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Blockchain Technology Adoption for Improved Environmental Supply Chain Performance: The Mediation Effect of Supply Chain Resilience, Customer Integration, and Green Customer Information Sharing

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Abstract: Due to the complexity of building supply chain resilience (SCR) towards long-term environmental sustainability amendments, the use of emerging technologies such as Blockchain Technology (BCT) can be adopted as an innovative tool to enhance the sustainability and resilience of supply chains, especially in uncertain environments. Drawing on the Knowledge-Based View (KBV) and Dynamic Capability View (DCV), this research aims to demonstrate how the adoption of BCT can enhance the environmental supply chain performance (SCP). A total of 603 valid surveys were collected from respondents from manufacturing and service organizations in Egypt. The collected data were analyzed using structural equation modelling, and results revealed that BCT adoption alone had a negative direct impact on environmental SCP. However, when this relationship was mediated by SCR and sequentially mediated by customer integration and green customer information sharing, the results were positive. This research presents insights on how organizations can adapt to dynamic business environments, and, in addition, it extends the theories of KBV and DCV in an empirical contribution by filling the gap in understanding regarding how environmental SCP can be enhanced through the adoption of BCT.

Keywords: blockchain technology; environmental; supply chain; performance; resilience; customer integration; green; information sharing

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1. Introduction

In the wake of the upsurge in environmental inadequacy and degradation of natural resources, environmental sustainability has acquired an increased global importance in recent years [1]. The post COVID-19 era ascertained the inevitability of the combination and the interaction of resilience, technology, and environmental sustainability [2]. Today, the world is witnessing various worldwide challenges in coping with the current dynamic market. Sustainable development is one key challenge that has occupied many researchers and policy makers [3]. Sustainable development now plays a vital role in business survival by enhancing regulatory pressures imposed by stakeholders and existing production practices [4]. Accordingly, businesses have realized that their economic development requires simultaneous attention to environmental protection [3], and especially that the consistent deuteration and destruction of ecology and its impact on human health are motivating individuals to consume responsibly and to demand that organizations fulfil environmental responsibilities [5]. Moreover, government institutions are also obliging organizations to enhance their compliance with the rules and directives governing environmental safeguarding [6]. Accordingly, organizations are converting their supply chains (SCs) towards more environmentally friendly decisions and moving towards having practices that are oriented towards the enhancement of environmental SC performance [7].

Organizations worldwide are applying innovative technologies to reduce the burden they are putting on the environment [8]. Organizations recognize the importance of innovative technologies and comprehend that customer value and their long-term organizational success and, indeed, their survival depends on their ability to integrate new innovations and technology solutions [9]. Industry 4.0 technologies, such as the Internet of Things, artificial intelligence, robotics, 3D printers, and BCT, offer immense support to sustainability practices that include reuse, recycling, green procurement, and remanufacturing [10–12]. These technologies need to be integrated in the business process in order to gain their full benefits [13,14], for they can help to coordinate and align business partner goals [15], which, in return, enhances the overall supply chain [16,17], with a special focus on sustainability [18,19].

Environmental fortification is now a prerequisite for achieving sustainable competitive advantage and is an integral part of the preemptive management of companies [20]. Businesses routinely encounter vital environmental issues, such as ecosystem conservation, waste control, air quality, integrity, and sustainability of resources to stipulate a clean and healthy environment [21]. Various enterprises have implemented effective solutions to address these issues, such as recycling in the workplace, promoting green communities, forming sustainable committees, and the ongoing new trend of digitalization [22]. As a result, new solutions incorporating the latest technologies are urgently required to maximize the movement towards environmental sustainability practices within supply chains [8]. The latest developments of digital transformations in artificial intelligence, the Internet of things, Robotics, Big Data, and BCT have paved the way for smarter, safer, integrated, more transparent, more economic, and more resource efficient processes along the SC [11].

BCT is recognized by practitioners and academia [23] as having the capacity to generate a transaction information ledger that is trusted and transparent [10]. As it presents potent solutions for businesses through efficiently improving their overall business operations [24,25], it can be argued that BCT has a special importance for the resiliency and sustainability of the supply chains of the future. BCT accelerates the identification of risk and pressure through collecting data quickly and efficiently, which can enhance transparency and visibility and, eventually, SCR [26]. In return, resilience permits organizations to take the initiative and to foster contingency plans to cope with volatile occurrences, and, also, to maintain enhanced organizational and environmental performance [27,28] that decrease manufacturing costs along with toxic materials and waste [29]. BCT information handling capability [10] can also lead to an enhanced customer integration and, eventually, more efficient green information sharing [30]. Collaborating closely with customers could enable organizations to cope better with the dynamic business environment, which could be achieved through enhancing customer integration in order to gain competitive advantage by accurately meeting customer needs and demands, since through customer integration, the customer is actively involved and can decide when, how, and where to gain access to their product/service [31]. Because of the benefits of creating close relations with the customers, it can be argued that it can eventually lead to enhanced environmental performance [32] through increasing customer green information sharing [33]. In other words, the relationship between BCT, SCR, customer integration, green information sharing, and environmental performance is complex and multifaceted. However, by leveraging these concepts in a strategic and coordinated way, companies can create more resilient, sustainable, and customer-focused supply chains that deliver value to all stakeholders.

