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Factors Affecting Organizations' Resistance to the Adoption of Blockchain Technology in Supply Networks

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Abstract: From a supply chain perspective, new technologies such as blockchain can improve the efficiency and competitiveness of logistics and increase customer satisfaction. Although blockchain technology has been lauded as a way for firms to build sustainable supply chain networks, the rate of acceptance of this technology remains low. Therefore, this study seeks to identify the factors that discourage firms from merging blockchain with the supply chain. Instead of providing further reasons for adopting blockchain technology, we try to understand what deters firms from adding blockchain to their operations. Following the deductive approach, a confirmatory factor analysis is conducted on pre-test questionnaires to test, improve, and verify the constructs (questions) to measure the hypothesized factors. A theoretical model is proposed based on the hypotheses, and structural equation modeling is applied. The results are estimated using the partial least squares approach and a sample of 83 respondents. Our findings based on our empirical data support most of our hypotheses. We find that various factors impede the adoption of blockchain technologies, including technological barriers, constraints rooted in organizations and the environment, and system-related governmental barriers. In addition, various factors are critical determinants of resistance to blockchain in the technological, organizational, and environmental dimensions.

Keywords: technology adoption barrier; blockchain; sustainability; sustainable supply chain; structural equation modeling

1. Introduction

Technological advancements provide us with value in various ways, with researchers in many fields seeking to invent tools that are more efficient, effective and provide greater security. A good example is the developments in network technology that culminated in the Internet. The purpose of network technology is to assist people in communicating and sharing information across time and space.

Although relatively new within the field of network technologies, blockchain technology holds diverse and promising benefits. For example, blockchain technology has been used in the financial sector to improve users' capabilities related to financial management and trade [1]. Blockchain was first publicized as a way to trade value (Bitcoin), one of its well-known functions [2].

However, with the advent of key functions such as ledgers and smart contracts, it is now clear that blockchain is much more than a Bitcoin platform [3]. The appearance of blockchain has changed the process through which businesses operate within the global economy. The technology, known for its top-end security features, is also valued for its ability to share information among participants in systems, owing to its manual verification and massive permanent record-keeping [4].

Blockchain technology appears to be an ideal solution to existing supply chain problems. Firms in various fields are currently considering whether to adopt this nascent technology and cultivate the benefits of being early adopters, or to wait until technology integration becomes less costly and the benefits become more promising. There are early and late adopters for every technology. The successful implementation of blockchain technology in supply chain networks begins with recognizing the hurdles and barriers that must be addressed. Understanding these obstacles and developing solutions to them can significantly help the effective adoption and implementation of blockchain technologies.

Although blockchain and the supply chain are familiar to organizations, the integration of the two varies and is interesting to both academia and business. Many large companies and organizations have publicly announced their investment in blockchain, while others are planning future investments. Such phenomena make the integration of blockchain and the supply chain appear to be ideal. Blockchain is often touted as a panacea for all supply chain problems [5]. Businesses and researchers are deploying this new technology based on their particular objectives, but the challenges and prerequisites of adoption in the supply chain have not yet been systematically assessed.

Despite the usefulness of the technology, the adoption rate is rather slow and may be hindered by hidden factors that impede firms' decisions. The process of introducing a new technology into an industry can be complicated and lengthy, as proposed by epidemic theory. Some firms may want to take the first step as early adopters, while others may prefer to play it safe. Others may be considering their decisions, either because they have limited resources, or because the supposed benefits are not sufficiently convincing. This leads to our research questions: (i) What are the causal relationships between technological, organizational, and environmental (TOE) factors and organizations' resistance to blockchain? (ii) Which of the determinants inside the TOE framework are most significant? (iii) What are the relationships between the factors?

Despite the many observations and studies related to blockchain in the literature, knowledge gaps remain wide. Existing findings emphasize the improvements this technology can bring to organizations' performance. However, to the best of our knowledge, few studies have sought to identify its barriers to adoption (the reasons why firms are hesitant to put blockchain into practice).

Thus, the aim of this research is to fill this small but significant gap, bringing blockchain one step closer to practice. We attempt to identify the determinants that drive the integration of blockchain and to highlight the main barriers stopping managers from embracing blockchain-based supply chains. It is understood that, although there are survey papers exploring the barriers, the authors believe that, from the perspective of supply networks, blockchain integration still requires more condensed attention. This study is not totally new from the point of view of blockchain technology, but our framing of the barrier in the TOE framework to understanding those blockades is relatively novel in the field. Based on our findings, we also provide precautions and possible mitigations for these concerns. Our results may serve to strengthen the arguments of future claims. We consider many factors in our analysis and evaluation process in order to gauge their appropriateness.

The remainder of this paper is structured as follows. In the literature review, we summarize relevant existing works. Then, we define some necessary terms and our theoretical framework, based on which we present our hypotheses in the following section. The research method is also described, along with its validity. Following this, we present and discuss our results. The final section concludes the paper, including a discussion of possible directions for future research.

2. Literature Review

2.1. Blockchain Technology in Supply Chains

The concept of blockchain technology was first introduced in 1991 by Stuart Haber and W. Scott Stornetta [6]. The initial intention was to develop a system that documented timestamps that could not be backdated or tampered with.

In addition, a blockchain has a decentralized mechanism (peer-to-peer network) that enables every stakeholder to have a full copy of the chain, which means each node can check that the chain is intact. When a new block is added to the chain, the majority of nodes verify this addition, and then add the new block to their chains [7] (Beck, 2017). These nodes create a safe network through consensus [1]. In other words, all participants agree on whether a block is valid. In short, a blockchain is a platform that is protected by the blocks themselves, proof-of-work, and a peer-to-peer structure (consensus) [8].

After defining the terms blockchain and supply chain, we examine their possible integration and identify some key roles. Because a supply chain structure is complex and involves many stakeholders, both upstream and downstream, there is a need for simplification. Blockchain is well equipped to tackle the challenges faced by supply chains. Iansiti and Lakhani [8] insist that, instead of replacing existing business processes, blockchain actually adds new value to current operations. This statement is well supported by a study initiated by [9]. The blockchain can function as a platform replacement that allows users to maintain their own data visibility and connect to the company's systems. In the same paper, the authors also gave explicit examples of blockchain usages such as supply chain risk assessments and supply chain flow optimization. By conducting a systematic literature review (SLR), [10,11], come to a conclusion that there are at least four major issues that have to do with blockchain in supply chain which are traceability and transparency, stakeholder involvement and collaboration, supply chain integration and digitalization, common frameworks on blockchain-based platforms. Similarly, Wang et al. [4] highlight some of blockchain's characteristics in supply chains that are familiar to the business environment, namely traceability, transparency, immutability, and trustworthiness.

Owing to its distributed ledger, blockchain can grant access to users, regardless of their location, to share electronic information within a set boundary. In the supply line, data errors are common and a longstanding problem. Many of these errors are created at the inputting stage. Using blockchain, errors in data entry can be reduced, because fewer people perform these tasks. Redundant jobs can thus be eliminated, because all parties can access the same information [12]. Because information is time-stamped and immutable once created, trustworthiness is ensured in the supply pipeline. A practical example of transparency requirements can be found in the supply line of the pharmaceutical industry. Fake and poor-quality pharmaceutical products present threats to patients and the whole sector [13]. Blockchain's public ledger can address these issues. Because blockchain allows all real-time information to be shared with all parties, if anything goes wrong, those who are responsible can take prompt action [14].

Another distinct key feature of blockchain technology is the smart contract. Cheng et al. (2019) studied the smart contract-based tracking process in supply chain and insisted that the supply chain industry is going to be re-engineered with the presence of blockchain. Given that all predefined conditions are met, an electronic contract triggers the process to move on to the next step (i.e., the payment process). Buyers can thus be confident that products are in a predetermined condition, and sellers can ensure that a payment of the right amount is made at the right time. Thus, blockchain applications can solve supply chain challenges and improve functionality and regulatory controls [15]. On an international level, traditional paper-based documentary credits (letters of credit) involve many business activities, actors, and are costly due to their insurance, in combination with logistics fees. Thus, to reissue letters of credit, a lengthy tedious and troublesome process is inevitable. This very issue can be simplified by the use of a blockchain-enabled platform [16].

With regard to security, blockchain provides users with an environment safe from cyber-attacks. Electronic data are normally collected and stored on a service provider's central servers, which can be susceptible to attacks. Blockchain has the potential to improve the security of private, sensitive data, owing to its highly protective mechanisms of distributed consensus and cryptography [17].

Nevertheless, blockchain-based supply networks may require a closed, exclusive, and permissions-required network with a limited number of participants. At least four actors must perform designated tasks in order to use a blockchain: registrars, standard organizations, certifiers, and actors. Each fulfills their own tasks to ensure usability [18].

2.2. Understanding Barriers and Impediments to Technology Adoption

2.2.1. Technology Acceptance Model

The technology acceptance model (TAM) is often used to explain the determinants of, and barriers to, technology adoption. It is specifically designed to model users' acceptance of technology in information systems. The model was modified in 1996 by Venkatesh and Davis, who found that perceived ease of use and perceived usefulness both directly influence behavior intention [19].

Understanding motivations is significant, but not sufficient to determine the success of a technology. Although it is important to recognize the factors that motivate adoption intentions, we cannot ignore factors that impede such intentions. In other words, both factors must be attended to enable a better adoption process. Rogers [20] provides a theory that focuses on resistance to technologies. He proposes compatibility, complexity, and trialability, among others, as the characteristics of innovation that play a role in technology resistance. The absence of these characteristics results in firms rejecting an innovation.

2.2.2. Diffusion of Innovation Theory

Considering the diffusion of innovations and technologies, Rogers [20] provides a five-factor model that concentrates on the characteristics of innovation at the organization level in the persuasion stage prior to the decision stage. The first factor that drives the speed of adoption is relative advantage, which can be interpreted as "the degree to which an innovation is perceived as better than the idea it supersedes". Rogers explains that innovations sometimes do not necessarily hold a significant advantage; what matters most is that decision makers identify the innovation as beneficial. The higher the perceived relative advantage of an innovation, the quicker the adoption rate will be. The second factor is compatibility, or the degree to which a technology can be integrated into the existing system. The innovation may be consistent with the extant values, past experience, and needs of prospective users. It may be difficult or time-consuming to adopt technologies that contrast with pre-existing norms. Third, complexity is the level of difficulty of comprehension and using a technology. Some technologies are highly complex, consisting of many interrelated sub-elements that require effort to understand and implement. The more complex a technology, the more likely it is to be rejected. Rogers also points out that managers react positively toward the adoption of a technology after they have had the chance to try it directly and precisely. He refers to this as trialability, or "the degree to which an innovation may be experimented with on a limited basis". Simply put, trialability is concerned with whether an innovation can be examined or tested before it is adopted. The last characteristic is observability, which is the degree to which the results of an innovation are not only visible, but also communicated and demonstrated to prospective users. Having the chance to see and examine the process of implementation and to obtain results from other organizations significantly push managers to consider new technologies.

2.2.3. TOE Context

The system itself and the adopters are hidden hurdles to the adoption of technologies that must be cautiously addressed. Because blockchain integration requires the involvement of all agents (Hald Kinra, 2019), its degree of complication is higher than that of other in-house adoptable technologies, such as barcodes. There are various sources of these barriers; they can be external, internal, or stem from the system itself [21]. In their study on blockchain technology and its relationships with sustainable supply chain management, Saberi et al. [21] suggest potential barriers, most of which require coordination from other departments to solve. Hence, we found the TOE framework to be suitable for use in this study.

Owing to its philosophical constructs, the TOE framework has been used to study the adoption of various types of IT innovations, especially at the organizational level. It provides a theoretical basis and consistent empirical support and is applicable to IT innovation domains, although specific factors within the three contexts may be interpreted differently. Since this framework covers a big portion of organizational operations, working on the three pillars would be of help in categorizing the types of hurdles and in the ease of treating them accordingly.

