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The Impact of Blockchain Technology Application on Supply Chain Partnership and Performance

Joon-Seok Kim and Nina Shin *

College of Business Administration, Sejong University, Seoul 05006, Korea; jskim@sejong.ac.kr
* Correspondence: ninashin@sejong.ac.kr; Tel.: +82-2-6935-2552

Received: 14 October 2019; Accepted: 4 November 2019; Published: 5 November 2019

Abstract: Blockchain technology is now considered a next generation information technology tool for sustainable growth in supply chain (SC) management. However, its study is relatively rare in the literature on SC collaboration and sustainability management research, despite its advantages in sustaining connectivity and reliability among SC partners. This study investigates how the use of blockchain in SC activities can influence (increase or decrease) SC partnership efficiency and growth, thereby affecting SC performance outcomes. Specifically, this study empirically validates a measurement and structural equation model with 306 SC experts from various industries. The findings show that the blockchain technology characteristics (information transparency, information immutability, and smart contracts) have significant positive effects on partnership growth and marginal effects on partnership efficiency. Though partnership growth has a positive effect on firm performance, partnership efficiency shows a negative effect.

Keywords: blockchain technology; information transparency; information immutability; smart contracts; partnership efficiency; partnership growth; supply chain performance

1. Introduction

An efficient and strategic partnership between a buyer and its suppliers is one of the critical success factors in supply chain management (SCM). Supply chain (SC) collaboration includes the sharing of key information derived from the market and global network operations, followed by rapid joint decision-making based on such information. Through joint efforts to match demand and supply, two trading partners can increase mutual benefits and reduce risks. Since the early stages of SCM, the importance of SC collaboration has been stressed in both the industry and academia. Particularly, information technology (IT), such as web services, bar code, and radio-frequency identification, has played a crucial role in the successful operation of SC collaboration. IT integration has made it possible to acquire operational information from the SC, and then share it with interconnected partners in real-time. Furthermore, recent advances in big data analysis, which includes IT, have enhanced visibility and predictability in the business environment. As new IT is developed, its potential application in SC collaboration should be investigated.

In recent times, electronic money, such as bitcoin, has attracted attention owing to increased usage in online and offline markets, as well as the sharp fluctuation of money value in the electronic money transaction market. This electronic money is based on blockchain technology (BCT) [1,2]. BCT has advantages such as information transparency, information immutability, and smart contract to support connectivity and reliability, which are required for SC collaboration [3]. We elaborate on these advantages as follows: First, information transparency means that relevant information, including transaction history, is visible and traceable to all participants; such data are automatically updated with the most recent authorized changes in related BCT networks. Second, information immutability prevents the information, or data, in the blockchain network from being modified, or deleted, without the approval of network participants. Finally, a smart contract reflects efficient and convenient management for contracts among SC partners. In sum, BCT is considered a technology that can enhance the efficiency and effectiveness of SC partnership processes. This study hypothesizes that all three advantages positively drive SC collaboration processes such as SC partnership, ultimately affecting performance.

In SCs, buyers and suppliers generally attempt to supply products or services through medium- or long-term contracts. During the implementation of a supply contract, two partners require a mutually agreed upon collaboration to successfully respond to uncertain situations in the market or to SC disruption. The SC partnership outcome is evaluated and considered for renewal after the contract has been terminated. The partnership, after several renewals of the contract, is often reviewed for strategic partnership. Strategic partnerships could become more efficient and show further growth. BCT, which has recently attracted attention in the digital commerce market, has technical characteristics that can be used in collaboration among SC partners.

On the basis of the potential usefulness of BCT technology in SC collaboration, the following research questions are raised: (i) How is the use of blockchain in SC activities expected to influence (increase or decrease) SC partnership efficiency and growth, thereby affecting SC performance outcome? (ii) How can practitioners strategically plan for BCT-driven improvement planning for a higher level of competitive advantage?

The specific objectives of the present study are as follows: (i) to identify and highlight key BCT attributes for the operationalization of BCT applications that are both theoretically and empirically appropriate; and (ii) to understand the influential linkage between BCT and SC collaboration, and thus provide managerial guidance in achieving success in BCT-driven SC partnership management.

Though BCT developed as a technical platform for electronic money, it is now considered a next generation IT tool in fields such as finance and healthcare. However, its study is rare in the research on SC collaboration and sustainability management. This study illuminates the impact of BCT on SC partnership performances through an empirical study. It provides strategic direction and managerial insights on the applications and uses of BCT for the purpose of enabling desirable SC outcomes.

The remaining paper is organized as follows: First, related research works on BCT and SC environments are presented in Section 2. A structural equation model for empirical research and hypotheses related to BCT, SC partnership, and SC performance is presented in Section 3. The research methodology and results of the analysis are discussed in Section 4. Finally, managerial insights based on the results as well as the final conclusions are presented in Sections 5 and 6, respectively.

2. Research Background

Consumer network (consisting of both firm- and individual-level participants) and technology-driven value transaction initiatives are beginning to compel changes in business strategy. Competitive advantages in the present context cannot be successfully achieved without successful integration of technology and SCM [4]. Despite the excitement surrounding BCT introduction, SCM researchers are currently facing a significant gap in the literature in examining the opportunities and challenges presented by BCT. Recent studies have begun to justify the technology application and its potential success and failures across SCs, but both theoretical and empirical investigations are limited [3,5,6]. This may be because of the asymmetric growth of investigation between two perspectives: functionality (e.g., how to mitigate the 51% attack through blockchain technique improvement) and applicability (e.g., how to reduce fraud risk through blockchain application). This section describes the relevance of BCT in the operations and SCM context, examines BCT-enabled SC partnership management, and proposes a conceptual model of BCT-driven partnership management based on the resource-based view and social capital theoretical perspectives.

