

Article

The Implications of Artificial Intelligence for Small and Medium-Sized Enterprises' Sustainable Development in the Areas of Blockchain Technology, Supply Chain Resilience, and Closed-Loop Supply Chains

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Abstract: In today's fast-paced business settings, the metaverse as a shared marketplace has gained popularity and is helping businesses to develop crucial business strategies in their pursuit of sustainable performance. However, a lack of understanding and knowledge about the effectiveness of the metaverse and its related technologies creates a barrier. Therefore, the current study fills this gap and uses organizational information-processing theory to develop the theoretical framework to examine metaverse-related technologies (artificial intelligence and blockchain technology—BCT) and their direct and indirect effects on sustainable business performance, which no other study has examined. Using purposive sampling, the sample data from 326 SMEs were gathered and analyzed using a partial least square structural equation modeling (PLS-SEM). This study's findings revealed that AI capabilities are vital for information gathering, analyzing, and decision-making in the metaverse context. BCT facilitates ensuring a transparent, visible, traceable, and immutable supply chain, which helps make it more resilient and improves the closed-loop supply chain (CLSC) system with positive technological advancements and significant effects on increasing sustainable business performance (SBP). This study's findings help organizations understand the potential benefits of AI-enabled SMEs' presence in the metaverse. The current investigation provides a strategy for managers to gain a competitive advantage, make the supply chain more robust, and enhance overall business performance.

Keywords: artificial intelligence; metaverse; blockchain technology; closed-loop supply chain; supply chain resilience; adaptive capabilities; sustainable business performance



Academic Editor: Lijun Ma

Received: 11 November 2024

Revised: 21 December 2024

Accepted: 22 December 2024

Published: 4 January 2025

Citation: Khan, S.A.R.; Sheikh, A.A.; Shamsi, I.R.A.; Yu, Z. The Implications of Artificial Intelligence for Small and Medium-Sized Enterprises' Sustainable Development in the Areas of Blockchain Technology, Supply Chain Resilience, and Closed-Loop Supply Chains. *Sustainability* **2025**, *17*, 334. <https://doi.org/10.3390/su17010334>

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1. Introduction

The widespread use of the internet and social networking platforms has significantly advanced virtual worlds. The metaverse has created a new world offering specific properties and influencing behaviors across industries. The acceptance and diffusion of the metaverse have substantially increased due to its function of providing and enhancing the digital virtual environment experience by using potential technologies such as AI, AR, and VR. The metaverse concept gained popularity in depicting immersive virtual settings [1]. In the metaverse, individuals meet in digital spaces for diverse purposes, such as joining

classes, shopping, and contributing to social communities by introducing and using digital assistants, also known as digital avatars [2]. In the metaverse, the users engaged in various activities in digital spaces through the use of artificial intelligence (AI), the Internet of Things (IoT), augmented reality (AR), virtual reality (VR), 3D modeling, blockchain technology (BCT), and cryptocurrency [3,4]. The metaverse is gaining popularity due to enhanced customer experiences, remote collaborations, innovative marketing, new business models, and earning streams for businesses [5]. Developments and advancements in artificial intelligence are directing individuals to engage and work together in digital environments [6]. Nowadays, organizations are diffusing AI-enabled metaverse technologies to compete with e-marketplaces and potential competitors [7–9].

Furthermore, implementing blockchain technologies enhances transparency, security, and utilization of AI in providing services to businesses across various operational functions such as marketing, manufacturing, supply chain, and transaction management to improve performance and reduce costs [10]. SMEs have a vital role in the economic development of a country by contributing to exports, global business generation, GDP, and employment by 60% [11].

The dynamic business environment creates continuous challenges for SMEs. It forces them to design strategies to compete with their rivals and meet the standards and expectations of the consumers [10], but they lack the ability and knowledge to understand the evolving offerings generated by the metaverse [12]. Due to data privacy, higher risks of information theft, and targeting non-accessible systems, extensively using the metaverse is not common, and people hesitate to use it [6,9]. Though the metaverse has been gaining popularity recently, very little literature is available that uses the metaverse as a predictor of sustainable performance [6,13].

Digital transformation is rapidly shaping Pakistan's economic orientation, and modern technology adoption is becoming inevitable to stay competitive. Though Pakistan is an agriculture-based country with rapid digital transformation, various modern technologies are becoming essential to the economy. The economy is shifting, and automation, with the help of technologies like AI and BCT, big data analytics, the Internet of Things, etc., is becoming more popular [14]. These technologies serve as a strategic asset for organizations, help them improve their performance, and, most importantly, provide SMEs with competitive advantages [10]. AI adoption not only enhances demand forecasting, risk assessments, supply chain visibility due to real-time monitoring, and informed and optimized decision-making, it also improves the collaboration and communication among the supply chain partners [15]. Moreover, the governments of developing countries, with a focus on economic growth and supportive policies for digital transformation, require their manufacturing sector to adopt digital transformation in order to meet the sustainability objective [16]. The higher cost to adopt such technologies, limited budgets, and the need for an expert workforce create more challenges for the firms. However, the scarcity of empirical evidence on how SMEs can use the metaverse to achieve sustainable business performance (SBP) has not yet been explored. These emerging technologies can equip organizations with the potential to have enhanced supply chain resilience (SCR) in times of disruptions [17] and mitigate supply chain risks [18].

Supply chain resilience is the “ability of the supply chain to quickly and effectively respond to interruptions” [19]. Past studies have confirmed that artificial intelligence (AI), the Internet of Things (IoT), blockchain technology (BCT), and big data analytics (BDA) can expand collaboration and shared assistance among supply chain cohorts, resulting in improved adaptability for companies [20]. Moreover, it is evident from the literature that “AI is related to advancing supply chain performance” [15]. Similarly, past research has focused on integrating artificial intelligence (AI) and significantly accentuated its capacity

to increase efficiency. Knowing AI-driven supply chain management methods is a reliable indicator of organizational performance. However, further examination is vital to reveal the effect of AI on improving supply chain resilience [21,22]. AI can enhance SCR; however, a scarcity of literature is observed to provide evidence of AI and BCT to provide SCR and SBP. Therefore, understanding the “link between AI, BCT, SCR, and SBP is vital, and it can present valuable insights concerning how the metaverse can elaborate and attain sustainable business performance”. The current study has considered only two metaverse technologies, AI and BCT, because AI facilitates complex decision-making processes, while BCT ensures transparency and secure, tamper-resistant transactions. In the context of the metaverse, these technologies reduce manual interventions and improve performance by reorganizing processes.

