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Research Article

Determinants of Blockchain Technology Adoption in Supply Chains by Small and Medium Enterprises (SMEs) in India

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In recent times, organizations are increasingly adopting blockchain technology in their supply chains due to various advantages such as cost optimization, effective and verified record-keeping, transparency, and route tracking. This paper aims to examine the factors influencing the intention of small and medium enterprises (SMEs) in India to adopt blockchain technology in their supply chains. A questionnaire-based survey was used to collect data from 216 SMEs in the northern states of India. The study has considered an integrated technology adoption framework consisting of the Technology Acceptance Model (TAM), Diffusion of Innovation (DOI), and Technology-Organization-Environment (TOE). Using this integrated TAM-TOE-DOI framework, the study has proposed eleven hypotheses related to factors of blockchain technology adoption. Confirmatory factor analysis (CFA) and structural equation modeling (SEM) have been used to test the hypotheses. The results show that relative advantage, technology compatibility, technology readiness, top management support, perceived usefulness, and vendor support have a positive influence on the intention of Indian SMEs to adopt blockchain technology in their supply chains. The complexity of technology and cost concerns act as inhibitors to the technology adoption by SMEs. Furthermore, the three factors, namely, security concerns, perceived ease of use, and regulatory support, do not influence the intention to adopt the technology. The study contributes to filling a significant gap in the academic literature since only a few studies have endeavored to ascertain the technology adoption factors by supply chains of SMEs in a developing country like India. The study has also proposed a novel integrated technology adoption framework that can be employed by future studies. The findings are expected to enable SMEs to understand important factors to be considered for adopting blockchain technology in their supply chains. Furthermore, the study may benefit the blockchain technology developers and suppliers as they can offer customized solutions based on the findings.

1. Introduction

In today's digital society, many next-generation communication technologies, such as blockchain, the Internet of Things, and cloud computing, have been introduced to offer unlimited competencies for various applications and contexts [1]. To seek a competitive advantage and improve operational performance, the business world has been adopting these technologies in various functional fields. In recent times, blockchain has emerged as a widely accepted transformative technology due to the various benefits like ease of collaboration for companies, ease of working and governance, process streamlining, cost optimization, effective and verified record-keeping, transparency, efficiency, etc. [2]. It is estimated that the adoption of the technology will originate a value of USD 3 trillion per year by the year 2030. The estimates also indicate that 10% of the world economy will be using this technology by the year 2025 [3].

The supply chains have seen an enhanced complexity in recent times due to the increased scale of the businesses, diversified product portfolio, enhanced customer preferences, uncertain demand conditions, need to collaborate with multiple suppliers, a large number of geographic locations to be served, and variety of intermediaries [4]. Hence, globally, organizations are shifting from traditional to technology-driven supply chain management systems for enhanced and effective collaboration across suppliers and buyers [5]. For increased efficiency, blockchain technology has been embraced by many supply chain management systems in recent times [6]. This technology works in a distributed network with each transaction being validated and recorded by consensus of the nodes in the chain [7]. The technology enables verifiable and immutable records along with data transparency and route tracking. However, the blockchain technology adoption in supply chains is inherent with many challenges like hardware and software requirements, training needs, cost and security concerns, etc. [4,8]. Thus, organizations are skeptical of adopting the technology in their supply chains [9]. Therefore, it is required to ascertain the influencers that impact the intention of organizations to embrace blockchain technology.

Blockchain technology has a special significance for supply chains of small and medium enterprises (SMEs) in a less developed country like India. SMEs act as the most vibrant and dynamic engine of growth in India due to their contribution to eradicating unemployment, poverty, income inequality, and regional imbalances [10]. Blockchain technology adoption by supply chains of SMEs is expected to optimize their operations and lead to enhanced performance and efficiency [8]. Thus, the benefits derived from blockchain technology by supply chains can enable SMEs to become more productive and competitive in dynamic market conditions. However, blockchain technology adoption by supply chains of SMEs in India faces major challenges due to the limited availability of various resources like skilled workforce, capital, technology penetration, etc. [11].

A review of the available literature indicates that not a very large number of SMEs have embraced blockchain technology in their supply chains in developing countries [11]. Furthermore, a limited number of studies ascertained the technology adoption by supply chains of SMEs in a developing country like India [8, 11]. The existing studies have used various theoretical models and constructs to ascertain the determinants of blockchain technology adoption by supply chains of the organizations [8, 9, 12, 13]. One of the major limitations as pointed out by most of these studies has been the use of only a few antecedents to assess the determinants of the technology. Thus, there is a need to use a comprehensive model to include the various available constructs proposed by the existing theoretical models and relevant to blockchain technology adoption by supply chains of SMEs. For this purpose, the present study integrates three widely used theoretical models and theories, namely, the Technology Adoption Model (TAM), Technology-Organization-Environment (TOE) Model, and Diffusion of Innovation (DOI) Model. The study findings are expected to enable SMEs to understand important factors that they should pay attention to while embracing blockchain technology. Furthermore, the study can benefit the blockchain technology developers and suppliers as they can offer customized solutions based on the findings.

In the Indian context, all manufacturing and service enterprises having investment in plant and machinery or equipment in the range of INR 10 million to 100 million and an annual turnover in the range of INR 50 million to 500 million are categorized as small enterprises. Furthermore, the medium enterprises have investments in the range of INR 100 million to 500 million and an annual turnover in the range of INR 500 million to 2.5 billion [14]. To meet the stated objectives, the present study has used the specified criteria of annual turnover to identify an organization as an SME.

The paper contributes to the existing literature by offering an insight into the factors influencing the intention of Indian SMEs to adopt blockchain technology in their supply chains. Hence, an opportunity is offered to the various stakeholders including SMEs, technology developers, vendors, and regulatory authorities to reflect on the determinants of intention to adopt blockchain technology. The study further contributes by putting forth a novel integrated technology adoption framework consisting of the Technology Acceptance Model (TAM), Diffusion of Innovation (DOI), and Technology-Organization-Environment (TOE). This proposed framework may be employed to explore the determinants of blockchain technology adoption in various micro, small, and large organizations across the manufacturing and service sectors in India and abroad.

