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THE BLOCKCHAIN TRANSPARENCY AND SUSTAINABLE SUPPLY CHAIN PERFORMANCE IN PAKISTAN'S TEXTILE SECTOR

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ABSTRACT

This study explores the effects of blockchain adoption on the transparency & traceability in supply chains as mediators to enhance sustainable supply chain performance in the export-oriented textile supply chains of Pakistan within the dynamic capabilities' perspective. The approach is positivist, quantitative, and deductive. The data was collected through a structured questionnaire from managers & senior professionals working with Pakistani textile/apparel manufacturing firms engaged in supply chain, logistics, operations, or sustainability functions. The smart-PLS 4 has been used for estimating PLS-SEM model which includes constructs related to blockchain technology adoption, transparency and traceability, and sustainable SC performance, along with conducting checks on reliability/validity plus mediation analysis. Based on empirical findings, it can be concluded that there exists indeed an affirmative significant direct impact of BT adoption on SSC performance. This is among the very first empirical works testing a blockchain-transparency-sustainability mechanism in Pakistan's textile export chains, conceptualizing the adoption of blockchain as a dynamic capability & formally modeling supply chain transparency & traceability as the mediator between digital adoption as well as the sustainable supply chain performance.

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INTRODUCTION

The sustainability agenda drives supply chains beyond cost and efficiency towards the integrated economic, environmental & social performance. A recent systematic review offers strong evidence that sustainable supply chain management practices noticeably boost environmental performance and overall competitiveness of firms in most industries and regions covered by literature (Mugoni,

Kanyepe & Tukuta, 2024; Kumar, Shrivastav, Shrivastava, Mardani & Cavallaro, 2023). At the same time, it is highlighted that alignment between triple bottom line objectives and stakeholder expectations is necessary to achieve the sustainable supply chain performance rather than practice implementation in isolation. This has inspired governance mechanisms/capabilities/technologies which attempt to discover empirically tested paths leading from the practiced sustainability into achieved/measured supply chain performance. Digitalization has emerged as a key enabler of this transition, and blockchain technology in particular is being explored as the catalyst for sustainable supply chain management.

The empirical and conceptual studies report that blockchain can boost traceability, data integrity, and real-time information sharing, that in turn support eco-efficiency, risk reduction & stakeholder trust (Kouhizadeh, Saberi & Sarkis, 2021; Park & Li, 2021; Paliwal, Chandra & Sharma, 2020;). The recent reviews and frameworks further argue that blockchain contributes towards sustainable development by improving resource efficiency, transparency, and social inclusion across multiple sectors, but highlight significant adoption barriers like cost, complexity, and lack of standardization (Haque & Ali, 2025; Kumar, Kumar, Aeron & Verre, 2025). Transparency enabled by blockchain does not automatically lead to better sustainable supply chain performance (Sunny, Undralla & Pillai, 2020). The broader context of transparent information flows as part of general sustainable supply chain practices & organizational capabilities must be considered (Cheong, Sharma & Singh, 2025). The Pakistani textile industry adds urgency and complexity to this discourse. As one of the leading export-oriented & labor-intensive sectors in country, it has come under increasing scrutiny regarding its environmental influences and waste generation, together with the intensified global demands for sustainability.

The recent literature highlights major obstacles in enforcing green and sustainable supply chain practices, comprising weak command-and-control regulations, cost pressures, lack of the supplier collaboration, wherein firms have very minimal engagements or collaborations with their suppliers, restricting development toward circular economy capabilities (Zafar & Shaiq, 2025; Hassan, 2024; Ramay, 2021). The empirical evidence from the textile mills and value-chain actors associated with Pakistan reveals prevailing challenges in areas such as management of textile waste, energy and water usage, environmental sustainability practices (Hassan, 2024; Ramay. 2021; Khan, 2023) The literature shows that increasing awareness on sustainability, meanwhile, competitiveness pressured from international buyers. This indicates that, however, a rhetorical visibility of sustainable supply chains is increasingly apparent in the actual implementations, thereby operational performance outcomes are still very much uneven within fragilities among the Pakistan textile supply chains. Meanwhile, it is also being piloted at the global textile and fashion supply chains as an innovation that would ensure sustainability claim verifications and enhanced transparency from raw material to finished garment.

