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The Effect of Blockchain Operation Capabilities on Competitive Performance in Supply Chain Management

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Abstract: Owing to blockchain characteristics such as transparency, traceability, and disintermediation, blockchain technology has been widely employed in sustainable supply chain management. The COVID-19 pandemic has accelerated the use of blockchain technology in the supply chain. Although most companies have realized the importance of blockchain technology, they often lack understanding of how to plan, measure, cultivate, and improve their own blockchain operation capabilities. Academic research has insufficiently explored the connotations and internal structure of blockchain operation capabilities and does not provide a clear understanding of how to transform blockchain operation capabilities to produce effective performance. In this context, we proposed a concept of blockchain operation capabilities for first time. We took the perspectives of the resource-based view and sociomaterialism theory, based on IT capabilities, big data analysis capabilities, and existing blockchain supply chain research, and explored the relationship between blockchain operation capabilities and competitive performance. We then constructed a hierarchical model for blockchain operation capabilities. To test our proposed research model, we used an online survey to collect data from 1206 firm managers with blockchain technology supply chain experience. The results showed that blockchain operation capabilities has a positive impact on supply chain integration and competitive performance, while supply chain integration has a strong mediating effect on the blockchain operation capabilities and competitive performance relationship. Implications for research and practice are discussed.

Keywords: blockchain operation capabilities; resource-based view; sociomaterialism theory; supply chain integration; sustainable supply chain management; competitive performance

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1. Introduction

The highly globalized industrial chain has been severely disrupted by the COVID-19 pandemic. Consequently, it is necessary to promote international exchanges and cooperation for rapid economic recovery. In this context, blockchain technology (BCT) can help effectively lower the trust threshold for multi-party collaboration and build an industrial chain and ecosystem for coordinated development [1,2]. Owing its technical characteristics—distributed collaboration, traceability, and tamper-proofness—BCT promotes rapid, efficient, and credible synchronization and sharing of information in cross-border trade, reduces the trust threshold for multi-party collaboration, and guarantees liberalization and convenience.

With the emergence of a "new normal" following the COVID-19 pandemic, uncertainties in the global economy and trade and instability in global industrial and supply chains have risen sharply (Boao Forum for Asia, 2021). Nonetheless, global industrial and supply chains have begun to show signs of repair, and many countries and multinational companies have made the reorganization of the industrial and supply chains a priority. The pandemic has also prompted many companies to turn to digitalization. Multi-echelon, geographically fragmented companies compete to service consumers in today's supply chains, which are intrinsically complicated [3,4]. In supply chain networks, globalization, various regulatory standards, and a wide range of cultural and human behaviors make assessing information and controlling risk difficult [5,6]. Inefficient transactions, fraud, pilferage, and underperforming supply chains are all factors that lead to a lack of trust, demanding enhanced information sharing and verifiability. Although supply chain logistics have a simple structure in theory, they are exceedingly difficult and time consuming to maintain in practice. Particularly, with the development of enterprises and the refinement of market specialization, the connectivity between different elements in supply chain logistics has gradually become inefficient, and BCT can effectively improve the operational efficiency of supply chain logistics [7].

Sustainable supply chain management (SCM) was divided into two dimensions: social and environmental. The environmental dimension is defined as a set of management practices that integrate environmental issues into SCM to improve the supply chain environmental performance. The social dimension involves the efforts by enterprises to reduce social risks, such as human rights' curtailment, and improve their local reputation [8]. BCT can overcome the shortcomings of the enterprise resource planning system in traditional SCM and solve the problems of errors, hacking, corruption, or attacks within single point of failure, which is conducive to the sustainable development of the global SCM system [1].

The blockchain report expects the global blockchain market to increase from USD 3 billion in 2020 to USD 29.7 billion in 2025, with a complex annual increase ratio of 67.3%. The reason behind this expectation is that people increasingly require transparency in the supply chain. The value of the "Internet of Things Economy" comes from the "Internet of Things". Currently, disputes regarding BCT-enabled supply chains have attracted much attention in academia and practitioner-oriented media [9–12]. As an emerging technology product, supply chain systems supported by BCT are expected to solve supply chain problems arising in contemporary society, especially in high-risk industries related to contract and process governance, supply chain information, and/or product counterfeiting [10,13,14].

Accordingly, an in-depth discussion of the application of BCT in supply chain logistics has important, practical value. At present, most application cases of BCT are concentrated in the financial field. Treble Maier [15] and Wang et al. [16] pointed out that there is little literature on BCT and SCM, and called for a systematic investigation based on inter-organizational theory to understand the broader impact of BCT on the supply chain. Our study is a response to their call for more BCT research in the supply chain context.

Manufacturing, electricity, maritime logistics, food, and agriculture are the most promising non-financial applications of blockchain supply chains. For example, Maersk and IBM developed TradeLens, a blockchain-enabled transportation solution, while Walmart used Hyperledger Fabric to provide unprecedented transparency in the food supply chain. These are areas that are well-suited to blockchain. In the early stages of blockchain development, these industrial-use cases were thought to deliver a real return on investment [17].

However, research on the commercial value of information system (IS) investment has reported mixed results, leading to the so-called "IT production paradox". Some scholars believe that IS investment does not necessarily improve operational efficiency or effectiveness [18]. The transaction security achieved by blockchain through its property of immutability must be reinforced by reliable transaction data. However, whereas BCT can guarantee the reliability and immutability of the data on the chain, it cannot guarantee the reliability of the inputted data. Flaws and problems in the data source itself can pose insuperable problems for the blockchain, subjecting BCT to "garbage in, garbage out" problems that lead to unmet expectations; if participants remain unconvinced about the benefits of blockchain, it becomes difficult to achieve transparency or trace good processes [1,2,10]. Blockchain realizes a fair intervention of information and data through decentralized accounting, but privacy concerns due to excessive transparency increase the security risks. Therefore, how to evaluate a firm's blockchain operating capability (BCOC) has become an important research issue, as it can help determine whether the firm can rely on BCT investment and obtain performance returns, thereby improving its competitive performance (CP).

In terms of information technology (IT) investment, a potential framework for strengthening the conceptual analysis of the impact of IT on firm performance is the resource-based view (RBV), which combines organizational performance with firm-specific, rare, difficult-to-imitate, or substitute resources linked to skills [19]. The RBV is currently the dominant theory in the strategic management literature, focusing on company attributes that are costly to replicate and that are seen as the basic drivers of performance [19,20]. From a resource-based perspective, researchers believe that—since investment in IT can easily be copied by competitors—IT investment by itself cannot provide any sustained advantage. On the contrary, how companies use their investments to create unique IT resources and skills determines the firm's overall efficiency [21,22].

Therefore, this article will integrate RBV into research on the business value of BCT-based SCM to expand research on BCOC. At present, much related academic research has been conducted on IT capabilities [23,24] and big data analysis capabilities [25,26]. However, most of the literature on BCT in the supply chain still focuses on the use of methods and concepts, and there is little research on BCOC and its impact on performance. We found that the original IT capability structure model is not suitable in the BCOC context. In this regard, we have made improvements to the original bases of IT capabilities and big data analysis capabilities to make it more convenient for enterprises to implement blockchain operation management. In this paper, we intend to expand this research stream by examining the factors that improve firms' CP in relation to BCOC.

Therefore, this research integrated relevant literature on IT capabilities, big data analysis capabilities, and blockchain supply chains; determined the constituent elements of blockchain operational capabilities; and demonstrated how they affect supply chain performance through the RBV. More specifically, the research aimed to study the following research questions: (1) How should BCOC be measured? (2) Is the overall use of BCOC linked with CP? (3) Does supply chain integration (SCI) play a mediating role in the relationship between BCOC and CP?