2.1. Blockchain in Operations and Supply Chain Management

Blockchain is an electronic database system that records and distributes transactional data, which is secured by cryptography and governed by a consensus among the participants involved in a system [4]. The chain refers to a list of data entries that system participants maintain using a computer network, whereas the block refers to the real time data that are updated by the system participants [4]. The benefits of BCT application have been primarily centered around how it can provide identical and verified information to supply network participants or members. Through such transparent and immutable information sharing mechanisms, the conventional need for collaborative activities for trust building naturally disappears [7]. Even with the absence of a trusted intermediary, network participants can rely on digitally recorded transaction history and terms to transfer assets such as digital money or even deeds of ownership [8]. In summary, BCT studies have commonly emphasized four characteristics or attributes: (1) distribution and synchronization of data or transaction information, (2) transition from centrality to peer-to-peer (P2P) networks, (3) implementation of smart contracts, and (4) enablement of data immutability. These characteristics are defined in the literature [3,5] as follows:

- Information distribution and synchronization: Every network system participant has access to the same data and ledger containing the complete history of transactions with maximal transparency.
- P2P networks and consensus: System participants collectively form and run the network without relying on a central authority or centralized infrastructure.
- Smart contract and payment: Legal provisions of contractual agreement are formalized into computer programming codes and verified through system participants. It automatically confirms pre-determined rules and penalties prior to executing the terms of agreements.
- Data immutability: Every transaction creation and/or modification must be verified by the consensus of most of the system participants, ensuring that the history of records is reliable and unaltered without collective verification

BCT application has been proliferating in cryptocurrency, new payment infrastructure, and identity verification [9]. However, it has not necessarily gained similar popularity in the SCM context, where blockchain not only offers visibility regarding who is performing which actions [10], but also provides potential solutions for identity management [11], smart city planning [12], real-time supplier management [13], reliable healthcare service management [14], and shipment management [15]. In light of the above observation, firms differ in the pervasiveness of technology integration along the value chain. However, BCT application is highly beneficial to all participants in the operations and SC network [4]. Though the possible applications of BCT and its barriers and challenges have undergone extensive investigation [16], Hackius and Petersen [7] pointed out the infancy of logistics and SCM research in blockchain.

On the basis of the four common characteristics of BCT, Table 1 summarizes the findings of notable studies in recent years. Though these studies refer to individuals or enterprises who partake in the BCT integration as "supply chains", "individual", "supplier–buyer", "partner", "clients", and "nodes", the current study refers to them collectively as "system participants" in order to remain focused on the understanding of overall blockchain characteristics. Readers are referred to the referenced articles for an exact identification of participants, or beneficiaries, of BCTs.

Table 1. Summary of blockchain characteristics in various contexts. SCM, supply chain management.

Context	Information Distribution and Synchronization	P2P Networks and Consensus	Payments and Smart Contracts	Data Immutability	Ref.
General	System participants benefit from real time data maintained and accessed by each participant	No central authority needed to manage the process, reducing governance requirements and reliance on a single participant	Payments are made automatically when data match, reducing manual processes and human errors	Forged paperwork will no longer be a risk and auditability is enhanced	[4]
Logistics	A digital version of a ledger is available to the decentralized system participants to track and follow data	System participant must share transaction with the blockchain's P2P network and ensure the copy of the ledger	Legal provisions are formalized into programming code and verified through a network of peers	The moment a transaction is approved through consensus algorithm, it prevails in a block, which is embedded into the blockchain	[5]
Healthcare	Allows all copies of a patient's record to be synchronized with system participant as updates are made regardless of their storage location	Each system participant holds a copy of the entire blockchain, and they communicate regularly to ensure data are up to date and authentic	Immutable records stored on blockchains and shared with an insurance provider can prevent common types of fraud	Enables creation of incorruptible databases for medical records and tracking pharmaceuticals through the entire manufacturing and distribution process	[14]
Green SCM	System participant has the same copy of the ledgers, which are updated with new information or changes in the recorded information in a decentralized manner	System participants can follow and audit the history of records, thereby verifying sustainability performance of transportation	Automatic payment that is performed when a certain regulation is met, or a particular value is added to a product	Enables the tracking of hazardous wastes, distributing responsibility to system participants for cleanup costs	[3]
Engineering	System participants interact with the blockchain via a pair of private and public keys	Every signed transaction is broadcasted by a user's node to its one-hop peer	Scripts, stored on the blockchain, can be regarded as roughly analogous to stored procedures in relational database management systems	The nodes verify that the suggested block contains valid transactions, and references via hash the correct previous block on their chain	[17]
Banking	Distributed clearing mechanism eliminates the intermediary link of third-party financial institutions	Performs data encryption, ultimately helping system participants control big data and establishing ownership	Ensures that payments are made automatically once a predetermined time and result is reached, thereby reducing manual operations risks	Once a piece of information enters the system, it cannot be modified, thereby eliminating the subsequent problems of fraud	[6]

2.2. Blockchain Application and Strategic Supply Chain Partnership Management

Advanced technologies and their successful integration can accrue potential benefits concerning strategic SC partnership management. Creating and managing partnerships within the SC, or network, in a conventional approach involves collaborative activities such as information sharing [18], resource sharing [19], decision synchronization [20], and interest alignment [21]. Because a SC is composed of a sequence, or network, of interdependent relationships, the SC's competitive advantage can only be maintained via successful partnership among SC partners [18]. Thus, partnership or collaborative advantages and business performances are determined by partnerships and strategic alliances that are successfully fostered [22].