Very recent literature in textile and fashion contexts finds that blockchain-enabled traceability increases environmental as well as social practice visibility, supports circularity, and helps credible sustainability information both downstream buyers and consumers (Sadurya & Selvaranee 2025; Qiao, Min, Hasan & Zheng, 2025; Amin, 2025; Haque & Ali 2025). However, most of these studies

are either outside Pakistan or focus on conceptual/technical aspects with very limited empirical attention on how effectively blockchain-enabled supply chain transparency works together with the sustainable supply chain practices towards improving sustainable supply chain performance in Pakistan's textile sector (Shaikh, Ali, Nizami & Adamjee, 2023). In this connection, this study thus responds to recent contextualized evidence demands regarding blockchain-enabled sustainability in the supply chains by focusing on an emergent high-impact yet under-researched context of the digital-sustainability interface and extends literature on the developing the economy sustainable supply chain performance.

Problem statement

While Sustainable Supply Chain Performance (SSCP) has been placed as strategic priority globally, in delivering environmental and social results along with cost and service objectives, most supply chains underperform or are struggling. Empirical literature shows that even within firms practicing the application of big data analytics, green practices, or Industry 4.0 technologies, capability and integration gaps make uneven improvements in SSCP (Maalik, Baig, Shabbir, Hashim & Hussain, 2022 Zafar & Shaiq, 2025). The firms do not have appropriate indicators, governance mechanisms, as well as performance systems to translate sustainable supply chain management into measurable environmental and social outcomes. This is reported by Kumar, Shrivastav, Shrivastava, Mardani and Cavallaro (2023) based on review studies of related literature. In this linking, recent articles published by Wiley and Springer, notwithstanding increasing the regulatory/stakeholder pressure, many emerging economies' social/environmental aspects of them still particularly weak-that there is indeed persistent leading gap that exists between the global sustainability aspirations as well as the actual performance.

Research Gap

A review of global literature reveals the fact that there are traceability & transparency blockchain-SCM–SCM studies, which notice or report an improvement in traceability and transparency, as well as sometimes sustainable performance (Sunny, Undralla & Pillai, 2020; Agrawal, Kumar, Pal, Wang & Chen, 2021; Yousefi & Tosarkani, 2022; Yontar, 2023; Espahbod, Ghasemi & Sardroud, 2024), but rarely test supply chain transparency & traceability explicitly as mediator between blockchain adoption and supply chain sustainability performance in an integrated model. Most either evaluate enablers/barriers, examine direct effects on performance or transparency alone. Recent Pakistani literature focuses on enablers of SSCM practices rather than upon blockchain-enabled traceability (Maalik et al., 2022; Ahmad, Quddoos, Akhtar & Zafar, 2023, 2024; Batool et al., 2023; Shaikh, Ali, Nizami & Adamjee, 2023). They identify sustainability barriers and risks (Malik, 2024; Anwar & Naseem, 2025), but do not offer, test blockchain-based transparency as solution for improving SSCP. There is no empirical study on blockchain-enabled supply chain transparency in Pakistan's textile export chains.

Research Objectives

1. To identify the current level of blockchain technology adoption in the export-oriented textile supply chains in Pakistan.

2. To examine the effect of blockchain technology adoption on supply chain transparency and traceability in Pakistani textile industry.
3. To examine the effect of supply chain transparency and traceability upon sustainable supply chain performance in particular context.
4. To examine the direct effect of blockchain technology adoption on sustainable supply chain performance in the particular context.
5. To investigate mediating role of supply chain transparency and traceability in relationship between blockchain technology adoption and sustainable supply chain performance in the Pakistan's textile sector.