We examined these research issues through the perspectives of the RBV and sociomaterialism theory. We believed that these two theories can help us develop appropriate research structures and gain insight into the concept of BCOC. RBV proposes that a firm's ability originates from its nature as a social organization, while sociomaterialism theory suggests that the social and material aspects are intimately and inseparably entangled or connected with each other in organizational life. Kogut and Zander assert that a firm's competencies stems from its nature as a social organization and a firm's competencies are critical to achieving the desired results from its resource base [27]. A firm's resources determine its capabilities, which in turn affect its sustainable competitive advantage [28]. Accordingly, we used the literature on SCM, IT capabilities, and big data capabilities to identify BCOC.

The remainder of this paper is organized as follows. Section 2 covers the theoretical background of BCOC, SCI, and CP, and proposes the research models and hypotheses. Section 3 explains the research methodology. Section 4 discusses the results of the empirical analysis, and the last section summarizes the academic and management implications and provides some suggestions for future research.

2. Theoretical Background and Hypothesis Development

2.1. BCOC and Competitive Performance

In the 2019 Global Blockchain Survey, Deloitte asked global managers about their attitudes toward blockchain investment. Of the participants, 86% agreed with the important role of blockchain in supporting new businesses and revenue streams. In addition, the survey found that 77% of the managers believed that if blockchain is not adopted, their firm would lose its sustainable competitive advantage (n = 1386 companies). This is because blockchain can protect the sensitive information of participants by using public and private keys. Institutional intermediaries are prone to centralized data manipulation, have high transaction costs, and decrease transaction efficiency [29,30]. Blockchain may assist in the recording of participants' credit and inventory histories, which can speed up the delivery of funds/loans from financial institutions [31]. This type of smart contract can ensure the supply chain's stability and long-term viability. Another significant benefit of blockchain transactions is their speed. Banking managers and policy makers are researching the blockchain ecosystem to make better judgments about resource allocation and the creation of new blockchain services [32]. When addressing the Walmart–IBM feasibility project, Keshetri pointed out that the project employs BCT to track food items in the United States and China [10]. Blockchain technologies have shortened the time it takes to track food from days to minutes, resulting in financial and sustainable development advantages for both companies [14].

Michelman discussed the commercial value of blockchain and proposed two cost advantages: (1) reduced costs related to transaction auditing and verification, and (2) reduced exchange costs as a result of not having to rely on expensive intermediaries to transact business between parties. The study links these business advantages to the blockchain's fundamental features, including its capacity to safely record and mark all transactions in every block record and time-stamp all transactions in each block [33].

These aforementioned reports and literature highlight the potential interest and perceivable benefits of firms wishing to invest in the technology. However, several researchers have approached this problem skeptically to conduct a more comprehensive evaluation of the technology.

Dobrovnik [34] conducted a pragmatic study of blockchain reformation in logistics, presenting the essential features of blockchain and posing the issue, "Is technique greater than existing practice?" The author used Iansiti and Lakhani's [35] methodology to leverage innovation and coordination to better grasp the organization's actual value potential. The study concluded that, under conditions of operational efficiency and lower transaction expenditures, blockchain may produce considerable savings, but major challenges must be overcome prior to the technology being used in main river applications [36]. Several studies have also pointed out that there are currently many obstacles to the completion and popularization of BCT in the supply chain [1,2,37,38].

Therefore, the present study argues that before deciding whether to invest in the blockchain supply chain, an organization needs to objectively evaluate its own BCOC as well as that of its partner companies. We believe that only companies with excellent BCOC can benefit from investment in BCT-based-SCM.

To research BCOC and CP, we used the RBV to construct a model. Previous research on IT commerce value explored the influence of IT input on tissular performance, especially on the enterprise [39]. To explain the relationship between IT and its economic value, researchers have recently relied mostly on the RBV as their chief academic frame. According to the RBV, a competitive edge results from the united blends of economically valued, limited, and hard-to-copy resources. The resources are dispersed among companies, and their inherent characteristics—path subordination, causal ambiguity, and embeddedness—allow them to serve as a gangplank for a competitive edge. Competence in mobilizing and arranging IT-based resources is a provenance of competitive edge [24,40]. The company's RBV shows that having the necessary resources can enable the company to create a competitive advantage and improve performance. The RBV's view helps companies formulate effective strategies to achieve their strategic goals and achieve a sustainable competitive advantage [40]. Therefore, we proposed the following hypothesis.

Hypothesis 1. *BCOC is positively associated with CP.*

2.2. SCI and Competitive Performance

Extensive research has been conducted on the relationship between SCI and action [41–43], and a meta-dissection by Leuschner et al. [44] detected a pivotal relationship between the two. Supply chain integration is a multifaceted notion, with each dimension having a varied effect on enterprise behavior. Flynn et al. [42] divided SCI into three aspects: supplier integration, enterprise internal integration, and customer integration. In terms of strategy, actions, and procedures, supplier integration refers to the implementation of collaborative operations between firms and important providers [45]. Many studies have shown that supplier integration can improve enterprise production flexibility by promoting information sharing between enterprises and suppliers, optimizing enterprise production processes, and lowering product costs [46,47]. Internal integration promotes synchronization and collaboration in firm decision making, practice, and behavior by focusing on cross-functional operations within the firm. Companies that prioritize internal integration are better able to respond to external changes and gain a sustainable competitive advantage by increasing their flexibility. As a result, some scholars consider internal integration to be a prerequisite for SCI [48,49], playing a positive role in enhancing firm performance. Finally, customer integration refers to sharing key customer information in order to better understand customer needs and serve customers. Customer integration can successfully decrease the risk posed by demand uncertainty while also improving the firm's performance through positive interactions with customers [47]. Customer integration, however, pays more attention to the relationship between firms and customers and meeting customer needs, and has no substantial impact on production costs, inventory turnover, or other operational performance parameters [50].

In summary, scholars have conducted extensive empirical research on this topic, but their conclusions have differed widely due to differences in research methods, contexts, and the selected variables. Based on the comment of the literature, we believed that integrating various dimensions of the supply chain is beneficial to CP improvement from the perspective of a larger sample space and a longer time horizon.

Therefore, we posited:

Hypothesis 2. *SCI is positively associated with CP.*

2.3. BCOC Dimensions

In order to explore the components of BCOC, we first referred to research on IT capabilities [24] that divides IT functions into three levels: physical, human, and organizational. IT, like marketing and research and development, is a stand-alone organizational function. As a theoretical foundation, most IS studies rely on Grant's [51] or Barney's [52] taxonomy of organizational resources. These taxonomic schemes are similar in that they similarly posit physical, human, and organizational components, despite their differences in terminology [22].

In terms of big data analysis capabilities, Wamba reviewed previous studies on big data analysis capabilities, finding three main components, namely, management, infrastructure, and personnel capabilities [26]. McAfee and Brynjolfsson [25] proposed personnel management, technical infrastructure, and firm decision making as the key functions of various firms in the data economy.

Based on IT and big data analysis capabilities, we reviewed the relevant literature on the blockchain supply chain. Saberi [1] and Lohmer [2] discussed the role of blockchain in sustainable supply chain and operations management as well as the various barriers confronting it as presented in the literature. Saberi [1] and Lohmer [2] divided the barriers into intra-organizational, inter-organizational, external, and system barriers. Concerning the barriers within and between firms, these are mainly difficulties associated with the BCT supply chain in terms of investment, communication, coordination, organizational culture, and trust. We believe that how a firm overcomes various difficulties in the use of BCT is representative of its ability.