Particularly, the food SC began acknowledging the importance of strategic SC partnership, thus collectively attempting to strengthen consumer confidence in the global food system [23]. The importance of transparency and accountability across supply networks particularly gained attention after the E.coli outbreak at Chipotle Mexican Grill, which resulted in 55 cases of infections [24]. Consequently, a group of the world's leading retailers and food companies, such as Dole, Unilever, and Walmart, began working with IBM on BCT usability for providing traceability information on the state of origin of food. Though BCT has not yet surfaced as a confirmed technology medium for optimal SC outcomes, engineers have already begun integrating blockchain and Internet of Things to provide "resilient, truly peer-to-peer distributed systems, offering the ability to interact with peers in a "trustless" (firms can transact without having to trust each other), auditable manner", rather than as another IT or database solution ([17], p. 2301). They believe that it can not only strengthen the trust across system participants (who are involved participants in a transactional relationship such as buyer, supplier, and distributors), but also enable a trustless system that assures the security sought by system participants.

Both technology service providers and researchers have positive outlooks for BCT-enabled opportunities, despite the immediate challenges of its use. Its benefits are identified as enhancements of product safety and security, quality management, illegal counterfeiting reduction, SC sustainability, inventory management and replenishment advancement, new product design and development, and SC transaction cost minimization [4]. Moreover, blockchain-based collaborative activities can lead to another level of SC partnership advantage, providing strategic benefits over competitors in the marketplace, namely, partnership efficiency and partnership growth.

Partnership efficiency refers to the cost competitiveness among primary competitors in terms of the partnership building process. Partnering firms share critical and proprietary information to sustain and support their partnership relationship [25]. The partnership relationship building process consists of sharing relevant, timely, accurate, complete, and confidential information with partner firms through financial and non-financial investments dedicated to the relationship. For example, Kwon et al. [26] noted that key collaborative tools or techniques such as vendor management inventory (VMI) and collaborative planning and forecasting replenishment (CPFR) can formalize the process between two trading partners. These authors noted that well-designed and well-executed collaborative tools can transform a disjointed and inefficient push system into a coordinated pull system, thus successfully achieving investment efficiency.

Partnership growth refers to an anticipated level of a growth in a relational, contractual, and operational partnership relationship with the associated SC partner. The value of the strategic partnership leads to desirable outcomes such as partnership success [27], a close supplier–manufacturer relationship [28], and a positive relationship outcome [29]. Similarly, the partnership growth opportunity implies a potential increase in long-term benefits for the SC based on a partnership relationship [25].

2.3. Blockchain Application from the Resource-Based and Relational Views

On the basis of the resource-based view (RBV) theory, firms that are able to uniquely combine and leverage resources may gain an advantage over competing firms that are unable to use their resources [30]. RBV explains that firm performances vary depending on strategic resources, capabilities, and assets, and that scarce resources and assets enable the development of core competencies and capabilities [31,32]. Similarly, the relational view argues that there exists a "supernormal profit jointly generated in an exchange relationship", which cannot be created by a sole individual firm and must be created jointly in a partnership [32]. Specifically, relation-specific assets such as SC collaboration are highly valuable for their rare and non-substitutable nature [33]. Both theories support the importance of SC partnership and collaboration management efforts, which can effectively lead to mutual benefits for participating firms. Particularly, SC collaboration can strengthen competitive advantages by increasing firm-specific skills and realizing economies of scale, thereby improving overall supply network competitive positions [32]. Consequently, the effectiveness of SC collaboration and partnership has become a significant resource in terms of predicting overall SC network performance, such as operational and financial performance.

As is often the case with emerging technology, the extent of the value provided by the blockchain-driven collaboration system is under investigation by various scholars from a variety of fields—from operations and information system management to system and computer engineering. Christidis and Devetsikiotis [17] stated that blockchain enables "trustless networks", as it allows firms to transact without having to trust each other. Through digitally signed documents, blockchain can validate the identities of individuals in order to confirm who is performing what actions, and when and where they are performing them [10]. Tijan et al. [5] noted that this emerging technology provides a basis for transactional data sharing across supply network without requiring trusted participations in food safety management. Regardless of the ongoing investigations on the depth of technology application, Cole et al. [4] emphasized the need to develop a new way to create trust for today's complex manufacturing ecosystem and lack of visibility across multiple tiers.

Accordingly, this study examines whether performance expectancy of BCT (information transparency, information immutability, and smart contracts) positively influences the strategic SC partnership advantage (partnership efficiency and growth) and positively drives the strategic SC partnership outcome (operational and financial), as shown in Figure 1.

Figure 1. Conceptual model of blockchain-based supply chain (SC) partnership and performance.