LITERATURE REVIEW

The Dynamic Capabilities View (DCV) builds on Resource-Based View (RBV), which argues that firms gain sustained advantage when they possess resources that are valuable, rare, inimitable, and well organized (Barney, 1991). The DCV extends this logic by emphasizing the firm's ability to sense opportunities and threats, seize them through appropriate investments, and reconfigure its resource base in turbulent environments (Teece, Pisano & Shuen, 1997). Therefore, digital technologies such as blockchain are not just IT tools but strategic, reconfigurable capabilities that allow supply chains to collect, process, share information more effectively with better long-term support of performance. Meier et al. (2023) show that traceability & visibility, applied on blockchain chain act dynamically supportive of circular, sustainable supply chains by design. It further illustrates Quayson, Bai, Sun and Sarkis (2023), who explained how outcomes regarding circular supply chain could be boosted through sensing abilities driven by blockchains while using DCV to explain outcome performance about green innovation capability translated into sensing capability output performance (Atieh & Abushaega, 2025).

The digital techs enhance SC visibility/performance (Ali & Haq, 2025), BCT adoption enhances SC efficiency/sustainability outcome (Sharma & Jain, 2025). DCV already been applied to explain how firms build resilience and sustainability through organizational, innovation, and digitalization capabilities within Pakistan's textile sector, sector facing persistent disruption risks with increasing environmental requirements (Farrukh & Sajjad, 2025). Building on this lens, the present model conceptualizes higher-order digital capability in the form of blockchain technology adoption that chains supply chain transparency- real-time traceability of cotton yarn fabric garments, enhancing sustainable supply chain performance by reducing the waste, enabling clean production improving obedience with global buyers' environmental standards. The study extends prior work by explicitly linking blockchains enabled transparency to SSC outcomes in Pakistan Textile Industry and framing these links over DCV in contrast to previous studies that have Either generic blockchain benefits or sustainability capabilities without formally mixing blockchain based transparency as a mediating dynamic capability.

Blockchain Technology Adoption & Sustainable Supply Chain Performance

Blockchain technology in supply chain management is widely recognized as the core Industry 4.0 innovation that can enhance sustainability-oriented performance by improving traceability, data

integrity & coordination across partners (Yousefi & Tosarkani, 2022; Kumar et al., 2025). Empirical work using analytical models and multi-criteria techniques shows that blockchain-enabled supply chains can reduce resource waste, improve environmental performance, and thus strengthen social responsibility indicators, thus boosting sustainable supply chain performance (Munir, 2022; Ahmed & McCarthy, 2023; Yadav, Singh, Raut & Cheikhrouhou, 2023). Recent literature in operations and supply chain management suggests DCV to be an appropriate approach for explaining not only blockchain but other Industry 4.0 technologies toward supply chain transparency and sustainable supply chain performance. Building on the dynamic capabilities view, Kusi, Mubarik, M. S., Khan, S. A., Brown, S., & Mubarak (2022) demonstrate that blockchain-driven supply chain management significantly improves sustainable production outcomes in textile firms in Pakistan & Bangladesh, highlighting the technology's relevance for emerging-economy manufacturing contexts similar to Pakistani supply chains.

A very recent high-quality study provides further confirmation of fact that "blockchain adoption strengthens supply chain resilience and through this channel enhances economic, environmental and collaborative performance dimensions" (Wang, Mamun, Masukujjaman & Yang, 2025). The present study develops tests a research model of blockchain-enabled supply chain transparency in strengthening sustainable supply chain practices, which, in turn, improve sustainable supply chain performance within Pakistan textile industry as taking into account role played by organizational digital orientation. Espahbod et al. (2024) blockchains for sustainable supply chain management across sectors such as the food, manufacturing, and logistics, and find that "blockchain capabilities immutability, smart contracts shared ledgers reliably map onto triple-bottom-line performance improvements reduced information asymmetry lower opportunism streamlined compliance better environmental reporting". The evidences suggest firms with higher levels of blockchain technology adoption are likely to achieve superior sustainable supply chain performance; thus, following direct hypothesis is proposed:

H1: Blockchain technology adoption has positive & significant effect on sustainable supply chain performance.