The remainder of the paper is structured as follows. The theoretical background to the study is presented. The third section describes the research framework. The fourth section explains hypotheses development followed by the next section on materials and methods. The sixth section on results and discussion describes data analysis and findings. Thereafter, the conclusions, the implications of the study, and future research directions are presented.

2. Theoretical Foundations

2.1. The Concept of Blockchain Technology. The concept of blockchain technology was first introduced in 1991 by Stuart Haber and W. Scott Stornetta [15]. Blockchain is a peer-to-peer transaction network that uses the distributed ledger technology (DLT) to hold any information and is capable of setting rules on how this information is updated [16]. In the blockchain, different entities involved in the transaction work as nodes (computers). Each participating node, having a copy of the distributed ledger, is further interconnected with other nodes in the distributed peer-to-peer networks. DLT maintains the ledger of each node of the chain where business transactions, also known as blocks, get stored in distributed ledgers in the chain overall participating nodes in an immutable manner. The new block is appended and chained (linked) to the previous block in the chain using a hash number, and thus, information on the ledger grows [17].

The hash number is generated by using different hashing algorithms and running the contents of the block in question through a cryptographic hash function. In the chain, all blocks stay connected while ensuring that hashes connecting two blocks remain in an immutable form. Each block is also having a timestamp with the date and time of its occurrence. The cryptographic hashes ensure that to alter an entry in a past block, all subsequent blocks also need to be altered. The ledger is validated and maintained by a network of nodes according to a predefined consensus mechanism with multiple nodes holding a full copy of the entire database. No single centralized authority is needed. Any change and validation of a transaction are the results of a consensus between the network members, and each member can trace the origin of the transaction [18–20].

2.2. Blockchain Technology in Supply Chains. The multiple partners in a typical supply chain generally include manufacturing plants, suppliers, distribution centers and intermediaries, transporters, and other logistic services that participate in information, material, and cash flow. The global supply chains have further expanded into import, export, forwarding, and delivery in international trading leading to increased complexity [21]. The application of blockchain technology to supply chains is expected to enhance overall performance and reliability by enabling various value-enhancing tasks like recording, tracking, and sharing information with speed and accuracy. This is possible through a real-time digital ledger of transactions and movements for all stakeholders in their supply chain network [4].

In a supply chain, the blockchain will assist in tracking the product journey from a raw material supplier to a consumer [22]. This will contribute to eliminating the counterfeited goods via traceability of the origin of the goods [23]. In a typical supply chain, data errors are common and generally created at the inputting stage. Since fewer people perform data entry tasks in a blockchain, the errors in data entry can be reduced. Furthermore, using blockchain, the redundant jobs can be eliminated as all parties can access the same information across the supply chain [24]. Blockchain technology in supply chains also enables accurate demand forecasting, efficient management of supply chain disruptions, and reduced inventory carrying cost due to its ability to create and share records of activities across the supply chain [25].

Due to its immutability and timestamp feature, blockchain technology when applied to supply chains does not allow any kind of backdated changes or data diddling which makes it more trustworthy and transparent to use [26]. Generally, electronic data are collected, collated, and stored on the central servers of the service provider in a typical traditional supply chain. These servers are susceptible to attacks. However, owing to its highly protective mechanisms of distributed consensus and cryptography, blockchain technology improves the security of data and offers an environment safe from cyberattacks [27].

2.3. Technology Adoption Models. Technology adoption can be explained as the intention of a user(s) or an organization to select a technology for utilizing it for their benefit [28]. Thus, technology adoption will lead to the diffusion of technology and, hence, its acceptance and use by the masses. The available literature shows [29] that various theoretical technology adoption models and theories like Theory of Reasoned Action (TRA), Technology, Organization, and Environment (TOE) Framework, Innovation Diffusion Theory (IDT)/Diffusion of Innovation (DOI) Theory, Technology Acceptance Model (TAM), etc. have been used by the researchers to understand the factors affecting the technology adoption.

Many studies have explored the adoption of blockchain technology in the operation and supply chain. For the purpose, the different models used by the available studies include TAM [30], UTAUT [31, 32], IDT [33], TOE [8, 34], and TRA [35]. Furthermore, a combination of TAM, technology readiness index (TRI), and the theory of planned behavior (TPB) model has also been used [4]. Another study used a combination of TAM, DOI, and UTAUT [36]. These studies have unearthed various factors that influence blockchain technology adoption in supply chains. These factors include relative advantage, compatibility, complexity, upper management support, cost, market dynamics, competitive pressure, regulatory support, security, perceived benefits, perceived usefulness, perceived usefulness, organizational readiness, organizational size, and data governance [34, 37]. In the Indian context, some studies [4, 11, 32, 38–40] have attempted to examine blockchain technology adoption in supply chains. A recent study [4] has further explored blockchain technology adoption by supply chains of SMEs in India. Thus, it seems that a limited number of studies have assessed the determinants of blockchain technology adoption in supply chains of SMEs in the Indian context. Hence, there is a need to explore this area further. The present study is an attempt in that direction.

3. Research Framework

To examine the determinants of blockchain adoption in supply chains of SMEs, the present study considers TAM, TOE framework, and DOI theory to propose an integrated TAM-TOE-DOI framework.

TAM [41] examines the behavior of the end-user when it comes to accepting technology innovation. TAM considers two variables, namely, perceived ease of use and perceived usefulness, to assess attitude toward using and behavioral intention to use the new technology. Furthermore, TAM2 [42] and TAM3 [43] which are extended versions of the TAM framework have also been suggested. The TAM model has been empirically used by previous studies to predict antecedents of technology adoption [36, 44, 45].

TOE framework [44] determines the acceptance of innovation at the enterprise level by considering the technology, organizational, and environmental contexts of an enterprise. The technology context considers the internal and external benefits of the new technology to the organization. The organizational context includes firm characteristics like organizational structure, departmentalization, roles of human resources, degree of control, etc. Furthermore, the environmental context refers to the regulatory environment, market factors, and competitors. The extant literature shows the use of the TOE framework for examining factors of blockchain technology adoption [8, 9, 13, 45].