3. Research Model and Hypotheses

3.1. Information Transparency and SC Partnership Efficiency and Growth

Information transparency refers to "the possibility of accessing information, intentions, or behaviors that have been intentionally revealed through a process of disclosure", in the field of information management [34], (p. 105). In the blockchain network, all participants have a copy of the ledger that is automatically and identically updated with the most recent information. Because the overall history of any updated information is visible and accessible to all authorized network participants, impure attempts to harm the fairness of information are easily detectable and traceable [2]. Though it enhances the fairness and efficiency of the process, it also reduces risks. In the SC network, there is a growing demand for transparency of information on SC processes [35]. The BCT application is expected to improve the reliability of the overall information on product and cash flows in transactions among SC partners [3]. It is expected that BCT-enabled information transparency leads to improved efficiency in the collaboration process among SC partners, and thus promotes partnership growth. On the above basis, this study proposes the following hypotheses:

Hypothesis 1a. *BCT-enabled information transparency has a positive effect on SC partnership efficiency.*

Hypothesis 1b. *BCT-enabled information transparency has a positive effect on SC partnership growth.*

3.2. Information Immutability and SC Partnership Efficiency and Growth

BCT also ensures the immutability of all information created and shared in the network. This so-called "data immutability" prevents the information, or data, in the blockchain network from being deleted, or modified, without the approval of network participants [4]. It is only possible to delete, or change, data if consent from network members is obtained according to predetermined and approved procedures. There would be a difference between a public blockchain and a private blockchain in how the alteration and removal of data takes place [36]. Upon the approval of the majority of members, information can be removed and changed in a public blockchain. However, in a private blockchain, the deletion and alteration of information is stricter and requires informing the network members and complying with certain approval requirements [37]. Along with information transparency, information immutability also provides a business value to the SC network partners. BCT-enabled information immutability is anticipated to contribute to the enhancement of SC partnership efficiency and SC partnership growth. On the above basis, this study proposes the following hypotheses:

Hypothesis 2a. *BCT-enabled information immutability has a positive effect on SC partnership efficiency.*

Hypothesis 2b. *BCT-enabled information immutability has a positive effect on SC partnership growth.*

3.3. Smart Contracts and SC Partnership Efficiency and Growth

The smart contract, defined as "a computerized transaction protocol that executes the terms of a contract", was initially introduced in 1994 [38], (p. 2296). These contracts enable the storage, sharing, and self-enforcement of contractual details in a blockchain. Each contract has its own unique address, which can be called up at any time and accessed by all stakeholders on the chain. Therefore, smart contracts in the blockchain can effectively prevent misunderstandings in the implementation and execution of contracts among SC partners, consequently improving the degree of mutual trust [6]. Moreover, the transaction terms and history of the negotiation can be easily shared with trading partners in a reliable form, thereby improving the process efficiency of contract renewal [39]. Li et al. [39] noted that partnership terms and promises are initially expressed in digital terms, and then built and stored on blockchain, which provides observability, verifiability, privacy, and enforceability for all involved partners. This digital automation offers an efficient partnership process while enabling a wide range of contractual processes (e.g., partners' review for confirmation or rejection of the initial contract, modification of contractual terms, and signing). The following hypotheses are established on the impact of smart contracts on the efficiency and growth of an SC partnership.

Hypothesis 3a. *BCT-enabled smart contract has a positive effect on SC partnership efficiency.*

Hypothesis 3b. *BCT-enabled smart contract has a positive effect on SC partnership growth.*

3.4. SC Partnership Efficiency, Growth, and Performance

Efficient partnerships that use formalized systems such as VMI or CPFR are anticipated to significantly reduce the time and costs involved in the communication process among trading partners [26]. They are also expected to improve the likelihood of collaborative decision-making with a high level of IT infrastructure [40]. Efficient collaborative management has been a long challenge from both the supplier and buyer perspective from various contexts from digital supply management to hospital service management [41,42]. Fundamentally, collaboration leads to a collaborative advantage, which then leads to overall performance improvement [32]. Particularly, both operational and financial performances with respect to inventory management can benefit from collaborative efforts that minimize the overbooking of supplies [4]. Such partnership efficiency has been perceived with a positive outlook as it can reduce the degree of variation and uncertainty of information, alleviating the bullwhip effect. For example, BCT-enabled partnership efficiency can create an open manufacturing system environment supporting both the range and depth of information sharing activities among supply network participants [39].

However, for a high degree of partnership efficiency, the SC must be equipped with tools for communication and information sharing, which are bolstered by more up-to-date and sophisticated technology implementation [41]. The BCT, which contains critical attributes for SC collaboration such as information transparency and information immutability, also contributes to the reliability of the shared information [9]. Though these attributes can improve mutual trust among SC members, they can be relatively less helpful in responding quickly to financial disruptions [43]. Even in the BCT-enabled SC collaboration process, time-consuming and human-driven communication processes cannot be eliminated when an uncertain event occurs. When immediate decisions, such as an alteration on a purchasing order, need to be entered into SC systems, the BCT attributes can rather become a bottleneck or disturbing factor [36]. Though previous literature generally claims that partnership efficiency will positively impact SC performance, the opposite effect must be considered as well with respect to BCT. According to the above discussion, partnership efficiency is expected to have conflicting effects on the SC financial and operational performance, respectively.