Tonatzky et al. [22] highlight three significant contexts that drive the process and speed of an organization's technology adoption. First, the technological context concerns characteristics of the technology that can be applied within or throughout the system, as well as the status of current technology use in the organization. Specifically, it includes both a firm's current practices and its equipment [18]. Second, the organizational context refers to the formal and informal structures of the organization, the status of innovation, the scope and size of the organization, slack resources, and the communication process and managerial structures [22]. Third, the environmental context is the combination of other factors that influence the firm externally [22]. This includes elements such as market structure, competition, external pressure/support available for adopting new technologies, and government regulations. These antecedents interact with each other to influence technology adoption decisions. These three pillars comprise all hurdles from previously mentioned theories (i.e., technology traits). This theory shows that the aforementioned barriers possess strong relations with technology resistance and speed of adoption at the organizational level. The following sections discuss the key inhibitors based on these categories. We found that the TOE was a suitable approach to use to achieve the aims of this study.

In research conducted by Sadhya and Sadhya [23], security and vulnerability were found to be barriers to adoption in the technological context. Trade-offs must be made between security and performance. Swan [3] adds that collusion is still possible through consensus among participants (51% attack). It is no doubt that privacy concerns are a priority. Blockchain allows for a high level of visibility, which results in an unwillingness to join adoption trends [24].

Another point of resistance could arise from a lack of standardization of actual practices. The absence of standardization recognized by regulators is a barrier to adoption intentions. Furthermore, the lack of a standardized computer language is a disincentive to IT departments when they discover that platforms cannot correspond without assistance [23,25]. Babich and Hilary [24] raise a further concern on why blockchain may not work, called the "black box effect", which results from the complexity of the automatic system. In practice, a blockchain is difficult to understand from the perspective of adopters. Algorithms may make errors that humans do not discover until they are too late to fix. The hesitation of potential adopters owing to concerns about blockchain's complex nature may increase resistance, outweighing implementation intentions.

Other factors to consider are scalability (block size) and speed, which is the ability of the platform to perform a transaction and accomplish its objectives in an acceptable period [26]. Currently, a blockchain can handle only seven transactions per second (tps), on average, and the block size is limited to just 1 megabyte (MB) [27]. If blockchain is to come into broader usage, this matter must be cautiously addressed. Blockchain in the supply chain area requires network involvement [28]. Strong support and reconciliation must be provided by partnering firms to put this technology into practice. Thus, the network structure of the technology adds another layer of problems for organizations [29].

Negative perceptions related to blockchain due to Bitcoin remain strong. The terms blockchain and Bitcoin are still misunderstood as interchangeable. It may take time to popularize the idea that blockchain and Bitcoin are not alike [23]. This technology has only recently been publicized, and its novelty remains an unresolved issue that causes obstacles. The number of use cases is fragmented, and successful implementations are limited by goals of adoption. Thus, it might not be the case that the technology will magically upgrade the system. Adopters are still in doubt, a limited number of actors are conducting research and development on the technology, and constraints imposed by companies' human resource policies prolong transition periods for the adoption of blockchain [24,30,31].

Moreover, another factor that should be considered when implementing a new technology is its interoperability (compatibility). Businesses must either procure or develop blockchain-based solutions that are compatible with their legacy systems or transform their present systems to be compatible with blockchain [23]. In addition, from a technological perspective, there is a need to re-engineer the business process. Supply chains consist of many interlinkages. It may be that integrating blockchain requires adjustments to be made to a legacy system. Organizations must be prepared to transform in order to obtain the benefits of the distributed nature of blockchain.

Financial factors stand out as one of the main reasons for resistance to adoption. The cost of implementing blockchain is not certain, which may hinder the support and commitment of the management team [32]. Implementation costs may vary because of several critical factors, including hardware, software, recruitment, and in-house training, and include both opportunity costs and accounting costs. Blockchain is believed to be a technology with high up-front investment costs, although it brings about advantages in cost reduction [25]. Table 1 lists some of the barriers mentioned in the literature.

Table 1. Technological barriers.

Technological Barriers
1. Complexity (black box effect)
2. Absence of standardization of programming languages (Java, C++, Python, etc.)
3. Security and vulnerability
4. Immaturity
5. Compatibility (interoperability)
6. Intensive energy consumption
7. Negative perspective due to Bitcoin
8. Network as a nature of technology
9. Scalability
10. Technology attributes: trial and reversibility
11. Cost of implementation

A study conducted by Clohessy and Action [33] in 2018 on companies on Ireland illustrates that top management support and organizational readiness are vital to the implementation of such a blockchain. Furthermore, the size of the organization, blockchain awareness and the insufficiency of information—regardless of industry influence—not only alter the speed, but also the motivation for the initiation of blockchain integration [31]. Barriers in the organizational context are split into two categories: inter-organizational and intra-organizational barriers (Table 2). First, with regard to intra-organizational barriers, some organizations face commitment constraints. However, the long-term commitment of the management team is key to the successful adoption of a technology [34]. Wang et al. [35] and Catalini and Michelman [36] assert that the slow speed of blockchain technology adoption is related to supply chain actors' reluctance and resistance to change, owing to their fear of being transparent or their previous heavy investments in existing infrastructure. Hoerl and Snee [37] propose several activities of the management team that affect the outcomes of technology adoption, including their support for financial and technical assistance, removing obstacles, providing support in solving problems, encouraging all staff to take part in the project, and sharing their vision. Blockchain resistance may also be related to the inadequacy of existing expertise inside a firm [24]. The recent development and sophistication of the technology have widened the gap between the demand and supply of skilled human resources and expertise. To grasp the full potential of this technology, one must be knowledgeable in both IT and daily processes [26]. Thus, it is expensive to either recruit or train human resources to use blockchain. Without enough qualified workers, businesses may not garner the full benefits offered by blockchain [28] and, therefore, may not be willing to adopt it.

Table 2. Organizational barriers.

Organizational Barriers
Intra-organization
1. Technological familiarity of the management team
2. Resistance and lack of management commitment and support
3. Lack of expertise and technical knowledge
4. Need for close coordination and collaboration
5. Lack of policies for blockchain
6. Other technology investments are taking priority
7. Perception vendor lock-in (platform supplier)
Inter-organization
1. Cultural differences between two firms
2. Privacy and information disclosure concerns
3. Perceived effort in collaboration and communication

Intra-organizational barriers also include problems related to collaboration between departments [38]. Change can be a painful process, leading to resistance from some members of a department. Not all parties view the value of change in the same way. Furthermore, the adoption of a new technology may change the existing organizational culture and, therefore, require new functions, duties, expertise, or aptitudes to be developed to supervise and assist various features [39]. Viscusi et al. [40] propose that monopolistic power may also be a barrier for new adopters. Blockchain platform providers and developers hold much power when designing the system [26]. Monopolies occur when one company puts other companies in an unfair situation by controlling the majority of the supply for a product or service in the marketplace. In this context, it is unclear whether a blockchain platform supplier may try to lock in users (vendor lock-in).

Second, with regard to inter-organizational barriers, which can be even more challenging, organizations may consider information to be a competitive advantage. In supply chain networks, the individual firms' thresholds for technology adoption should be considered by other firms' decisions within a network, together with their own organizational attributes. Due to this heterogeneity across firms, such as different network sizes, prior beliefs, and the amount of information observed, each firm makes a decision for adoption at different times [41]. Therefore, they may not be willing to share information, and may instead impose extreme protection [42]. Internal information is highly sensitive and hidden from outsiders. To break this resistance, companies must possess enough necessary information [43]. In addition, because each organization possesses a unique culture and cultural differences may be points of conflict in supply chain relationships [44]. The four horsemen of the blockchain in supply chains—registrars, standards organizations, certifiers, and actors—must be in place in order to adopt the system. If one of these fails to perform, the whole system may suffer the consequences; network effect theory can be applied directly in this context. As such, performance issues can be a barrier to adoption for some participants as well [45].

The last category is related to concerns about external parties who are not actively involved in the chain, but who influence supply chain activities, such as governments, institutions, and industries [21] (Table 3). The paucity of governmental and industrial policies moderates the speed of adoption and discourages stakeholders from engaging with blockchain [46]. Blockchain is not only narrowly implemented in supply chains, but also in other areas. Firms of all sizes are still questioning its applications, frequently adopting a wait-and-see approach, rather than being the first movers. To accelerate the involvement of external stakeholders, catalysts such as political and economic governmental aid and support are required [21,31]. Prioritizing firms with blockchain projects and providing legal support, financial subvention, workshops, training programs, and the like should lower businesses' resistance to blockchain adoption. Finally, a good infrastructure is needed, and should be the highest priority in new technological transformations. The current technology infrastructure is not yet efficient. Here, uninterrupted, high-speed Internet and electricity are critical elements that support usability [31].

Table 3. Environmental barriers.

Environmental Barriers
1. Perceived constraint on encouragement program
2. Perceived constraint on government support
3. Perceived constraint on proper regulations and legal framework within blockchain
4. Perceived constraint on efficient technological infrastructure
5. Perceived constraint on governance
6. Lack of successful examples

From the aforementioned list, 13 factors were identified for examination. These were the most frequently mentioned factors, both in the literature and on blockchain media sites, related to implementation issues. The remaining barriers were not selected for further examination, not because they are not critical, but because they were not encountered in the majority of our panel discussions. As such, we have attempted to keep our identification of barriers within the TOE framework.

In Table 4:

1. Complexity (black box effect);
2. Absence of standardization of programming languages (Java, C++, Python, etc.);
3. Security and vulnerability concerns;
4. Immaturity;
5. Immutability and flexibility;
6. Interoperability (compatibility);
7. Intensive energy consumption;
8. Need for reengineering the process;
9. Negative perspective due to Bitcoin;
10. Network as a nature of technology;
11. Lack of scalability;
12. Technology attributes: trial and reversibility;
13. Cost of implementation;
14. Technological familiarity of the management team (awareness);
15. Resistance and lack of management commitment and support;
16. Need for close coordination and collaboration;
17. Lack of expertise and technical knowledge;
18. Lack of policies for blockchain;
19. Other technology investments are taking priority;
20. Perceived risk (vendor lock-in);
21. Cultural differences between two firms;
22. Privacy and information disclosure concerns;
23. Collaboration and communication efforts;
24. Lack of encouragement programs;
25. Lack of government support;
26. Lack of proper regulations and legal frameworks within blockchain;
27. Lack of strong governance and regulations;
28. Lack of successful examples;
29. Poor infrastructure.

Table 4. Technological, organizational, and environmental (TOE) barriers.