A closed-loop supply chain (CLSC) has gained significance in recent times. Souza (2013) [23] described the CLSC concept as “a phenomenon where the chain looks to maintain and recover the value from returns, keeping the resource consumption and waste at minimum levels”. Integrating the forward and reverse logistics in a novel design are the crucial characteristics of CLSC [24], which includes an objective of its structure, operations, and control to increase value creation through the product life cycle [25,26]. In manufacturing SMEs, “CLSC is vital to proficiently using resources, minimizing costs, promoting environmental protection practices, meeting customer expectations, making resilient supply chains, creating innovation opportunities, and distinguishing the marketplace”. Therefore, it becomes essential to examine the impact of the metaverse, particularly AI and BCT, on providing a business model that facilitates sustainable performance. Using digital technologies to automate business operations depends on the firm’s adaptive capabilities (ACs), which support the development of the organization’s transformability, resilience, and stability [27]. AC is an organization’s ability to learn, adapt, and respond effectively to internal and external environmental changes [28]. Examining the firm’s influencing role of innovation-driven adaptive capabilities is essential to developing the metaverse (AI, BCT) capabilities and improving the SCR [29].

Maintaining a specific combination of traits that help satisfy the stakeholder’s interests for a long time is termed sustainable business performance [30]. Sustainable business performance (SBP) considers social, environmental, and economic performance from a broader perspective and at a narrow level [31]. It is achieved through operational functions an organization performs by using sufficient human resources, building relationships with its stakeholders, and meeting the expectations related to corporate social responsibilities [32]. Businesses are under continuous pressure to develop a business model that ensures a competitive advantage and meets the stakeholders’ expectations [33]. Though an abundance of literature is available on achieving SBP, to the author’s knowledge, very little is known about how the metaverse (AI, BCT) affects the relationship.

The above-highlighted research gaps highlight the investigation of the following research questions in the current study:

RQ1: What are the effects of AI capabilities on BCT, SCR, CLSC, and SBP?

RQ2: How does AC affect the interplay between AI and CLSC?

Based on organizational information-processing theory (OIPT), a conceptual framework is developed to address the above RQs and test the hypothesis. Data from 326 manufacturing SMEs were collected and analyzed using a partial least square structural equation model (PLS-SEM). Accordingly, the following are the novelties and relevant contributions of the current study. First, the intersection between AI capabilities, BCT, and the metaverse is relatively unexplored. Recently, the metaverse has been under the scholarly radar; however, its implications for enhancing sustainable performance are underexplored. So, this study provides a distinct understanding of this phenomenon. Second, SMEs are critical

contributors to generating employment opportunities and making a significant share in the economic growth of a country. However, the literature lacks empirical studies exploring SMEs' role in embracing the metaverse and taking advantage of AI and BCT capabilities to improve their performance. Therefore, recent research attempts to fill this gap, provide deep insights, and develop a roadmap for SMEs to navigate and take advantage of the metaverse, gain a competitive advantage, and enhance their sustainable performance. Third, the literature shows evidence of firms using modern technologies to develop supply chain resilience. The lack of literature using the integrated approach with AI and BCT to improve SCR and SBP motivates us to delve into this unexplored area and gain valuable insights for developing SME business strategies incorporating the metaverse to attain SCR and SBP.

This article is organized as described below. The following section explains and discusses the relevant literature regarding the underlying theory for the constructs utilized in this study. The third section presents the proposed conceptual framework for this research, with comprehensive support from the literature. The fourth part covers the research methodology used for this study. The fifth part discusses the essential findings, and the sixth part covers this study's conclusion and implications.

2. Literature Review

The current study investigates AI, BCT, and CLSC's roles in developing SCR and improving SBP with the moderating effects of adaptive capabilities. To achieve this objective, the current study adopts the organizational information-processing theory as an underpinning theory to develop the theoretical framework. The following section presents the justifications for the applicability of OIPT in building the conceptual framework to enhance sustainable business performance. Figure 1 presents the general structure of the current study.

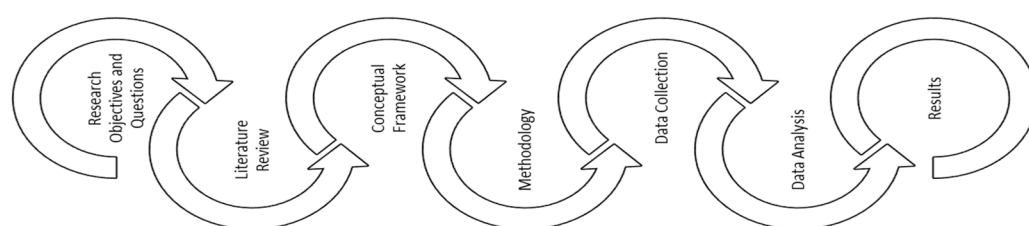


Figure 1. General framework of this study (author's own work).

2.1. Organizational Information-Processing Theory (OIPT) as Underpinning Theory

The OIPT proposes that information-processing capabilities and needs are the key predictors of firm information performance. The environmental uncertainties affect the outcomes and the relationship between the capabilities related to information processing [34,35]. As a result, developing capabilities and proactively engaging and communicating with the supply chain partners to improve the visibility and tractability of the supply chain operations becomes very necessary. The OIPT-related literature shows that the BCT is a general-purpose capability that helps unlock valuable information [36]. Implying the complementary procedures enables businesses to use new processes and explore new opportunities [37]. It is the firm's choice to depend upon automated resources and reduce its information dependence, or it can develop and improve its information-processing capabilities for improved performance. Organizations opting for automation solutions tend to schedule interconnected operations, divide the work, and use centralized decision-making [38]. They tackle complex problems using rules, organizational hierarchy, and pre-defined goals in "exceptional scenarios". However, the related costs also increase with the number of "exceptional scenarios" [39]. Therefore, firms could develop their information-processing capabilities as an alternative solution to such scenarios.

OIPT signifies that organizations develop the capabilities to meet information-processing needs. Noticeably, OIPT suggests that to sustain performance levels, organizations must take initiatives to improve such capabilities and efficiently handle the associated risks [38]. The current study conceptualizes AI as an information-processing capability that helps organizations alleviate the complexities and uncertainties of a firm's operations [35]. In addition, the OIPT framework facilitates the cultivation of these competencies to assist in effectively managing interruptions within the supply chain.