Hypothesis 4a. *BCT-driven SC partnership efficiency posits a negative effect on SC financial performance.*

Hypothesis 4b. *BCT-driven SC partnership efficiency posits a negative effect on SC operational performance.*

Partnerships based on trust tend to foster a cooperative culture, thereby leading to positive relationship behavioral intentions and outcomes [44]. In the presence of trust, partners are willing to dedicate more resources, which then can be used to gain a competitive advantage with appropriate technology integration [41]. Particularly, the growth of an SC partnership can be viewed from both quantitative and qualitative aspects. The quantitative aspect includes diversification of trade items and expansion of volume, whereas the qualitative aspect includes the enhancement of collaborative culture in joint technology and new product development [4,25,45]. Through a strategic use of BCT, the rapid growth of SC partnerships can lead to both financial and operational performances. For example, a high level of confidence among SC partners is considered a precondition for risk sharing owing to its significant influence on the overall SC collaboration level [46,47]. Similarly, a partnership confidence can lead to overall improvement in SC collaboration with respect to information sharing, decision synchronization, collaborative communication, and joint knowledge creation [33]. A high level of SC collaboration leads to collaborative advantages such as process efficiency, business synergy, and innovation, which then improve the firm's performance [21,32]. Therefore, the following hypotheses are established on SC partnership growth and SC financial and operational performance.

Hypothesis 5a. *BCT-driven SC partnership growth posits a positive effect on SC financial performance.*

Hypothesis 5b. *BCT-driven SC partnership growth posits a positive effect on SC operational performance.*

4. Research Methodology and Results

4.1. Measurement Item Generation

The objective of the generation of measurement items is to secure the construct's content validity based on literature reviews and consultations with academic and industrial experts. To ensure that measurement items cover the content domain of a construct, extensive review of prior research for an initial listing of potential measurement items is recommended [18]. The degree of BCT applicability and the level of SC partnership and performance from a focal firm's perspective are operationalized based on literature reviews (Appendix A). BCT application was represented by the degrees of information transparency, immutability, and smart contracts' applicability. Information transparency, defined as visibility of the complete history of transactions to network participants in order to enable auditability and traceability, was measured using three items adopted by Queiroz et al. [48]. Information immutability, defined as securing the unchanged assets without the network participants' consensus, was measured using four items adopted by Kouhizadeh and Sarkis [3]. Smart contracts, defined as an automatic mechanism of proceeding contract terms only after confirming pre-determined conditions such as rules and penalties that are agreed between the contracted parties, was measured using three items adopted by Kouhizadeh and Sarkis [3] and Francisco and Swanson [49]. SC collaboration was represented with the anticipated levels of partnership efficiency and growth. Partnership efficiency, defined as the extent to which a firm's partnership-building process with the SC partner is cost competitive among primary competitors, was measured using three items adopted by Cao and Zhang [32], Dubey et al. [50], and Yadlapalli et al. [51]. Partnership growth, defined as the extent to which a firm's SC environment supports relational, contractual, and operational growth with an SC partner, was measured using four items adopted by Cao and Zhang [18] and Kwon and Suh [52]. Lastly, SC performance was captured with the anticipated growth in financial and operational performances. Both financial and operational performances were measured using four items adopted by Kim [53].

A seven-point Likert scale was used to indicate the extent to which managers agree or disagree with each statement, where 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neutral, 5 = somewhat agree, 6 = agree, and 7 = strongly agree. The items measure the degree of perceived BCT application, SC collaboration, and SC performance from a focal firm's (respondent firm's) perspective. In the questionnaire, the SC partner is defined as a partner firm of a focal firm with one or more of the following attributes: (i) is directly connected without an intermediary or brokerage in between; (ii) contributes the majority of revenue to the focal firm; (iii) is strategically considered a core partner to the respondent's firm; and/or (iv) is currently involved in critical operational issues such as technology application, collaboration, and performance improvement.

4.2. Data Collection

The original instrument was translated into Korean by two different English–Korean bilinguals, and then back-translated to English to verify its equivalence and accuracy. The initial screening of the Korean instrument was developed by seven scholars and professionals involved in blockchain-enabled SC initiatives. Minor modifications were made in consideration of business practices and terminologies in Korea. A pilot survey of 52 practitioners (exceeding the recommended size of 10% of the targeted sample size by Um and Kim [54]) was employed to assess the feasibility and practicability of the proposed study (i.e., the level of understanding of respondents with respect to BCT and the expected amount of time to complete the survey). The final questionnaire was managed by a leading nationwide market research provider in the following steps: listing survey respondents, screening, and conducting the survey. A cross-section list of more than 1693 professionals with over three years of partnership management in operations and SC context was created. A filtering process was used to remove respondents without sufficient direct involvement in SC partnering activities such as lack of participation in service- or product-based business transactions or communication with a partner firm.

Three-hundred and six responses (response rate of 18.07%) passed the screening and completed the survey. The subjects' characteristics are summarized in Table 2.

Table 2. Demographic characteristics of respondents (n = 306).

Characteristics	n	%
Number of years working in the organization		
Less than 10 years	94	30.72
10–15 years	95	31.05
15–20 years	52	16.99
20–25 years	31	10.13
25–30 years	21	6.86
Over 30 years	13	4.25
Number of years in partnership management		
Less than 5 years	55	17.97
5–10 years	118	38.56
10–20 years	111	36.28
20–30 years	15	4.9
Over 30 years	7	2.29
Job title		
Operation manager/Director	36	11.76
Manager	63	20.59
General Manager	99	32.35
Vice President	45	14.71
Executive Vice President/President	63	20.59
Industry		
Manufacturing	122	39.87
Information and communication	30	9.8
Professional, scientific, and technical activities	26	8.5
Construction	23	7.52
Human health and social work activities	17	5.55
Wholesale and retail trade	16	5.23
Education	11	3.59
Transportation and warehousing	9	2.94
Finance and insurance activities	7	2.29
Other service areas	45	14.71

4.3. Measurement Model Assessment

Prior to hypotheses testing, AMOS 24.0 software was used to assess and confirm the validity and reliability of the survey. As part of a confirmatory factor analysis (CFA), (i) reliability, (ii) convergent validity, (iii) uni-dimensionality, and (iv) discriminant validity analyses are carried out.