Years	Authors	Barriers (TOE)																												
		Technological Barriers													Organizational Barriers										Environmental Barriers					
															Intra-Org						Inter-Org									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2016	[45]			✓						✓	✓						✓													
2019	[24]	✓	✓		✓	✓	✓				✓							✓					✓							
2018	[47]				✓								✓	✓		✓	✓									✓	✓	✓		✓
2011	[48]						✓			✓	✓	✓	✓	✓	✓								✓							
2018	[43]			✓			✓			✓		✓	✓		✓		✓				✓		✓	✓			✓	✓	✓	
2017	[38]	✓		✓	✓		✓	✓				✓	✓					✓	✓		✓		✓			✓	✓	✓	✓	
2020	[30]			✓	✓	✓				✓	✓	✓	✓	✓	✓	✓		✓	✓				✓				✓	✓		
2019	[28]			✓							✓	✓	✓	✓	✓			✓	✓				✓				✓	✓		
2018	[49]			✓	✓					✓		✓	✓													✓	✓	✓		
2017	[50]	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓			✓			✓		✓				✓	✓	✓	✓
2018	[51]			✓			✓			✓	✓	✓	✓			✓	✓		✓		✓		✓	✓		✓	✓	✓		
2017	[29]	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓					✓		✓	✓				✓
2020	[31]			✓	✓							✓	✓																	
2017	[52]						✓			✓		✓	✓		✓			✓		✓			✓				✓	✓	✓	
2018	[53]			✓				✓		✓	✓	✓	✓		✓		✓						✓	✓			✓			
2018	[54]			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓		✓	✓	✓		✓
2020	[26]			✓	✓		✓		✓			✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	
2018	[21]			✓						✓																	✓	✓	✓	
2018	[24]	✓	✓				✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	
2017	[55]	✓		✓	✓		✓			✓	✓	✓	✓		✓			✓	✓		✓		✓			✓	✓	✓	✓	✓
2020	[56]			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓					✓			✓	✓	✓	✓	✓
2018	[4]	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓				✓	✓			✓	✓		
2019	[34]	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓		✓	✓				✓		✓	✓		✓	✓	
2019	[57]						✓								✓			✓	✓								✓	✓		

1. Complexity (black box effect); **2.** Absence of standardization of programming languages (Java, C++, Python, etc.); **3.** Security and vulnerability concerns; **4.** Immaturity; **5.** Immutability and flexibility; **6.** Interoperability (compatibility); **7.** Intensive energy consumption; **8.** Need for reengineering the process; **9.** Negative perspective due to Bitcoin; **10.** Network as a nature of technology; **11.** Lack of scalability; **12.** Technology attributes: trial and reversibility; **13.** Cost of implementation; **14.** Technological familiarity of the management team (awareness); **15.** Resistance and lack of management commitment and support; **16.** Need for close coordination and collaboration; **17.** Lack of expertise and technical knowledge; **18.** Lack of policies for blockchain; **19.** Other technology investments are taking priority; **20.** Perceived risk (vendor lock-in); **21.** Cultural differences between two firms; **22.** Privacy and information disclosure concerns; **23.** Collaboration and communication efforts; **24.** Lack of encouragement programs; **25.** Lack of government support; **26.** Lack of proper regulations and legal frameworks within blockchain; **27.** Lack of strong governance and regulations; **28.** Lack of successful examples; **29.** Poor infrastructure.

3. Proposed Hypotheses

3.1. Technological Context

This study defines complexity as the level of difficulty required to understand a technology from a business perspective. The more complex a technology is, the less likely it is to be quickly implemented. When a technology is difficult to apply, its adoption is frequently either abandoned or postponed. Hence, we propose that blockchain complexity has a positive effect on organizations' resistance to blockchain. Here, technological maturity is defined as the extent to which blockchain technology has been used since its first appearance. It is typically easier for an organization to apply a technology if the latter has matured and is used widely in industries, owing to the richness of its resources and clear understanding. In other words, immaturity clouds the evaluation mechanism. From an innovation perspective, we define compatibility as the degree to which a technology corresponds with an organization's legacy system, practices, information technology infrastructure, and other networks with which it is expected to work. It is easier for an organization to apply a technology if it has a high compatibility level. Blockchain technology is unique compared to other technologies. Security features are compensated for by the speed of the transactions. Here, scalability refers to the speed of transactions and the block size. The technology has been criticized since it was first introduced for its scalability issues, with many researchers noting that, if it were not for these limitations, blockchain could now have a different position. In general, systems are better if they spend less time processing a transaction and have a bigger block size.

Although blockchain is now one of the most secure platforms, organizations are reluctant to invest in a technology that may become obsolete. First, because blockchain is a distributed ledger, it does not have a database, so no records/data can be removed. In addition, there is no guarantee that those who use the platform will not be exploited once other technologies (e.g., quantum computers) are developed. As always, cost is one of the biggest barriers to the integration or development of a new technology [58]. The implementation cost is large, because it includes facilities, software, operational downtime, and maintenance. Hence, we propose the following hypotheses for the technology context:

Hypothesis 1 (H1). *Higher technological complexity increases organizations' resistance to blockchain.*

Hypothesis 2 (H2). *Lower technological maturity increases organizations' resistance to blockchain.*

Hypothesis 3 (H3). *Lower technological compatibility increases organizations' resistance to blockchain.*

Hypothesis 4 (H4). *Lower technological scalability increases organizations' resistance to blockchain.*

Hypothesis 5 (H5). *Higher technological security and privacy concerns increase organizations' resistance to blockchain.*

Hypothesis 6 (H6). *Higher implementation costs increase organizations' resistance to blockchain.*

3.2. Organizational Context

When a new form of technology is introduced into an industry, managers are key decision makers with regard to adoption. However, the managers' level of familiarity with the technology is correlated with their response. Decision makers tend to exercise caution when encountering uncertainty. Blockchain is not only new, it is also known as a sophisticated network technology. Since its initiation, few organizations have possessed sufficient expertise or technical knowledge to use the technology. One must have professional information technology knowledge to be able to grasp the potential, costs and benefits of this novel technology. Blockchain platform providers and developers hold much power when designing systems [26], which puts client firms in an unfair position. In this context, blockchain platform suppliers may try to lock in their users. For instance, adoption requires a heavy investment in infrastructure, which makes it difficult to switch to another platform supplier in the future. Because blockchain is a network technology similar to RFID, implementing it alone is not practical. Active participation is required from all related parties. Although communication is important, it is also challenging, because organizations need to be cautious about sharing internal information. In this sense, each party tries to make sure that access is provided only to information or data significant for the application, while maintaining good relationships. We propose the following hypotheses:

Hypothesis 7 (H7). *Lower technological knowledge and awareness of the management team increases organizations' resistance to blockchain.*

Hypothesis 8 (H8). *Lower expertise and technical knowledge increase organizations' resistance to blockchain.*

Hypothesis 9 (H9). *A higher perceived risk of vendor lock-in increases organizations' resistance to blockchain.*

Hypothesis 10 (H10). *A higher perceived effort required for collaboration between firms increases organizations' resistance to blockchain.*

3.3. Environmental Context

Support from the government is important in promoting the adoption of new technologies. The perception of a lack of backing by the government in the form of finance or supportive policies discourages firms from considering adopting the technology. Concepts and methods such as cryptographic signatures and smart contracts have been introduced, despite the lack of regulations. Firms and organizations are uncertain about the regulation of blockchain; for example, it is still unclear who will act as an arbitrator in conflict scenarios. Efficient technological infrastructure is necessary for organizations to be able to fully realize the benefits of such technology. For example, uninterrupted and high-speed Internet and electricity are critical elements. Therefore, we hypothesize as follows:

Hypothesis 11 (H11). *A higher perceived constraint on government support increases organizations' resistance to blockchain.*

Hypothesis 12 (H12). *A higher perceived constraint on existing regulations and legal frameworks increases organizations' resistance to blockchain.*

Hypothesis 13 (H13). *A higher perceived constraint of an efficient technological infrastructure increases organizations' resistance to blockchain.*

Figure 1 illustrates the research structure and hypotheses.

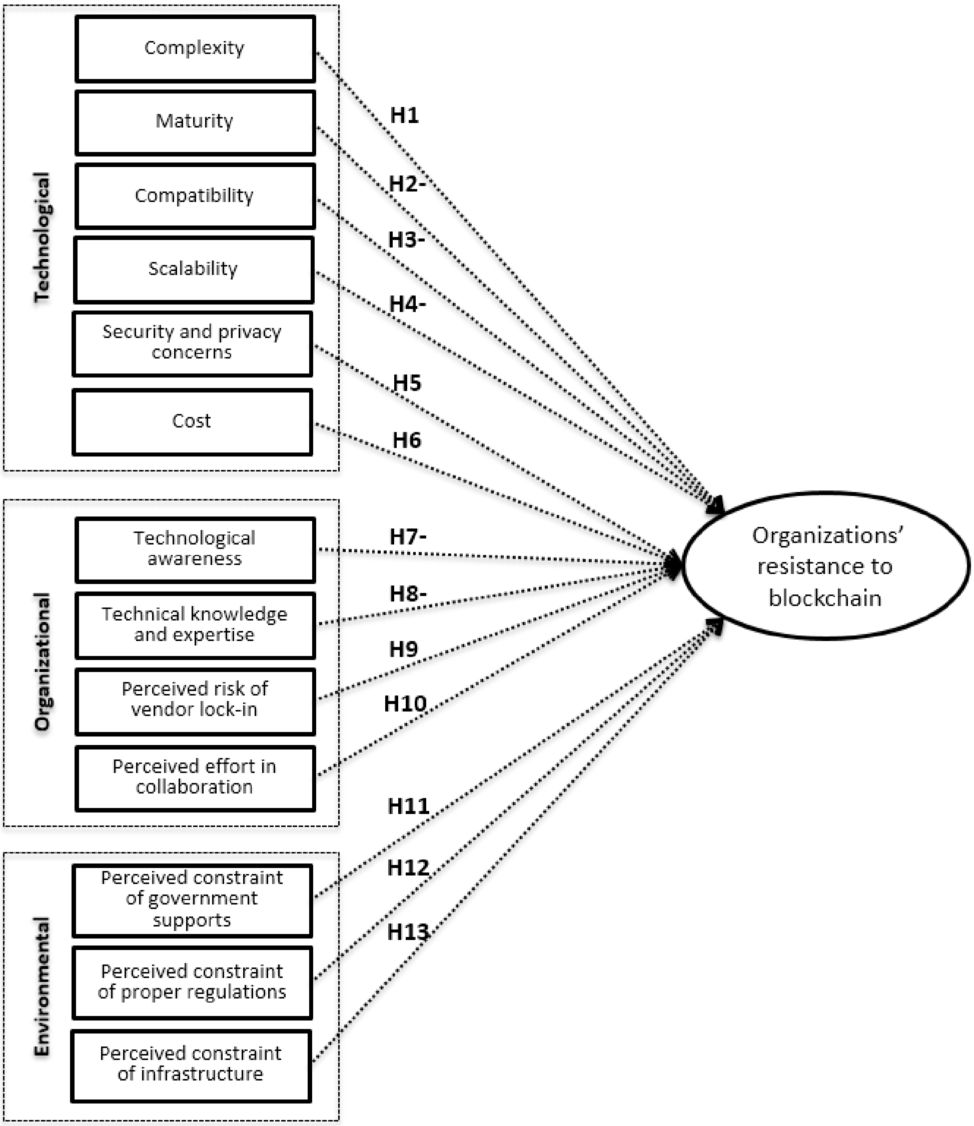

Figure 1. Research structure.

4. Methodology

4.1. Research Approach

This study attempts to identify and gauge the barriers and key factors that slow down digital innovation in the supply chain at the organization level. Because blockchain is a novel, rapidly emerging, and distinguished space [59], to gain insights into the barriers and challenges of the technology, we conducted a traditional literature review in a variety of fields, including business and organizational management, information science, manufacturing, and operations. Although these fields do not specifically apply to blockchain, they illustrate several interesting impedances that can be useful for further research. They uncover different points of view that share regular characteristics, and can be used as factors in this investigation. We employed an online questionnaire survey strategy, because Black and Champion [60] suggest that sample sizes between 30 and 500 are suitable for most research [61]. Therefore, a questionnaire survey was considered appropriate for use in this study. We use primary data obtained from the questionnaire.

4.2. Data Collection

There are two sources of data collection: primary and secondary. The former refers to information gathered firsthand by the researcher, and the latter refers to information obtained from pre-existing sources [62]. Often, it is not possible to achieve research objectives using one source alone [63].

First, we captured factors for each dimension of the diffusion barriers from six integrated databases covering heterogeneous disciplines: Emerald, ResearchGate, Springer, Academia, Taylor & Francis, and ScienceDirect. We also obtained data from various useful sources such as Business Insider, Coindesk, Cointelegraph, Forbes, and Reuters. Keywords were used to identify factors in various combinations. In addition, "block chain", "distributed ledger", and "shared ledgers" were used as synonyms for "blockchain", and "challenges", "hurdles", and "obstacles" were used as synonyms for "barriers".

Related articles extracted from these sources were examined thoroughly to identify hurdles in applications. Titles, keywords, and abstracts were investigated to pinpoint their relativeness and appropriateness for inclusion. The main texts of the articles were consulted to avoid misinterpretation. Articles that mention challenges for—or barriers to—adoption were gathered for further comprehension. The publications of leading consulting companies and IT service providers, such as Gartner, McKinsey, and IBM, were also examined, because they are often at the forefront of the discussion around emerging technologies. We included data outside of academic studies because academia tends to lag behind in both application and practice. Relying on journal publications alone would yield a somewhat narrow view of the literature. The inclusion of various sources is essential to identifying challenges. The final list contained 29 possible barriers, which we categorized into three groups. Each category has a specific variable, as presented in Figure 1. Thus, to meet the original purpose of this study, namely to improve our understanding of the factors inhibiting the integration of blockchain into the supply chain, we employed a quantitative research approach.