Diffusion of Innovation (DOI) [46] theory examines user response and acceptance for a new concept to explore the adoption rate of new technology. These attributes include relative advantage, technology compatibility, the complexity of technology, observability of innovation, and trialability of technology. This theory presents a widely used adoption model employed by studies in the past [36, 47, 48].

The present study posits that various constructs of TAM, TOE, and DOI have an important role in influencing the blockchain technology adoption of supply chain users. Hence, to meet the objectives of the study, an integrated TAM-TOE-DOI framework has been proposed. TAM examines the end-user behavior toward technology adoption by considering factors at the individual level, whereas TOE explores technology adoption by considering factors at the enterprise level. Furthermore, DOI considers attributes of innovation that can attempt technology adoption.

Considering the objectives of the present study, 11 factors of technology adoption under five aspects of innovation characteristics, technology context, organizational context, environmental context, and individual characteristics adapted from the integrated TAM-TOE-DOI framework are found relevant. In the case of innovation characteristics, three attributes of DOI theory, namely, relative advantage, technology compatibility, and complexity of technology, are considered relevant for blockchain adoption in supply chains by SMEs. The technology context that belongs to the TOE framework ascertains the technology readiness of SMEs to adopt the technology. The organizational context of TOE ascertains the role of top management support, security concerns, and cost concerns of SMEs in influencing their intention to adopt blockchain technology in supply chains. Furthermore, the environmental context of the TOE framework examines the contribution of regulatory support and vendor support in impacting the intention of SMEs. Lastly, the individual characteristics consider perceived ease of use and perceived usefulness of blockchain technology to explore the technology adoption intention of SMEs in India. Both these individual characteristics belong to the TAM model.

4. Hypothesis Development

The review of the pertinent literature and the integrated TAM-TOE-DOI model indicated the relevance of a total of five characteristics/contexts with eleven factors to influence blockchain technology adoption in supply chains by SMEs. In the following paragraphs, hypotheses related to the considered factors have been presented.

4.1. Hypothesis Development-Innovation Characteristics. As per the preceding paragraphs, three attributes considered relevant as innovation characteristics for the adoption of blockchain technology in supply chains are relative advantage, technology compatibility, and complexity of technology.

Rogers [49] has explained the relative advantage of technology as the degree to which the benefits it offers are perceived as better than that offered by the existing technology. The adoption of blockchain technology in supply chains is expected to offer distinct features like the transparency of data [31, 50], supply chain traceability [8, 50], reliability [45], and immutable and verifiable records with timestamp [6, 32], The existing studies have found relative advantage as an essential factor in the adoption of blockchain technology by organizations [8, 37, 51].

The compatibility of innovation has been explained in respect of its consistency with potential adopter's present needs, existing values, and past experiences [49]. Furthermore, compatibility of technology also involves consideration of organizational culture [52] and the available technology infrastructure [53]. It is easier for an organization to apply blockchain technology to its supply chains if it has a high compatibility level [9]. The existing studies have confirmed that the compatibility of blockchain technology positively influences the intention to adopt it in supply chains by the organizations [13, 51, 54].

The complexity of technology is associated with the relative difficulty to understand and use it [49]. Wong et al. [8] have reported that blockchain technology is challenging to understand by the users. The errors due to algorithms may be difficult to discover or are found too late to fix. Hence, there could be concerns about implementing blockchain technology to supply chains [9]. The complexity of blockchain technology has also been found as a major barrier to its implementation in supply chains by the available studies [9, 13, 55].

In light of the above discussion, the following three hypotheses are formulated for the factors of innovation characteristics:

H1: relative advantage of blockchain technology will positively influence the intention of SMEs to adopt it in supply chains

H2: blockchain technology compatibility will positively influence the intention of SMEs to adopt it in supply chains

H3: the complexity of blockchain technology will negatively influence the intention of SMEs to adopt it in supply chains

4.2. Hypothesis Development-Technological Context. The technology context examines the technology readiness of organizations to adopt blockchain technology in supply chains.

Technology readiness of an organization includes the availability of the required hardware, software, and specialized manpower to enable the adoption of new technology [56]. The organization should be sufficiently prepared with technological knowledge, training, expertise, and skillset to implement the new technology [56, 57]. The organizations with blockchain technology readiness are in a better position to adopt the technology in supply chains. The extant literature [6, 58, 59] has also reported the positive role of technology readiness in influencing the adoption of blockchain by SMEs in India. Thus, the following hypothesis is proposed:

H4: technology readiness will positively influence the intention of SMEs to adopt blockchain technology in supply chains

4.3. Hypothesis Development-Organizational Context. The organizational context explores the top management support, security concerns, and cost concerns for adopting blockchain technology in supply chains by organizations in India.

Top management support can be explained as the degree to which top management comprehends the significance of new technology and is involved in the technology adoption process [60]. The allocation of adequate human, financial, and infrastructural resources by top management plays a significant role in the adoption of new technology like blockchain [37, 59, 61]. The existing literature has highlighted the positive role of top management support in the adoption of blockchain technology [6, 54, 62].

Most of the transactions through blockchain are transparent, authentic, traceable, and verifiable, and this can prevent fraud across supply chains [32]. However, with consensus among participants, it is possible to collude, and hence, security may be compromised [59]. There can also be user apprehensions about privacy and security of the data due to concerns like data vulnerability with respect to distributed ledgers [12], high level of available visibility of data [8], the tradeoff between speed of transactions, and security [9]. The extant literature has also reported security concerns as an important consideration in the adoption of blockchain technology by organizations [9, 12, 51].

The adoption of blockchain technology is expected to increase operational efficiency and reduce waste and transaction and processing costs [55]. However, the huge up-front cost with investment in hardware and software infrastructure is required for obtaining and implementing the technology [63]. The implementation of the technology may also be hindered due to the cost of human resources and skill acquisition [9]. Hence, many SMEs in India may be skeptical about adopting blockchain technology in supply chains as confirmed by the previous studies [8,9].