Through this literature review, we concluded that the main differences among BCOC, IT capability, and big data analysis capability lie in the fact that BCOC pursues data transparency and authenticity when inputting data; therefore, we believe cooperative relationships and trust between firms to also be very important. The smooth use of BCT logistics not only depends on the system of internal cooperation within the organization, but also requires perfect cooperation between the organization's external environment and the upstream and downstream enterprises of the supply chain. Moreover, according to sociomaterialism theory, we know that the social and material aspects are entangled or connected with each other in organizational life and that they are inseparable and related. Sociomaterialism theory suggests that organizational (i.e., IT management), physical (i.e., IT infrastructure), and human or social (e.g., skills and knowledge) dimensions are interlinked and it is difficult to measure these dimensions separately [53]. Thus, this study proposes BCOC as a third-order, hierarchical model manifested via three second-order constructs—intra-organization management capabilities, external management capabilities, and BCT managers' multi-skilling—and 10 first-order constructs: blockchain planning, investment, organization culture, trust, coordination, compatibility, business knowledge, modularity, technology management knowledge, and relational knowledge (see Table 1). Below, we discuss the three second-order dimensions.

2.3.1. BCOC Intra-Organization Management Capabilities

Plan: A key element in the implementation of any supply chain practice. However, many managers lack long-term commitment and support for adopting new technologies and adhering to sustainable values. Lack of management plans can hinder the integrity of sustainable development practices through supply chain processes [54]. The lack of management planning in the supply chain challenges resource allocation and financial decisions [1,2].

Investment: Acceptance of BCT requires investment in new hardware and software for information collection, which is expensive for organizations and network partners [1,2]. The energy consumption in a blockchain-based system is very high, and it does require sufficient infrastructure and initial capital investment [34,55]. Therefore, investment capability is very important in organizations.

Organizational culture: BCT is an information technology that can be destructive [56] and, therefore, requires a change in or replacement of the old system [55]. Switching to a new system may change the organizational culture or hierarchy and lead to resistance and hesitation from individuals and organizations [57]. A good organizational culture with a good belief and shared spirit can more easily overcome the changes effected by the BCT.

2.3.2. BCOC External Management Capabilities

Compatibility: Owing to the lack of common standards, various blockchains cannot work together (Deloitte Blockchain Survey, 2018; PricewaterhouseCoopers Blockchain Survey, 2018). Studies reveal that the flexibility of the information technology infrastructure is reflected by the enterprise's intra-organizational and inter-organizational system functions for compatibility, which makes it possible to exchange and remove information and data, regardless of the system or technology [24,26].

Coordination: At the beginning of BCT logistics, it was very difficult to reach a consensus between the upstream and downstream industrial chains. The use of blockchain will increase the logistics' costs of enterprises and also involve staff training. Excellent coordination among enterprises can rapidly popularize BCT logistics among supply chain enterprises [1,2].

Trust: Complete trust and transparency of data may be the possible obstacles, and it is difficult to share valuable information in real time [26]. Similarly, data manipulation in SCM networks may be a major problem [58]. Although the use of BCT provides each participant in the supply chain network with an opportunity to verify transactions, collusion is still possible through the consensus of the participants [56]. Data security and privacy issues are also challenges when using BCT [55]. A good internal trust atmosphere can help organizations and individuals avoid the loss of economic benefits caused by knowledge sharing [59].

2.3.3. BCT Managers' Multi-Skilling

As BCT-based SCM involves many cross-border activities, multiplicity of skills is preferable to depth of skills. When faced with a dynamic and highly uncertain environment, companies increasingly rely on managers with multiple skills to handle multiple tasks flexibly [60,61]. Thus, multiskilled managers represent the ability of SCM. Therefore, in this study, we identified multiple skills as an important aspect of BCOC.

When constructing a BCOC, the human factor is the core factor. As intangible assets, human factors are difficult to imitate or substitute. These manages' skills are embedded in business processes and activities; hence, they are not easy to transfer. For example, when communicating and cooperating with cooperative enterprises and facing government laws and regulations, BCT management, professional knowledge, and business and communication knowledge are required. Therefore, we believe that the breadth of knowledge as a manager is more important than the depth of expertise; multi-skills are also intangible assets required for internal and external integration. We recommend that members of the organization possess different skills and knowledge to enhance BCOC. The basic qualities required for members of an organization are listed below.

Business knowledge: Business operations should be able to meet emerging challenges. A BCT manager should be familiar with business issues to develop appropriate BCT-based SCM solutions according to business changes [1,34]. For example, when implementing BCT visualization technology on the client side, popularization of applications among customers and increasing customer stickiness require BCT managers to propose corresponding solutions.

Module: The coding process and vulnerabilities are the main problems of blockchain-based systems [62]. Effective system design requires BCT managers to add, delete, and modify BCT systems or software components to ensure the smooth operation of BCT logistics.

Technical management knowledge: Multiskilled managers are not necessarily required to possess a technical background, but they require knowledge of technical management, including planning, deployment, and operation [1]. This can guide technical professionals with programming capabilities to better serve businesses.

Relational knowledge: Relational (or interpersonal) knowledge is the ability to communicate and collaborate with people from different business functions [24]. In the early days of BCT logistics' building, it was difficult for companies to cooperate, owing to corporate confidentiality issues [1,2]. However, the transparency of BCT logistics necessitates the disclosure of information by all large- and medium-sized enterprises in all supply chains, making the supply list of all enterprises public. This may threaten the survival and development of small- and medium-sized companies. Moreover, in the face of strict governmental supervision, timely communication is also necessary. Therefore, we think that relationship knowledge is also crucial for a BCT manager.

2.4. The Mediating Effect of SCI

SCI refers to a firm's level of strategic collaboration with its supply chain partners, as well as its cooperative management of intra- and inter-organizational processes, which results in an efficient and effective flow of goods, services, money, information, and other items to final customers at a low cost and high speed, thereby increasing their value [63,64]. It entails forging strategic alliances with supply chain partners [65,66]. Pagell considers it to be the core of the SCM philosophy, and Horvath considers it the most important aspect in generating value for the entire supply chain [67,68].

Although the relationship between BCOC and SCI is an important research topic, there is no conclusive evidence as to whether BCOC directly contributes to firm SCI; in fact, the exact nature of the relationship between BCOC and SCI remains unclear. IT capability refers to a firm's ability to mobilize IT-based resources to gain a competitive advantage [23]. IT functions enable firms to disseminate useful information effectively in all relevant functional areas [69]. As far as the supply chain is concerned, some of the positive features of BCT include speeding up transaction approval through a decentralized consensus mechanism, the ability to track transaction history, instant information access, and data security, which together greatly enhance the supply chain's integrative capabilities. For example, a firm can simply use the public blockchain network to execute and settle financial transactions, thereby making use of the blockchain network for faster transaction approval. However, another firm may use secure smart contracts on the blockchain network to purchase the required products automatically. Other companies with advanced blockchain supply chains may have a private blockchain network that integrates information systems and smart devices in their supply chains. Some companies may also use complex smart contracts to exchange business-critical information and cooperate with their suppliers [9,10]. The integration of information and operations between buyers and suppliers using BCT reduces the uncertainty caused by changes in orders, fluctuations in demand, and fluctuations in delivery time. The results of previous research showed that the use of BCT directly promotes SCI and indirectly improves supply chain performance [1,2]. However, we believe that only excellent BCOCs have these functions. An excellent BCOC can reduce input data errors and increase the transparency and traceability of the supply chain, which can greatly enhance the integration capabilities of the supply chain to enable the upstream and downstream industrial chains to execute strategic cooperation more smoothly. At the same time, an excellent BCOC is centered on multiskilled managers and employees, can create a flexible BCT logistics' infrastructure, guide people to quickly and fully deploy, coordinate and integrate BCT logistics' infrastructure components, allocate and manage various resources (including hardware, software, data, and network), and improve the management process of BCT logistics. These processes are critical for SCI and competitive performance. This includes making strategic decisions, managing processes within and between organizations, and providing support resources. They may have more experience in SCI activities, and their functional background may affect managers' behavioral preferences. For example, managers with sales and marketing knowledge may be more sensitive to changes in demand. People with experience in purchasing and marketing functions may have a better understanding of customers and suppliers, which will promote customer integration and suppliers' integration. Those with knowledge in operations and R&D may pay more attention to technology development and product design, which can promote firm internal integration.