However, owing to limited time and resources, surveying all 29 barriers at once is not practical. Therefore, we first treated the inhibitors based on their frequencies. Note that the perceived risk of vendor lock-in and the lack of regulations and legal frameworks within blockchain are not often mentioned in the literature. However, we recognize the need to include these two factors in our study because blockchain is quite novel and is not an off-the-shelf technology. After shortlisting the constructs and developing items for the survey, we conducted a pre-test on selected graduate students, professors, and some close connections who are knowledgeable about supply chain networks, blockchain, and information systems.

The pre-test questionnaire is divided into five sections. The first section is an introduction and consent form. The second section gathers respondents' demographic details (gender, firm size, industry, etc.). The third, fourth, and fifth sections collect data on respondents' opinions on barriers to blockchain adoption related to technology, organizations, and the environment.

As discussed above, we decreased the number of least critical hurdles before creating a final version of the questionnaire. Again, primary data were used at this stage. A confidential online questionnaire survey was conducted to target organizations in the supply chain industry that could potentially employ blockchain in their operations. In the final form of the questionnaire, all items adapted from relevant previous studies were rephrased to relate specifically to blockchain and the current study context.

To facilitate our data analysis process, each item on the questionnaire is measured on a five-point Likert scale, from "strongly disagree" to "neutral" to "strongly agree". The measurement items are listed in Appendix A. The questionnaire was delivered by e-mail, with a link to the survey. From the shortlisted barriers in the previous section, 13 constructs were included in the questionnaire (originally 62 measurement items). All practices with experience in technology/digital innovation were selected. Thus, the data needed in this study were provided efficiently by supply chain networks or organizations that have not yet adopted blockchain in their operations, and/or have attempted to adopt the technology. The data were collected between May and June 2020. Initially, only an online survey was planned and distributed. Participants were mainly recruited via social networks (e.g., posts were made in logistics-, supply chain-, and blockchain-interested groups on LinkedIn, Xing, Hi5, Facebook, and WhatsApp).

The presence of subject-related groups, such as "Blockchain in Supply Chains", in these social platforms was useful. However, the use of blockchain in supply chains is still immature and novel, which limited the size of the sample population. Furthermore, in anonymous online surveys, careless responses must be handled cautiously [64]. As a result, we excluded nine of the 92 data sets from our analysis because they possessed clear patterns or nonsensical answers. The total respondents have had experience with blockchain for between 6 and 20 years, are both male and female, and hold a Bachelor's degree (8%) or a Graduate degree (92%). The main contributions to our data came from the field of transportation and warehousing (48%) followed by manufacturing and wholesale (25%), finance and insurance (16%), and other industries (11%).

4.3. Statistical Methods

Structural equation modeling (SEM) is a statistical method that allows separate relationships to be defined for each dependent variable set, and provides an efficient estimation procedure for separate multiple regression equations that are assessed concurrently. Because this study assesses many factors using different variables, a multivariate analysis using SEM was considered appropriate. Multivariate analyses are statistical procedures for data analysis that include two or more types of measurements at the same time [65]. SEM is interpreted into two components: a measurement model and a structural model. The measurement model makes it possible for researchers to use multiple indicators to measure independent or dependent variables [65,66]. The structural model is a known path model that associates dependent variables with independent variables; in our case, we have 13 factors as independent variables, and resistance to blockchain as the dependent variable.

4.3.1. Structural Equation Modeling

We used Anderson and Gerbing's two-component approach [66]. First, the measurement model was used to assess the reliability and validity and the structural model, was then inspected to examine the overall model fit. After collecting the data, we used a statistical analysis application. Prior to that, a full-version questionnaire was developed to acquire data for analysis, and to identify whether any unimportant or irrelevant items (poor loadings) needed to be excluded. A total of 92 responses were collected and examined.

In the measurement model, correlations between each construct (variable) and its items (indicators) were measured [65]. We conducted the measurement model assessment following the guidelines provided by Hair et al. [67]. We first examined the reflective indicator loadings of the construct, internal consistency reliability, convergent validity, and discriminant validity. Reflective indicator loadings depict how the items measure their constructs in ratios [65].

We conducted an internal consistency reliability analysis based on composite reliability [68], and used Cronbach's alpha method to examine the reliability of the empirical data. Cronbach's alpha indicates how well a survey measures what it aims to measure. The answers for items in the same construct should be consistent with each other. In general, the correlations between the latent variables and the construct scores are the upper bound and Cronbach's alpha is the lower bound for internal consistency reliability [65]. For the sake of certainty, they should both be considered when assessing composite reliability. Convergent validity indicates the degree to which the variable clarifies the variance of its items. It is a calculation of the average variance extracted (AVE) value for every item on each construct [69]. Thus, the higher the value, the better.

Discriminant validity is the degree to which a construct is statistically different from others in the structural model. Fornell and Larcker propose a metric, advocating that each construct's AVE value should be measured for the squared inter-construct correlation (as a measure of shared variance) of that same construct and all other reflectively measured constructs [70]. The share of variance should not be larger than their AVEs [68].

Another approach is to use a cross-loading assessment. The cross-loading value, also known as item-level discriminant validity, is a traditional assessment of discriminant validity. Stone [71] demonstrates that discriminant validity can be identified when each item of measurement is not highly correlated with others, excluding the one to which it is theoretically connected. According to Mulaik [72], the cross-loadings approach can be applied to an EFA, in which researchers consistently assess indicator loading patterns to pinpoint indicators with high loadings on the same factor, and those with high loadings on multiple factors.

Barclay et al. [73] and Chin [74], in studies using the partial least squares (PLS) method, propose that each indicator loading must have a higher value than its cross-loadings; otherwise, those items will not be properly placed in the construct they initially attempt to measure.

The structural model coefficient for the relationship between constructs is acquired from the estimation of a series of regression equations. Thus, in the guideline provided by Hair et al. [67], the variance of inflation factor (VIF) value must be calculated before assessing the structural relationship. Collinearity testing based on the VIF value should be performed to ensure that the model does not bias the regression results. A VIF value above five indicates a probable collinearity issue among the predictor constructs. However, collinearity issues can also be found when the value is between three and five [75,76]. Thus, researchers are advised to accept VIF values close to three or less [67].

After testing for collinearity, we evaluate the coefficient of determination or predictive power (R^2) value of the internal constructs. The coefficient of determination or predictive power (R^2) helps us measure the model's explanatory power [77]; in other words, it estimates the accuracy of the model [78]. The value ranges between zero and one, and 0.75, 0.50 and 0.25 can be counted as significant, tolerable, and weak, respectively [67,79]. The final step is to run the blindfolding algorithm to check the Q^2 value, which is another means of assessing the predictive accuracy of the PLS path model [80]. In general, the value of Q^2 should always be positive. As a rule of thumb, values of 0.5, 0.25, and 0 represent the large, medium, and small predictive relevance of the PLS path model, respectively [67].

4.3.2. Hypothesis Testing

Following the SEM, the results are estimated with the help of SmartPLS software to test the hypotheses. Examining the values and the signs of the coefficients, we consider the t-values (t-statistics) and *p*-values, following the rule of thumb a t-value > 2 and a *p*-value less than 0.05 are significant and the cutoff criteria to accept or reject the hypotheses.

Most researchers and reviewers are more likely to have been exposed to the covariance-based structural equation model (CB-SEM) than they are to the PLS-SEM [81]. Those who employ the PLS approach are expected to provide supportive commentary as to the rationale for their decision [81]. However, the two are rather more interdependent than competitive. The PLS is often called for when the CB-SEM approach fails to perform assigned tasks in specific empirical contexts and objectives. Thus, we apply the PLS in this study because it allows us to test a small sample size, and the structural model is complex and includes many constructs. Running a PLS offers high accuracy in less time and provides sufficient results that fulfill the purpose of this study. Nevertheless, we understand its drawbacks and treat its advantages with caution.

A PLS is used to predict the linear conditional expectation relationship between dependent and independent variables [82]. It is used in a manner similar to a multiple regression analysis to find the relationship formulated in a model. Currently, the most prevalent implementation as a part model is SmartPLS. Unlike AMOS or LISREL, SmartPLS is not as sensitive to the sample size, and is able to produce good results. To find the strength and direction between constructs, the factor correlation is tested. The latent variable correlations obtained from SmartPLS pinpoint the type, direction, and intensity of the relationships between our variables.

4.4. Reliability and Validity

The factor of trust in research cannot be overstressed. Readers can be convinced if there is academic evidence that the study was conducted based on the right guidelines with strong support. Throughout this study, we were attentive to three arenas of trustworthiness: the reliability and validity of the data, the source of the empirical data, and the application used to acquire the results. Because this is a quantitative study, it is not difficult to replicate. The empirical data were saved in Excel (.csv) format, so retesting the results is simple.

To test the reliability and validity of our data, we followed steps taken by senior researchers. Many senior researchers have studied our hypothesized factors and adoption intention, and instruments have been developed and applied to measure these factors. To provide additional validity and reliability to this study, we modified the instruments (questions) to measure the barriers and our dependent variable. Although instruments developed by various researchers to measure the hypothesized factors and adoption intention have established good validity and reliability, it was important for us to test the validity and reliability of the factors and the variable constructs used to measure these factors [61]. Reliability testing checks the trustworthiness and unbiasedness of the empirical data in the guidelines of consistency techniques. In theory, reliability is the extent to which a variable/construct or a set of variables/constructs are consistent with what they are originally intended to measure [62]. In a similar vein, validity tests focus on how something has been measured [62]. Put simply, validity is concerned with how accurately a test measures what it is supposed to measure.

In this study, reliability and validity tests were conducted using a measurement model that makes evaluations in accordance with the guidelines of Hair et al. [67] against reflective indicator loadings to test each item's reliability, Jöreskog's composite reliability and Cronbach's alpha to test internal consistency reliability, AVE to test convergent validity, and Fornell and Larcker's criteria [64] to test discriminant validity. Saunders et al. [63] suggested that pre-tests are important to establish face and content validity. With regard to face validity, we asked senior graduate students to verify the wording and clarity of the language used to determine whether they measure what they intend to measure. For the content validity, we obtained items from the literature on the constructs, and checked the degree of relevancy and representativeness based on the definitions and terminology to determine whether the items measure the content they were intended to measure [83].

The developed questionnaire aimed to measure different factors and organizations' resistance, where some of the factors are somehow opposed to each other. For instance, maturity is the opposite of complexity, compatibility, and scalability. Hence, we rearranged the questions in a logical order to measure all constructs in an efficient manner. This allowed us to measure constructs together that are more or less the same. Organizations' resistance to blockchain and the constraints on technological knowledge and the awareness of top managers, which we assumed to be sensitive, were measured in a manner that allowed respondents to provide their opinion on where resistance can be measured indirectly. To measure organizations' resistance to blockchain indirectly, we follow the studies of Mirella et al. [84], Szmigin and Foxall [85], and Kamran and Kim [86] on the concept of resistance. For technological knowledge and the awareness of top managers, we follow Leimeister et al. [87] and Koh et al. [88] on issues and critical success factors in new technology implementation.

The sources of empirical data depend on the population and sampling methods. As discussed above, convenience sampling is considered the most appropriate sampling method. Although it is used widely, one of its major disadvantages is the presence of sampling errors. In this study, efforts were made to minimize sampling errors by attempting to obtain many responses from a variety of demographics who are non-adopters. Another purpose of conducting a web-based questionnaire was to address the problem of observer bias. The questionnaire (web-link) was e-mailed to potential respondents, so we do not know the context within which they completed the questionnaire (i.e., alone, or with colleagues who may have biased their answers). All respondents were at least employees in relevant fields. Hence, we believe they all understood how to respond to a questionnaire (provide answers) in an unbiased manner.