Moreover, dynamic capability view (DCV) is another theory that explains the proposed framework. According to DCV, firms evolve according to dynamic environments [40]. Firms use their resources to develop several capabilities that facilitate effective supply chain management, help develop supply chain resilience, and efficiently manage the closed-loop supply chain. DCV focuses on change and innovation to obtain a competitive advantage. Firms adopting modern technologies like blockchain technology, artificial intelligence, and big data analytics build capabilities to encounter supply chain-related matters by managing them more efficiently and improving sustainability [41].

2.2. Artificial Intelligence (AI) Capacity for Processing Data

Artificial intelligence develops the capabilities to acquire information from internal and external environments and analyze it to gain valuable insights and learnings to make new processes and plans and adapt to these environmental changes [15]. It consists of the algorithms and techniques enabling the acquisition of information from the data without knowing the consequences [42]. Though AI is not a new field, it has recently gained popularity and widespread utilization in manufacturing, operations, and supply chain management [43]. Studies exploring (robotics process automation, predictive model control, and computer vision), exploiting (includes robust optimization, big data analytics, and machine learning for addressing the cognitive information-processing shortcomings), and expanding (generation of new ideas based on machine learning) these three information-processing capabilities that are acquired due to AI systems (Haefner et al., 2021) [44].

2.3. Supply Chain Resilience (SCR)

The supply chain's ability to instantly deal with disruptive events is called resilience [19]. SCR has three phases: the first phase is the readiness phase (proactive, pre-disruption), the second phase is the response phase, and the third phase is the recovery phase (reactive, post-disruption) [45]. The outbreak of COVID-19 has caused global supply chain disruption challenges and raised concerns about the adaptive resilience capability of firms under such a disruptive event. Therefore, the AC of resilience is a learned capability acquired over time [46]. Firms that develop SCR can deliver products and services to their customers without disruption.

2.4. Blockchain Technology (BCT)

BCT is regarded as an innovation in computer science and a "super trend" that can shape a better world [47]. BCT is considered a software unit that consists of the algorithms connecting the content collections, their related encrypted data blocks, and security technology that enables the firm to maintain its integrity by providing extended transparency, visibility, immutability, and traceability [8]. The BCT-based supply chain is equipped to keep essential records of updated information related to the smart contract and ensure its visibility to all stakeholders [48].

2.5. Closed-Loop Supply Chain (CLSC)

CLSC comprises a unique forward and reverse logistics system, including the design, process systems, and control mechanisms to maximize value creation throughout the

product life cycle. Souza (2013) described the CLSC concept as a phenomenon where the chain looks to maintain and recover the value from returns, keeping the resource consumption and waste at minimum levels. Firms design ad hoc product return processes in their pursuit of CLSC [49].

2.6. Adaptive Capabilities (ACs)

Adaptive capabilities are strongly connected to an organization's strategic plans that it nurtures to respond to the rapid changes that the business faces. In a continuously changing business environment, AC enables the firm to gain competitive advantages [50]. AC is categorized into three dimensions: horizon scanning (regular information accumulation about the customers, suppliers, society, technology, and competitors) [51], change management (modification in the strategies, goals, objectives, structure, plans, and system of governance) [52], and resilience (the ability to endure all kinds of disruptions) [53].

3. Hypotheses Development

3.1. The Effect of AI on SBP

Digital transformation is making business processes easy, and organizations are adopting modern technologies to achieve their sustainability-related objectives [7]. Developing AI capabilities enhances product design, quality, customer satisfaction, and supply chain operational performance. AI-embedded technologies enabled the firms to perform better in the health sector with contingency plans and efficiently handle pandemic-related situations [14]. AI equips firms with needed information and know-how about stakeholders' expectations and helps them design supply chain management decisions to satisfy the interests of all stakeholders (Philsoophian, Akhavan and Namvar, 2022 [54]). Despite all the uncertainties, AI adoption arguably enhanced the firm's performance [55].

From the OIPT perspective, the current study proposes that AI capabilities enable firms to develop comprehensive information-processing capabilities by decrypting, interpreting, and learning from the acquired information to reduce the uncertainties related to demand and supply [38]. The dependence on human capabilities has limitations that force firms to keep certain levels of inventory [55]. AI intervention helps firms reduce carbon emissions and influence environmental performance [56]. The use of AI has several mishaps, like biases, stereotypes, and unaccountable decisions that highlight the need for governance and ethical development of AI [57]. The above arguments signify that AI adoption can potentially improve sustainable business performance. Therefore, we hypothesize the following:

H1. *AI significantly and positively affects the SBP in SMEs.*

3.2. The Effect of AI on SCR

COVID-19 has disrupted the global supply chain, and organizations have had to shift to online business to cope with the changes that occurred during COVID-19 [58]. Several organizations seriously suffer due to a lack of readiness and response to sudden changes, which demand higher SCR levels [37]. Implementing modern technologies like AI can help firms strengthen their SCR position. AI capabilities help firms identify the areas of disruption and assist firms in having better visibility of the supply chain [59]. AI equips the firm with clear inventory visibility and helps align the inventory levels accordingly [58]. AI also enables firms to analyze the exact skill sets required to mitigate uncertainties [42]. Dynamic capabilities build resistance in firms dealing with dynamic environments and reach sustainable goals [60]. The arguments mentioned above propose that AI capabilities

have the potential to track uncertainties more rapidly and make the SCR. Therefore, the following hypothesis is proposed:

H2. *AI has a positive impact on SCR in SMEs.*

3.3. *The Effect of SCR on SBP*

Previous literature on SCR provides evidence that building SCR is essential against disruption events and for maintaining the current performance levels [61,62]. A resilient supply chain develops the capability to instantaneously respond to exceptional situations, absorb the occurring changes, and track and monitor performance to meet customer expectations under uncertainty [27]. SCR has the potential to mitigate disruptions and improve performance [63]. SCR strategies like redundancy, flexibility, collaborative planning, and contingency planning facilitate the effective avoidance of supply chain disruptions, and implementing digital technologies like AI, BCT, and IoT facilitates reducing opportunistic behavior among the supply chain partners [64]. Military, perishable commodities, food, humanitarian aid, and reverse logistics are the areas severely affected by SC disruptions [65]. Another study proposed a framework and highlighted that supply chain strategies to show resilience against disruption under uncertain events help the firm preserve business performance [66]. Firms that fail to develop SCR have no choice but to entirely or partially close their business operations [45,62]. The above-highlighted arguments indicate that SCR has positive effects on SBP. Therefore, the following hypotheses are proposed:

H3. *The SCR has a positive impact on SBP in SMEs.*

H4. *The SCR mediates the relationship between AI and SBP in SMEs.*

3.4. *The Relationship of AI, BCT, and CLSC*

Smart technologies act as a critical success factor and are essential elements for developing sustainable business models [7,67]. AI creates a collaboration system by analyzing the data and providing the information to design strategies and store the data, whereas the BCT ensures the traceability and visibility of this information [68]. The AI systems can be leveraged to build security solutions to manage all stakeholders' transactions and enhance BCT's efficiency [69]. AI and BCT help build a metaverse [70]. Information quality is necessary for improved performance [71]. AI enhances BCT transparency governance. In a metaverse, AI is a cognitive intelligence required in developing or predicting the models that facilitate designing a framework to make trusted, immutable, smart contracts [72].

Next, blockchain technology is a cutting-edge financial idea that significantly impacts international trading. It enhances the efficiency of supply chains by facilitating faster and more precise financial transactions. BCT has the potential to mitigate supply chain challenges related to data fragmentation, absence of source, and regulatory complexities [73]. BCT enables supply chain management to establish trust, transparency, and trackability, enabling the firm to have more control over waste reduction and product returns [74]. Through improved trust mechanisms and immutable record-keeping, BCT facilitates redefining the roles of supply chain intermediaries, enhancing efficiency and reducing dependence on contemporary intermediaries [75]. This study proposes a complete framework for designing blockchain technology that would impact closed-loop supply chains. A closed-loop supply chain network is established with a specific focus on the financial flow facilitated by blockchain technology [76]. To enhance the efficiency of this supply chain, the objective is to maximize efficiency derived from the blockchain network. Therefore, we hypothesize the following:

H5. *AI positively impacts the BCT of SMEs in the metaverse.*

H6. *BCT positively impacts CLSC of SMEs in the metaverse.*

3.5. The Effect of BCT on SBP

Digital transformation is making firms adopt modern technologies, and BCT is a widely accepted technology through which businesses can develop sustainable models [67]. BCT is very effective in tracing and tracking the products in the supply chain and helps build the product's authenticity and trust for its stakeholders [77]. Knowledge shared through BCT becomes valuable for the SC decision-making, and trust, visibility, transparency, and security are the attributes that enhance the supply chain resilience of the firm (Philsoophian, Akhavan and Namvar, 2022 [54]). Through improved trust mechanisms and immutable record-keeping, BCT facilitates redefining the roles of supply chain intermediaries, enhancing efficiency and reducing dependence on contemporary intermediaries [75]. An investigation into BCT enables smart contracts, allowing firms to build sustainable business models that increase trust, reduce costs, increase resilience, and foster social proof [78]. The arguments mentioned above propose that BCT adoption improves the firm's performance. Therefore, the following are hypothesized:

H7. *The BCT positively impacts SMEs' SBP in the metaverse.*

H8. *BCT positively impacts SMEs' SCR in the metaverse.*

H9. *BCT mediated the relationship between AI and SBP of SMEs in the metaverse.*

H10. *SCR mediated the relationship between BCT and SBP of SMEs in the metaverse.*

3.6. The Effect of AI and BCT on CLSC

Modern applications such as machine learning, IoT, and AI are being developed as a consequence of digital transformation in the manufacturing sector, which is used to automate the systems for better communication and overcome the constraints associated with closing the loop in the supply chain [79]. In an investigation of different network typologies to understand the functions and planning strategies of CLSC, the findings highlighted that reverse ordering, transfer, inventory, and repair are significant concerns that can be dealt with using modern applications [80]. Consumer-preferred AI push was associated with profits from remanufacturing consumer products [81]. AI-based capabilities enable firms to counter the constraint and obtain better insight into resolving CLSC-related matters [56]. A study highlighted that AI techniques could enhance supply chain management and become very effective for CLSC [41]. The above-stated arguments indicate that AI techniques have a positive effect on CLSC. Therefore, the following hypothesis is proposed:

H11. *AI positively impacts the CLSC of SMEs in the metaverse.*

3.7. The Effect of CLSC on SBP

The literature is scarce about CLSC and performance. The impact of CLSC on economic and environmental performance concluded that CLSC systems need to be engineered due to the lack of economic sustainability [82]. In another investigation to examine the effects of CLSC on the return process effectiveness, Shaharudin et al. (2017) [83] revealed that CLSC is positively associated with return process effectiveness. In addition, internal and external returns were identified as two categories, but no empirical evidence was provided regarding the effect on performance [84]. CLSC facilitates improving the relationship with

the supply chain partners by reducing costs and enhancing the overall performance [85]. Simultaneously, the collaborative working environment among the supply chain partners with thorough transparency helps build trust, goodwill, and credibility among the stakeholders [86]. Through an integrated and collaborative supply chain achieved using AI technologies, the SMEs get closer to achieving the optimum resource allocation, streamlining the operations, and achieving the set objectives of sustainability [87]. The above literature indicated a gap in the empirical investigation of the benefits of CLSC on firm performance. Consequently, the following hypotheses are put forward:

H12. *The CLSC positively impacts SMEs' SBP in the metaverse.*

H13. *CLSC has a positive relationship with SCR.*

H14. *The CLSC mediated the relationship between AI and SBP of SMEs in the metaverse.*

H15. *SCR mediated the relationship between CLSC and SBP of SMEs in the metaverse.*

3.8. The Moderating Role of AC

The literature shows that access to external knowledge is essential to compete with global competitors, and AC is one vital source of becoming competitive in the market. Previous research has demonstrated that artificial intelligence (AI) offers an effective means of emulating adaptability through its ability to learn from external environments and streamline intricate systems, transforming them into more structured, readily modifiable, and flexible entities [88]. Moreover, AC creates conducive environments where AI techniques can facilitate the reverse logistics systems [89]. Belhadi et al. (2021) [29] concluded that AI positively results in AC and improves supply chain performance. Adaptive organizations become capable of solving universal problems and dealing with dynamic environments [90].

Moreover, ref. [91] highlighted that firms developing the AC on digital platforms have better opportunities to design a better CLSC system. The above-stated arguments propose that AC plays an influencing role. Therefore, the following is hypothesized:

H16. *The AC moderates the relationship between AI and CLSC.*

Figure 2 represents the proposed conceptual framework.