Therefore, managers with multiple skills can better understand the processes of internal and external partners. For internal management, multiskilled managers can effectively integrate the goals and practices of different functions. They can better promote effective information exchange and manage cross-functional teams. For external integration, versatile managers have a better understanding of supplier information and customer needs. Thus, versatile managers can help maintain strategic alliances, promote communication and cooperation with suppliers and customers, and directly affect SCI, thereby improving the company's competitive performance. Therefore, we believe that an excellent BCOC can integrate the supply chain directly, then indirectly affecting competitive performance.

Table 1. Definitions of research constructs and antecedent variables.

Constructs Dimensions	Definition
Supply chain integration	Strategic capabilities that result from a firm's operations being strategically aligned with its upstream and downstream supply chain partners. Strategic capabilities enable a firm to gain a competitive edge by modifying its resource base, continuously enhancing operational capabilities, and/or bringing about change in its external environment [70,71].
Competitive performance	Competitive performance is measured through innovation, customer satisfaction, and competitive advantage [40,60].
Blockchain operation capability	Blockchain Operational Capability (BCOC) is widely defined as an organizational capability in terms of production relations, including the internal and external management capabilities of the enterprise, as well as the capability of managers' multi-skilling. The company and other companies in the supply chain should maintain a high degree of consistency to ensure the authenticity of the input data inside and outside the company. At the same time, it can reasonably use and manage blockchain resources and convert them into performance [1,2,10,24].
Intra-organization management capabilities	Intra-organization management capabilities are a prerequisite for external integration [72], which represents the advanced stage of SCI [73].
Planning	The level at which BCT deployment and use planning is organized using formal and informal methods [1].
Investment	The level at which formal and informal procedures are used to frame investment decisions concerning BCT resources [1].
Organization culture	Employee behavior patterns are shaped by organizational culture, which is defined as the common ideas and values that exist inside the firm [74,75].
External management capabilities	External management capabilities refer to how well a firm understands and interacts with its clients (customers and suppliers) to establish inter-organizational strategies, common practices, and procedures in order to meet their demands [42].
Trust	An atmosphere of trust within the organization [1].
Coordination	Based on the blockchain, from order entry to order follow-up, a firm's operational skills enable it to manage transaction-related operations with its functional units and supply chain partners [76–78].
Compatibility	Ability to communicate a variety of forms of data and information, independent of the technical foundation in blockchain [1,24].
BCT managers' multi-skilling	Professional skills or knowledge in managers that qualify them for a variety of functional positions and activities [79].
Business knowledge	Managers' knowledge about several firm activities and the business environment [24].
Modularity	Adding, removing, and modifying BCT system or software components is possible [24].
Technology management capabilities	Managers' understanding of BCT resource management [24].
Relational knowledge	The capacity of managers to interact and collaborate with personnel from a different firm or IT functions [24].

Therefore, we posited:

Hypothesis 3. *BCOC is positively associated with CP and mediated by a positive effect on SCI.*

Therefore, based on the BCT and SCI arguments proposed in the literature, we proposed the following hypotheses and research model (Figure 1).

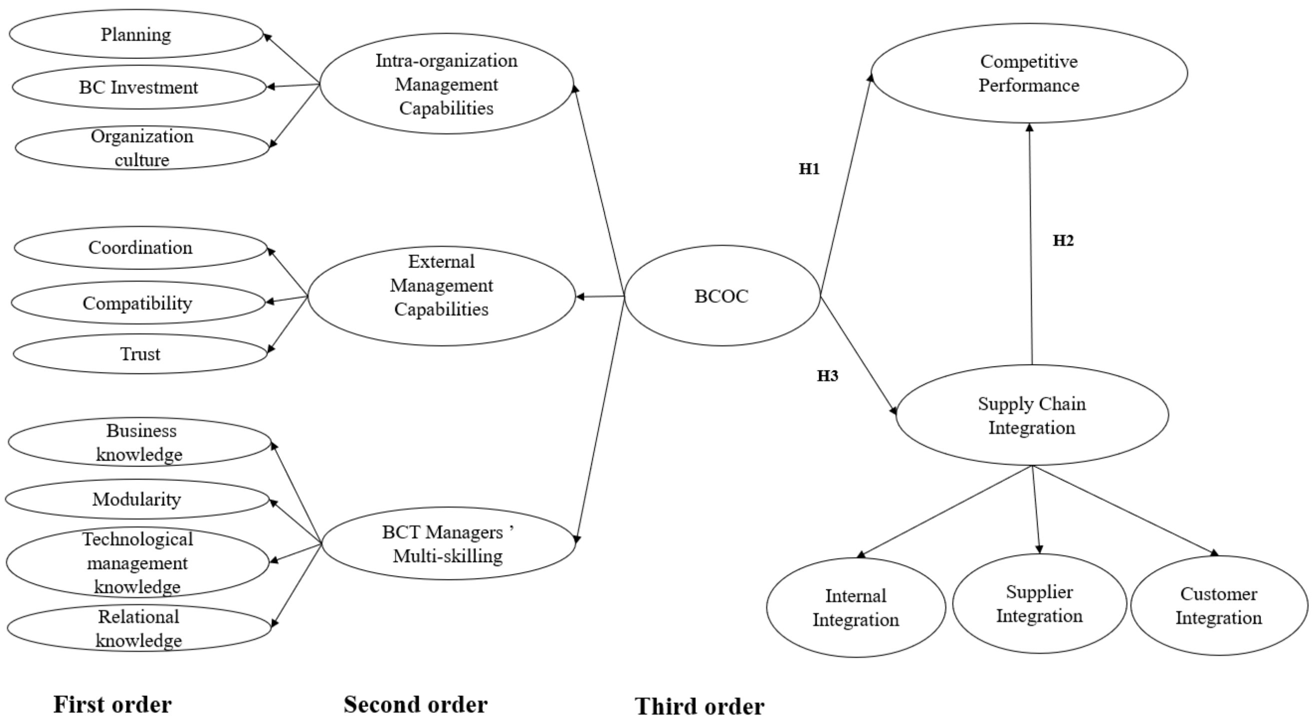

Figure 1. Research model.

3. Research Methodology

This study employed positivist research methodologies, assuming that the world of phenomena has an objective reality that can be expressed in causal relationships and measured in data, to determine the BCOC through inquiry, thereby resolving the research problem and mastering the objective and social realities [80]. In order to establish the extent of the BCOC impact on CP and the mediating role of SCI in the relationship between BCOC and CP, we conceived a research model using partial least squares (PLS)-based structural equation modeling (SEM) as the basis for our investigations.