Based on the above discussion, the following hypotheses regarding the considered factors of organizational context are formulated:

H5: top management support will positively influence the intention of SMEs to adopt blockchain technology in supply chains

H6: security concerns with respect to blockchain technology will negatively influence the intention of SMEs to adopt it in supply chains

H7: cost concerns with respect to blockchain technology will negatively influence the intention of SMEs to adopt it in supply chains

4.4. Hypothesis Development-Individual Characteristics. The perceived usefulness and perceived ease of use of adopting blockchain technology have been considered as the individual characteristics that can influence the technology adoption intention of organizations in supply chains.

Perceived usefulness refers to the degree to which a user believes that using a specific technology will improve his or her job performance [64]. It has been regarded as the primary influencer to positively induce intention for using new technology [42]. Furthermore, perceived ease of use describes the degree to which a user believes that using a specific technology would minimize his or her efforts [64]. It is linked with ease of learning, simplicity, clarity, and understandability of the technology [42]. Both these constructs are closely related since an easy-to-use technology is perceived to be more useful [4]. The available studies have described perceived usefulness and perceived ease of use as two major behavioral beliefs that are the fundamental factors for predicting user acceptance of a technology [53]. Given the above, the following hypothesis is proposed in respect of the Indian SMEs:

H8: perceived usefulness will positively influence the intention of SMEs to adopt blockchain technology in supply chains

H9: perceived ease of use will positively influence the intention of SMEs to adopt blockchain technology in supply chains

4.5. Hypothesis Development-Environmental Context. The environmental context explores the regulatory support and vendor support for adopting blockchain technology in supply chains by the Indian SMEs.

Regulatory support refers to policies and laws that play an important role in promoting the adoption of new technology [51]. Blockchain technology introduces concepts like cryptographic signatures and smart contracts, which are not addressed by the existing regulations [9]. Thus, the advent of technology calls for the review and resolution of legal issues, and the potential adopters may be more inclined to the technology if the regulatory environment is favorable [13, 54, 59].

Vendor support is vital for the successful implementation of new technology [10]. Vendor support is manifested in terms of security controls, data availability [53], user training, technical support [8], and no threat of vendor locking [9]. Hence, vendor support can positively influence the intention of users to adopt the new technology [9, 53].

Based on the previous discussion, the following hypotheses follow:

H10: regulatory support will positively influence the intention of SMEs to adopt blockchain technology in supply chains

H11: vendor support will positively influence the intention of SMEs to adopt blockchain technology in supply chains

5. Materials and Methods

The present study has used quantitative research that involved data collection through personal interviews and online surveys. For this purpose, a survey instrument in the form of a structured and pretested questionnaire was developed. Furthermore, both primary and secondary data sources were used in the study.

5.1. Sampling and Data Collection. To collect secondary data, the relevant research papers, articles, and other publications have been reviewed. The survey method has been used to collect primary data. The SMEs selected for the study consisted of enterprises having membership of the Confederation of Indian Industries (CII), Chandigarh in India. CII is a nongovernment, not-for-profit, industry-led, and industry-managed organization with a membership of over 300,000 enterprises including SMEs across India [65]. CII Chandigarh is a regional arm of CII in India. CII regularly organizes training workshops and seminars on new technologies for its members to enhance their competitiveness. Hence, it is expected that member firms of CII are conversant with the latest technologies like blockchain.

The SMEs chosen for the study based on the CII Chandigarh database belonged to three northern states/union territories of India, namely, Punjab, Haryana, Himachal Pradesh, and Chandigarh. The owners/partners of the selected SMEs were approached with a request to authorize the relevant supply chain functional head for sharing the required data. In case the supply chain functional head was not available, the SME owner/partner was requested to participate in the survey on behalf of the SME. From the available CII Chandigarh database, the list of SMEs that could potentially employ blockchain in their supply chains was initially prepared. This list was finalized based on discussion with academicians and practitioners in the area of supply chain management. Only manufacturing SMEs were covered in the survey. Thus, the final list contained a total of 498 SMEs for data collection.

A Google form with a questionnaire link was sent to the e-mail IDs of the respondents. The questionnaire link was hosted online from 15th September 2020 to 15th October 2020. The details of the research objectives were shared with the respondents to seek their consent to participate in the study. The participation was kept voluntary with follow-up emails at frequent intervals by the researcher with a request to participate in the survey. Some of the participants were also approached using contacts.

Out of the total 498 SMEs approached for the data collection, only 228 responded with filled questionnaires. Due to the illegible responses or missing data, twelve filled questionnaires were rejected. Hence, the final sample size for the study was 216. The sample description indicating organization type, industry type, employee strength, etc., is presented in Table 1.

5.2. Research Instrument. The structured questionnaire used as a research instrument contained constructs of the integrated TAM-TOE-DOI model. The responses were measured by using a five-point scale that ranged from 1 (strongly disagree) to 5 (strongly agree). All the items of the scale were adapted from the previous studies in respect of blockchain adoption. These scale items were reviewed after discussion with four subject experts from the area of supply chain management and blockchain technology. To further revise and finalize the scale items, a pilot survey was undertaken, and the questionnaire was administered to ten supply chain professionals associated with various industries including automobile, logistics, food delivery, and logistics. Thus, the total scale items finalized for data collection were 42. The data analysis led to the final count of 39 scale items as presented inTable 2.

5.3. Data Analysis. To safeguard the confidentiality of the study participants, their identity was concealed and not analyzed. Exploratory Factor Analysis (EFA) and Structural Equation Modeling (SEM) were applied to analyze the data collected from 216 supply chain professionals. For this purpose, IBM SPSS Statistics 26 and Amos 21.0 were used. As recommended by Ruscio and Roche [66], EFA was carried out before SEM to establish the basic structure of factors. The reliability of the scale and each of the subscales consisting of individual factors was confirmed by Cronbach's alpha. Then, as suggested by Anderson and Gerbing [67], SEM was applied by using two components, namely, the measurement model and structural model. Firstly, the measurement model was formulated for using multiple indicators to measure the independent and dependent variables. This measurement model was further examined for the goodness of model fit and construct validity through CFA. Thereafter, the structural model associated intention to adopt blockchain technology as the dependent variable and various factors as independent variables. Finally, path analysis was carried out to test the hypotheses.