According to systems theory, SC is a system that withholds various resources that must be handled properly and efficiently in order to sustain survival in the current dynamic market [34]. Understanding and application of the systems theory enables managers to take a systems approach in the design and management of SC systems and subsystems [35]. Accordingly, one uprising subsystem for SCs is BCT [36], which could be used to make the SC system more efficient and thus enhance the environmental performance of SCs. BCT adoption in the SC is still at a premature stage, its' applications in distinctive sectors is rising precipitously [37], as it supports features such as transparency, traceability [38], and data security, which facilitate environmental sustainability performance [39]. BCT has the potential to reshape SCs by incorporating sustainable activities with a special focus on environmental protection [40]. Despite the evident association between BCT, environmental SCP, SCR and customer integration, these topics tend to be analyzed separately, with various authors agreeing that further efforts are necessary to investigate the interactions between the four constructs [30,41–43]. Thus, a gap in the literature exists regarding interlinking BCT, environmental sustainability, resilience, customer integration, and customer green information sharing, and calls for more research [44]. In addition to the realization that in the current dynamic market, organizations are obliged to become more resilient, integrated, and innovative [45], the aim of this research is to reconcile BCT adoption, SCR, and customer integration in the context of environmental SCP.

The contribution of this research can be summarized as follows. First, the study addresses how BCT can be adopted to enhance environmental SCP. Second, the research extends the use of DCV theory and KBV theory by identifying SCR, customer integration, and green information sharing as critical dynamic capabilities for achieving a subtle steadiness between BCT adoption and environmental SCP. DCV is extended from previous research, such as [46], which utilized the DCV to conceptualize BCT as a dynamic capability, but their research explored BCT's direct influence on the various types of SC integration and its indirect influence on sustainable SCP while focusing only on the Indian automotive industry. Similarly, the KBV theory was utilized by [47], which applied BCT adoption for improving sustainable organization performance, but this research used SC visibility as a mediating variable and was limited only to the Chinese manufacturing industry. Third, given the deficiency of empirical accounts of how BCT adoption serves as a subsystem that aids in the evolution of environmental SC performance enhancement, the findings of this research provide valuable practical implications for organizations and stakeholders to evaluate their readiness and capabilities for inspiring environmental SCP through BCT adoption.

The research is structured as follows. The theoretical background for the theory and constructs of interest is reviewed in Section 2, which leads to the development of the hypotheses and research model. Section 3 is the description of the methodological tools and methods applied to evaluate the proposed model, followed by Section 4, which is the discussion of the research. Finally, the conclusion and recommendations for further studies are drawn in Section 6.

2. Theoretical Background and Hypotheses Development

2.1. Blockchain Technology Adoption and Environmental Supply Chain Performance

BCT has profoundly evolved since Nakamoto [48] introduced the technology in a Bitcoin context. It is now recognized by various sectors as a potential game-changer. It is renowned for being a distributed ledger technology, which operates in the form of a decentralized immutable ledger able to store, process, validate, and authorize transactions. Figuratively, every transaction recorded on the blockchain at a given point in time is stored in a single block. Each block comprises a digital fingerprint of the user that implants the data, and this is known as a hash. Thus, the cryptographic identifier creator of the previous block is added.

Accordingly, BCT allows for the creation of an immutable and transparent record of every transaction that takes place within the SC [49]. This means that it is possible to trace the origin of every component, raw material, or finished product through the SC. This transparency can help companies identify and address inefficiencies and areas where they can improve their environmental performance [50]. Driven by sustainable development goals, BCT is one of the technologies substantiating its value in different sectors as well as various areas of SCM, and increasingly so in the area of sustainability performance [39,50].

The adoption of BCT for environmental sustainability of SCs has been recognized by Baralla, Pinna [51], who shed light on the capabilities of BCT to benefit waste management and circular economy through enabling information transparency, reliability, and automation.

In the financial (cryptocurrency) market, Wang, Lucey [52] illustrated that there is a negative significant relationship between BCT and environmental performance. Meanwhile, in the manufacturing SC sector, ref. [53,54] illustrated that there is a significant positive impact of BCT adoption and environmental SCP. Furthermore, ref. [55] confirmed the positive influence of BCT adoption on environmental SCP in the automotive industry. Finally, in the agricultural sector, ref. [56] confirmed the positive impact of BCT adoption on environmental SCP.

Previous literature mainly investigated the positive significant impact of BCT adoption on the overall SC performance and survival, especially in the post COVID-19 era [55]. Various literature has also focused on the negative effects of BCT adoption, as an energy consuming technology, on the environmental SCP [52,56]. However, limited studies have investigated the effect of BCT adoption, particularly on environmental SCP [41]. Accordingly, the following hypothesis could be proposed:

H1: *There is a relationship between blockchain technology adoption and environmental supply chain performance.*

2.2. Blockchain Technology Adoption and Supply Chain Environmental Performance Mediated by SCR

Resilience refers to the ability of a system to return to its original state in the event of disruptions [57]. It accentuates the necessity of efficiently managing the consequences of interferences relative to preventing a disruption that may be beyond the immediate control of the system [28,58]. This was well grasped in the recent COVID-19 pandemic, which underlined the significance of resilience in SCs and the influence that disruptions could have on the global network scale when individual SC connections and nodes fail.

Previous studies focused on resilience and sustainability simultaneously, as sustainability can help in enhancing organizational performance [59–62]. As previous research has shown, organizations that adopt resilient strategies have the necessary mechanisms to cope with disruptions and achieve a superior business performance [59,63,64]. Therefore, for such a prosperous field of research, more steps are needed towards completing and promoting this relationship. For instance, the implementation of technological solutions [65], such as BCT [43,66].

Recognized for its potential, BCT can apprehend data on environmental conditions along the SC to accelerate the identification of risk and pressure, since a BCT enabled SC is more resilient and transparent due to the fact that it enables visibility in every activity of the SC and allows for real-time interactions [26].

As constructing SC visibility is amongst the utmost vital solutions for creating a resilient SC and correspondingly affects the performance of environmental sustainability, technologies such as BC are vital in creating SC visibility [66–68]. Moreover, technological innovation has proved to play a vital role in enhancing organizational performance as well as the attainment of sustainable growth and competitiveness [66]. Thus, BCT adoption has become an essential tool for leveraging competitive advantage, which leads to the enhancement of environmental SCP. Therefore, visibility and innovative technologies are contemplated as fundamental aspects for refining the daily operations of organizations as well as assisting organizations to alleviate the undesirable influence of the disruptions caused by uncertainty.