Survey, Scaling, and Sampling

This study employed a questionnaire-based survey method, which can help capture the causal relationship between structures and provide a general statement about the research environment [81]. Furthermore, surveys can be used to reliably capture norms, detect extreme data, and clarify the relationships between variables in a sample [80,82]. To guarantee that the results are correct, it is also recommended to research explanatory and predictive ideas, as this increases the likelihood of generalizability. This study used a formerly launched, multi-item scale with good psychometric features as a questionnaire (see Table 2). A 7-point Likert scale (*strongly disagree* to *completely agree*) was employed to measure all model constructs. Cross-sectional surveys were conducted to gather information and examine the research models. The data gathered contained three parts.

First, we circulated our questionnaire in Chinese. Since the scales were originally in English, each item underwent a translation–back translation process [83]. Some items were first translated by a management professor, and the items were measured in the current study in Chinese; subsequently, another professor translated the Chinese version of the questions into English.

A multilingual management scholar was also tasked with reviewing the Chinese and English versions of the questionnaire and making any required adjustments to rectify discrepancies. Furthermore, five graduate students and three professors pretested the questionnaire before the main study, paying close attention to question substance, wording, sequence, structure and layout, question difficulty, and instructions [84]. We observed the respondents during this pre-test to check how they reacted to the questionnaire and how they felt about it. We made modest changes to the questionnaire based on the difficulties they reported.

A pilot study was conducted prior to the main investigation to ensure that these measures were useful and dependable. Only those with experience in the blockchain supply chain were requested to participate in the survey. A total of 48 useful questionnaires were collected, indicating their validity and reliability.

The final items utilized in the questionnaire, as well as their sources, are listed in Table 2. In this study, we focused on a few Chinese enterprises that use BCT logistics and cooperated with the JD BaaS (Blockchain as a Service) platform, but these methods are not exclusive to China and are adaptable to other countries. We believe our findings can be expanded to other nations by designing research on the broad capabilities these practitioners need in BCT and avoiding the usage of culturally sensitive terminology. A major survey was conducted by an investment bank because this investment bank has information on hundreds of BCT logistics companies and the contact information of more than 50,000 IT managers. Then, we randomly selected 70 companies that use BCT logistics and randomly sent online surveys to more than 10,000 company managers. We received responses from 1452 people in a month. The study did not allow missing values due to the online nature of the data collection: If a specific question was not answered, the respondent was not allowed to proceed to the following question.

We also omitted replies from managers who had no prior experience with BCT logistics. Following these steps, a final set of 1206 questionnaires was included in the analysis. Males made up 54% of the interviewees, and the vast majority (almost 90%) had at least a college diploma. The demographic characteristics of the respondents, as well as the characteristics of their companies, are listed in Table 3. We also performed a chi-square test on the data received in the first 2 weeks (n = 785) and the next 2 weeks (n = 421). The result showed that, in the early and late stages of the questionnaire collection, there was no significant difference (i.e., homogeneity) between the respondents' answers to the basic data. Therefore, the non-response bias in this study was not a problem [85].

Table 2. Questionnaire.

Intra-Organization Management Capabilities	**Mean**	**SD**
Planning ([24]) (α = 0.926; CR: 0.947; AVE: 0.818)	5.25	1.814
PLAN 1. We're always looking for new ways to leverage blockchain for strategic purposes.		
PLAN 2. We put in place appropriate preparations for SCM to benefit from BCT.		
PLAN 3. The BCT planning process is carried out in a methodical manner.		
PLAN 4. To better react to changing situations, we often alter our BCT plan.		
Investment ([24]) (α = 0.929; CR: 0.946; AVE: 0.778)	5.3	1.798
INVE 1. We consider and evaluate the impact of BCT investment decisions on work quality and productivity when making BCT investment decisions.		
INVE 2. When making BCT investment selections, we think about and predict how much these alternatives will aid end users in making faster decisions.		
INVE 3. We examine and assess whether BCT investments will consolidate or remove jobs when making investment choices.		
INVE 4. We consider and estimate the amount and expense of the training that end users will require when making BCT investment decisions.		

Table 2. *Cont.*

Intra-Organization Management Capabilities	**Mean**	**SD**
INVE 5. We analyze and estimate the time managers will need to spend supervising the change when making BCT investment selections.		
Organization culture ([75,86]) (α = 0.932; CR: 0.946; AVE: 0.746)	5.21	1.817
OC 1. The people I work with are open and honest with one another.		
OC 2. The people I work with are able to take criticism without becoming defensive.		
OC 3. I collaborate with the function as a group.		
OC 4. I deal with difficulties in a productive manner.		
OC 5. The people I work with are excellent listeners.		
OC 6. There is a positive working relationship between labor and management.		
External management capabilities		
Coordination ([11]) (α = 0.916; CR: 0.94; AVE: 0.798)	5.28	1.83
COD 1. Based on the blockchain supply chain, we meet with other upstream and downstream industrial chain businesses on a regular basis to address critical problems.		
COD 2. Based on the blockchain supply chain, employees from various departments attend cross-functional meetings with business personnel from other supply chain firms on a regular basis in our organization.		
COD 3. In our organization, we can harmoniously coordinate work with other upstream and downstream industrial chain companies.		
COD 4. Based on the blockchain supply chain, information is widely shared among all supply chain companies so that employees can make choices.		
Compatibility ([24]) (α = 0.915; CR: 0.94; AVE: 0.797)	5.29	1.785
COMP 1. Software programs are portable and BCT can be used on various systems.		
COMP 2. Based on blockchain, all platforms and apps are accessible through our user interfaces.		
COMP 3. Based on blockchain, regardless of location, information is transferred effortlessly across our business.		
COMP 4. For external end users, our firm provides several interfaces or access points.		
Trust ([1,87]) (α = 0.901; CR: 0.931; AVE: 0.771)	5.25	1.762
TRU 1. We rely on our supply chain upstream and downstream partners.		
TRU 2. Our supply chain's upstream and downstream partners are trustworthy.		
TRU 3. Our supply chain is secure both upstream and downstream.		
TRU 4. I believe that our partners throughout the supply chain are trustworthy, and all employees can input information honestly.		
BCT managers' multi-skilling		
Business knowledge ([24,26]) (α = 0.913; CR: 0.939; AVE: 0.793)	5.29	1.81
BK 1. Our managers have a thorough understanding of our firm's rules and plans.		
BK 2. Our managers are excellent at discussing firm issues and finding effective solutions.		
BK 3. Our managers are well-versed in business operations.		
BK 4. Our managers understand the business environment very well.		
Modularity ([26]) (α = 0.909; CR: 0.936; AVE: 0.785)	5.27	1.757
MOD 1. Managers can use BCT modules (e.g., Hyperledger, IBM) to create new systems.		
MOD 2. Managers can develop their own BCT apps using a BCT module.		
MOD 3. Managers can use BCT modules to reduce the time it takes to create new apps.		
MOD 4. Our organization's old system limits the creation of BCT apps.		
Relational knowledge ([26]) (α = 0.906; CR: 0.934; AVE: 0.78)	5.33	1.78
RK 1. Our project managers are very skilled in planning, organizing, and leading projects.		
RK 2. Our managers are extremely capable of organizing and executing tasks in a group setting.		
RK 3. In terms of educating others, our managers are quite skilled.		
RK 4. Our managers establish positive user/client connections by working closely with them.		
Technological management knowledge ([24,26]) (α = 0.923; CR: 0.945; AVE: 0.812)	5.29	1.859
TMK 1. Our managers have a keen knowledge of technical developments.		
TMK 2. Our managers have demonstrated a remarkable capacity to learn new technology.		
TMK 3. Our management team is well aware of the key players in our organization's success.		
TMK 4. Our managers understand the importance of BCT as a tool, and not a goal in itself.		