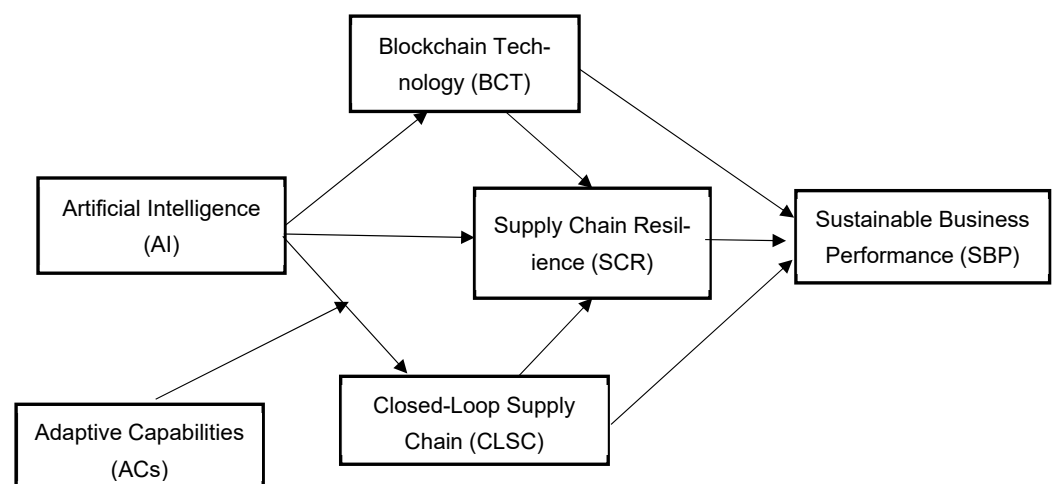


Figure 2. Conceptual framework.

4. Methodology

The current study adopted a cross-sectional approach to quantitative research. The current study collected the primary data by developing a survey questionnaire, which is the most helpful method of saving time. The questionnaire consists of two sections. Section one contained the questions related to the demographics of the respondents. In Section two, information about the study constructs was collected. The scale of artificial intelligence was adopted from Dubey's study [55] and consisted of five items. The construct of CLSC was adopted from the studies of Shaharudin et al. (2017) [83] and Bhatia & Kumar Srivastava (2019) [82] and contained six items. BCT contained four items adopted from a well-established study [92]. SCR was measured using a five-item scale developed by Altay et al. (2018) [93] and Yu et al. (2019) [61]. SBP had six scale items adopted from the studies of [94–96]. Three scale items of AC were adopted from the study of Tarafdar & Qrunfleh (2017) [97] and Srinivasan & Swink (2018) [38]; items were estimated using the Likert scale of “1 = strongly disagree” and “5 = strongly agree”. The developed questionnaire was vetted by a pool of experts consisting of professionals and professors (see Measurement constructs used in the study in Supplementary Materials). Figure 3 presents different stages performed throughout the Methodology section.

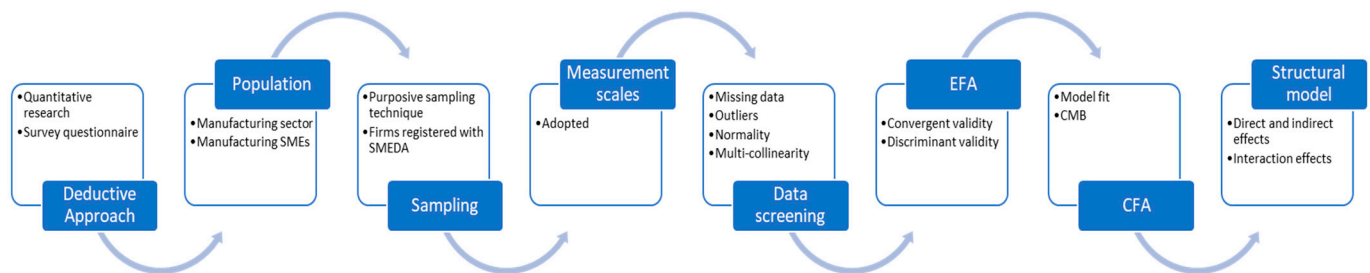


Figure 3. Stages of the methodology (author's own work).

This study was conducted in the context of Pakistani SMEs because of the country's evolving economic context and the rapid adoption of modern technologies across different manufacturing sectors. In addition, the SMEs adopting or intending to implement digital transformation had multiple networks and associations, making accessing related data easier. Moreover, the identical cultural aspect of establishing connections further influenced our choice to make more generalized findings in Asia.

The developed questionnaire was distributed to the firms selected from a list gathered through small and medium enterprise development authorities [98]. After verification from the secondary sources of the companies that these SMEs have an interest in circular economy and focused on digital transformation, the questionnaire was distributed to the owner, production manager, marketing manager, supply chain manager, procurement manager, logistics manager, and distribution manager working in the SMEs of Pakistan. Pakistan has four provinces: Punjab, Sindh, Balochistan, and Khyber Pakhtunkhwa (KPK). The surveys were disseminated to the small and medium-sized enterprises (SMEs) operating in the principal urban areas of these provinces.

Further, 497 questionnaires were distributed over four months (Nov-2022 to Feb-23), and 331 questionnaires were returned. However, only 326 responses were usable after initial data screening, indicating a response rate of 66.5% of the target sample. A minimum response rate of 20% is also acceptable in operations management [99].

5. Results

5.1. Sample Demographics

The data about SMEs were collected through SMEDA-registered members, and none of the registered members were below the age of 38. Most of the SME owners and managers were aged above 35 years. According to the responses in Table 1, 52% of the responding firms had an average annual sale beyond PKR 100 million, and 45% of the responding organizations had a workforce exceeding 200 employees. A total of 14% of the respondents were the owners, 22% were the general managers, 14% were managing directors, 9% were the supply chain managers, and 16% were recovery managers. In contrast, sales/marketing and departmental heads were 12% and 13%, respectively. A total of 16% of the responding firms were from textiles, 12% were from the food and beverage sector, 11% were from petroleum products, 12.50% were from pharmaceuticals, 10% were from chemicals, 24% were from non-metallic metal products, 13.50% were from automobiles, and approximately 2% were from iron and steel products.

Table 1. Sample demographics (N = 326).