Prior studies mainly investigated the direct positive impact of resilience on the overall organization performance and subsistence, particularly in the post COVID-19 era. However, limited research focused on investigating the impact of BCT-supported resilience on the environmental SCP.

Finally, as previously discussed, resilience in SCs alleviates the undesirable influence of contingencies through recognizing and incorporating strategies and action plans to get back to its original or better state [28,69]. Beyond the positive impact of resilience on performance, if enabled by BCT, this could maximize the benefits of resilience and thus lead to the enhancement of environmental SCP more efficiently. Thus, based upon the previous discussion, the hypotheses outlined below were developed.

H2: *SCR mediates the relationship between BCT and Environmental SCP.*

2.3. Sequential Mediating Role of Customer Integration and Customer Green Information Sharing

SC integrations, which symbolize the transition from conventional functional business processes to integrated process architectures, are a basic tenet of SCM [70]. Customer integration is the process of working together and sharing information with a focal company's important clients to better understand and meet their demands [71]. It is implied that the literature on SC integrations tends to favor its positive impact on performance, but the results are inconclusive (e.g., Chavez et al., 2015), and they call for investigation of the mechanisms by which SC integration can drive the enhancement of environmental performance [72].

In the current era of globalization, organizations must support the transition from traditional to modern thinking, where, traditionally, businesses concentrate on applying cost reduction strategies to achieve a competitive advantage. However, today's competitive environment requires a more 'customer-centric' approach, integrating the customer as a fundamental element of the SC [73]. Thus, previous literature recognized customer integrations as a necessary and critical component for successful integration efforts [72].

Moreover, since customer integration is regularly associated with collaboration activities, the integration of information sharing technologies such as BCT becomes fundamental for optimization. SC collaboration processes always contain some form of information sharing; however, the type of information can ultimately determine how successful the integration effort is, thus representing a sequential relationship of the two constructs, as BCT can facilitate collaboration and data sharing among stakeholders within the SC. This can help companies identify areas where they can work together to reduce their environmental impact, such as by sharing best practices, pooling resources, or collaborating on research and development [30]. Thus, considering the organizational shift towards environmental focus, the efforts for green information sharing, as previously mentioned, have becomes crucial because customer integration has a strong sequential effect on the quality of green information sharing [74,75], which ultimately impacts the environmental SCP.

Hence, previous studies confirmed the positive impact of customer integration and green information sharing in the marketing industry [76], while Qu and Liu [33] also confirmed the positive influence of customer integration and green information sharing within manufacturing SCs. Finally, Woo, Kim [77] confirmed the positive impact of customer integration and green information sharing in the construction industry.

Moreover, a previous study by Kouhizadeh and Sarkis [30] identified that enhancing BCT enabled customer integration and green information sharing can lead to the enhancement of the environmental SCP. Therefore, organizations should focus on enhancing customer integration and green information sharing through the adoption of BCT in order to enhance environmental SCP, as has been investigated by Najjar, Alsurakji [32] in the multi-tier supply networks. Thus, the more that an organization can optimize customer integration and green information sharing, the better the environmental performance will be. Based on the preceding discussion, the hypothesis outlined below can be proposed:

H3: *Customer integration and Customer green information sharing sequentially mediate the relationship between BCT adoption and Environmental SCP.*

Based on the previous discussion, the hypothesized framework is illustrated in Figure 1:

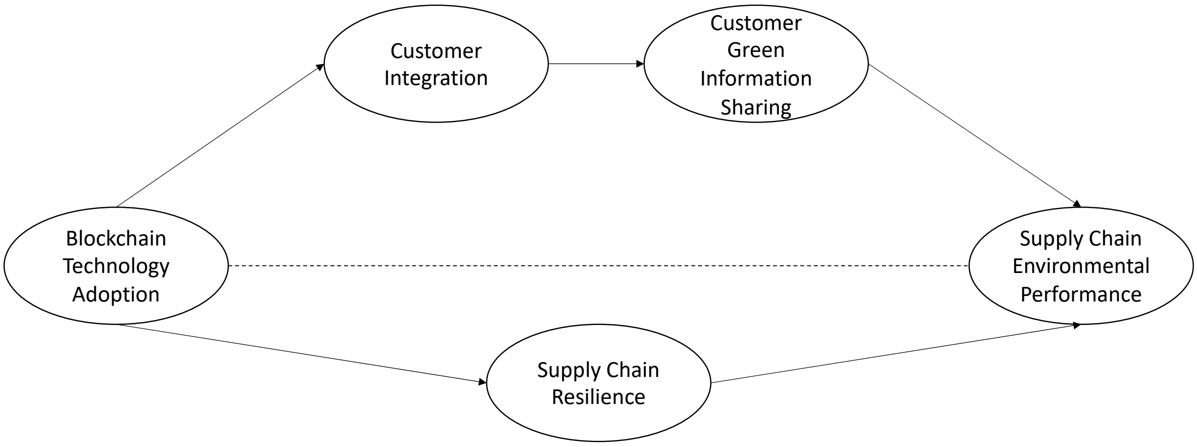

Figure 1. Research Model and Proposed Relationships.

The above figure illustrates the hypothesized framework for the research, which is conceptualized in order to aid an organization to optimize their capabilities to deal with the external dynamic market through the collaboration of the KBV and DCV theories. The DCV approach contends that competitive advantage depends on dynamic capabilities that allow one to react to changes in the business environment, contrary to the KBV view, which suggests that the capacity to learn faster than a competitor yields competitiveness [78]. The two views are in essence complementary. Knowledge-based processes are naturally dynamic as they aid in the regeneration and configuration of resources, while, on the other hand, dynamic capabilities are integrally knowledge-based because variations in the business environment are detected and then seized with the assistance of knowledge processes and capabilities [78].