Owing to the nature of this study and the need for a multivariate analysis, an SEM was implemented. In the SEM, two approaches, AMOS and PLS, were used to derive results from the empirical data. The PLS approach was then chosen over AMOS, because it was the most suitable for this study.

5. Empirical Findings

5.1. Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) is a statistical technique used to verify the factor structure of a set of observed variables. CFA allows the researcher to test a hypothesis on the existence of a relationship between observed variables and their underlying latent constructs. The researcher uses knowledge of the theory, empirical research, or both, postulates the relationship pattern a priori, and then tests the hypothesis statistically.

Factors deemed less significant were removed from the final form of the questionnaire. A list of measurement items was developed and deployed. The results sheet was downloaded from Google Sheets and then run using SmartPLS after cleaning errors and labeling items.

Four main steps were used to access the measurement model. First, we checked the item's reliability (reflective indicator loadings), followed by its internal consistency reliability (Joreskog's composite reliability and Cronbach's alpha). Next, we calculated the convergent validity (AVE), and then the discriminant validity (Fornell and Larcker's criteria) [67]. Table 5 is the final version of the items that were retained (with loading values higher than 0.7).

Table 5. Outer loadings analysis.

Variables	Items	Measurement Items	Outer Loading	References
Maturity		In terms of maturity, we think that		
	IMM1	there have been many concrete examples of operation in real environments.	0.892	[89]
	IMM2	the potential and utility have been proven.	0.829	
Compatibility		In terms of compatibility, we believe that blockchain platforms are		
	INC1	compatible with our operations.	0.818	[90]
	INC2	not compatible with our business process.	0.853	
Scalability		In terms of scalability, we believe that		
	SCA1	the speed of block generation is decent.	0.715	[4,31]
	SCA2	block size is decent for practical use.	0.783	
	SCA3	overall speed and block size are excellent.	0.779	
Complexity		In terms of complexity, we think that		
	COM1	blockchain is conceptually difficult to understand from a business perspective.	0.784	[91]
	COM2	blockchain is conceptually difficult to understand from a technical perspective.	0.737	
	COM3	using blockchain technology is difficult.	0.795	
Security and privacy concerns		Regarding security concerns, our organization		
	SEC1	does not feel secure in providing sensitive information related to the company (e.g., transaction data) when working with a blockchain platform.	0.784	[92]
	SEC2	does not feel secure sending sensitive information about the company to the platform.	0.743	
	SEC3	does not feel that blockchain is a safe platform for operating business with sensitive information overall.	0.837	

Table 5. *Cont.*

Variables	Items	Measurement items	Outer Loading	References
Cost		In terms of cost of implementation, we believe that blockchain adoption would		
	COS1	increase hardware and software facility costs.	0.795	[93]
	COS2	increase costs for training and recruiting.	0.706	
	COS3	require high up-front investment costs.	0.787	
Technological knowledge and awareness of top managers		Regarding technological knowledge and awareness, top managers in our company		
	AWN1	agree blockchain projects may have important intangible benefits that should be funded.	0.767	[94]
	AWN2	recognize blockchain as a competitive weapon.	0.837	
	AWN3	recognize the strategic potential of blockchain.	0.829	
Expertise and technical knowledge		Regarding expertise and technical knowledge, we think that our organization		
	KNW1	has the relevant technical knowledge about blockchain technology.	0.807	[87,88]
	KNW2	has professional staff trained in blockchain technology use.	0.758	
	KNW3	is familiar with this type of technology and its applications.	0.796	
Perceived risk of vendor lock-in		In terms of the perceived risk of vendor lock-in, we are concerned that our platform suppliers would		
	VEN1	make us significantly invest in their specialized tools and equipment that are dedicated to only their platform.	0.850	[31]
	VEN2	try to lock us in (vendor lock-in).	0.703	[95]
Perceived effort in collaboration and communication between firms		In terms of collaboration efforts, we believe that collaboration with other organizations to allow for blockchain adoption		
	COL1	is challenging.	0.845	[42,96]
	COL2	requires a lot of mental effort.	0.878	
Perceived constraint on government support		Regarding constraints on government support, we think that		
	GOV1	the government actively supports blockchain technology.	0.752	[89]
	GOV2	the government has introduced relevant policies to boost blockchain technology adoption.	0.808	
	GOV3	there is support (e.g., training) from the government regarding blockchain technology.	0.776	
Perceived constraint on existing regulations and legal framework within blockchain		Regarding constraints on proper regulations and legal frameworks within blockchain, we think that		
	REG1	the regulatory body is not yet well-established to deal with blockchain issues.	0.719	[21,23,97]
	REG2	there is no authority to solve disputes.	0.787	
	REG3	legal structures do not satisfactorily protect users from problems happen on blockchain platform.	0.799	

Table 5. *Cont.*

Variables	Items	Measurement items	Outer Loading	References
Perceived constraint on technological infrastructure		In terms of the constraint of technological infrastructure, we think that		
	INF1	the current technological structure is not adequate for blockchain.	0.801	[31,98,99]
	INF2	the current Internet service is not efficient enough for blockchain.	0.795	
	INF3	there is not sufficient access to blockchain technology.	0.802	
Resistance to blockchain		Regarding our stance on blockchain technology, our organization		
	RES1	will NOT adopt blockchain unless it proves beneficial for us.	0.795	[84,85]
	RES2	will wait for the right time and required capability to adopt blockchain.	0.753	
	RES3	needs to clarify some queries and justify adopting blockchain.	0.738	
	RES4	does not need blockchain.	0.701	
	RES5	is unlikely to adopt blockchain in the near future.	0.733	
	RES6	believes that blockchain is not for our organization.	0.775	

A consistency analysis was conducted using SmartPLS to determine the reliability of the empirical data. An internal consistency analysis was calculated based on Cronbach's alpha and the composite reliability. The Cronbach's alpha value ranges from zero to one, where a value closer to one indicates greater internal consistency among the variables. With regard to the decision of the alpha value, George and Mallery [100] provide the following rule of thumb: $\alpha > 0.9$: excellent; $\alpha > 0.8$: good; $\alpha > 0.7$: acceptable; $\alpha > 0.6$: questionable; $\alpha > 0.5$: poor; and $\alpha < 0.5$: unacceptable.

Note that the value of alpha depends on the number of questions (items) on the scale. The higher the number of questions, the less consistent it will be. Table 6 presents the consistency of each factor and its associated *p*-value. Most of the factors are found to have good and acceptable consistency. Only three constructs (compatibility, scalability, and perceived risk of vendor lock-in) were found to be questionable. Therefore, we applied the second method, composite reliability, for verification.

Table 6. Cronbach's alpha analysis.

Factors	Cronbach's Alpha (α)	*p*-Value
Complexity	0.724	0.000
Maturity	0.715	0.000
Compatibility	0.630	0.000
Scalability	0.694	0.000
Security and privacy concerns	0.758	0.000
Cost	0.703	0.000
Technological knowledge and awareness of top managers	0.800	0.000
Expertise and technical knowledge	0.754	0.000
Perceived risk of vendor lock-in	0.625	0.000
Perceived effort in collaboration and communication between firms	0.714	0.000
Perceived constraint on government support	0.738	0.000
Perceived constraint on existing regulations and legal framework within blockchain	0.715	0.000
Perceived constraint on technological infrastructure	0.778	0.000
Resistance to blockchain	0.844	0.000

The composite reliability of Jöreskog [69] ranges between zero and one. A higher value simply refers to a greater reliability level. A reliability value of 0.6 to 0.7 indicates "acceptable in explanatory research"; 0.7 to 0.9 indicates "satisfactory to good"; and a value higher than 0.95 indicates "problematic" [101]. From our results h, none of the constructs possess a value of reliability below 0.7. The values range from 0.755 to 0.885, which can be interpreted as satisfactory (Table 7). Thus, we are certain that this research satisfies the threshold of consistency reliability.

Table 7. Composite reliability analysis.

Factors	Composite Reliability	*p*-Value
Complexity	0.816	0
Maturity	0.851	0
Compatibility	0.823	0
Scalability	0.803	0
Security and privacy concerns	0.832	0
Cost	0.807	0
Technological knowledge and awareness of top managers	0.853	0
Expertise and technical knowledge	0.83	0
Perceived risk of vendor lock-in	0.755	0
Perceived effort in collaboration and communication between firms	0.852	0
Perceived constraint on government support	0.822	0
Perceived constraint on existing regulations and legal framework within blockchain	0.813	0
Perceived constraint on technological infrastructure	0.842	0
Resistance to blockchain	0.885	0

Convergent validity is the extent to which a construct converges to explain the variance of its measurement items [67]. To measure convergent validity, researchers normally use a metric known as the AVE (Average Variance Extracted). The value of the AVE that can be considered acceptable when it is 0.5 or greater. In our study, the AVE value for each construct is well above 0.55, which represents good convergent validity (Table 8). For instance, an AVE value of resistance to blockchain of 0.562 indicates that the construct explains at least 56% of the variance of its items. The threshold above 0.5 is thus fully satisfied.

Table 8. Average variance extracted.

Factors	AVE (>0.5)	*p*-Value
Complexity	0.597	0
Maturity	0.741	0
Compatibility	0.699	0
Scalability	0.577	0
Security and privacy concerns	0.623	0
Cost	0.583	0
Technological knowledge and awareness of top managers	0.659	0
Expertise and technical knowledge	0.62	0
Perceived risk of vendor lock-in	0.609	0
Perceived effort in collaboration and communication between firms	0.743	0
Perceived constraint on government support	0.607	0
Perceived constraint on existing regulations and legal framework within blockchain	0.592	0
Perceived constraint on technological infrastructure	0.639	0
Resistance to blockchain	0.562	0

The final step of the measurement model involves assessing its discriminant validity. Discriminant validity is the extent to which a construct is different from others in the structural model. To assess discriminant validity, Fornell and Larcker [70] propose a metric, advising that each construct's AVE should be higher than any other square inter-construct correlation of the same constructs (Table 9).

Table 9. Discriminant validity.

	COMPX	MATR	COMPA	SCAL	SECU	COST	AWNS	EXPT	RISK	COLL	SUPP	REGU	INFR	RESS
COMPX	0.77													
MATR	0.62	0.86												
COMPA	0.76	0.63	0.84											
SCAL	−0.59	−0.51	−0.68	0.76										
SECU	0.74	0.59	0.61	−0.57	0.79									
COST	0.65	0.55	0.74	−0.51	0.73	0.76								
AWNS	−0.67	−0.53	−0.72	0.61	−0.71	−0.68	0.81							
EXPT	−0.67	−0.47	−0.73	0.53	−0.72	−0.7	0.78	0.79						
RISK	0.55	0.45	0.56	−0.61	0.56	0.52	−0.67	−0.64	0.78					
COLL	0.61	0.53	0.65	−0.54	0.66	0.67	−0.74	−0.66	0.59	0.86				
SUPP	0.68	0.67	0.72	−0.59	0.69	0.71	−0.73	−0.66	0.58	0.7	0.78			
REGU	0.68	0.64	0.76	−0.58	0.77	0.75	−0.7	−0.69	0.54	0.59	0.69	0.77		
INFR	0.74	0.57	0.71	−0.47	0.72	0.67	−0.66	−0.69	0.62	0.75	0.67	0.75	0.8	
RESS	0.68	0.55	0.72	−0.66	0.69	0.69	−0.72	−0.71	0.63	0.71	0.72	0.72	0.71	0.75

Several steps must be taken in the structural model to verify the overall model fit. First, before assessing the structural relationship, we calculate the VIF values. Here in Table 10, a value above 10 is often regarded as representing collinearity, and values lower than five are considered tolerable [67]. The values in our study are all below five, and thus are acceptable. Because collinearity is not an issue, we examine the R^2 and Q^2 values from the PLS algorithms and blindfolding. From our calculations, the R^2 value is 0.792 and the Q^2 value is 0.458, indicating a good model fit overall.