Characteristics	No. of Respondents	%
Gender		
Male	312	95.71
Female	14	4.29
Age		
38–45	84	25.76
46–50	95	29.14
51–55	105	32.2
Above	42	12.88
Educational Background		
Intermediate	77	23.62
Bachelor	113	34.66
Master	83	25.46
M.Phill/MS	53	16.25
Work Experience		
6–10	69	21.16
11–15	114	34.96
16–20	71	21.77
Above	72	22.08
Designation		
Owner	47	14.41
General manager	71	21.77
Managing director	44	13.49
Supply chain manager	29	8.89
Recovery manager	53	16.25
Sales/marketing manager	39	11.96
Departmental head	43	13.19
SME Sector		
Textile	52	15.95
Food, beverages, and tobacco	38	11.65
Petroleum products	35	10.73
Pharmaceuticals	41	12.57
Chemicals	31	9.50
Non-metallic mineral products	79	24.23
Automobile	44	13.49
Iron and steel products	6	1.84

Table 1. *Cont.*

Characteristics	No. of Respondents	%
Annual Sales (In million PKR)		
<10	29	8.89
6–10	49	15.03
51–100	78	23.92
>100	170	52.14
Number of Employees		
<50	39	11.96
50–100	62	19.01
101–200	78	23.92
>200	147	45.09
(Source: author’s work)		

5.2. Measurement Model Assessment

After completing initial data screening using SPSS v24, the primary step involved evaluating the normalcy of the data. The results of this assessment indicated that the skewness and kurtosis values were within the pre-defined threshold, as determined by [100]. Next, the second step was performed using PLS-SEM. The dataset was analyzed for multicollinearity, and the variance inflation factor (VIF) values ranged from 1.485 to 2.842, revealing no significant concerns, and the values are considered within a threshold [101]. Convergent and discriminant validity were used in the next phase to assess the concept validity of the dataset. The authors of [102] proposed evaluating the average variance extracted (AVE) values against a predetermined threshold of 0.50. The composite reliability (CR) and Cronbach alpha values are above the criterion of 0.70. The levels of AVE and CR both fell within the specified threshold, as stated by [101]. The values are displayed in Table 2.

Table 2. Convergent validity, reliability, factor loadings, and variance inflation factor.

Constructs	Items	Loadings	VIF	Cron. Alpha	CR	AVE
Adaptive Capabilities	AC1	0.890	2.083	0.849	0.908	0.768
	AC2	0.868	2.135			
	AC3	0.870	1.994			
Artificial Intelligence	AI1	0.811	1.811	0.784	0.861	0.609
	AI3	0.689	1.573			
	AI4	0.779	1.815			
	AI5	0.833	1.884			
Blockchain Technology	BCT1	0.812	1.714	0.821	0.882	0.652
	BCT2	0.791	1.804			
	BCT3	0.882	2.357			
	BCT4	0.739	1.485			
Closed Loop Supply Chain	CLSC1	0.751	1.622	0.864	0.902	0.648
	CLSC2	0.830	2.793			
	CLSC3	0.868	2.131			
	CLSC4	0.766	1.912			
	CLSC5	0.806	1.994			
	CLSC6	0.806	1.994			

Table 2. Cont.

Constructs	Items	Loadings	VIF	Cron. Alpha	CR	AVE
Sustainable Business Performance	SBP1	0.821	2.804	0.902	0.924	0.669
	SBP2	0.815	2.341			
	SBP3	0.793	2.063			
	SBP4	0.805	2.597			
	SBP5	0.825	2.788			
	SBP6	0.848	2.842			
Supply Chain Resilience	SCR1	0.790	1.989	0.853	0.895	0.630
	SCR2	0.792	2.238			
	SCR3	0.834	2.443			
	SCR4	0.802	1.970			
	SCR5	0.747	1.785			

The dataset's discriminant validity was estimated, and the results were checked using the correlation matrix [102]. According to Claes Fornell and Larcker (1981) [102], the diagonal values must be greater than vertical and horizontal values. The results are shown in Table 3.

Table 3. Discriminant validity (Fornell–Larcker criterion).

	AC	AI	BCT	CLSC	SBP	SCR
AC	0.876					
AI	0.602	0.780				
BCT	0.594	0.622	0.808			
CLSC	0.643	0.716	0.736	0.805		
SBP	0.594	0.463	0.722	0.638	0.818	
SCR	0.659	0.596	0.674	0.648	0.591	0.794

In addition, the heterotrait–monotrait ratios were examined, and the findings indicated that all the values were below the maximum threshold of 0.90. This demonstrates that the discriminant validity has been proven (Table 4).

Table 4. HTMT.

	AC	AI	BCT	CLSC	SBP	SCR
AC						
AI	0.7410					
BCT	0.7040	0.7660				
CLSC	0.7370	0.8570	0.8700			
SBP	0.6740	0.5350	0.8230	0.7060		
SCR	0.7750	0.7190	0.8030	0.7460	0.6640	

5.3. Structural Equation Model (SEM) and Hypotheses Testing

According to the requirements, the next step was calculating the structural equation model and examining the suggested cause-and-effect link as stated in several hypotheses [101]. Subsequently, every hypothesis underwent testing. Initially, the direct hypotheses were estimated, and the coefficient values were analyzed using structural model analysis, also known as regression analysis, on a one-tailed basis. This approach was used because all the hypotheses were directional, as indicated by the literature. In addition, obtaining a t-value of 1.64 or higher is essential for a one-tailed analysis.

Furthermore, the data were subjected to 5000 iterations of resampling to obtain a consistent output. However, in the present study, all outcome values surpass this threshold.

Consequently, the results indicate that all the hypotheses are statistically significant. The outcomes of the explicit hypotheses are displayed in Table 5.

Table 5. Direct path effect coefficients.

Hypotheses	Direct	Beta	SD	T Stats	<i>p</i> Values	Decision
H1	AI -> SBP	0.132	0.070	1.888	0.030	Supported
H2	AI -> SCR	0.194	0.082	2.375	0.009	Supported
H3	SCR -> SBP	0.163	0.078	2.079	0.019	Supported
H5	AI -> BCT	0.622	0.038	16.181	0.000	Supported
H6	BCT -> CLSC	0.405	0.051	7.890	0.000	Supported
H7	BCT -> SBP	0.510	0.069	7.358	0.000	Supported
H8	BCT -> SCR	0.390	0.068	5.713	0.000	Supported
H11	AI -> CLSC	0.349	0.052	6.711	0.000	Supported
H12	CLSC -> SBP	0.251	0.075	3.346	0.000	Supported
H13	CLSC -> SCR	0.222	0.087	2.552	0.005	Supported

Next, the values for indirect hypotheses were estimated. This study used a bootstrap of 5000 samples with a confidence interval of 95% and a 5% error. Current research has proposed five hypotheses for mediation; the results are shown in Table 6.