Accordingly, the theoretical approach of this research entails the following two theories, which correspond with one another. First, the theoretical approach applied is the DCV [79]. It has already been mobilized in previous literature related to general sustainability [80,81] and sustainable supply chain management [82,83]. Many scholars have suggested that the DCV withholds the aptitude to initiate and support the organizational revolution towards sustainable strategies [84] and also withholds the aptitude to boost innovation for sustainability [80], thereby contributing to the formulation of sustainable business models and those that require supplementary in-depth changes (as, arguably, is the case with SCR).

Accordingly, to extract the most out of the DCV theory, the need for a knowledge-driven approach becomes essential in sustaining and retaining a competitive advantage in this knowledge-driven global economy, where knowledge is becoming even more central to the strategic development and entrenchment of an organization's performance. As the KBV theory focuses on the knowledge embedded in both an individual employee and the overall firm, this corresponds with the DCV theory that emphasizes the firm's ability to make decisions, solve problems, identify opportunities and threats, and modify existing resources [79,85,86]. The KBV theory addresses a wide range of fundamental aspects related to the theory of the firm, including knowledge coordination within the firm, the organization's structure, the role of management, and the theory of innovation. The KBV contends that the utilization of knowledge within the firm creates values through input and output transformation. Knowledge, i.e., intellectual capital, is the most crucial strategic resource.

Following the DCV, it is believed that the organizations can create "value" by modifying SC processes and resources, one of which is the ability to utilize the knowledge that could be established through BCT. As BCT is perceived to enhance the performance and productivity through its high information integration capability [87], this will ultimately influence the environmental SCP system.

Therefore, in this study, BCT adoption is considered as a dynamic capability that provides the ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments [79]. Moreover, the organizational capability that has been discussed in the previous literature reveals that a firm's internal and external integrations are associated with each other, which leads to performance enhancements [88]; this supports the selected constructs of SCR as well as the sequential mediation of customer integration and customer green information sharing that are presented in the present study. Accordingly, this study concentrates on empirically investigating the hypothesized framework.

3. Materials and Methods

This research aims to investigate the impact of BCT adoption on environmental SCP mediated by SCR, customer integration, and green information sharing in the Egyptian context, with empirical evidence on both the manufacturing and the service sector. The data collection measurement scale was adopted from previous research papers in order to develop the questionnaire on the basis of the measurement scale of each construct, and this was to enable the investigation of the relationship between the constructs of the proposed framework. The target respondents of this study included experienced senior management levels that withhold adequate knowledge and experience in order to ensure their capability of providing reliable information. Moreover, the strategic capabilities of senior management were mandatory, as it enables them to be up-to-date with their current macroenvironment and to enhance their strategic capabilities (i.e., digital technologies and sustainability).

3.1. Study Context

Egypt has recognized the importance of digital transformation as a key objective in achieving development goals and advancing its place in the global economy [89]. Complying with the "Egypt Vision 2030", the government has launched various initiatives to promote the use of technology across different sectors, including the establishment of the Ministry of Communications and Information Technology [MCIT], which is responsible for developing the country's Information and Communication Technology [ICT] sector. The MCIT has launched several programs, including the "Digital Egypt" initiative, aimed at promoting digital transformation across different sectors [90]. In addition, the government has been investing in digital infrastructure, promoting e-commerce and e-government services, and supporting the growth of the startup ecosystem [91]. These startups are driving innovation in various sectors, including fintech, health-tech, and edtech.

Overall, Egypt's digital transformation efforts are aimed at promoting economic growth, improving public services, and enhancing the quality of life for citizens. While there are still challenges to be addressed, the country is making significant progress in its journey to become a digitized nation. This transition has surely made the need for the adoption of technologies high, especially given that Egypt is a developing nation eager for economic growth.

Compared to other countries in the North African region, digitalization in Egypt has progressed at a faster pace, albeit still lagging behind the global average [92]. According to the 2020 edition of the Global Innovation Index (GII), Tunisia ranks 74th globally and 1st in North Africa in terms of ICT access, use, and skills, while Egypt ranks 96th globally and 2nd in North Africa [93]. However, due to Egypt's large population of over 109 million as well as its strategic location, diversified economy, significant natural resources, and historical and cultural significance [94], Egypt is a "pivotal player in the Arab world and the North African region", as stated by the U.S. Department of State. As a result of Egypt's high level of economic activities in comparison to other countries in the region, too, the country is more in need of adopting digital technologies in order to maximize the efficiency and sustainability of the massive amount of activities that are conducted daily without causing additional destruction to the environment [95], and this is a concern that the country has been attempting to control recently.

Nonetheless, the Egyptian government has adopted digitalization as a strategic goal, and several initiatives have been implemented to promote innovation and increase access to technology. Thus, in recent years, the country has seen significant growth in the e-commerce sector, with numerous online platforms emerging to serve various industries [92].

On the contrary, neighboring countries, such as Algeria and Morocco, still struggle with slow internet speeds and limited infrastructure, making Egypt and Tunisia more digitally advanced in the North African region [96]. While Tunisia is documented to be more digitally advanced than Egypt, Egypt was recognized by the World Bank in 2021 as the most economically important country in the North African region [94]. While there are certainly concerns about Egypt's political status quo under the current government's leadership, it does not fit neatly into any predetermined category when compared to its neighbors [97]. Hence, Egypt's situation is quite unique compared to other countries in the region, and while it is indeed suffering from political instability, it is still considered more politically established in comparison to the other countries in the North African region [91].

