), all at p < 0,001, SEM further confirmed the model. These results emphasize the necessity of leadership commitment to improve preparedness, lower cost worries, comply with laws, and react to partner pressure which are critical facilitators of successful blockchain deployment in SMEs. The investigation's decisions may not be as broadly applicable because it only includes SMEs in particular industries and geographical areas. Self-reported data is also used, which raises the possibility of response bias or subjective interpretation. To further understand adoption behavior in various SME situations, further investigation might examine the long-term implications of blockchain adoption, compare different nations, and incorporate qualitative findings.

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