The assessment result of the survey (Table 3) confirms the reliability (consistency of measurement items) with Cronbach's alpha (α) ranging from 0.916 and 0.956, which demonstrates a high degree of internal consistency. Convergent validity was ensured based on (i) item loadings ranging from 0.847 and 0.957, which are statistically significant and exceed 0.70; (ii) the composite reliability (CR) of the latent constructs ranging from 0.923 and 0.968, which thus exceeds 0.70; and (iii) the average variance extracted (AVE) of latent constructs ranging from 0.782 and 0.885, which thus exceeds 0.50 [55]. These results indicate strong convergent validity of the measurement constructs relating to specific latent constructs. For uni-dimensionality assessment, the model fit indices including the normed chi-square (χ^2) (<3.0), comparative fit index (CFI) (>0.70), Tucker–Lewis index (TLI) (>0.90), and root mean square error of approximation (RMSEA) (<0.10) are evaluated based on the recommended statistical values by Hair et al. [56]. The model fit was adequate with values of χ^2/df = 1.542, $p < 0.001$, CFI = 0.98, TLI = 0.98, and RMSEA = 0.04.

Table 3. Measurement model results (descriptive statistics, standardized loadings, and reliability). CR, composite reliability; AVE, average variance extracted.

Construct(s)	Item(s)	Mean	*SD*	Loadings
Information Transparency (TRNS) $\alpha = 0.922$; $CR = 0.923$; $AVE = 0.801$	TRNS1	4.967	0.926	0.847
	TRNS2	4.915	0.926	0.918
	TRNS3	4.869	0.963	0.918
Information Immutability (IMM) $\alpha = 0.946$; $CR = 0.948$; $AVE = 0.822$	IMM1	4.840	0.925	0.890
	IMM2	4.964	0.973	0.888
	IMM3	4.912	0.963	0.922
	IMM4	4.794	0.934	0.925
Smart Contract (SMRT) $\alpha = 0.916$; $CR = 0.940$; $AVE = 0.839$	SMRT1	4.882	0.926	0.897
	SMRT2	4.775	0.950	0.913
	SMRT3	4.784	0.965	0.937
Partnership Efficiency (PEFF) $\alpha = 0.941$; $CR = 0.942$; $AVE = 0.802$	PEFF1	4.516	0.976	0.871
	PEFF2	4.549	0.998	0.936
	PEFF3	4.585	0.965	0.916
	PEFF4	4.569	0.997	0.857
Partnership Growth (PGRW) $\alpha = 0.938$; $CR = 0.935$; $AVE = 0.782$	PGRW1	4.820	0.885	0.892
	PGRW2	4.958	0.959	0.908
	PGRW3	5.013	0.965	0.888
	PGRW4	4.791	0.963	0.849
Financial Performance (FPERF) $\alpha = 0.956$; $CR = 0.968$; $AVE = 0.885$	FPERF1	4.680	0.949	0.936
	FPERF2	4.660	0.959	0.957
	FPERF3	4.667	0.985	0.940
	FPERF4	4.631	0.981	0.929
Operational Performance (OPERF) $\alpha = 0.951$; $CR = 0.950$; $AVE = 0.826$	OPERF1	4.739	0.960	0.917
	OPERF2	4.814	0.962	0.898
	OPERF3	4.725	0.987	0.903
	OPERF4	4.771	0.962	0.917

To assess discriminant validity, the square root of an AVE (denoted in brackets on the diagonal in Table 4) was compared with the absolute value of the correlative coefficients of the other latent variables [55]. All correlations satisfied this condition, with the exception of the correlation between partnership growth and operational performance, partnership growth and information immutability, and operational and financial performance. A chi-square discriminant validity test of these sets of constructs revealed that these were significantly distinct ($p < 0.001$). Moreover, an additional CFA with two separate constructs had a better fit index than a CFA with two combined constructs for all three set of constructs. For example, a CFA with two separate constructs of partnership growth and operational performance ($\chi^2/df = 2.039$; CFI = 0.99; TLI = 0.99; RMSEA = 0.05) had a better fit index than a CFA with two combined constructs ($\chi^2/df = 5.929$; CFI = 0.97; TLI = 0.95; RMSEA = 0.13). This result implies that the two constructs should be assessed separately rather than together.

Table 4. Convergent and discriminant validity results.

	CR	AVE	TRNS	IMM	SMRT	PEFF	PGRW	FPERF	OPERF
TRNS	0.923	0.801	(0.895)						
IMM	0.948	0.822	0.880	(0.906)					
SMRT	0.940	0.839	0.837	0.877	(0.916)				
PEFF	0.942	0.802	0.710	0.718	0.729	(0.896)			
PGRW	0.935	0.782	0.848	0.900	0.852	0.787	(0.885)		
FPERF	0.968	0.885	0.741	0.729	0.745	0.670	0.863	(0.941)	
OPERF	0.950	0.826	0.815	0.811	0.825	0.687	0.921	0.928	(0.909)

4.4. Structural Equation Model Result

A structural equation model (SEM) was used to first assess the validity and reliability of the proposed model, and thus examine the sequential relationship of BCT, SC partnership, and SC performance. The model showed a good fit with normed-χ^2 = 2.07, CFI = 0.97, TLI = 0.97, and RMSEA = 0.06. A good fit between the model and the data implies the plausibility of the model. The findings of the developed SEM analysis are presented in Figure 2.