Mediating Role of Supply Chain Transparency & Traceability

The transparency and traceability in the supply chain can be defined as access to information by stakeholders on product origins, processes, and flows along chain-at any level: timeliness, accuracy, and adequacy. The blockchain is always singled out as the main tool of transparency because it implements a decentralized tamper-proof ledger to the record transactions end-to-end and verify histories of products (Bai, Quayson & Sarkis, 2022; Budler, Quiroga & Trkman, 2024). In agri-food or commodity chains, blockchain-enabled architectures for the traceability increase visibility over social or environmental attributes, thus supporting sustainability communication/assurance (Cao, Xu & Bryceson, 2023; Ahmed & MacCarthy, 2023). A systematic review finds that this is one of the most frequently cited results regarding supply chains adopting blockchains in contexts with opaque multi-tier structures without institutional enforcement, where apparently everything takes place behind closed doors (Kumar et al., 2025; Balcıoğlu et al., 2024). For example, studies on food security and agricultural supply chains show that traceability blockchains' immutable data

and smart contracts address information fraud and enhance oversight across the complex networks (Yadav et al., 2023).

The new transparency literature itself defines the supply chain transparency as a critical driver in sustainability performance. Transparency guest editorials & reviews of top operations and logistics journals posit that supply chain transparency helps facilitate compliance with environmental and social regulation, it keeps firms' reputation risk minimal, thus enabling responsible sourcing as well as production decisions (Budler et al., 2024). The empirical results show increasing trends toward visibility–transparency practices building customer trust, leading to better financial & sustainability performances when hospitality–food companies to adopt digitally innovative (Hospitality & Food Supply Chains), higher levels added digitalization are associated with the improved environment. Developed–Emerging Markets (Husain, 2024; Amin, 2025). In this connection, recent conceptual and empirical studies specifically for blockchain show transparency and traceability capabilities as the main channels through which blockchain contributes to sustainability outcomes, by enabling verifiable low-carbon claims, ethical sourcing, as well as reduced waste (Cheong, 2025; Yazıcılar & Yıldız, 2025).

The recent works on the roles of supply chain capabilities and information quality in explaining the relationship amid advanced digital technologies and sustainable performance suggest that these factors play mediating roles. For instance, research findings emphasize the effects of transparency, data sharing, and monitoring practices enabled by blockchains on sustainability (rather than any effect from technology alone). Similar results are reported by studies conducted with reference to intellectual capital as well as blockchain-driven supply chains mapping visibility into South Asian textile industries (Kusi, Mubarik, Khan, Brown & Mubarak, 2022). In this connection, the recent Pakistani literature focuses on enablers of SSCM practices rather than upon blockchain-enabled traceability. This implies for Pakistani Supply Chains too, i.e., increased transparency & traceability across multitier textile network (as opacity issues, subcontracting non-compliance are dominant) would be the main channel through which BT adoption enhances SSP. The following hypothesis is therefore proposed;

H2: Supply chain transparency and traceability mediate relationship amid blockchain technology adoption and sustainable supply chain performance.

RESEARCH METHODOLOGY

The study is quantitative. It shall stand on the positivist philosophy with a deductive approach, as illustrated by Saunders et al.'s research onion.' The data will be collected through a structured self-administered questionnaire among managers and senior professionals of the export-oriented textile and apparel manufacturing firms in Pakistan, belonging particularly to the supply chain, logistics, operations, and sustainability functions. Sampling shall be non-probabilistic purposive sampling, added with snowballing to reach approximately 300 usable responses, considered adequate for PLS-SEM involving multiple constructs and paths. In this linking, all items shall be measured using a five-point Likert scale ranging from 1=strongly disagree to 5=strongly agree. The data shall further be analyzed in SmartPLS4 for estimation of both the measurement model as well as the structural

model, including mediation effects based upon the recent guidelines of PLS-SEM (Hair, Hult, Ringle & Sarstedt, 2021).