However, Egypt's environmental situation is one of the most critical issues facing the country currently, according to the African Development Bank Group (2022) [98]. According to Environmental Performance Index (EPI) 2020, Egypt is one of the least environmentally sustainable countries, ranking 6th out of 7 countries assessed, ahead of only Libya. Despite having a lower carbon footprint and CO_2 emission than other countries in the region due to a shift towards renewable energy, the country still faces significant challenges in waste management, pollution, and water scarcity [95]. Nevertheless, tighter regulations and investments in renewable energy are strengthening efforts towards environmental sustainability in Egypt as the country strives to catch up with European standards [96]. Environmentalists agree that effective collaboration between government bodies and citizens must continue if progress is to be sustained or accelerated towards reversing the decades of damage that has been done to natural reserves while still advancing prosperity for its people and meeting their needs [90].

Indeed, the sufficient movement towards digitalization in Egypt is intended to also serve and enhance the county's sustainability development [95]. This can serve as a blueprint for neighboring countries who are eager for economic growth through sustainable digitalization. This implicates the use of the latest digital technologies to make sustainable developments, such as lowering environmental impacts or raising resource efficiency [99]. Hence, the arguments above justify the need for the adoption of the proposed framework of this research in a significant country such as Egypt, which has major prominence in the North African region, as previously noted. Moreover, in line with the "Egypt Vision 2030", Egypt requires potential schemes to facilitate their transition towards digitalization and sustainability.

3.2. Sample and Procedure

Egypt's transformation towards digitalization has been a gradual process, but significant progress has been made in recent years, as previously mentioned. With continued investment and support from the government, Egypt is poised to become a leading player in the digital economy in the region [89]. Accordingly, this research uses data from developing markets, particularly the Egyptian manufacturing and service sector.

As a result of the pandemic, major acceleration in digital transformation has taken place in Egypt, and Egypt now has a unique opportunity to leverage the ICT sector to become a platform for a digital economy while generating opportunities for individuals and enterprises and also impacting economic development and growth. According to the International Monetary Fund's World Economic Outlook, in April 2021, Egypt's economy has only grown by 3.6%, which is lower than the 5.9% that was forecast before the COVID-19 pandemic, with a projected economic expansion of 2.5% in FY2020/2021 and 5.2% in FY2021/2022 [100].

Since the COVID-19 pandemic struck, and due to its various repercussions on society, a lot has changed in the behavior and attitude of many Egyptians towards technology adoption, diffusion, and adaptation. Digital transformation offers ample opportunities for Egypt. With strong support from the government and the international community, Egypt's dynamic sectors are gearing up to adopt Industry 4.0 technologies. Accordingly, in this study, an online survey was conducted to collect data from Egyptian organizations—i.e., the manufacturing sector. Proposing a tool to enhance environmental performance is particularly important in the Egyptian market [101], especially given the environmental awareness and environmental knowledge now exists regarding the climate crisis, yet this tool is still in their early stages in developing countries and North Africa [102].

The hypothetical framework was validated and tested through a self-administrated questionnaire, where data were collected from June 2022 to September 2022. For both the pilot and the main study, a snowball sample technique was applied, which is a method recognized as the most appropriate sampling technique when the research population is unknown and there is no access to or availability of such data. Moreover, Confirmatory Factor Analysis (CFA) and Covariance-Based Structural Equation Modelling (CB-SEM) methods were implemented to analyze the collected data. CFA and CB-SEM accepted an adequate sample size with a minimum of 200 valid responses [103]. A total of 233 participants in the pilot trial and 690 participants in the main study each received an online survey. First, a total of 220 respondents responded to the pilot, with 7 invalid responses and 213 valid ones, which was a response rate of 91.42%. Second, the overall response rate for the main study was 87.39%, with 630 respondents returning a total of 27 incomplete surveys and 603 valid ones. Table 1 provides an illustration of the characteristics of the research sample for the main study in terms of years of experience, city, gender, size, and organizational sectors.

Table 1. Respondents' demographic information.

Control Variables	Category	Frequency	Percentage
City	Cairo	168	27.9
	Alexandria	225	37.3
	Giza	121	20.1
	Other	89	14.8
Gender	Male	344	57.0
	Female	259	43.0
Size	Large	248	41.1
	Small and medium	355	58.9
Type	Manufacturing	340	56.4
	Service	263	43.6
Years of experience		Mean: 22.6	

3.3. Measures

The survey instrument consisted of the following six sections: BCT adoption, customer integration customer green information sharing, SCR, environmental SCP, and respondents' demographics. The original questionnaire was in English. Thus, the English version was translated into Arabic by using the back-translation method. Bilingual scholars ensured conceptual equivalence in the Arabic version.

The measurement items for BCT adoption were measured by using three items adapted from Fosso Wamba, Queiroz [104], which was conducted in the SC performance context. Scholars used and validated the customer integration eleven-item scale that was proposed by Flynn, Huo [105] in the operational and business performance context, including studies on manufacturing companies [106]. Customer green information sharing was then assessed with the five-item scale proposed by Han and Huo [107]. For SCR, six items from the research of Golgeci and Ponomarov [108] on supply chain disruptions were adopted. Finally, the measurement items of the environmental SCP were measured through the four items adopted by Han and Huo [107].

All items were assessed through a seven-point Likert-type scale (1 = strongly disagree, 7 = strongly agree). Appendix A illustrates the details of the measurement items. Finally, the questionnaire was pretested by presenting it to both industry experts and academics in order to ensure the content validity of the survey.

3.4. Pilot Study and Pre-Test

Confirmatory Factor Analysis (CFA) was used to assess the reliability and validity of the data collection instrument. It can be concluded from Table 2 that factor loadings for all items are above 0.4, except for 3 items that were dropped [109]. In addition, composite reliability for all variables recorded a value above 0.7 [110]. Finally, model fit indices indicate the good fit of the model [46].