Table 10. Variance of inflation factor (VIF) values.

Factors	VIF
COMPX	2.887
MATR	1.268
COMPA	4.486
SCAL	1.58
SECU	3.484
COST	3.692
AWNS	3.278
EXPT	3.768
RISK	1.555
COLL	2.543
SUPP	2.393
REGU	3.628
INFR	4.167

5.2. Descriptive Findings

Table 11 summarizes the results of the questionnaires from our data collection process, showing that most of our respondents still perceive blockchain as a new, immature technology that requires further development. It can thus be understood that investors do not yet trust the technology. The complexity and shortcomings related to compatibility complement this finding. Because this technology involves many complicated algorithms, it is difficult to understand it sufficiently in order to see its potential for applications. One of the main reasons for this resistance is the uncertainty in the cost of implementation. This agrees with the findings of many previous studies that depict cost barriers as one of the main determinants [102].

Table 11. Descriptive statistics.

Descriptive Statistics			
Factors	**N**	**Mean**	**Standard Deviation**
COMPX	82	3.305	0.913
MATR	82	3.367	0.911
COMPA	82	3.283	0.834
SCAL	82	3.193	0.924
SECU	82	2.598	0.792
COST	82	3.249	0.889
AWNS	82	3.578	0.962
EXPT	82	2.271	0.875
RISK	82	3.124	0.867
COLL	82	3.249	0.889
SUPP	82	2.586	0.911
REGU	82	3.237	0.917
INFR	82	3.161	0.948
RESS	82	2.9	0.792

6. Analysis

After obtaining empirical data from the questionnaire, we cleaned the data by searching for careless responses and removed them from the data set. The statistical program SmartPLS version 3 was used to run the PLS.

6.1. Partial Least Squares

Figure 2 shows the output from SmartPLS's configurations. In this figure, the number inside the dependent variable (resistance) is the value of R^2. The values with arrows pointing from independent variables to the dependent variable are the indicators of the regression coefficients. A regression coefficient is the rate of increase (or decrease) in the value of the dependent variable if the independent variable increases (or decreases). In other words, it functions like the slope of the line of the regression equation. The numbers lying between each construct (round) and its items (rectangular) are the values of the outer loading. This helps determine which items have a weak loading under the cutoff criteria (0.7). Only items with outer loading values above the cutoff point were retained. Appendix B provides more details on regression coefficients between each construct and all items.

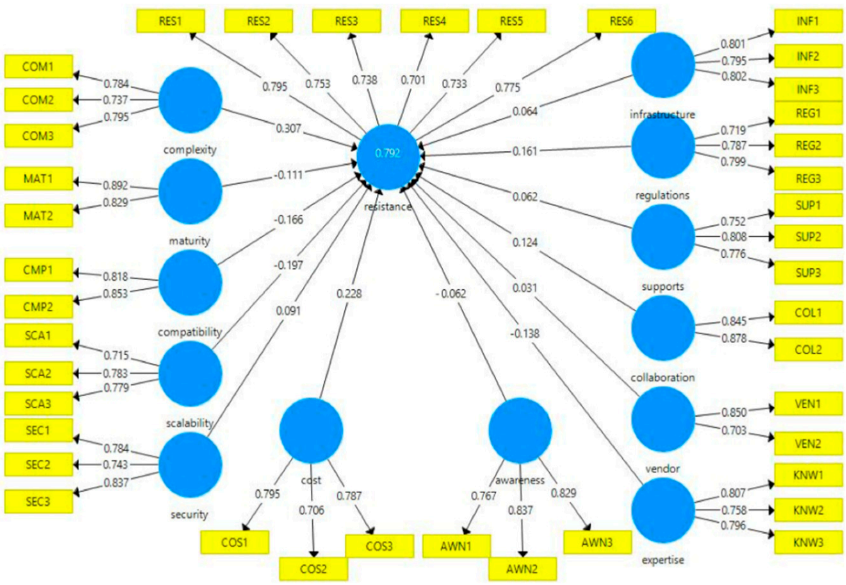

Figure 2. Path coefficient and coefficient of determination or predictive power (R^2).

In SmartPLS, the beta (β) values are represented as regression coefficients, and the *p*-values and t-statistics are used to determine whether they are significant. We follow the criteria of significance at a *p*-value = 0.05 and a t-statistic higher than 1.96. The results obtained from running the PLS algorithm are shown in Table 12.

Table 12. Path coefficient results from partial least squares (PLS) software SmartPLS.

Factors	Hypothesis	Beta, β	T-Statistics	*p*-Values	Significance
Technological complexity	H1	0.307	8.768	0	Significant
Technological maturity	H2	−0.111	3.735	0	Significant
Technological compatibility	H3	−0.166	4.099	0	Significant
Technological scalability	H4	−0.197	6.237	0	Significant
Security and privacy concerns	H5	0.091	2.179	0.029	Significant
Cost of implementation	H6	0.228	7.198	0	Significant
Technological knowledge and awareness of management team	H7	−0.062	1.582	0.114	Non-significant
Expertise and technical knowledge	H8	−0.138	3.398	0.001	Significant
Perceived risk of vendor lock-in	H9	0.031	1.16	0.246	Non-significant
Perceived effort in collaboration	H10	0.124	4.018	0	Significant
Perceived constraint on government support	H11	0.062	1.829	0.068	Non-Significant
Perceived constraint on existing regulations	H12	0.161	3.933	0	Significant
Perceived constraint on technological infrastructure	H13	0.064	1.722	0.085	Non-significant

The above results show that, among the 13 hypotheses, four failed to obtain support. These were H7 (technological knowledge and awareness of management team), H9 (perceived risk of vendor lock-in), H11 (perceived constraint on government's support), and H13 (perceived constraint on technological infrastructure).

The support for H1 (higher technological complexity increases organizations' resistance to blockchain) shows that complexity positively affects organizations' resistance to blockchain. This is in line with the findings of previous research [102–105]. Thus, respondents who felt that blockchain was complex and difficult to understand showed more resistance. This can be explained through behavioral logic. Managers are expected to exercise extra precautions in the face of a lack of familiarity, as in the case of the complex mechanism of blockchain.

The support for H2 (lower technological maturity increases organizations' resistance to blockchain), H3 (lower technological compatibility increases organizations' resistance to blockchain), and H4 (lower technological scalability increases organizations' resistance to blockchain) is expected. The past literature has consistently indicated that immaturity, incompatibility, and shortcomings related to the size and speed of transactions are the main problems that prevent blockchain technology from obtaining large-scale implementation.

A negative relationship between compatibility and resistance was also found in studies by Babich and Hilary [24], Dunphy and Herbig [103], Gordon and Catalini [43], Holak and Lehmann [106], and Ram [102]. When an innovation or technology is introduced, prospective adopters examine its compatibility and potential use cases in their existing legacy systems. Normally, if a new technology is to be adopted, they prefer to merge it with an existing technology instead of entirely replacing the old system, which is costly and time-consuming. From this result, we can assume that high interoperability motivates firms to resist the adoption of blockchain.

This reverse relationship between scalability and resistance is also in agreement with the findings of Ølnes et al. [29] and Öztürk and Yildizbaşi [31]. Furthermore, Kohad et al. [107] also present the limitations of block size and the speed of block generation as main issues. In comparison to other network technologies, such as Visa or PayPal, blockchain is underdeveloped. It understandable that, in this data-driven age in which ultra-speed 5G Internet is imminent, such latency is seen as obsolete. Potential adopters are deterred by such limitations.

Similarly, the support for H5 (higher technological security and privacy concerns increase organizations' resistance to blockchain) represents a positive relationship between security concerns and risk prevention. This statement is in line with the findings of Ram [102], Dunphy and Herbig [103], Yiu et al. [105], Laukkanen et al. [104], and Kamran and Kim [86]. Respondents who feel insecure about sharing data or information tend to behave skeptically toward such platforms; hence, they perceive them as risky and show a high level of resistance.

As expected, H6 (higher cost increases organizations' resistance to blockchain) is supported in our study, as in many previous studies, including those of Tornatzky and Klein [58], Kim and Kankanhalli [108], and Kim [109], in which switching costs play a central role in increasing resistance. The cost of implementation does not stop at hardware and software expenses, but also includes the cost of human resources and skill acquisition. Because blockchain is a new technology, highly skilled and qualified employees are scarce. Thus, organizations must offer significant incentives to acquire and retain competent staff. Kim [109] shows that uncertainty related to implementation costs, including sunk costs, transition costs, and loss costs, directly and indirectly increases resistance. Shi and Yan [93] also found this reverse relationship in their study.

In the organizational context, two of the four hypotheses were supported: H8 (lower expertise and technical knowledge increase organizations' resistance to blockchain), and H10 (a higher perceived effort in collaboration between firms increases organizations' resistance to blockchain). For H8, this negative relationship is also supported by information system management researchers such as Lucas [110], Robey [111], Leimeister et al. [87], Koh et al. [88], and Shi and Yan [93]. Although blockchain technology has existed for some time, the gap between the supply and demand of technical staff and expertise remains wide. This is because of its complexity and immaturity. When organizations have obtained the relevant knowledge and skills pertaining to this new form of technology, they can effectively assess its potential and influence adoption.

In Hypothesis 10, the factor "perceived effort in collaboration and communication between firms" has a parallel relationship with resistance to blockchain. This argument complies with the findings of Fawcett et al. [112]. Collaboration exposes decision makers to vulnerability, making them unwilling to invest [113]. There are many reasons for the existence of this positive relationship. For instance, in every collaboration, there is a possibility that a firm's identity and market share can be jeopardized. Such collaboration may be perceived as tedious, time consuming, and troublesome, which, in turn, discourages firms from cooperating.

With regard to the environmental aspects, only one hypothesis was supported: H12 (a higher the perceived constraint on existing regulations and legal frameworks increases organizations' resistance to blockchain). This is in line with the findings of Öztürk and Yildizbaşi [31], Saberi et al., [21], and Schatsky et al. [25], who point out that for blockchain to be widely adopted, regulatory issues must be sorted out. Schatsky et al. [25] proposed that there is still much to be done on the regulatory side before blockchain adoption is clear. However, this technology introduces concepts and methods, such as cryptographic signatures and smart contracts, which are not addressed by existing regulations. In other words, potential adopters may be deterred by the government's lack of control over and involvement in the technology.

The data collected for this study failed to support Hypotheses 7, 9, 11, and 13. Surprisingly, we failed to confirm H7 (the relationship between top managements' technological knowledge and awareness and their organization's resistance to blockchain). Further assumptions on this matter would be premature, owing to our relatively small sample size. However, although the significance of this relationship is not sufficiently strong via the factor coefficient, we can still identify a reverse relationship, which is in line with the findings of, for example, Kearns and Sabherwal [94]. Similarly, the factor "perceived risk of vendor lock-in" was found to be positively related to resistance, supporting previous findings [114,115]. The significance of this relationship (according to our empirical data) is the very least. We are unable to make further elaborations from this result, but we can assume that the perceived risk of vendor lock-in is not yet a critical issue.

The relationship between perceived constraints on government support and an organization's resistance in Hypothesis 11 is the least significant of the others and is found to be positive, in agreement with Li [89] and Shi and Yan [93]. Governmental support may be a factor that motivates and accelerates adoption, but its absence may not stop organizations from accepting the technology.