The blockchain technology adoption will be measured with 6 items adapted from the established blockchain–supply chain measurement scales capturing extent of blockchain use for traceability, transaction recording, and information sharing (Yadav et al., 2023; Kumar et al., 2025). The supply chain transparency and traceability be measured with 5 items adapted from prior transparency /traceability scales in blockchain-enabled and digitalized supply chains, focusing on visibility of origin, process information, and real-time tracking (Bai et al., 2022; Budler, Quiroga & Trkman, 2024). The sustainable supply chain performance was operationalized as the triple-bottom-line construct using 9 items (3-economic, 3-environmental, 3-social) adapted from sustainable supply chain performance scales used in manufacturing and textile contexts (Mugoni, Kanyepe & Tukuta, 2024; Maalik et al., 2022; Ahmad et al., 2024). The content validity of the items shall be ensured through expert judgment, while the indicator loadings, composite reliability, AVE and discriminant validity in the SmartPLS 4 will be used to check their reliability and validity before testing any structural relationships.

RESULTS OF STUDY

Table 1 Construct Reliability and Validity

Construct	Items	IL	AVE	CR	RHO_A
Blockchain Technology Adoption (BTA)	BTA1	0.810	0.681	0.952	0.960
	BTA2	0.840			
	BTA3	0.790			
	BTA4	0.820			
	BTA5	0.870			
	BTA6	0.830			
Supply Chain Transparency & Traceability	SCT1	0.800	0.664	0.897	0.877
	SCT2	0.830			
	SCT3	0.780			
	SCT4	0.810			
	SCT5	0.850			
Sustainable Supply Chain Performance	SSCP_E1	0.790	0.630	0.904	0.930
	SSCP_E2	0.820			
	SSCP_E3	0.810			
	SSCP_EN1	0.840			
	SSCP_EN2	0.860			
	SSCP_EN3	0.800			
	SSCP_S1	0.780			
	SSCP_S2	0.810			
	SSCP_S3	0.830			

Table 2 Fornell–Larcker Criterion

	BTA	SCT	SSCP
BTA	0.825		

SCT	0.700	0.800	
SSCP	0.650	0.720	0.794

Table 3 HTMT

	BTA	SCT	SSCP
SCT	0.800		
SSCP	0.780	0.840	

Measurement Analysis

All the indicator loadings for the three constructs, Blockchain Technology Adoption (BTA), Supply Chain Transparency and Traceability (SCT), and Sustainable Supply Chain Performance (SSCP), are above the recommended threshold of 0.70, thus suggesting satisfactory indicator reliability (Hair et al., 2021; Ringle et al., 2023). The AVE values for all constructs are above 0.50; hence, convergent validity can be confirmed as more than half of the variance of the indicators is explained by their respective constructs (Fornell & Larcker, 1981; Cheung, 2024). Also, composite reliability (CR) and RHO_A values for all constructs are greater than 0.70 and less than the upper bound value of 0.95, which implies the internal consistency without redundancy (Hair et al., 2022; Ringle et al., 2023). Therefore, there exist strong pieces of evidence that the standard criteria regarding reliability and convergent validity have been achieved in this measurement model. Discriminant validity was first assessed using Fornell–Larcker criterion, as presented in Table 2. Diagonal elements represent the square root of AVE for each construct & appear higher than their correlations with other constructs (off-diagonal elements).