Table 2. Pilot analysis based on confirmatory factor analysis.

Construct	Items	Factor Loadings	Composite Reliability
Blockchain technology adoption	BCT1	0.813	0.903
	BCT2	0.830	
	BCT3	0.963	
Customer integration	CI1	0.909	0.939
	CI2	0.954	
	CI3	0.933	
	CI4	0.961	
	CI5	0.389 Removed	
	CI6	0.383 Removed	
	CI7	0.391 Removed	
	CI8	0.843	
	CI9	0.771	
	CI10	0.814	
	CI11	0.844	
Supply chain resilience	SCR1	0.881	0.957
	SCR2	0.996	
	SCR3	0.746	
	SCR4	0.916	
	SCR5	0.877	
	SCR6	0.899	
Customer green information sharing	CG1	0.937	0.948
	CG2	0.81	
	CG3	0.859	
	CG4	0.953	
	CG5	0.865	
Supply chain environmental performance	EP1	0.848	0.919
	EP2	0.837	
	EP3	0.899	
	EP4	0.860	
Model fit: Chi-Square (X2) = 475.721, *p*-value = 0.00, Degree of Freedom (df) = 284, X2/df = 1.6, GFI = 0.854, AGFI = 0.819, NFI = 0.924, IFI = 0.968, TLI = 0.963, CFI = 0.968			

4. Results

4.1. Descriptive Analysis

A total of 603 respondents were analyzed to test the hypothetical model. The demographic characteristics of the respondents were as follows: 344 males and 259 females; 255 respondents allocated in Alexandria, while 168 were from Cairo, 121 in Giza, and 89 others. Moreover, 56 respondents had 25 years of experience, 45 respondents had 16 years of experience, while only 11 respondents had 10 years of experience. Moreover, 344 respondents were males, while 259 were females. Furthermore, 340 respondents were from the manufacturing sector while 263 were from the service sector. Additionally, 248 respondents were from firms with a size of more than 250, 107 were from firms with the size of 51–250, and 248 were from firms with a size of 10–50. Detailed information of the respondents' characteristics is illustrated in (Table 1).

4.2. Validity and Reliability

Square roots of the AVE illustrated in Table 3 indicate that there is no problem regarding discriminant validity [54].

Table 3. Reliability and validity of the data collection instrument.

Construct	Items	Factor Loadings	Composite Reliability	AVE	Cronbach's Alpha
Blockchain technology adoption	BCT1	0.845	0.899	0.748	0.900
	BCT2	0.885			
	BCT3	0.865			
Customer integration	CI1	0.931	0.959	0.750	0.963
	CI2	0.977			
	CI3	0.945			
	CI4	0.975			
	CI5	0.805			
	CI6	0.670			
	CI7	0.784			
	CI8	0.794			
Supply chain resilience	SCR1	0.766	0.938	0.718	0.936
	SCR2	0.784			
	SCR3	0.768			
	SCR4	0.910			
	SCR5	0.937			
	SCR6	0.901			
Customer green information sharing	CG1	0.942	0.933	0.737	0.931
	CG2	0.803			
	CG3	0.779			
	CG4	0.908			
	CG5	0.851			
Supply chain environmental performance	EP1	0.880	0.937	0.789	0.941
	EP2	0.849			
	EP3	0.920			
	EP4	0.904			
Model fit: Chi-Square (X2) = 1511.608, *p*-value = 0.00, Degree of Freedom (df) = 333, X2/df = 4.5, GFI = 0.856, AGFI = 0.825, NFI = 0.916, IFI = 0.933, TLI = 0.924, CFI = 0.933					

The results illustrated in the previous table show that all of the constructs' items achieved statistically acceptable levels where the converging analysis for validity and reliability reached an adequate level. The discriminant value will then be evaluated by calculating the square root of AVE to compare it with the correlation between the research variables, as recommended by [111], and as illustrated in Table 4. In addition, the widely used Cronbach Alpha was employed, as illustrated in Table 3, to assess internal consistency, where the entire alpha coefficient measured above 0.707, as recommended by the previous literature [112].

Table 4. Discriminant validity for the main study.

	BCT	CG	CI	SCR	EP
BCT	(0.865)				
CG	−0.027	(0.866)			
CI	0.145	0.194	(0.847)		
SCR	0.276	−0.013	0.001	(0.858)	
EP	−0.106	0.200	0.137	0.258	(0.888)

Note: Diagonally numbers between brackets represents square

4.3. Non-Response and Common Method Bias

Results revealed that no statistical significance between the early and late group as *p*-values were greater than 0.05. It was additionally observed that variance of a single factor was less than 50% [113], which clearly indicates that there are no common method bias issues [114].

4.4. Hypothesis Testing

Figure 2 illustrates the estimated path coefficient and significance level along with a structural model using (AMOS 24.0), where the results showed that H1 was supported as the empirical data depicted a negative direct relationship between BCT adoption and environmental SCP (β = −0.267 and *p*-value < 0.005), contradicting the previous literature (Arunmozhi, Venkatesh [55], Chittipaka, Kumar [115]), which proposed a direct positive relationship between the two constructs. However, H2 proposed that SCR mediates the relationship between BCT and Environmental SCP, was confirmed and supported, as the results shows the path coefficient is (β = 0.057), and it is significant at *p*-value ($p < 0.009$), supporting H2. Likewise, H3, which propositioned that customer integration and customer green information sharing sequentially mediate the relationship between BCT adoption and Environmental SCP, was additionally supported as the results show (β = 0.006 and *p*-value < 0.013), which presents a positive significant relationship between BCT adoption sequentially mediated by customer integration and customer green information sharing on environmental SCP, thus supporting H3 as illustrated in Table 5.