Table 6. Indirect effects.

Hypotheses	Indirect	Beta	SD	T Stats	<i>p</i> Values	Decision
H4	AI -> SCR -> SBP	0.037	0.018	2.056	0.021	Mediation
H9	AI -> BCT -> SBP	0.317	0.050	6.297	0.000	Mediation
H10	BCT -> SCR -> SBP	0.064	0.031	2.060	0.020	Mediation
H14	AI -> CLSC -> SBP	0.087	0.031	2.815	0.002	Mediation
H15	CLSC -> SCR -> SBP	0.036	0.019	1.895	0.032	Mediation

The current study also developed one moderation hypothesis, and Figure 4 shows the moderation effects of adaptive capabilities in the relationship between AI and CLSC. The results in Figure 4 indicate that AC moderates the relationship between AI and CLSC.

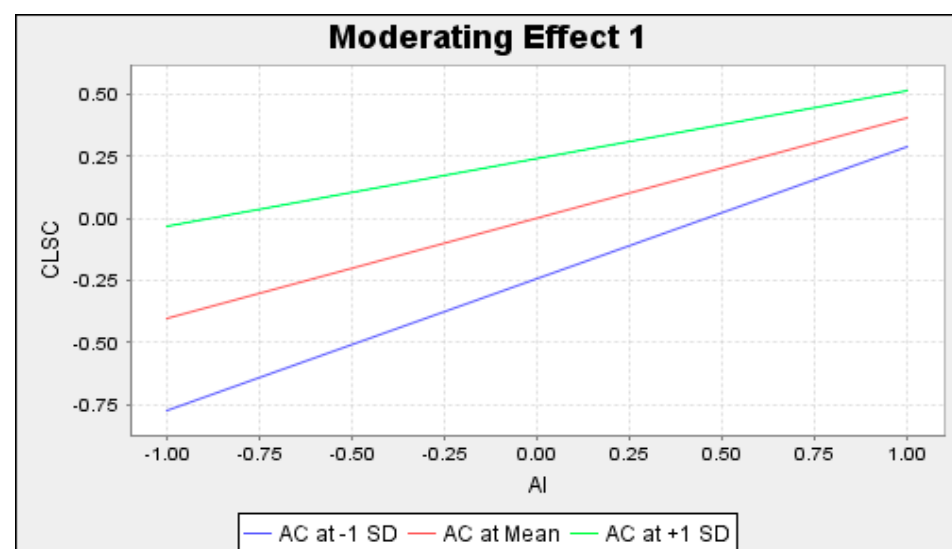


Figure 4. Moderation effects of AC in the relationship between AI and CLSC.

6. Discussion

Technological transformation is forcing firms to find new ways to achieve a competitive advantage, which is why the metaverse is gaining popularity in multiple fields. The current study proposed a conceptual framework and examined the associations between artificial intelligence (AI) capabilities, blockchain technology (BCT), supply chain resilience (SCR), closed-loop supply chain (CLSC), and sustainable business performance (SBP) [76,103]. The organizational information-processing theory (OIPT) developed the proposed framework. This study's findings highlighted that developing AI capabilities helps increase the SBP in the metaverse. The information-processing capabilities, the system of self-learning, and the infrastructure to predict the changes in the environment help organizations improve decision-making and increase their performance. Previous studies also shared similar findings, concluding that AI adoption arguably enhanced the firm's performance [55].

The current study's findings highlight that AI capabilities also facilitate SCR design. Both the direct and indirect effects resulted in improved SBP. Past studies mentioned that AI capabilities help firms identify the areas of disruption and assist firms in having better visibility of the supply chain [59]. These findings match our results. The findings also revealed that AI capabilities positively affect BCT and provide firms with extended visibility and traceability to stakeholders. The past literature also showed that AI enhances BCT transparency governance [104]. Moreover, the indirect effects of BCT also indicated an improved SBP.

Several scholars have shared that consumer-preferred AI-push were found to be associated with profits from remanufacturing consumer products [81], and AI-based capabilities enable the firms to counter the constraint and obtain a better insight to resolve the CLSC-related matter [56]. This study's findings also show similar findings: capabilities facilitate building the improved CLSC system in the metaverse and achieving the SBP objectives. These findings help answer RQ1 and provide deep insights into the role of AI, BCT, SCR, and CLSC in improving the SBP.

Additionally, we found the influencing role of AC in links between AI and CLSC. The findings indicated that when the firm has low AI capabilities, even when the AC reaches its maximum capacity, the CLSC does not improve. Nevertheless, when the firm has high AI capabilities, slight variation in the AC shows remarkable results, and the CLSC system improves efficiency. AC enhances the effect size of AI capabilities in adjusting according to the disruptive event or the external environments (variation in customer's expectation or the expectations of any other stakeholder), thus improving the CLSC systems. These findings are aligned with past research where Ye et al. (2022) [91] highlighted that firms developing the AC on digital platforms have better opportunities to design a better CLSC system. These findings answer RQ2 and give detailed insights into the role of AC in building an effective CLSC system.

Digital transformation and modern technologies like AI adoption require SMEs with a high initial cost, especially SMEs in developing countries like Pakistan. Similarly, the scarcity of technical experts, low supply of skilled workforce, and other compatibility-related matters in the existing systems further challenge SMEs to adopt digital technologies. Moreover, the adoption of digital technologies like AI, BCT, IoT, etc., also brings the associated threats of cyberattacks. Potential data breaches or exploitation of sensitive information by malicious actors may result in problems for the organizations [105]. Simultaneously, AI systems carry inherent vulnerabilities, such as algorithmic biases or susceptibility to adversarial attacks, which could undermine their effectiveness in decision-making or supply chain management. Furthermore, considering the contextual factors is essential for a better understanding of digital transformation using AI and BCT adoption by SMEs in Pakistan. SMEs must consider their attitude towards technology as a deeper understanding,

which will facilitate the improvement of their willingness to embrace modern technological solutions. Similarly, existing governmental policies and regulations also play a crucial role in implementing these technologies.