6. Results and Discussion

The findings of the study including testing of hypotheses are presented and discussed in the following paragraphs.

6.1. Exploratory Factor Analysis. To make factor analysis to the finalized 42 scale items, exploratory factor analysis (EFA) using principal component analysis (PCA) and varimax rotation was employed. Cross-loadings suggested dropping of 3 scale items, and thus, the scale items left were 39 in number. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (0.693) and Bartlett's Test of Sphericity (significance of 0.00) were found appropriate for the application of EFA. The eigenvalues (at least a value of 1) were used to group the scale items into twelve factors indicating 71.98 percent of the explained variance. Furthermore, the Cronbach alpha values indicating the scale reliability coefficient (0.712) and the subscales reliability coefficients (0.693 to 0.901) were more than the threshold value of 0.50 [68]. Thus, twelve factors were extracted for the factor structure.

6.2. Structural Equation Modeling: Measurement Model. IBM SPSS AMOS 21 was used to develop the measurement model. Furthermore, the maximum likelihood method was

Table 1: Sample description for sample size $N = 216$.

Annual turnover range (organization type)	Number	Percentage
Small enterprise	94	43.52
Medium enterprise	122	56.48
Industry type		
Electrical and electronic products/components	38	17.59
Pharmaceuticals and healthcare	22	10.19
Auto ancillaries	20	9.26
Food and agro products	14	6.48
Chemical and paints	12	5.56
Textile and garments	11	5.09
Stationary and paper	10	4.63
Packaging	10	4.63
Others	79	36.57
Employee strength		
Less than 20	52	24.07
Between 21 and 40	34	15.74
Between 41 and 60	31	14.35
Between 61 and 80	33	15.28
Between 81 and 100	25	11.57
More than 100	41	18.98
Plan to adopt blockchain technology in supply chains		
Already adopted blockchain technology in supply chains	29	13.43
Intend to adopt blockchain technology in supply chains in the next 1–3 years	109	50.46
Not planning to use cloud computing in the near future	78	36.11

Table 2: Questionnaire items.

Construct	ID	Item
Relative advantage	RA1	Blockchain technology enables transparency of data across various supply chain participants
	RA2	Blockchain technology allows tracking of the route of the material from its origin to the delivery point
	RA3	Blockchain technology provides the availability of data with an exact timestamp
	RA4	Blockchain technology enables a verifiable record of each and every transaction across the supply chain
Technology compatibility	TC1	The current hardware and software infrastructure in our organization can be compatible with blockchain technology
	TC2	The use of blockchain technology is consistent with our organization's culture and values
	TC3	The changes introduced by blockchain technology are consistent with the existing practices in our organization
Complexity of technology	CX1	The skills necessary for using blockchain technology are too complicated for our staff
	CX2	It is difficult to learn how to apply blockchain technology in supply chain management
	CX3	The tools of blockchain technology are not easy to use
Technology readiness	TR1	Our organization understands how blockchain technology can support our supply chains
	TR2	Our organization is dedicated to acquiring the required managerial and technical skills for implementing blockchain technology in supply chains
	TR3	Our organization is dedicated to ensuring that employees are regularly updated with knowledge on blockchain technology
	TR4	Our organization adequately understands how to utilize blockchain technology in supply chains
Top management support	TOP1	Our top management supports the implementation of blockchain technology
	TOP2	Our top management is ready to provide the necessary resources for the introduction of blockchain technology
	TOP3	Our top management is willing to take the possible risks involved in the adoption of blockchain technology
Security concerns	SC1	Degree of organization's concern with data security while using blockchain technology
	SC2	Degree of organization's concern with the security of online transactions while using blockchain technology
	SC3	Degree of organization's concern about privacy while using blockchain technology
Cost concerns	CA1	Blockchain technology adoption requires high hardware and software facility costs
	CA2	Blockchain technology adoption requires a high cost of training and recruiting
	CA3	Blockchain technology adoption requires high up-front investment costs

Table 2: Continued.

Construct	ID	Item
Perceived usefulness	PU1	Using blockchain technology will allow us to improve supply chain performance
	PU2	Using blockchain technology will allow us to improve supply chain productivity
	PU3	Using blockchain technology will allow us to improve supply chain efficiency
Perceived ease of use	PEOU1	It is easy-to-use blockchain technology
	PEOU2	The features of blockchain technology are clear and understandable
	PEOU3	As compared to conventional ways of supply chain management, blockchain technology can be used with more ease
Government support	GS1	The government actively supports the adoption of blockchain technology
	GS2	The government policies are in favor of the adoption of blockchain technology by the industry
	GS3	There is a legal framework to solve disputes arising out of the use of blockchain technology
	GS4	The regulations are sufficient to protect the use of blockchain technology
Vendor support	VS1	Blockchain technology vendors are providing incentives to our organization for the adoption of their products and services
	VS2	Blockchain technology vendors provide our organization with adequate technical support for blockchain technology adoption
	VS3	Blockchain technology vendors provide our organization with appropriate training for the use of this technology
Adoption intention	AI1	Our organization intends to adopt blockchain technology in supply chain management in the near future
	AI2	Our organization intends to digitally transform the supply chain management in the near future
	AI3	Our organization is likely to use blockchain technology in supply chain management on a regular basis in the near future

applied for model estimation. The standard residual values did not suggest dropping any scale item. The model fit indices were determined to ascertain the measurement model fit. These model fit indices are shown in Table 3.