Table 2. *Cont.*

Intra-Organization Management Capabilities	Mean	SD
Supply chain integration capabilities ([42,88])		
Internal integration (α = 0.938; CR: 0.953; AVE: 0.802)	5.3	1.81
IINT 1. Integration of internal activities with enterprise applications		
IINT 2. Inventory management that is integrated		
IINT 3. Real-time search for inventory levels		
IINT 4. Real-time search for logistical operational data		
IINT 5. Real-time integration and connectivity of all internal operations, from raw material management through manufacturing, shipping, and sales		
Supplier integration (α = 0.943; CR: 0.954; AVE: 0.777)	5.21	1.783
SINT 1. Computerization level of major customer orders		
SINT 2. The level of market information sharing from our major customers		
SINT 3. The level of information exchange with our main suppliers through the information network		
SINT 4. A quick order system for our main suppliers		
SINT 5. The level of strategic partnerships with our major suppliers		
SINT 6. Stable procurement through the network from our major suppliers		
Customer integration (α = 0.946; CR: 0.957; AVE: 0.787)	5.3	1.808
CINT 1. We communicate with our consumers frequently.		
CINT 2. We receive feedback from our consumers on quality and delivery performance.		
CINT 3. Our consumers have an active role in the development of our products.		
CINT 4. We aim to be extremely sensitive to the demands of our customers.		
CINT 5. We regularly investigate customer needs.		
CINT 6. We cooperate with customers.		
Competitive performance ([60]) (α = 0.969; CR: 0.972; AVE: 0.746)	5.25	1.79
CP 1. We have lower manufacturing unit costs than our competitors.		
CP 2. We meet product specifications better than our competitors do.		
CP 3. We can deliver on time more than our competitors can.		
CP 4. We deliver faster than our competitors do.		
CP 5. We have better flexibility to change our product portfolio compared to our competitors.		
CP 6. We are more flexible than our competitors are in changing production capacity.		
CP 7. We have a better inventory turnover rate compared to our competitors.		
CP 8. Our cycle time (from raw materials to delivery) is shorter than that of our competitors.		
CP 9. We have better functions and performance compared to our competitors.		
CP 10. We launch new products in a more timely manner compared to our competitors.		
CP 11. We are more innovative than our competitors are.		
CP 12. We provide more customer support and services than our competitors do.		

Table 3. Demographic profile of respondents (n = 1206).

Dimension	Category	Percentage (%)
Education	No formal qualification	0
	Primary school qualification	2.99
	Secondary school qualification	5.97
	College qualification (diploma/certificate)	26.87
	Undergraduate degree	56.72
	Postgraduate degree (Master/Ph.D.)	7.46
Age	18–25 years old	19.4
	26–34 years old	31.34
	35–42 years old	22.39
	43–50 years old	14.93
	50 years old or older	11.94

Table 3. *Cont.*

Dimension	Category	Percentage (%)
Gender	Male	53.73
	Female	46.27
Industry	Accommodation and food service activities	2.99
	Wholesale and retail trade; repair of motors	6.53
	Mining and quarrying	2.43
	Arts, entertainment, and recreation	2.99
	Construction	7.46
	Professional, scientific, and technical activities	1.49
	Water supply, sewerage, and waste management	5.79
	Real estate activities	4.48
	Human health and social work activities	7.46
	Public administration and defense	3.46
	Manufacturing	5.50
	Agriculture, forestry, and fishing	7.47
	Education	5.97
	Information and communication	8.96
	Vehicles and motorcycles	4.48
	Financial and insurance activities	2.99
	Transportation and storage	7.46
	Electricity, gas, steam, and air conditioning supply	4.5
	Other service activities	7.59

4. Results and Discussion

This study used PLS-SEM to analyze the data. The reasons for selecting PLS for data analysis are as follows. First, this study established a theoretical model of the interaction between BCOC, CP, and SCI for the first time. No scholar previously conducted a reliable empirical analysis of this type of model nor is there sufficient literature to provide direct evidence. Based on a strong theoretical foundation, this model was exploratory in nature [89–91]. Second, the SEM in this paper contained one third-order variable and three second-order variables, and belonged to a more complex statistical analysis model [91–94]. Third, the purpose of this study was to explore the CP prediction capabilities of various dimensions of BCOC to guide BCT deployment strategies, instead of pursuing the best model parameter estimation results and the most accurate and reasonable model structure [90,91]. Depending on the link between the latent variables and manifest variables, hierarchical modeling can be done in two ways: hierarchical reflective modeling and hierarchical formative modeling. The latent variables affect the manifest variables (LVs→MVs) in the reflective model, whereas the manifest variables affect the latent variables (MVs→LVs) in the formative model. The reflective construct is thought to produce its indicators, whereas, with the formative construct, its indicators are considered to be defining traits [95]. This work, therefore, used PLS-SEM to estimate the third-order, reflective BCOC model based on existing hierarchical modeling standards [96–98].

4.1. Measurement Model

To evaluate the hierarchical study pattern, PLS 3.0 [99–102] was employed to assess the parameters in the outward and inward models. For the inside approximation, PLS-SEM was used with a route weighting technique. Standard errors of the estimates were then calculated using non-parametric bootstrapping [100,101] with 5000 replications [102]. Prior to structural modeling, the estimation pattern was assessed for construct reliability, discriminant validity, unidimensionality, and convergent validity. Comprising 71 components, the BCOC pattern is a third-order hierarchical pattern with three second-order constructs and 10 main constructs. Table 2 presents a few descriptive statistics of the constructs.

Convergent validity is assessed in the subsequent sections, as are unidimensionality and discriminant validity. Convergent validity was confirmed by Anderson and Gerbing [103]. A higher-order confirmatory factor analysis (CFA) [104] was used to examine the convergent validity of each construct. In Table 4, convergent validity is demonstrated by the normal loadings of CFA, and all item loadings exceeded the 0.70 threshold [105].

Table 4. Standardized loadings of the latent constructs in the model (*** $p < 0.001$).

First-Order Constructs	Indicators	Loadings	Second-Order Constructs and Their Loadings	Third-Order Construct and Loading
Planning (PLAN)	PLAN1	0.89 ***	Intra-organization management capabilities (0.76–0.83)	BCOC (0.74–0.83)
	PLAN2	0.90 ***		
	PLAN3	0.90 ***		
	PLAN4	0.92 ***		
Invest (INVE)	INVE1	0.90 ***		
	INVE2	0.87 ***		
	INVE3	0.86 ***		
	INVE4	0.89 ***		
	INVE5	0.89 ***		
Organization Culture (OC)	OC1	0.89 ***		
	OC2	0.87 ***		
	OC3	0.84 ***		
	OC4	0.88 ***		
	OC5	0.85 ***		
	OC6	0.87 ***		
Coordination (COD)	COD1	0.89 ***	External management Capabilities (0.78–0.85)	
	COD2	0.89 ***		
	COD3	0.90 ***		
	COD4	0.90 ***		
Compatibility (COMP)	COMP1	0.90 ***		
	COMP2	0.90 ***		
	COMP3	0.88 ***		
	COMP4	0.89 ***		
Trust (TRU)	TRU1	0.89 ***		
	TRU2	0.90 ***		
	TRU3	0.87 ***		
	TRU4	0.90 ***		
Business knowledge (BK)	BK1	0.89 ***	BCT personnel Expertise (0.76–0.85)	
	BK2	0.90 ***		
	BK3	0.87 ***		
	BK4	0.90 ***		
Modularity (MOD)	MOD1	0.88 ***		
	MOD2	0.89 ***		
	MOD3	0.89 ***		
	MOD4	0.88 ***		