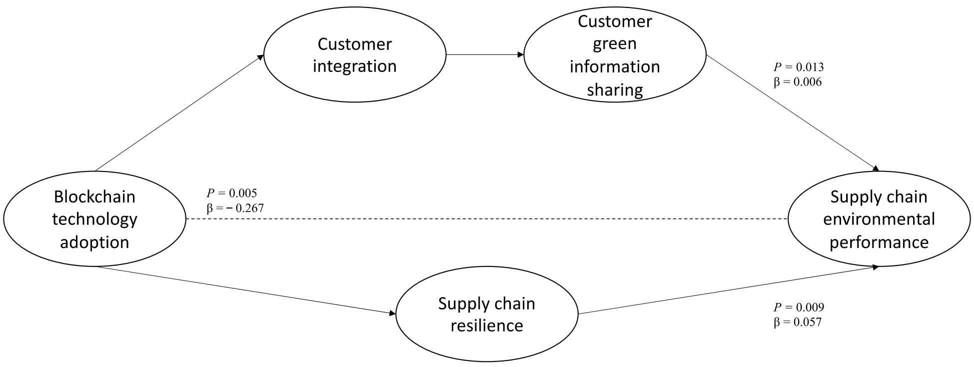

Figure 2. Research model results.

Table 5. Summary of hypothesis tests.

Hypothesis	Path	Std. β	Results
H1	BCT adoption → environmental SCP	β = −0.267	Supported
H2	BCT adoption → SCR → environnemental SCP	β = 0.057	Supported
H3	BCT adoption → Customer integration → Customer green information sharing → environmental SCP	β = 0.006	Supported

5. Research Discussion

This research has focused on the impact of blockchain adoption, SCR, customer integration, and customer green information sharing on environmental SCP, empirically investigating Egyptian organizations. The findings of this research will aid companies that are trying to use their technological capabilities to efficiently cope with increasing pressures to increase sustainable SCP, which has become essential for efficient operations and the survivability of organizations (i.e., members of the chain).

Firstly, the empirical data as demonstrated in Table 5, depicts that there was a negative direct relationship between BCT adoption and environmental SCP (H1). This contradicts the previous literature, where authors showed that there was a positive impact of BCT adoption on SC environmental performance (e.g., Chittipaka, Kumar [115]), which empirically tested whether BCT adoption can enhance the level of environmental SC performance. Similarly, Yu, Umar [64] tested the positive impact of BCT adoption on environment SC performance. However, our results contradicted these studies, and instead proposed that BCT alone will not be able to positively enhance the environmental performance of SCs. This is due to the economic crisis that Egypt is currently experiencing, where the Egyptian market is currently dealing with the economic and political repercussions of the said crisis. As a result, organizations are unfortunately putting off their environmental worries and are finding it difficult to keep up a high standard of green performance as, in times of crises such as the one that Egypt is currently facing, organizations invariably prioritize their financial performance. As a result, businesses began implementing and investing in technologies such as BCT as a means of survival in the Egyptian market, with its current political and economic instability. Thus, the proposed framework of the study suggests that the adoption of BCT could have positive impacts when leveraging the proposed concepts of BCT, SCR, customer integration, green information sharing, and the environment in a strategic and coordinated way, and that companies can create more resilient, sustainable, and customer-focused supply chains that deliver value to all stakeholders. Hence, we advocated that from a DCV, by utilizing the adoption of BCT through various mediating variables, BCT could have the potential to aid organizations to enhance their environment performance.

Secondly, the significant positive relationship between BCT adoption and environmental SCP mediated by SCR (H2) addresses the importance of SCR enabled by BCT to enhance the environmental SCP [65]. Although the findings of the current study depicts that BCT alone cannot enhance the performance of environmental SCs, it is evidently critical to the profitability and survival of any company to have a resilient SC [63]. This is especially true in a developing country such as Egypt, which is undergoing cultural changes towards the implementation of the latest technologies, as people recognize that technology adoption has become a primary source of economic development. Accordingly, this research sheds light on the potential of BCT-enabled SCR and its relevance to the overall performance of environmental SCs. As previously mentioned, BCT can be used to minimize vulnerabilities along the SC and act as a backbone to SCR through enabling real-time visibility, which can support decision making and support smooth functioning in the event of disruptions [87].

Hence, establishing SCR enabled by BCT could aid organizations to properly respond to the ongoing changes occurring in the market. Thus, BCT adoption in SCR could strengthen the organizations' competencies and enhance environmental SCP. This result is similar to previous research, where the impact of BCT adoption on SCR was empirically tested by [87], and the impact of SCR on environmental performance was empirically tested by [29]. However, this study measures the interrelationships of the three constructs combined, which were empirically found to be highly constructive jointly, and this is reflected as a contribution to the current knowledge of the literature, especially in emerging markets such as Egypt that lack empirical testing of such research models [89]. Therefore, organizations should adopt BCT to improve SCR in order to better enhance SC environmental performance.

Finally, the sequential mediator role of both customer integration and customer green information sharing between BCT adoption and environmental SCP (H3) was empirically supported through our results. That is, customer integration and customer green information sharing provide an additional benefit in acquiring the highest feasible efficiency of BCT adoption on environmental SCP. This result is in line with [116], which found a significant positive impact between customer integration and green customer information sharing on environmental SCP. However, this research is expected to deepen the understandings of BCT adoption and environmental SCP through the proposed framework, which was not conducted previously in the same context. Thus, organizations should benefit from the proposed framework to adopt BCT in order to enhance customer integration, which sequentially enhances customer green information sharing that ultimately leads to the enhancement of SC environmental performance. This empirically supports the KBV and DCV theories regarding using knowledge/information wisely in order to be more responsive to the market change towards sustainability, thereby enhancing the environmental SCP.