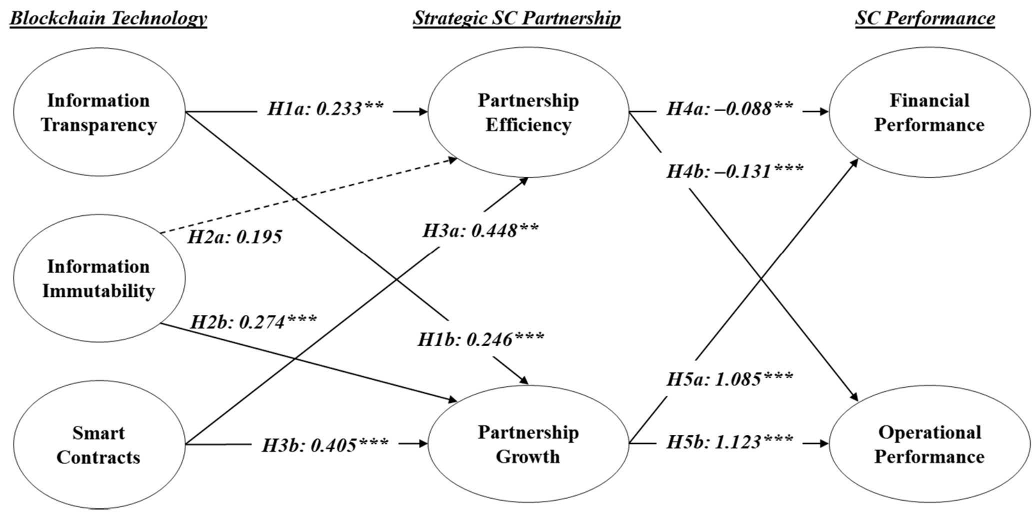

Figure 2. Hypotheses test result (*** path significant at 0.001; ** significant at 0.05).

The results primarily confirm that a higher level of BCT application leads to positive growth of collaboration performance. The statistical significance of *Hypothesis 1* and *Hypothesis 3* reveals that the higher the information transparency and smart contract applicability, the more likely it is that a focal firm anticipates a higher level of partnership efficiency and growth (H1a: $\beta = 0.233$; $p < 0.05$; H1b: $\beta = 0.246$; $p < 0.001$; H3a: $\beta = 0.448$; $p < 0.05$; H3b: $\beta = 0.405$; $p < 0.001$). However, *Hypothesis 2* demonstrates a mixed finding. Though higher information immutability leads to an anticipated growth in the partnership from social, contractual, and operational perspectives (H3b: $\beta = 0.274$; $p < 0.001$), it may not necessarily lead to improved partnership efficiency in financial and non-financial resource allocations (H2a: $\beta = 0.195$; $p < 0.135$).

Moreover, the empirical findings provide support for significant relationships between collaboration performance depicted as partnership efficiency and growth with SC performance such as financial and operational performances. *Hypothesis 4* reveals that the higher the attainment of partnership efficiency, the lower the expected financial and operational performance (H4a: $\beta = -0.088$; $p < 0.05$; H4b: $\beta = -0.131$; $p < 0.001$). Partnership efficiency achieved through a reduction in financial and non-financial efforts in relationship development, information sharing, and joint decision may not necessarily lead to desirable improvements in SC performance. Rather, it can lead to lower financial (i.e., return on investment) and operational performances (i.e., overall operation cost improvement). Lastly, *Hypothesis 5* demonstrates that a higher partnership growth will lead to an increase in financial and operational performance (H5a: $\beta = 1.085$; $p < 0.001$; H5b: $\beta = 1.123$; $p < 0.001$). This implies that increases in the growth of contractual agreement, trust, and commitment in the inter-organizational relationship, as well as operational flexibility, lead to positive SC performances.

5. Discussion

Our empirical findings showed that higher information transparency and higher smart contract applicability lead to a higher level of partnership efficiency and growth. Information transparency is a characteristic of BCT that shows how quickly and reliably information is delivered to all participants within a BCT network. If the BCT applies to the entire SC of an end item, it will promptly transmit information, whenever it is required, to all authorized participants in the SC, including the suppliers of the components of the item. This can be said to be the ultimate form of information sharing in the SC that is needed to overcome the massive obstacles to SCM, namely, the *bullwhip effect*. Overcoming the bullwhip effect improves almost all SC performance measures such as revenues, fill rates, and inventory levels. In this respect, higher information transparency will improve SC partnership performance and lead to the growth of the SC partnership.

A smart contract is a more sophisticated version of contract management that has been discussed in the field of procurement. The details of the contract, including the terms of the contract and the transaction, can be shared among participants in a BCT network, thereby facilitating the subsequent contracting process. It also significantly reduces the possibility of a dispute among partners. It can thus stabilize the supply process, which will lead to improved SC partnership performance and growth.

Information immutability is a characteristic of data reliability whereby the deletion, or modification, of information shared on the blockchain cannot be arbitrary. Changes requiring mandatory consent of all participants can become time-consuming. Thus, this aspect should be thoroughly evaluated in terms of securing information reliability. It becomes more difficult to rapidly respond when some of the planning and/or execution information needs to be changed because of an exception in an SC. This reflects the fact that information immutability has a positive impact on the SC partnership growth, but not on partnership efficiency.