Table 4. *Cont.*

First-Order Constructs	Indicators	Loadings	Second-Order Constructs and Their Loadings	Third-Order Construct and Loading
Relational knowledge (RK)	RK1	0.85 ***		
	RK2	0.89 ***		
	RK3	0.89 ***		
	RK4	0.90 ***		
Technological managementknowledge (TMK)	TMK1	0.89 ***		
	TMK2	0.91 ***		
	TMK3	0.90 ***		
	TMK4	0.90 ***		
Internal integration (IINT)	IINT1	0.89 ***	Supply chain integration (0.78–0.87)	
	IINT2	0.89 ***		
	IINT3	0.90 ***		
	IINT4	0.90 ***		
	IINT5	0.90 ***		
Supplier integration (SINT)	SINT1	0.88 ***		
	SINT2	0.90 ***		
	SINT3	0.89 ***		
	SINT4	0.89 ***		
	SINT5	0.88 ***		
	SINT6	0.86 ***		
Customer integration (CINT)	CINT1	0.87 ***		
	CINT2	0.90 ***		
	CINT3	0.89 ***		
	CINT4	0.89 ***		
	CINT5	0.90 ***		
	CINT6	0.89 ***		
Competitive performance (CP)	CP1	0.85 ***		
	CP2	0.85 ***		
	CP3	0.86 ***		
	CP4	0.87 ***		
	CP5	0.87 ***		
	CP6	0.87 ***		
	CP7	0.87 ***		
	CP8	0.86 ***		
	CP9	0.87 ***		
	CP10	0.87 ***		
	CP11	0.89 ***		
	CP12	0.84 ***		

We used four criteria to ensure that the measurement model was unidimensional. First, increased internal consistency aided the unidimensionality (i.e., loadings > 0.70, $p < 0.01$) of the items under each construct [100]. Second, Cronbach's alpha, which exceeded 0.70 for all structures, was used to establish unidimensionality [106]. Third, the average variance extracted values (AVEs) of each construct were >0.50, a good indication of unidimensionality [107]. The observed items explain more variance than the error terms, as indicated by the higher AVEs. Finally, the fact that the composite reliability(CR) of each construct was above the 0.80 cutoff value supports unidimensionality [108]. As CR puts first items based on their dependability in assessing survey models, it is the most powerful indicator of a construct's inward conformance [109].

We also checked whether the chief element was responsible for most of the diversity interpreted to rule out the ordinary approach prejudice [110]. The first factor was responsible for 61% of the overall diversity; the consequence is a bit soaring, implying the probability of an ordinary approach prejudice. Nevertheless, the relationship matrix (Table 5) showed that the most-soaring inter-construct relationship was 0.84, and exceptionally high correlations are usually indicative of the common method bias (r > 0.90) [111]. Consequently, ordinary approach prejudice was not a significant issue in our research, and we employed collinearity diagnostics for constructs to assess multicollinearity. The permissible cutoff value (VIF < 5) common in the literature [112] exceeded the collinearity indicator (variance inflation factor, VIF), which indicated that multicollinearity was not a problem in this research. Finally, we estimated the goodness of fit, $\sqrt{0.74 \times 0.85} = 0.79$, following Tenenhaus et al. [113], for PLS path modeling, and the results showed that the model had adequate goodness-of-fit, $\sqrt{\overline{communality} \times \overline{R}^2}$, as it exceeded the criterion of 0.36 suggested by Wetzels et al. [98].

Table 5. Inter-correlations of the first-order latent constructs.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. BK	**0.89**													
2. CINT	0.784	**0.887**												
3. COD	0.757	0.738	**0.893**											
4. COMP	0.741	0.801	0.74	**0.893**										
5. CP	0.78	0.821	0.721	0.766	**0.863**									
6. IINT	0.765	0.825	0.728	0.761	0.844	**0.896**								
7. INVE	0.805	0.785	0.728	0.754	0.743	0.745	**0.882**							
8. MOD	0.747	0.812	0.723	0.786	0.773	0.781	0.785	**0.886**						
9. OC	0.727	0.759	0.737	0.728	0.773	0.782	0.753	0.817	**0.864**					
10. PLAN	0.758	0.727	0.735	0.693	0.774	0.716	0.735	0.719	0.72	**0.904**				
11. RK	0.732	0.753	0.779	0.731	0.823	0.775	0.723	0.74	0.764	0.775	**0.883**			
12. SINT	0.814	0.818	0.77	0.776	0.835	0.808	0.751	0.754	0.745	0.768	0.802	**0.881**		
13. TMK	0.767	0.822	0.762	0.811	0.777	0.789	0.783	0.766	0.742	0.714	0.754	0.795	**0.901**	
14. TRU	0.745	0.758	0.729	0.733	0.813	0.802	0.733	0.765	0.761	0.782	0.76	0.771	0.738	**0.878**

Note: The square roots of AVE are shown by the bold numbers on the diagonal. BK–Business Knowledge; CINT–Customer Integration; COD–Coordination; COMP–Compatibility; CP–Competitive Performance; IINT–Internal Integration; INVE–Invest; MOD–Modularity; OC–Organization Culture; PLAN–Planning; RK–Relational Knowledge; SINT–Supplier Integration; TMK–Technological Management Knowledge; TRU–Trust.

4.2. Structural Model

The structural model indicated that BCOC and SCI enhanced CP with path coefficients of 0.38 ($p < 0.001$) and 0.53 ($p < 0.001$), respectively, explaining 81% of the variance. BCOC enhanced SCI with a path coefficient of 0.933 ($p < 0.001$), explaining 87% of the variance. Thus, all three hypotheses, H1 to H3, were supported, as the path coefficients were significant at $p < 0.001$. In sum, the R^2 scores for all dependent variables (CP: 81%; SCI: 87%) explained by the research model were significantly large according to the effect sizes defined for R^2 by Cohen [114] and Chin [100].

4.3. Test for Mediating Effects

Potential mediation effects were included in our proposed study paradigm. SCI may, in particular, mediate the effect of BCOC on CP. The route coefficients and standard errors of the direct paths between the (1) independent and mediating variables (i.e., $iv \rightarrow m$) and (2) mediating and dependent variables (i.e., $m \rightarrow dv$) are used to perform mediation analysis. The PLS analysis results are used to determine the extent to which a concept mediates the link between the independent and dependent variables [115]. In this study, the product of the standardized routes between *iv* and *m* determined the degree of the mediation effect of SCI (*m*) in the relationship between BCOC (*iv*) and CP (*dv*). Based on the magnitudes and variances of the pathways among *iv*, *m*, and *dv*, the standard deviation of the mediated path may be calculated. Table 6 shows the outcomes of the path analyses. Using the Sobel test, the results demonstrated that SCI mediated the relationship between BCOC and CP with a *z*-statistic of 9.83.

Table 6. Significance of mediated paths.

Indirect Effect	Mediated Path	Path Coefficient	*Z*-Value
BCOC- > CP	BCOC- > SCI- > CP	0.495	9.83 ***

Statistic is significant at *** $p < 0.001$. The standard error of the mediated path was approximated based on the formula sqrt ($b^2S_a^2 + a^2S_b^2 + S_a^2S_b^2$), where *a* and *b* are the magnitudes of the paths between *iv*, *m*, and *dv*, and S_a and S_b are the standard deviations of *a* and *b*.