Lastly, the relationship between perceived constraints on efficient technological infrastructure and organizational resistance failed to reach a significant level, and is the second least significant following the above construct. The positive relationship between the two is also demonstrated by Maruping et al. [99] and Öztürk and Yildizbaşi [31]. However, this result indicates that we cannot claim that higher perceived constraints on technological infrastructure increase an organization's resistance. We cannot be completely certain, because the sample size limitation might mean that a different demographic mixture could yield different results. Thus, we can respond to the first research question as follows:

1. The causal relationships between technological factors and resistance to blockchain: Table 13 shows that, for technological aspects, there are positive causal relationships between technological complexity, security and privacy concerns, cost of implementation, and organizations' resistance to blockchain. However, there are also negative causal relationships between technological maturity, compatibility, scalability, and organizations' resistance to blockchain. Thus, advancements in technological maturity, compatibility, and scalability will reduce organizations' resistance to blockchain.
2. The causal relationships between organizational factors and resistance to blockchain: With regard to organizational aspects, there are negative causal relationships between the expertise and the technical knowledge possessed by the organization and resistance to blockchain, and positive causal relationships between perceived effort in collaboration and resistance to blockchain. Therefore, increasing the perceived effort of collaborating between firms increases organizational resistance to blockchain.
3. The causal relationships between environmental factors and resistance to blockchain: With regard to the environment, there is a positive causal relationship between perceived constraints on existing regulations and organizations' resistance to blockchain. In other words, reducing the perceived constraints on existing regulations and legal frameworks reduces the resistance to blockchain.

Table 13. Causal relationships between factors and resistance.

TOE	Factors	Causal Relationship with Resistance	Score (β)
Technology	Technological complexity	Positive	0.307
	Technological maturity	Negative	−0.111
	Technological compatibility	Negative	−0.166
	Technological scalability	Negative	−0.197
	Security and privacy concerns	Positive	0.091
	Cost of implementation	Positive	0.228
Organization	Expertise and technical knowledge	Negative	−0.138
	Perceived effort in collaboration	Positive	0.124
Environment	Perceived constraint on existing regulations	Positive	0.161

The goodness-of-fit of a model indicates how well it fits a set of empirical data [79,115]. The hypothesized factors in the model represented almost 79% (coefficient of determination, $R^2 = 0.792$; see Figure 2) of the variation in the resistance to blockchain caused by these factors. In other words, the 79% variation in an organization's resistance to blockchain can be explained by TOE factors, which can be interpreted as a significant goodness-of-fit for the model.

For the second research question (which aims to capture the most significant determinants inside the TOE framework), complexity, cost of implementation, scalability, compatibility, the perceived constraint on existing regulations and legal frameworks, and expertise and technical knowledge were found to be important factors that influence adoption, ordered from the most to the least influential.

6.2. Factor Inter-Relationships

In this section, we examine the relationships between factors to identify correlations between the latent variables. Complexity is found to be negatively correlated with maturity, compatibility, the management team's technological awareness. Expertise is positively correlated with security and privacy concerns, implementation costs, a perceived lack of infrastructure, efficient regulations, collaboration efforts, and the risk of vendor lock-in. Respondents who perceive blockchain as complex also perceive it as being relatively immature, incompatible, and less scalable. In addition, they tend to think that their organization does not have adequate human resources to realize the usage, and are concerned about security matters, implementation costs, vendor lock-in risk, perceived efforts in collaboration, a perceived lack of governmental support of an efficient technological infrastructure, and existing regulations.

Technological maturity was found to be positively correlated with compatibility, scalability, technological awareness of managers, and expertise and technical knowledge, and adversely correlated with security concerns, costs, perceived risk of vendor lock-in, collaboration efforts, and perceived limitations of government support of regulations and an inefficient technological infrastructure.

Similarly, compatibility, scalability, technological knowledge and awareness of top managers, and technical knowledge were found to have the same type of correlation between maturity and the others. This means that maturity and the aforementioned factors move in parallel directions. Thus, the cost of implementation, regulation concerns, perceived constraint support, and the like are bound to decline as blockchain technology matures and becomes increasingly compatible, and expertise develops in the field.

The security and cost factors move in parallel with technological complexity. In short, the two have a negative correlation with maturity, compatibility, the management team's technological awareness, and expertise factors, and are positively correlated with the rest. Respondents who perceive blockchain as complex are more skeptical and concerned about security and cost factors than are those who do not. As a result, they are convinced that current regulations and infrastructure are not yet adequate for adoption (Table 14).

Table 14. Factor correlations.

Factors	COMPX	MATR	COMPA	SCAL	SECU	COST	AWNS	EXPT	RISK	COLL	SUPP	REGU	INFR
COMPX	1												
MATR	−0.755	1											
COMPA	−0.757	0.734	1										
SCAL	−0.588	0.51	0.781	1									
SECU	0.737	−0.688	−0.613	−0.767	1								
COST	0.745	−0.554	−0.740	−0.510	0.729	1							
AWNS	−0.672	0.733	0.716	0.609	−0.705	−0.677	1						
EXPT	−0.668	0.768	0.73	0.533	−0.717	−0.803	0.78	1					
RISK	0.553	−0.454	−0.563	−0.612	0.563	0.522	−0.666	−0.643	1				
COLL	0.609	−0.532	−0.645	−0.538	0.659	0.666	−0.744	−0.661	0.59	1			
SUPP	0.678	−0.667	−0.718	−0.588	0.686	0.71	−0.726	−0.656	0.577	0.7	1		
REGU	0.679	−0.644	−0.766	−0.576	0.766	0.747	−0.701	−0.690	0.539	0.588	0.686	1	
INFR	0.738	−0.570	−0.711	−0.473	0.72	0.766	−0.662	−0.688	0.621	0.646	0.771	0.754	1

7. Managerial Implications

This section presents a discussion and recommendation of implementations that can be leveraged to enhance the effectiveness of existing and future blockchain systems.

To respond to the technological challenges of blockchain, it is important to integrate more innovative methods to ensure data security. Such challenges are best solved from the developer side. One possible solution to the scalability issue is the addition of a second layer to the main blockchain networks to facilitate faster transactions [116] (e.g., a lightning network). Another possible solution is to divide the networks into subsets or smaller groups that only pertain to their own areas. It is possible to integrate these subsets with a legacy system by linking them with the current database. The database remains intact throughout this process, and data integrity is ensured by calculating the metadata of the records and storing it on the blockchain (e.g., the Modex Blockchain Database). The maturity issue can be overcome only after all other relevant challenges (e.g., scalability, security, and lack of human resources) are addressed. Technology with high usability will sell itself. Therefore, we need to comprehend its functions and be well prepared.

At the organizational level, not much can be done about the technological limitations. However, managers can be catalysts for organizational challenges. Increasing staff awareness at all levels through workshops and training can greatly assist the introduction of blockchain. In addition, managers are highly encouraged to obtain new knowledge in novel technologies such as blockchain and oracle platforms. Managers can foster knowledge by coordinating with educational institutes and suggesting prospective requirements. It is also recommended that managers reorganize their organization's data structure to ensure that information sharing does not hurt its competitive advantages. In this sense, selective disclosure of information based on the type of interaction would be appropriate. Petersson and Baur [54] found that companies could integrate blockchain into their operations without completely restructuring their processes. This indicates that implementations can be conducted on top of current systems without having to invest in an entirely new system. If this is the case, attitudes toward adoption will be positive. We are convinced that, for the efficient implementation of blockchain, organizations must satisfy the prerequisites from within the firm—for instance, starting with having employees acquire technical knowledge.

With regard to inter-organizational aspects, we rely on the basic supply chain theory related to long-term agreements and collaboration [117]. Implementing blockchain may hurt the current legacy system, but is advantageous in the long run. Those who are well prepared and embrace this change gain the most reward. This incentive alignment concept suggests that companies must have a common goal and make decisions together to advance their overall performance in the supply chain [118]. For successful collaboration, parties need to share benefits, costs, and risks [119]. Each party must have something of value to contribute, and it is important to attract all related stakeholders to take part in implementing the benefits. All parties must work from the same perspective. Furthermore, what ties multiple firms together is the need to be interdependent and complementary.

In selecting the most appropriate platform, firms should first consider whether the platform provides ideal features. These include a smart contract that meets the business needs; a protective mechanism that matches the business requirements, including security, privacy, and scalability; and a perceived difficulty of switching to a different platform at some point in the future. Some open-source platforms may lock in their users via an expensive propriety service or technological infrastructure [55]. Overall, firms should embrace blockchain rather than taking a wait-and-see approach. This will enable them to capture first-mover advantages in the competitive landscape formed by blockchain and its allied technologies.

8. Conclusions

In this section, conclusions are presented based on the research questions and purpose of the study. Our model of organizations' resistance indicates that the factors identify 79% (0.792 in Figure 2) of the variation in organizations' resistance.

With regard to the causal relationships between technological factors and resistance to blockchain, our empirical data supported all our hypotheses in the technological context. Hypotheses H1–H6 are all supported by the data, supporting the findings of previous studies [24,42,103–107]. For hypotheses H1, H5, and H6, we conclude that higher complexity, security and privacy concerns, and implementation costs increase organizations' resistance to blockchain. Thus, complexity, security and privacy concerns, and implementation costs have positive causal relationships with organizations' resistance.

With regard to H2, H3, and H4, we conclude that the lower technological maturity, compatibility, and scalability of blockchain increase organizations' resistance to the technology. Thus, maturity, compatibility, and scalability constructs have a negative causal relationship with organizations' resistance to blockchain, where organizations' resistance is the dependent factor.

With regard to the causal relationships between the organizational factors and the resistance to blockchain, our empirical data supported two and failed to support two hypotheses (H7 and H9). As a result, the empirical data cannot confirm that "lower technological knowledge and awareness of management team increase organizations' resistance to blockchain", or that "a higher perceived risk of vendor lock-in increases organizations' resistance to blockchain". Nevertheless, hypotheses H8 and H10 were supported by the empirical data. Thus, we conclude that lower expertise and technical knowledge increase organizations' resistance to blockchain, yielding a negative causal relationship, where resistance to blockchain is the dependent variable. In other words, increasing an organization's expertise and technical knowledge will decrease its resistance to blockchain, and vice versa. Supporting H10, we conclude that "a higher perceived effort for collaboration between firms increases organizations' resistance to blockchain". This indicates a positive causal relationship, where resistance to blockchain is the dependent factor: a firm's resistance to blockchain is lower if there is a decline in the perceived effort of collaborating with other firms.

With regard to the causal relationships between environmental factors and resistance to blockchain, we could not confirm two of the three hypotheses. Hypotheses H11 and H13 were not supported, which means that we cannot validate the claim that "a higher perceived constraint of government support increases organizations' resistance to blockchain", or that "a higher perceived constraint of an efficient technological infrastructure increases organizations' resistance to blockchain". Only hypothesis H12 is supported. Thus, we conclude that a higher perceived constraint on existing regulations and the legal framework increases organizations' resistance to blockchain. Thus, the "perceived constraint on existing regulations and the legal framework" and the "organization's resistance to blockchain" were found to have a parallel relationship, where resistance to blockchain is the dependent variable. An increase (or decrease) in "perceived constraint on existing regulations and the legal framework" increases (or decreases) an organization's resistance to blockchain.

In response to the second research question, the complexity, cost of implementation, scalability, compatibility, and perceived constraints on existing regulations and legal frameworks were found to be the most critical factors (in order of intensity) that determine organizations' resistance to blockchain. Complexity has a coefficient value of 0.307, implementation cost has as value of 0.228, scalability has a value of −0.197, compatibility has a value of −0.166, and the perceived constraint on existing regulations and legal frameworks has a value of 0.161. Thus, when "scalability" increases by one, the "organization's resistance to blockchain" decreases by 0.197 if all other factors remain unchanged.

Complexity, security and privacy concerns, implementation cost, perceived collaboration efforts, and perceived constraints on efficient regulations were found to be strongly positively correlated. Second, maturity, compatibility, scalability, and expertise and technical knowledge were found to be positively correlated. However, the correlation between the two groups is found to be negative. Despite many successful implementations of blockchain in supply chains, the acceptance rate is considerably low. Here, we have identified the main barriers and possible solutions for blockchain technology adoption at the pre-adoption and adopting stages. In addition to inter-organizational and intra-organizational hurdles, system-related and governmental barriers negatively affect the adoption of blockchain.

The findings revealed that the technological maturity, cost, compatibility and scalability of blockchain are significant disablers of blockchain adoption. They suggest that the lack of regulations has a bad influence on the company adoption process. This study also demonstrates that companies are more likely to wait to adopt blockchain due to its complexity and immaturity.