Lastly, partnership efficiency has a negative impact on SC performance when BCT is applied. Whether BCT-enabled partnership efficiency contributes to SC performance is controversial. BCT is a new technology with distinct technical benefits, but there may be questions on whether it can accommodate all of the necessary collaborative activities such as exchanging opinions and decision-making between buyers and suppliers. When an exception occurs, it is necessary to exchange various opinions and make quick decisions. This cannot be achieved solely through the connectivity and reliability of BCT; instead, SC partnership efficiency might become an obstacle. On the one hand, that BCT-enabled SC partnership can be expected to operate with efficiency and grow is the current prevailing opinion. On the other hand, BCT as a new technical platform needs to be supplemented with more detailed functions or processes to help improve SC performance.

6. Conclusions

This study investigated the impact of BCT application on SC partnership and performance. The blockchain—a recent IT platform—has been mainly applied in electronic money markets. Its application to SC collaboration is expected to be useful because of BCT attributes such as information transparency, information immutability, and smart contracts.

In this study, for partnership growth, all BCT attributes demonstrated positive effects. For partnership efficiency, only information transparency and smart contracts displayed positive effects, whereas information immutability did not. Among the SC collaboration capabilities based on BCT, partnership growth has a significant impact on both SC financial and operational performance. Interestingly, partnership efficiency has a negative impact on both performances.

This study's findings are expected to deepen our understanding of BCT design and application through collective opinions of SC system managers from various industries. Moreover, they illustrate future research avenues of BCT application with respect to BCT-enabled partnership efficiency for desirable SC performance and BCT application design. IT development has been effective in improving efficiency, speed, and accuracy in various fields. BCT is also expected to play an important role in the overall SC performance improvement over the long term in the area of SC collaboration. However, technical means such as BCT can hardly replace all the work done by human intervention in the short term. If a BCT application is implemented in SC collaboration processes at a high cost, BCT technology attributes may become a disruptive factor in a situation wherein rapid joint decision-making is required because of an exception in an SC. Therefore, future research could explore other antecedents to partnership efficiency and growth management that might enhance coordination or inter-organizational capabilities. This knowledge may help us understand under what context operational and financial performance may improve. Managers should thus closely examine the elements to be implemented within SC collaboration before employing BCT.

Author Contributions: All authors contributed equally to the research presented in this paper and to the preparation of the final manuscript.

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

Appendix A. Measurement Instrument

These items measure your firm's anticipated application of blockchain technology with your supply chain partner, and partnership- and supply chain- performance using a seven-point Likert-type scale to indicate the extent to which you agree or disagree with each statement as applicable to your firm: 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neutral, 5 = somewhat agree, 6 = agree, and 7 = strongly agree.

Information Transparency

TRNS1	Information transparency has become a critical element to maintain a strong partnership.
TRNS2	Our firm would be willing to make further investment in importing information transparency to facilitate communication with the partner firm.
TRNS3	"Information transparency" technology is highly applicable to our firm and may be considered to replace the current contractual relationship with a partner.

Data and Information Immutability

IMM1	Data and information immutability has become a critical element for maintaining a strong partnership.
IMM2	Data and information immutability ensures that change and removing information on a private or permissioned blockchain requires notifying the network members and follows certain agreements and approval requirements.
IMM3	Our firm can count on the partner to be sincere based on data and information immutability.
IMM4	"Data and information immutability" technology is highly applicable to our firm and may be considered to replace the current contractual relationship with a partner.

Smart Contract

SMRT1	Smart contracts in the form of digital contracts remove human judgment from transactions and rather follow pre-determined conditions including rules and penalties that are agreed upon with a partner.
SMRT2	Smart contracts have become a critical element to maintaining a strong partnership.
SMRT3	"Smart contract" technology is highly applicable to our firm and may be considered to replace the current contractual relationship with a partner.

Partnership Efficiency

PEFF1	Our firm anticipates a decrease in significant investments in resources dedicated to the relationship with the partner firm.
PEFF2	Our firm anticipates a decrease in financial and non-financial efforts in sharing relevant, timely, accurate, complete, and confidential information to the partner firm.
PEFF3	Our firm anticipates a decrease in financial and non-financial efforts in obtaining relevant, timely, accurate, complete, and confidential information from the partner firm.
PEFF4	Our firm anticipates a decrease in joint efforts in aligning benefits, risks, and costs with the partner firm.

Partnership Growth

PGRW1	Our firm anticipates an increase in growth of contractual agreement.
PGRW2	Our firm anticipates an increase in growth of trust in the inter-organizational relationship.
PGRW3	Our firm anticipates an increase in growth of commitment of both partners.
PGRW4	Our firm anticipates an increase in growth of operational flexibility.

Financial Performance

FPERF1	Our firm anticipates an increase in growth in sales.
FPERF2	Our firm anticipates an increase in growth of return on investment.
FPERF3	Our firm anticipates an increase in growth of profit margin on sales.
FPERF4	Our firm anticipates an increase in growth in market share.

Operational Performance

OPERF1	Our firm anticipates an increase in growth of service and product quality performance.
OPERF2	Our firm anticipates an increase in growth of on-time delivery of service and product.
OPERF3	Our firm anticipates an increase in growth in degree of service, product, and content variety.
OPERF4	Our firm anticipates an increase in growth of overall operations cost improvement.

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