Table 3 reveals that the chi-square value, when divided by the degrees of freedom ($\chi 2/\text{DF} = 1.515$), is lower than the threshold value of 3 [69–72]. Furthermore, Table 3 also suggests acceptable values for other fit indices as proposed by various researchers [69]. Hence, model fit indices reveal an overall good fit of the data to the 12-factor measurement model without any need to conduct post hoc modifications. This supports further analysis using a structural model [73]. The quality of the measurement model was further evaluated by testing the convergent and discriminant validity of the model.

As per the available recommendation [67], average variance extracted (AVE) and composite reliabilities (CRs) were estimated to examine the convergent validity. It is found that the values of AVE and CR for all the constructs are more than the threshold values of 0.5 and 0.7, respectively [74], as shown in Table 4. Thus, the convergent validity of the measurement model is established.

The discriminant validity of the measurement model is examined by finding if the square root of the AVE of each construct is greater than the correlation coefficient of each pair of constructs [74]. The diagonal values in Table 5 show the square root of AVE in the case of each of the constructs. These values are found to meet the required criterion of discriminant validity. Hence, the discriminant validity of the measurement model is confirmed.

6.3. Structural Equation Modeling: Hypothesis Testing. The measurement model was converted into a structural model for testing the proposed hypotheses. Figure 1 shows the simplified structural model with hypothesized relationships among the latent variables. The structural model explained 57.8 percent of blockchain technology adoption in supply chains by SMEs in India. The proposed hypotheses were tested using standardized regression weights as presented in Table 6.

The structural model in Figure 1 reveals that out of the 11 paths, 8 paths are significant. Thus, as indicated in Table 6, eight hypotheses concerning relative advantage (H1, $p < 0.01$), technology compatibility (H2, $p < 0.01$), complexity (H3, $p < 0.01$), technology readiness (H4, $p < 0.05$), top management support (H5, $p < 0.01$), cost concerns (H7, $p < 0.05$), perceived usefulness (H8, $p < 0.01$), and vendor support (H11, $p < 0.05$) are supported. Hence, these eight factors have significant effects on the behavioral intention to adopt blockchain technology in supply chains. The innovation characteristics, namely, relative advantage and technology compatibility; technology readiness in the technology context; top management support in the organizational context; perceived usefulness, an individual characteristic; and vendor support in the environmental context, affect behavioral intention positively. However, complexity, which is an innovation characteristic, and cost concerns in the organizational context have a negative effect. Furthermore, hypotheses concerning security concerns (H6, $p = 0.207$) in the organizational context; perceived ease of use (H9, $p = 0.779$), an individual characteristic; and regulatory support (H11, $p = 0.917$) in the environmental context are not supported. This indicates that these three factors do not significantly affect behavioral intention. These findings are discussed further in the following paragraphs.

6.3.1. Innovation Characteristics. As far as innovation characteristics are concerned, two factors, namely, relative advantage and technology compatibility, are found to have a

Table 3: Model fit indices.

Model fit statistic	Recommended value	Obtained value
Chi-square (χ^2)/degree of freedom (DF)	≤3.0 [69] $p \leq 0.05$	963.274/636 = 1.515, p = 0.001
Root mean square error approximation (RMSEA)	≤0.06 [70]	0.029
Comparative fit index (CFI)	≥0.95 [70]	0.979
Goodness-of-fit index (GFI)	≥0.90 [71]	0.932
Adjusted goodness-of-fit index (AGFI)	≥0.90 [71]	0.898
Tucker–Lewis index (TLI)	≥0.95 [70]	0.966
Normed fit index (NFI)	≥0.90 [71]	0.919
Incremental fit index (IFI)	Close to 1 [72]	0.981

Table 4: Convergent validity tests.

Measure	Average variance extracted (AVE)	Composite reliability (CR)
Relative advantage (RA)	0.712	0.796
Technology compatibility (TC)	0.789	0.884
Complexity (CX)	0.617	0.762
Technology readiness (TR)	0.586	0.714
Top management support (TMS)	0.631	0.804
Security concerns (SC)	0.602	0.785
Cost concerns (CC)	0.701	0.821
Perceived usefulness (PU)	0.611	0.798
Perceived ease of use (PEoU)	0.698	0.834
Regulatory support (RS)	0.722	0.736
Vendor support (VS)	0.684	0.892
Blockchain technology adoption (BTA)	0.804	0.889

Table 5: Discriminant validity test.

Latent variable	RA	TC	CX	TR	TMS	SC	CC	PU	PEoU	RS	VS	BTA
RA	0.84											
TC	0.32	0.89										
CX	0.32	0.40	0.79									
TR	0.29	0.35	0.42	0.77								
TMS	0.35	0.44	0.50	0.44	0.79							
SC	−0.19	0.24	−0.28	0.11	0.42	0.78						
CC	0.22	−0.18	0.27	−0.19	0.46	−0.16	0.84					
PU	0.31	0.31	0.37	0.32	0.33	−0.17	−0.18	0.78				
PEoU	0.40	0.51	0.57	0.32	0.24	0.21	0.28	0.44	0.84			
RS	0.20	0.37	0.49	0.41	0.31	0.15	-0.15	0.31	0.51	0.85		
VS	0.38	0.41	0.49	0.34	0.22	0.30	0.25	0.51	0.42	0.22	0.83	
BTA	0.43	0.53	0.39	0.41	0.52	0.20	0.16	0.56	0.49	0.27	0.56	0.89

positive influence on the intention of Indian SMEs to adopt blockchain technology in their supply chains. Relative advantages of blockchain technology in supply chains as shown by the study are tracking of transactions, verifiable records, transparency, and availability of data with an exact timestamp. This is consistent with the previous studies on the blockchain technology adoption intention [51, 59]. Furthermore, when it comes to technology compatibility, it is revealed that the Indian SMEs intend to adopt blockchain technology in supply chains if their culture, values, hardware and software infrastructure, and existing practices are compatible. Other studies [6,55] on blockchain technology adoption have reported similar results. The complexity of technology significantly influences blockchain technology adoption by SMEs in India in a negative manner. This indicates that users have an initial apprehension and anxiety about the complexity associated with the usage or skills required for working on blockchain technology. This has also been validated by the earlier findings [8, 59, 75]. Given the above, it may be presumed that innovation characteristics have a significant influence on the intention of Indian SMEs to adopt blockchain technology in supply chains.