7. Conclusions

The metaverse provides new avenues for firms to achieve sustainable business performance (SBP). In this perspective, the current study used the organizational information-processing theory (OIPT). It developed a conceptual framework to examine the direct and indirect effect of artificial intelligence (AI)-enabled information-processing capabilities on achieving SBP in SMEs. The current study tried to find answers about the effects of AI capabilities on BCT, SCR, CLSC, and SBP. Additionally, how does AC affect the interplay between AI and CLSC? The findings revealed that AI helps firms design and build efficient and effective supply chain resilience (SCR).

AI facilitates forecasting disruptions, identifying potential threats, and providing real-time visibility of the entire supply chain, enabling the identification of the supply chain bottlenecks. The information processed using AI capabilities becomes transparent, immutable, and visible to supply chain partners through blockchain technologies (BCTs). The AI techniques also provide helpful information and help firms improve their closed-loop supply chain systems.

Conversely, BCT reduces the chances of potential fraud, mistakes, or tampering of the stored data. It also enhances real-time data sharing to improve collaboration among the supply chain partners and thus provides the benefits of developing a resilient supply chain. Digital technologies equip the firms with competitive advantages, leading them to achieve higher SBP. Moreover, AI capabilities are influenced by the firm's adaptive capabilities (ACs). When the AC is high, AI capabilities improve the metaverse's CLSC system and produce positive firm performance. These findings provided the answers to the raised research questions and helped to devise the strategies SMEs can utilize to improve their sustainable performance.

Although AI-based systems and blockchain technology offer transformative potential, the implementation of such technologies comes with its challenges. Firms making decisions to utilize AI-based systems are required to make noticeable initial investments to build the required infrastructure, skilled workforce, and regular maintenance, which makes it a resource-intensive project. Similarly, the adoption of blockchain technology may also encounter challenges such as higher costs, limitations of its scalability, and difficulties in integrating it with the organization's existing systems. Therefore, SMEs in developing countries must face the challenges and opportunities of adopting these digital technologies with their existing labor-intensive setups and shortage of experts and skilled workforce. Additionally, the differences in regulatory environments, cultural attitudes toward technology, or variations in digital maturity across regions also play a vital role in SMEs' willingness to adopt AI and BCT.

7.1. Theoretical Implications

The current study has several theoretical implications. First, the metaverse is an emerging concept in marketing, manufacturing, and order bookings. Thus, the current study contributes to the metaverse literature using this concept in operations management. Second, the current study extends the literature on organizational information-processing theory (OIPT) by studying the relationships of the proposed constructs. Next, the current study used AI and BCT as two information-processing technologies and examined their direct and indirect effects on SBP. Past studies have used AI to examine operational performance [15] and risk-taking behavior [10], whereas the current study has studied the impact

of AI on SBP. As per the literature review, scarcity of research presented this gap, and our research fills the gaps by examining these constructs in the context of the metaverse. Additionally, AI capabilities have not been studied to improve the CLSC systems; therefore, the current study makes significant contributions to the literature by studying the effects of AI on CLSC. Finally, the current study contributes to the literature by examining the influencing role of adaptive capabilities in the relationship between AI and CLSC.

7.2. Managerial Implications

The current study proposes several practical implications for supply chain managers. First, this study's findings can help managers develop AI and BCT capabilities for better information visibility, transparency, and immutability. The managers must develop AI capabilities in their firms to obtain these benefits. Second, these AI capabilities should facilitate the development of supply chain resilience under unpredictable, uncertain environments. AI capabilities develop collaborative systems among the partners, which direct the firms to achieve sustainable performance. SMEs need to access their existing supply chain processes to identify areas for improvement. Managers should also develop contacts with technology providers and other expert members in their supply chain to take advantage of their expertise in implementing AI and BCT and develop comprehensive SCR and sustainable development strategies. Third, AI capabilities also help firms develop and improve CLSC systems based on the self-learning acquired through AI. Even though AI capabilities allow firms with more AC, they can have an improved CLSC system, thus serving customers better and improving performance. Moreover, the findings also suggest that adaptive capabilities are vital catalysts in generating the SCR and SBP. These findings suggest that managers need to build adaptive capabilities, as these strengthen the implementation of AI and BCT to demonstrate improved performance.

7.3. Limitations and Future Research

The current study used OIPT as the underpinning theory; other theoretical lenses, like the dynamic capability view, can better understand the proposed framework. Therefore, future research endeavors may employ alternative hypotheses to gain a more comprehensive understanding of the postulated associations. The present study employed a cross-sectional methodology; however, a longitudinal investigation would offer more comprehensive insights and validate the link in different disruption scenarios. However, the study sample was collected from heterogeneous sectors associated with manufacturing, so it cannot be generalized to other industries. Therefore, to generalize this study, conducting it in different contexts and industries like services, healthcare, or transportation is recommended. Future research endeavors may explore the longitudinal approaches to understand better the long-term impacts of AI and BCT adoption. Moreover, due to concerns related to data dependence, explainability, and bias in outcomes, predictive AI has its own limitations. Therefore, future research could incorporate other technological factors. Finally, future research could incorporate additional factors such as big data analytics, the Internet of Things (IoT), smart technologies, green innovation, green manufacturing, product design, and circular economy principles to replace the mediating and independent variables to assess their impact on sustainable business performance.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su17010334/s1>, Measurement constructs used in the study.

Author Contributions: S.A.R.K. and A.A.S.: conceptualization, methodology, software I.R.A.S., Z.Y. and A.A.S.: data curation, writing—original draft preparation. S.A.R.K., A.A.S., I.R.A.S. and Z.Y.: visualization, investigation. A.A.S.: supervision. S.A.R.K. and A.A.S.: software, validation: A.A.S.,

Z.Y. and I.R.A.S.: writing—reviewing and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research is funded by the National Natural Science Foundation of China (72250410375) and the Natural Science Research Project of Higher Education Institutions in Jiangsu Province (No. 20KJA120003).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the Adnan Ahmed Sheikh (A.A.S.); adnan.a@uob.edu.om.

Conflicts of Interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

List of Abbreviations

AI	Artificial intelligence
BCT	Blockchain technology
CLSC	Closed-loop supply chain
SCR	Supply chain resilience
ACs	Adaptive capabilities
SBP	Sustainable business performance
OIPT	Organizational information-processing theory
SMEs	Small and medium enterprises
SMEDA	Small and medium enterprises development authority
SEM	Structural equation model
PKR	Pakistani Rupee

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