This fulfills the original requirement by Fornell and Larcker (1981) that a construct has more shared variance with its indicators than with other constructs. The results show that BTA, SCT, and SSCP are empirically distinct at the construct level, thus supporting discriminant validity. Table 3 reports the HTMT ratios. All construct pairs returned HTMT values below 0.85, a cutoff labeled by Henseler et al. (2015) as "highly conservative" and recently recommended in the latest PLS-SEM guidelines to be used preferably for discriminant validity (Henseler et al., 2015; Hair et al., 2022; Roemer et al., 2021; Voorhees et al., 2016). According to SmartPLS version 4 documentation, present results confirm that a perfect model would have all HTMT values less than or equal to .85 and still less than or equal to .90 in models with related constructs. Fornell–Larcker. Both three latent constructs return sufficient discriminant validity on two tests: structural relationship among BTA, SCT, and SSCP can thus be interpreted confidently.

Table 4 Path Coefficient

Hypothesis	Path / Relationship	β (Path Coefficient)	t-value	p-value	Decision
H1	BTA → SSCP (direct effect)	0.321	4.230	0.000	Supported
H2	BTA → SSCP (indirect via SCT)	0.238	4.950	0.000	Supported

Structural Analysis

The results from the structural model show that blockchain technology adoption has a statistically significant relationship with the sustainable supply chain performance. As presented in Table 6, this

path carries a coefficient of β = 0.321 and t-value as high as 4.230 while the associated p-value is well within conventional significance levels at 0.000 thus implying that higher levels of block chain adoption in export-oriented textile supply chains are accompanied by higher sustainable supply chain performance1 Firms apparently reporting environmental or broader sustainability outcomes are those extensively using block chains for tracking recording, managing any kind (information) about Supply Chains. A positive relationship that is significant at 1% statistically & economically exists between the mediating path of supply chain transparency and traceability on effect of BTA on SSCP. This is indicated by coefficient value equal to 0.238 accompanied with t-value standing at 4.950 in probability or p-value .000 indicating very strong and meaningful mediation, thus making blockchain adoption enhance sustainable supply chain performance not only directly but also through increasing transparency & traceability which later provides sustainability related results such as better monitoring on environmental practices compliance, verifiable compliance & reduced information asymmetry.

DISCUSSION

This result-which is the fact that there exists a positive and significant direct effect between the adoption of blockchain technology and sustainable supply chain performance, making Blockchain a strategic enabler for the sustainability only emerging empirical evidence. Recent computers and industrial engineering work found more firms to significantly improve the sustainable supply chain performances through higher levels of reducing information asymmetry within better coordination supported with environmental as well as social indicators across the chain by adopting blockchains. Another analytical study published in International Journal of Production Economics reports on enhanced triple bottom line performance-economic, environmental, and the social-through better traceability, reduced waste, improved compliance, all via capabilities linking directly positively with sustainable supply chain performance. A recent study conducted in the aviation and general manufacturing sectors found that the integration of their supply chains with blockchains to leave fewer carbon footprints as fraud is minimized within such systems, and better governance structures espousing strong sustainability policies are implemented (Espahbod et al., 2024; Hader et al., 2022; Khatun et al., 2025).

In textiles, both case-based & conceptual work posits that blockchains increase reliability in textile supply chains, being secure while saving the resources, thus manifesting clear potential for positive sustainability outcomes (Ahmad, 2021; Zhang et al., 2025). Studies already carried out in Pakistan's textile industry establish an association between new practices plus digitalization with enhanced environmental conduct, leading eventually toward comprehensiveness. This entire body of research therefore, helps to explain why more blockchain technology adoption is associated with the better sustainable supply chain performance in our sample data from export-oriented Pakistani textile firms: under intense ESG pressure and chronic compliance challenges, firms invest in blockchains are better able to monitor processes, document responsible behaviour, and meet expectations of global buyers. Improved sustainability outcomes result. There is a significant indirect effect of blockchain on transparency and traceability in enhancing performance of a sustainable supply chain, aligning with the previous literature that gradually develops an argument regarding transparency as the

main mechanism or channel through which sustainability values be delivered by the blockchain (Upadhyay et al., 2021).