6.3.2. Technological Context. The present study examines technology readiness in the technology context. The findings reveal that SMEs with technology readiness have more likelihood to adopt blockchain technology in supply chains. It is further indicated blockchain technology adoption is enabled by the understanding of SMEs regarding the utility

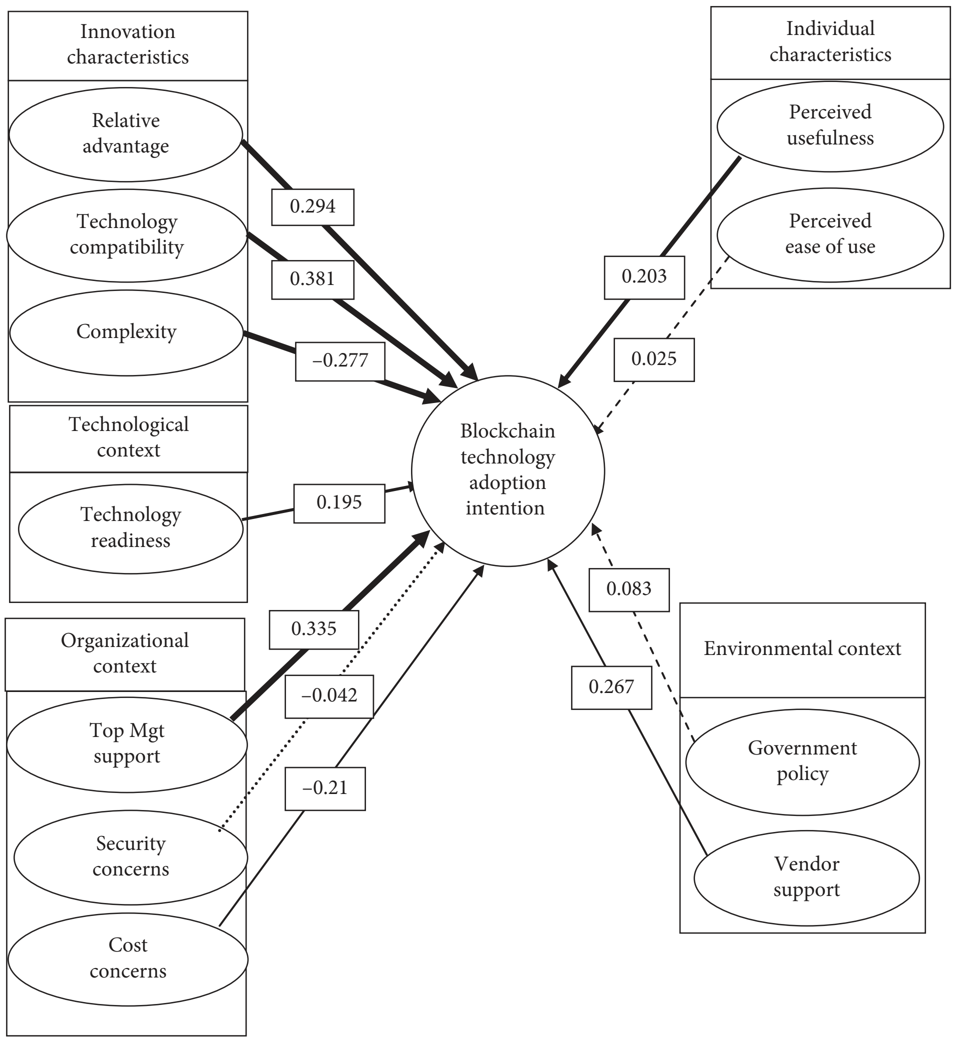

Figure 1: Structural model.

Table 6: Standard path coefficient estimates and hypothesis testing.

S. no.	Path	Standardized path coefficients (β)	CR	p value	Results
H1	Relative advantage⟶adoption intention	0.294	3.307	0.001	Supported ($p < 0.01$)
H2	Technology compatibility⟶adoption intention	0.381	4.748	0.001	Supported ($p < 0.01$)
H3	Complexity⟶adoption intention	−0.277	−2.294	0.008	Supported ($p < 0.01$)
H4	Technology readiness⟶adoption intention	0.195	2..198	0.037	Supported ($p < 0.05$)
H5	Top management support⟶adoption intention	0.335	4.075	0.004	Supported ($p < 0.01$)
H6	Security concerns⟶adoption intention	−0.042	-0.768	0.207	Not supported
H7	Cost concerns⟶adoption intention	−0.206	−1.875	0.019	Supported ($p < 0.05$)
H8	Perceived usefulness⟶adoption intention	0.203	2.416	0.004	Supported ($p < 0.01$)
H9	Perceived ease of use⟶adoption intention	0.025	0.779	0.348	Not supported
H10	Regulatory support⟶adoption intention	0.083	0.917	0.428	Not supported
H11	Vendor support⟶adoption intention	0.267	2.883	0.032	Supported ($p < 0.05$)

of blockchain technology in supporting their supply chains. The availability of manpower with the requisite skillset and regular updating of their knowledge on blockchain technology is also important. Similar results have been reported by the available studies on technology adoption intention [76, 77]. Hence, the technological context influences the intention of SMEs to adopt blockchain technology in their supply chains.