5. Conclusions

The primary goal of this research was to determine the measurement structure of BCOC and examine both the direct effects of BCOC on CP and the mediating effects of SCI on the link between BCOC and CP. All of the causal relationships proposed by our model were validated by the findings. More specifically, both BCOC and SCI accounted for 81% of the variance in CP, with the mediator accounting for 56% of the variance. The amount of the indirect effect was calculated using the variance accounted for (VAF), which represents the ratio of the indirect effect to the total effect ($0.93 \times 0.53/0.93 \times 0.53 + 0.38$). According to the data, the impact of SCI on CP was greater than that of high-level BCOC structures. This shows that SCI is an important mediator, which means that CP can be improved by enhancing BCOC and SCI.

Of the dimensions of BCOC, intra-organization management capabilities (β = 0.97), external management capabilities (β = 0.96), and BCT managers' multi-skilling (β = 0.98), the discrepancies were so small that all three dimensions should be given equal weight in the construction of BCOC. The data also demonstrated a substantial positive relationship between second-order constructs and their corresponding first-order components (Figure 2). Overall, the study's nomological validity was established because the findings revealed that BCOC had a considerable favorable effect on both SCI ($R^2 = 0.87$) and CP ($R^2 = 0.81$), whereby SCI was found to be a strong mediator.

5.1. Implications for Research

Theoretically, this result has various implications for BCOC research. Firstly, this study was the first to define BCOC, and one of the first to examine the effects of BCOC on CP and SCI, as well as the role of SCI in mediating the relationship between BCOC and CP, which has contributed to the theoretical development of RBV. Secondly, different from the previous classification methods of IT capabilities [24] and big data analysis capabilities (organizational, physical, and human) [26], we used sociomaterialism theory to classify them according to organizational management capabilities, external management capabilities, and managers' multi-skills for the first time. Thus, our study contributes to the development of theory on BCOC and sociomaterialism theory and offers an integrated conceptual model. Finally, we decomposed BCOC into three constructs as given in the theoretical model (Figure 1) and showed that this method helps to clarify the linkage between BCOC and CP.

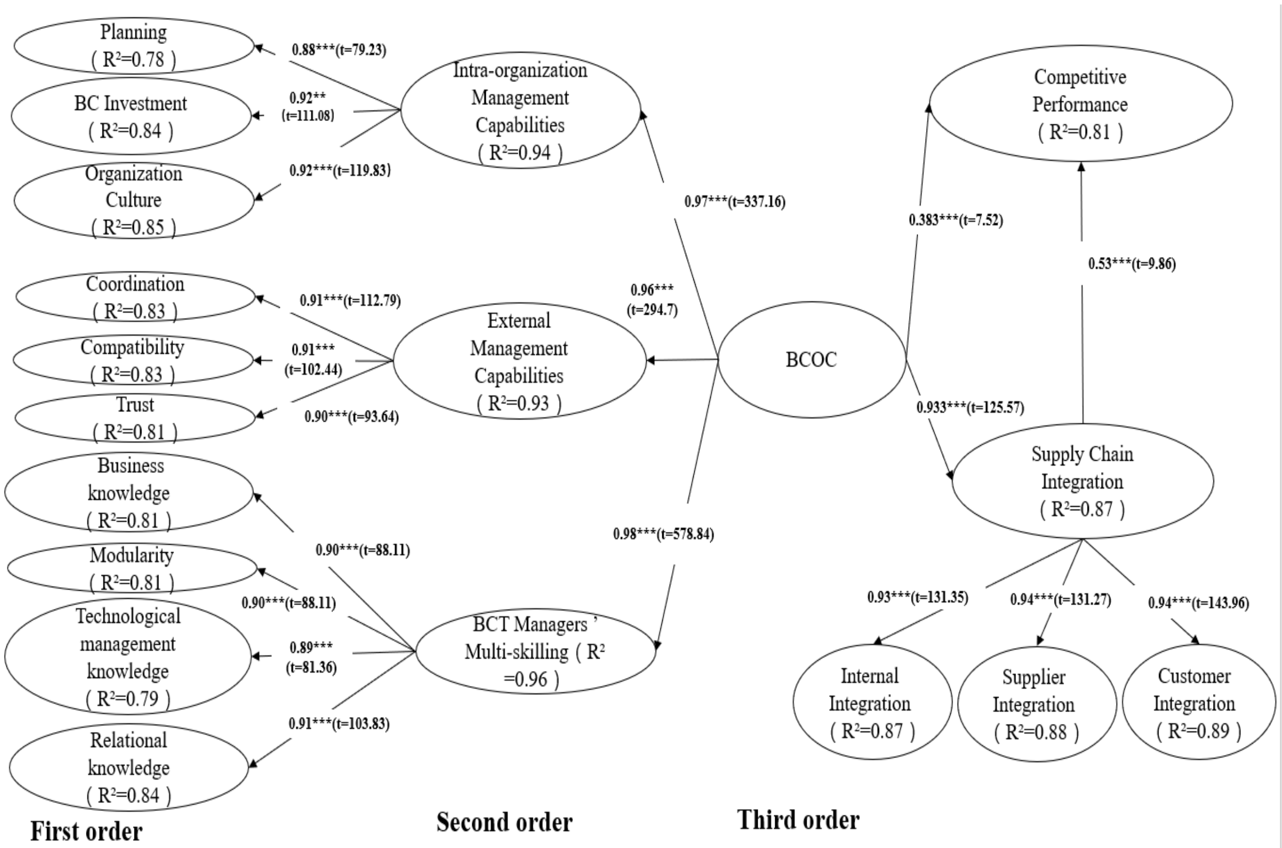

Figure 2. Structure model. Note: *** $p < 0.001$, ** $p < 0.01$.

5.2. Implications for Practice

Many of our findings can help managers and consultants who are adopting BCT in their companies. The mediating role of SCI clearly demonstrates how BCOC can function as a source of long-term, sustainable competitive advantage in uncertain circumstances. By contrast, if SCI is absent, BCOC, which may be effective in the current situation, may lose its sustainable competitive edge, because SCI requires strategic coordination among suppliers, customers, and firms.

When establishing a BCOC system, we suggest the following. (1) Planning and investment are needed within the organization to ensure the implementation of BCT in sustainable SCM, and a good organizational culture is needed to ensure the authenticity of the data input into the blockchain. (2) Outside the organization, the combination of the Internet of Things and BCT is needed to ensure real-time monitoring and solve the trust problem in sustainable SCM. Moreover, various firms must be actively coordinated to ensure transparency and traceability, and the more companies participating in the supply chain, the more valuable is the use of blockchain. Of course, this requirement is contrary to the confidentiality of institutional information. Thus, in the early stage, large companies must provide incentives to smaller companies in the industrial chain. Additionally, the compatibility of upstream and downstream industries in software systems must be ensured. (3) A firm's managers should have multiple skills, including business knowledge, technical management knowledge, modularity ability, and relationship knowledge. Only in this way can agreement be reached on technology and cooperation inside and outside of the organization.

5.3. Limitations and Future Research

Our model appears to be empirically and theoretically sound, after tests with reputable survey tools and data. Some restrictions and unsolved questions must, however, be addressed. First, the research was conducted within a single context pertaining to the unique area of BCT-based SCM. Second, according to the characteristics of the BCT supply chain, many aspects remain that need to be researched, such as the impact of BCOC on the transparency, flexibility, and robustness of the supply chain, as the transparency, traceability, and disintermediation of blockchain are its salient characteristics. Scholars can use a technology acceptance model or unified theory of acceptance and technology theory to test the use intention of BCT with each supply chain partner before using the BCT. Third, we used subjective performance measures in our study, which may be substituted with objective ones, such as the firms' BCT ranking and financial statements, for analysis of their relationship, to offer a more solid picture of BCOC's impact on CP.

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