This study makes several contributions to the literature. First, it serves as a starting point in response to the dearth of formal studies conducted in this framework. Second, this study has identified the main hurdles that hinder the adoption of blockchain and suggests solutions to these barriers, rather than additional reasons for adoption. The former is often as useful as the latter. This study also provides insights for professionals interested in investing in this new platform. It can thus serve as a compass for managers to advance their organizations as well.

Nonetheless, like all studies involving surveys, this study's limitations come from its level objectivity. Participants' responses depend largely on other factors, such as their position, sector, and experience with blockchain. Furthermore, our study was conducted during a global pandemic, which affected the data collection process. Other limitations of this study include the low number of participants, owing to the infancy of blockchain technology, and the unfavorable conditions during the data collection process. However, these limitations do not affect the reliability of the results, because the main targets are firms that have hesitated to adopt the technology. Another limitation is derived from the literature review process. Our findings show that the body of knowledge in this area is still at an initial stage, and is just beginning to gain recognition. On the one hand, the number of barriers we examined was limited by those identified in previous studies, and the literature search was somewhat limited, owing to selected portals. On the other hand, we address this limitation by examining the available online sources from leading consulting firms that are known to be at the frontline of the development and implementation of blockchain technology.

Consequently, a more concrete examination of this area is required as we approach the stage at which this technology becomes sufficiently mature for broad practical use. Future research should provide deeper investigations of the possible challenges and, more importantly, the possible solutions for the mitigation of these barriers.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Measurement items.

	1	2	3	4	5
In terms of maturity, we think that					
blockchain is still growing.					
there have not been many concrete examples of operation in real environments.					
the potential and utility has not been proven.					
further development is required for blockchain to be put into practice.					
In terms of compatibility, we believe that blockchain platforms are					
not compatible with the way we work.					
not compatible with our operations.					
not compatible with our business process.					
not compatible with other information systems (e.g., ERP, MIS, WMS).					
not compatible with all aspects of our work.					

Table A1. *Cont.*

	1	2	3	4	5
In terms of scalability, we believe that					
the speed of transaction (7 transactions per second) on blockchain is quick.					
the speed of block generation is decent.					
block size (1 megabyte) is large.					
block size is decent for practical use.					
overall speed and block size are excellent.					
In terms of complexity, we think that					
blockchain is conceptually difficult to understand from a business perspective.					
blockchain is conceptually difficult to understand from a technical perspective.					
when using blockchain technology, it is difficult to resolve transactional errors.					
using blockchain technology is difficult.					
With regard to security concerns, our organization					
does not feel secure in providing sensitive information related to the company (e.g., transaction data) when working with blockchain platforms.					
does not feel secure sending sensitive information about the company to the platform.					
does not feel safe uploading sensitive information about the company to the platform.					
does not feel that blockchain is a safe platform for operating business with sensitive information overall.					
In terms of cost of implementation, we believe that blockchain adoption would					
increase hardware and software facility costs.					
increase costs for training and recruiting.					
be expensive due to trial-and-error.					
require high up-front investment costs.					
With regard to technological knowledge and awareness, top managers in our company					
recognize blockchain as a competitive weapon.					
recognize blockchain as a tool to increase the productivity of clerical employees.					
recognize blockchain as a tool to increase the productivity of professionals.					
recognize the strategic potential of blockchain.					
believe blockchain contributes significantly to the firm's financial performance.					
agree blockchain projects may have important intangible benefits that should be funded.					
With regard to technical knowledge and expertise, we think that our organization					
has the relevant technical knowledge about blockchain technology.					
has professional staff trained in blockchain technology use.					
has interest in projects related to blockchain technology.					
is familiar with this type of technology and its applications.					

Table A1. *Cont.*

	1	2	3	4	5
In terms of the perceived risk of vendor lock-in, we are concerned that our platform suppliers would					
make us significantly invest in their specialized tools and equipment that are dedicated to only their platform.					
develop procedures and routines tailored to their platform.					
provide training that cannot be used in other vendors' platforms.					
try to lock us in (vendor lock-in).					
In terms of collaboration efforts, we believe that collaboration with other organizations to allow for blockchain adoption					
is not easy.					
is challenging.					
requires too much time.					
requires a lot of mental effort.					
With regard to constraints on government support, we think that					
the government has not provided incentives to encourage the adoption of blockchain technology.					
the government does not actively support blockchain technology.					
the government has not introduced relevant policies to boost blockchain technology adoption.					
there is no support (e.g., training) provided by the government concerning blockchain technology.					
With regard to constraints on regulations and legal frameworks related to blockchain, we think that					
the regulatory body is not yet well-established to deal with blockchain issues.					
there may be changes in regulations that would interfere with our usage of blockchain in the future.					
there is no authority to solve disputes.					
legal structures do not satisfactorily protect users from problems on blockchain platforms.					
In terms of the constraints of technological infrastructure, we think that					
the current technological structure is not adequate for blockchain.					
the current Internet service is not efficient enough for blockchain.					
there is not sufficient access to blockchain technology.					
With regard to our stance on blockchain technology, our organization					
will NOT adopt blockchain unless it proves beneficial for us.					
will wait for the right time and required capability to adopt blockchain.					
needs to clarify some queries and justify adopting blockchain.					
needs to get solutions for some of our complaints/objections before adopting blockchain.					
does not need blockchain.					
is unlikely to adopt blockchain in the near future.					
believes that blockchain is not for our organization.					

Appendix B

Table A2. Regression coefficients.

	COMPX	MATR	COMPA	SCAL	SECU	COST	AWNS	EXPT	RISK	COLL	SUPP	REGU	INFR	RESS
COM1	0.784	0.373	0.525	−0.508	0.636	0.475	−0.581	−0.574	0.573	0.476	0.468	0.515	0.52	0.66
COM2	0.737	0.506	0.585	−0.354	0.542	0.526	−0.478	−0.484	0.288	0.498	0.552	0.47	0.517	0.511
COM3	0.795	0.561	0.652	−0.483	0.525	0.504	−0.491	−0.484	0.392	0.446	0.563	0.582	0.671	0.627
MAT1	0.588	0.891	0.625	−0.469	0.59	0.52	−0.55	−0.487	0.383	0.565	0.622	0.578	0.487	0.513
MAT2	0.461	0.83	0.453	−0.406	0.406	0.428	−0.35	−0.303	0.403	0.329	0.519	0.529	0.498	0.416
CMP1	0.621	0.496	0.819	−0.624	0.471	0.619	−0.562	−0.597	0.521	0.52	0.543	0.666	0.553	0.572
CMP2	0.644	0.562	0.853	−0.522	0.551	0.619	−0.632	−0.624	0.426	0.558	0.654	0.619	0.633	0.629
SCA1	−0.441	−0.371	−0.39	0.714	−0.411	−0.339	0.44	0.462	−0.516	−0.322	−0.347	−0.376	−0.332	−0.434
SCA2	−0.476	−0.382	−0.588	0.784	−0.397	−0.412	0.442	0.411	−0.408	−0.512	−0.521	−0.428	−0.375	−0.537
SCA3	−0.423	−0.411	−0.557	0.779	−0.487	−0.405	0.506	0.354	−0.485	−0.378	−0.456	−0.504	−0.369	−0.509
SEC1	0.547	0.493	0.422	−0.405	0.784	0.531	−0.455	−0.561	0.514	0.402	0.518	0.564	0.59	0.64
SEC2	0.599	0.505	0.46	−0.428	0.743	0.503	−0.633	−0.443	0.267	0.537	0.571	0.619	0.533	0.534
SEC3	0.605	0.41	0.562	−0.507	0.837	0.678	−0.597	−0.669	0.521	0.621	0.546	0.637	0.58	0.694
COS1	0.469	0.403	0.65	−0.372	0.491	0.795	−0.559	−0.561	0.394	0.541	0.585	0.665	0.673	0.662
COS2	0.61	0.487	0.549	−0.462	0.601	0.706	−0.503	−0.612	0.328	0.403	0.541	0.545	0.473	0.542
COS3	0.415	0.39	0.49	−0.345	0.593	0.787	−0.487	−0.676	0.472	0.572	0.499	0.493	0.595	0.597
AWN1	−0.565	−0.39	−0.627	0.519	−0.592	−0.522	0.766	0.598	−0.467	−0.517	−0.554	−0.581	−0.583	−0.553
AWN2	−0.502	−0.437	−0.585	0.56	−0.509	−0.546	0.838	0.627	−0.638	−0.553	−0.592	−0.604	−0.511	−0.616
AWN3	−0.574	−0.468	−0.536	0.403	−0.622	−0.58	0.829	0.673	−0.509	−0.74	−0.621	−0.521	−0.524	−0.587
KNW1	−0.557	−0.401	−0.591	0.439	−0.673	−0.664	0.689	0.807	−0.509	−0.515	−0.58	−0.647	−0.526	−0.639
KNW2	−0.475	−0.367	−0.538	0.367	−0.545	−0.661	0.579	0.758	−0.479	−0.553	−0.495	−0.482	−0.522	−0.56
KNW3	−0.541	−0.338	−0.594	0.449	−0.471	−0.574	0.569	0.796	−0.529	−0.498	−0.473	−0.494	−0.578	−0.618
VEN1	0.518	0.415	0.541	−0.559	0.453	0.484	−0.537	−0.512	0.851	0.466	0.52	0.467	0.558	0.557
VEN2	0.325	0.28	0.312	−0.378	0.431	0.313	−0.507	−0.499	0.702	0.462	0.366	0.366	0.396	0.41
COL1	0.505	0.547	0.637	−0.417	0.549	0.586	−0.612	−0.52	0.459	0.845	0.609	0.522	0.652	0.577
COL2	0.543	0.379	0.485	−0.508	0.585	0.564	−0.667	−0.614	0.553	0.878	0.6	0.494	0.636	0.644
SUP1	0.576	0.532	0.631	−0.464	0.521	0.555	−0.571	−0.433	0.428	0.6	0.752	0.6	0.493	0.551
SUP2	0.563	0.527	0.561	−0.404	0.498	0.455	−0.59	−0.526	0.459	0.449	0.807	0.416	0.424	0.491
SUP3	0.455	0.499	0.492	−0.492	0.572	0.626	−0.538	−0.567	0.458	0.571	0.777	0.567	0.625	0.62
REG1	0.495	0.486	0.448	−0.289	0.64	0.554	−0.527	−0.453	0.316	0.505	0.488	0.719	0.647	0.547
REG2	0.513	0.419	0.653	−0.527	0.55	0.602	−0.569	−0.598	0.444	0.423	0.571	0.787	0.503	0.631
REG3	0.559	0.592	0.657	−0.5	0.585	0.564	−0.518	−0.532	0.477	0.435	0.519	0.799	0.603	0.562
INF1	0.486	0.377	0.575	−0.418	0.566	0.689	−0.586	−0.629	0.602	0.691	0.623	0.683	0.802	0.636
INF2	0.649	0.469	0.621	−0.421	0.55	0.596	−0.511	−0.544	0.476	0.585	0.455	0.496	0.794	0.619
INF3	0.641	0.526	0.506	−0.292	0.613	0.548	−0.487	−0.472	0.404	0.507	0.529	0.628	0.803	0.592
RES1	0.535	0.418	0.483	−0.476	0.616	0.585	−0.517	−0.535	0.501	0.593	0.488	0.526	0.539	0.795
RES2	0.55	0.356	0.487	−0.35	0.63	0.688	−0.473	−0.548	0.323	0.547	0.529	0.629	0.632	0.759
RES3	0.623	0.362	0.598	−0.517	0.674	0.538	−0.502	−0.652	0.485	0.476	0.585	0.58	0.572	0.74
RES4	0.56	0.389	0.494	−0.478	0.597	0.572	−0.518	−0.576	0.54	0.421	0.552	0.595	0.54	0.703
RES5	0.607	0.458	0.517	−0.496	0.486	0.544	−0.56	−0.548	0.516	0.522	0.478	0.474	0.562	0.729
RES6	0.639	0.463	0.644	−0.613	0.564	0.615	−0.672	−0.6	0.466	0.627	0.594	0.588	0.616	0.769

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