6.3.3. Organizational Context. To study the organizational context of blockchain technology adoption, three factors, namely, top management support, security concerns, and cost concerns, have been examined. The top management support has a significantly positive influence on the blockchain technology adoption of SMEs. The findings also indicate the importance of the availability of requisite resources and inclination on the part of top management to bear the risks involved in adopting blockchain technology. The extant literature [8, 55, 77] has reported similar findings in the context of blockchain technology. The results further show that security concerns do not negatively influence the intention of SMEs to adopt blockchain technology in supply chains. This result is similar to an existing study [4]. This could be owing to the belief that the full-proof adoption of blockchain technology provides a high level of security and privacy [4]. Organizations may be aware of the security benefits of blockchain technology like safety from cyberattacks, protection of data, and cryptography [27]. The cost concerns have a significantly negative influence on the intention of SMEs to adopt blockchain technology in supply chains. The implementation cost of blockchain technology including the cost of hardware, software, training, and recruitment could be a major reason for resistance to adopting the new technology by organizations as confirmed by the existing studies [8, 37]. Thus, two factors of organizational context have a significant influence on blockchain technology adoption intention of the organizations. Therefore, it may be presumed that organizational context has a partial influence on the intention.

6.3.4. Environmental Context. Out of the two considered factors of the organizational context, namely, regulatory support and vendor support, only vendor support impacts SMEs' intention to adopt blockchain technology in a significantly positive manner. The study reveals that vendor support is required in terms of technical support, training, and incentives to adopt the new technology. Similar findings are reported by the existing studies [41]. Furthermore, the insignificant effect of regulatory support on the intention to adopt blockchain technology indicates that intention to adopt blockchain technology is not driven by regulatory support. This may be because blockchain standards are still in the infancy stage in India, and hence, SMEs are uncertain about the regulations concerning blockchain technology [9]. This calls for the urgent development of standards and regulations [51]. Similar results have been presented by a study [8] in the Malaysian context. Since only one factor of the organizational context is found significant, it shows that environmental context has a partial influence on the blockchain technology adoption intention.

6.3.5. Individual Characteristics. One individual characteristic, namely, perceived usefulness, is found to have a significantly positive influence on organizations' intention to adopt blockchain technology in supply chains. This indicates that supply chain professionals are perhaps already conversant with blockchain technology and understand its utility to the supply chains. Similar results have been reported by the existing studies [4, 78, 79]. Furthermore, the other individual characteristic, that is, perceived ease of use, is not found to have a significantly positive influence on the intention to adopt blockchain technology. This indicates that users perceive blockchain technology as a complex technology with respect to use, clarity, and understanding. This result is in line with the previous finding that indicates that the complexity of technology has a significantly negative influence on blockchain technology adoption by SMEs in India. Since only one individual characteristic is found significant, it can be presumed that individual characteristics partially influence the blockchain technology adoption intention.

7. Conclusions

The present study explores the factors influencing the intention of Indian SMEs to adopt blockchain technology in their supply chains. The considered integrated TAM-TOE-DOI framework comprises innovation characteristics, technological context, organizational context, environmental context, and individual characteristics. Out of a total of eleven hypotheses proposed, eight were supported by the study. The findings reveal a significant influence of relative advantage, technology compatibility, complexity, technology readiness, top management support, cost concerns, perceived usefulness, and vendor support on the intention of Indian organizations to adopt blockchain technology in supply chains. The study further indicates that the complexity of technology and cost concerns with respect to blockchain technology implementation are the significant reasons for the reluctance to adopt the technology. The rest of the factors have a positive influence on the adoption intention. The three factors, namely, security concerns, perceived ease of use, and regulatory support, do not influence the intention to adopt the technology.

The study contributes to filling a significant gap in the academic literature since only a very few studies have endeavored to ascertain the technology adoption factors by supply chains of SMEs in a developing country like India [8,11]. Furthermore, the study has proposed a novel integrated technology adoption framework consisting of three widely used theoretical models and theories, namely, Technology Acceptance Model (TAM), Diffusion of Innovation (DOI), and Technology-Organization-Environment (TOE). This is a comprehensive model to include the various available antecedents for assessing the determinants of the technology. This model may be employed by academic researchers in India and abroad to explore the adoption factors in the case of various evolving technologies.

The findings can further help regulatory authorities and industry practitioners including technology developers, vendors, and suppliers as the study offers them an opportunity to reflect on the determinants of intention to adopt blockchain technology. The SMEs in India will be oriented to adopt blockchain technology if vendors can convince them of the relative advantages of the technology like data availability, transparency, record verification, route tracking of the stock, etc. Blockchain technology developers should understand the compatibility requirements of SMEs and offer customized technology solutions. The findings further reveal that user apprehension about the complexity with respect to skills required or usage of blockchain technology can act as a barrier to technology adoption. The technical and training support by vendors is critical to overcoming this apprehension. The results indicate a positive tendency to adopt blockchain technology if SMEs are confident of their readiness for the technology in terms of having adequately trained and skilled manpower. Top management support is further revealed as an important determinant in the decision of SMEs to adopt blockchain technology in supply chains. In the Indian SME's context, the top management generally refers to the owner and final decision-making authority. An SME will be more inclined to adopt blockchain technology if top management has a favorable attitude to the technology. This finding is important because this technology is perceived to be costly to implement. This can act as an inhibitor to technology adoption if the top management does not provide sufficient resources. Therefore, the developers and vendors need to convince the top management regarding the utility of the technology to the supply chain of the organization. Furthermore, it is recommended that Indian policymakers should establish the necessary regulatory framework to regulate the use of blockchain technology.

8. Limitations and Direction for Future Research

This study is based on a limited sample of 216 SMEs in India. Attention should be paid to this aspect while generalizing the results of the study. In the future, research regarding blockchain technology adoption may be carried out in micro and large organizations in India and other geographies. Future research can further engage in longitudinal studies to explore the factors that impact blockchain technology adoption in supply chains across various types of organizations. This would assist developers to ensure client-specific changes in their offerings. The blockchain technology application and adoption can also be explored in various contexts such as the Internet of Things [80], surveillance systems [81], transportation systems [82], smart cities [27, 81], tourism and hospitality [30], agriculture [40], and healthcare [1]. Furthermore, future studies may extend the proposed integrated TAM-TOE-DOI framework to explore the determinants of blockchain technology adoption in various micro and large organizations across the manufacturing and service sectors.

Data Availability

The data used in this study can be obtained from Amit Kumar Bhardwaj (akbhardwaj@thapar.edu).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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