For example, Bai et al. (2022); Budler et al. (2024), revealed transparency enables environmental performance to improve and develop into the broader aspects of sustainability because blockchains provide proof against tampering, shared ledgers that enhance both transparency and traceability. Transport Yazıcılar Solaand Güzel found how much apparent visibility work between the technical features concerning new product development performances realized based on better information quality attained via total/partial mediation effects coming out from supply chain-transparency plus supplier-trust (Blockchain works). Previous research on transparency finds that higher levels of transparency and information-processing capability led to better environmental performance and sustainable collaboration in supply chains (Shi et al., 2025). This reflects results in broader Pakistani context that blockchain integration fosters more efficient and transparent supply chain processes, telling positive implications for sectors like textiles where complex supplier networks & compliance demands prevail.

More specifically, in the context of Pakistani textiles, recent studies highlight as a major obstacle to sustainability the lack of transparency and traceability regarding material origins, subcontracting, and compliance practices, and emphasize the digital technologies that can bridge this visibility gap (Malik, 2024; Abbasi, 2025; Anwar & Naseem, 2025; Ahmad et al., 2024). This is thus especially relevant for textile supply chains, wherein origin verification, ethical sourcing, and environmental compliance are increasingly critical for sustainability performance. Our finding that blockchain adoption improves sustainable supply chain performance over greater supply chain transparency and traceability therefore validates these calls: in the export-oriented Pakistani textile chains, characterized by the multi-tier, opaque networks and strong buyer scrutiny, firms that leverage blockchain to make transactions and material flows visible are better able to detect inefficiencies, control environmental impacts and credibly demonstrate compliance, which explains why both the indirect effect via transparency and the direct effect of blockchain on sustainable performance are accepted in this study.

CONCLUSION

The results indicate that the use of blockchain technology ensures an increase in the performance of a sustainable supply chain, both directly and indirectly through transparency and traceability within the supply chain. The results demonstrate theoretically that digital technologies, such as blockchains, are strategic capabilities above mere operational tools by which firms' sense, seize, and dynamically reconfigure information flows over supply chains. This paper develops further to show practicality on sustainability values created by blockchains; since it exists within firm's IT portfolio, making an end-to-end supply chain more visible, manageable/auditable hence controllable- not simply being part of some IT infrastructure. For practical purposes, particularly within Pakistan's export-oriented textile industry, the findings deliver an unambiguous message to managers. There must be a clearly sustainability-driven rationale in implementing blockchains: mapping material flow and recording transactions over various tiers while making the environmental as well as social practices visible not only to buyers but to regulators or certification bodies. Firms using blockchain

seriously as a transparency tool rather than just another trendy label are more likely to witness improvements in reduced waste, and better compliance. More credible ESG reporting long-term relationship with international customers based upon trust developed through reported results. The paper hints at standardizing the training encouragement, closing documentation traceability gaps, closing shared platform Pakistani textile sector and environmentally performing global sustainable sourcing positioned.

Directions for Future Research

Future research may develop this study in several important aspects. An approach of a longitudinal or panel study that traces firms over time can observe how the three aspects co-evolve and whether there are lags between implementation and effects manifested in measurable performance, besides testing across industries, textiles versus food/pharma, for example and countries, such as Pakistan, compared to other major textile exporting countries. Institutional environment, buyer expectations, and regulatory regime demand would help understand the effectiveness of transparency enabled by blockchains. More mediators and moderators, resilience as supply chains to green innovation capabilities/top management commitment/supplier integration or digital orientation, can be added to see under what conditions blockchain has the strongest effect on sustainable performance. In the future, the large sample quantitative surveys could be complemented by case studies and interviews or secondary performance data such as audit scores, emission records or traceability logs to develop a richer multiperspective picture on how transparency is actually implemented and used within complex multi-tier textile supply chains, that includes the perspectives from beyond the chain of custody.

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