According to the previous discussion, it was concluded that Egyptian organizations in the current dynamic market should focus on enhancing their SCR, customer integration, and green customer information sharing through the adoption of technologies such as BCT, which eventually lead to the enhancement of their SC environmental performance. Additionally, companies should focus on enhancing their capabilities through BCT as the adoption of such technology may furthermore lead to the development of significant capabilities, increasing sustainable performance and enabling the development of sustainable strategies that can enhance the position of companies in the market.

6. Conclusions

The primary objective of this study was to empirically investigate the impact of BCT adoption on SCR and customer integration in the context of environmental SCP for both manufacturing and service sectors in the Egyptian market, as improved environmental performance can lead to increased customer satisfaction and loyalty. By adopting sustainable practices and technologies, companies can demonstrate their commitment to environmental responsibility and differentiate themselves from competitors. This can help to build customer trust and strengthen brand reputation.

Based on the review of the literature and previous studies, the research model was generated to conceptualize the theoretical concepts and discover the research gap as well as to extend the theories of KBV and DCV through empirical evidence. In support of the originality of the study to determine the relationship between BCT adoption, SCR and customer integration, and environmental SCP, the results obtained confirmed the positive and significant relationship between these things. Therefore, this research sheds light on unexplored areas regarding the adoption of BCT in Egypt. In addition, the proposed framework may serve as a valuable tool to be used by decision makers and stakeholders to upgrade the environmental performance of their SCs, as it is currently mandatory to be sustainable due to the deterioration of business conditions. Hence, this research could potentially be applied to developing nations with a similar macro economical context to the Egyptian market, although nations with different macro economical context must take into consideration their economic, political, and cultural differences in order to acquire the benefits of the proposed framework.

Accordingly, the results of this research obtain potential managerial and theoretical implications. From a managerial lens, the proposed model of the study showed that BCT alone cannot benefit the members of a SC system to manage their resources properly to enhance environmental SCP. However, the SC members must focus on adopting BCT to enhance SC resilience, manage customer integration and green information sharing to achieve environmental SCP. Even though, the relationship between these concepts is complex and multi-faceted. However, by adopting a holistic approach that integrates these concepts, organizations can create more resilient, sustainable, and customer-focused supply chains that deliver value to all stakeholders. On the contrary, although care was taken to approach respondents familiar with the BCT and environmental performance concepts, the level of understanding was expected to vary, which reflects the benefits of BCT adoption and environmental performance.

Furthermore, this study implies that organizations should exert more effort to enhance their understanding of this relationship. In terms of a theoretical approach, this research has revealed to the SCM community the potentially beneficial relationship that could be used as a tool to cope with the dynamic business environment between BCT adoption and environmental SCP when it is mediated by SCR, customer integration, and green customer information sharing. This emphasizes the need for a more impactful role and more robust empirical studies that can help to tackle the new challenges of the current digital era. Thus, this research opens up a new research avenue for scholars and practitioners interested in improving the understanding of the relationship between BCT and environmental SCP in other areas and contexts. Moreover, the results of this study could be generalized by considering various organizations not only in Egypt but also in other emerging and developing countries, such as China, India, etc. Lastly, we suggest that further studies should explore alternative qualitative methods, such as conducting interviews and focus groups where the results may contribute to the triangulation, provide further support, and shed light on the findings of the SEM model.

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Appendix A. Scale Items

Construct	Items	Statements	Adapted from
Blockchain technology adoption	BCT1	My company invests resources in blockchain-enabled supply chain applications.	Fosso Wamba, Queiroz [103]
	BCT2	Business activities in our company require the use of blockchain technologies.	
	BCT3	Functional areas in my company require the use of blockchain technologies.	
Customer integration	CI1	The level of linkage with our major customer through information networks.	Flynn, Huo [104]
	CI2	The level of computerization for our major customer's ordering.	
	CI3	The level of sharing of market information from our major customer.	
	CI4	The level of communication with our major customer.	
	CI5	The establishment of quick ordering systems with our major customer.	
	CI6	Follow-up with our major customer for feedback	
	CI7	The frequency period contacts with our major customer.	
	CI8	Our major customer shares Point of Sales information with us.	
	CI9	Our major customer shares demand forecasts with us.	
	CI10	We share our available inventory with our major customer.	
	CI11	We share our production plan with our major customer.	

Construct	Items	Statements	Adapted from
Supply chain resilience	SCR1	Our firm's supply chain is able to adequately respond to unexpected disruptions by quickly restoring its product flow.	Golgeci and Ponomarov [107]
	SCR2	Our firm's supply chain can quickly return to its original state after bring disrupted.	
	SCR3	Our firm's supply chain can move to a new, more desirable state after being disrupted.	
	SCR4	Our firm's supply chain is well prepared to deal with financial outcomes of supply chain disruptions.	
	SCR5	Our firm's supply chain has the ability to maintain a desired level of control over structure and function of the time of disruption.	
	SCR6	Our firm's supply chain has the ability to extract the meaning and useful knowledge from disruptions and unexpected events.	
Customer green information sharing	CG1	Green data sharing between our major customer establish communication channels to share green information.	Han and Huo [106]
	CG2	Our company and our major customer establish communication channels to share green information.	
	CG3	Our company and our major customer can search for green-related operational data in real time.	
	CG4	Our major customer shares green requirements information with us.	
	CG5	Our company shares green information of products with our major customer.	
Supply chain environmental performance	EP1	Our company reduces waste (air, water, and/or solid) emission.	Han and Huo [106]
	EP2	Our company decreases the consumption of hazardous/harmful/toxic materials.	
	EP3	Our company decreases the frequency of environmental accidents.	
	EP4	Our company decreases energy consumption.	

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