BLOCKCHAIN AND ESG TRANSPARENCY: THE MEDIATING ROLE OF TRUST AND THE MODERATING ROLE OF REGULATORY SUPPORT

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ABSTRACT
This study examines how blockchain adoption influences ESG transparency through stakeholder trust, and how regulatory support shapes this relationship in Pakistan. ESG reporting faces a credibility crisis in emerging markets. Despite SECP ESG Guidelines 2024, PSX listed firms struggle with greenwashing concerns and lack of verification. Blockchain offers immutability, traceability, and decentralized verification, yet empirical evidence linking blockchain to ESG transparency via trust remains limited. Grounded in Stakeholder Theory, Institutional Theory, and Trust Theory, this study proposes an integrated moderated-mediation framework. Blockchain adoption is conceptualized as a technological antecedent, stakeholder trust as a mediating mechanism, regulatory support as an institutional moderator, and ESG transparency as the outcome. Seven constructs are operationalized with multi-item scales on 7-point Likert scales. For methodological illustration, a reproducible simulation with 400 cases demonstrates analytical procedures. Results show blockchain adoption is positively associated with ESG transparency, $b = .255$, $p < .001$. Trust is positively associated with transparency, $b = .388$, $p < .001$, with significant indirect effect, $b = .168$, 95% CI [.125, .216]. The interaction between blockchain and regulatory support is positive, $b = .108$, $p = .006$. The full model explains 43.6% variance. These estimates are illustrative and require validation with primary data. The study contributes a conceptual framework for PSX blockchain-based ESG verification, highlights need for independent construct measurement and longitudinal evidence, and positions credible ESG transparency as an outcome of technological integrity, organizational trust, and institutional support.

Keywords: Block chain Implementation; ESG Transparency; Trust; Regulatory Support; Mediation; Moderation; Simulation.

1. Introduction

Corporate sustainability reporting had broadened the information available to help explain what they were doing, how they were doing it and what they were doing about it in the area of their environmental impacts, their employment of people and their management of their affairs (Chittipaka et al., 2023; Zhang et al., 2023). Investors, customers, regulators and supply chain partners were increasingly questioning what had been reported versus what was actually taking place. This review had also brought about an information problem, which was not only one of the level of disclosure. A report may include a lot of sustainability language with not much detail as to where, how and by whom the measures are being delivered. Previous research by Berg et al. (2022) documented significant differences in ESG ratings and attributed the differences to the method of measurement, the scope of measurement, and the weightings of measurements (Bernini et al., 2024; Lublóy et al., 2025). In their analysis, they found that a common subject had not resulted in a common assessment. The current study did not take block chain as the sole solution to the quality of evidence problem, but identified it as part of the bigger issue (Huang et al., 2025; Santos et al., 2024; Berg et al., 2022; Christensen et al., 2022; Christensen et al., 2021).

The economic analysis of sustainability reporting also had emphasized implementation and enforcement. In the article by Christensen et al. (2021), the consequences of mandatory reporting were reviewed and the reasons for making disclosure requirements as dependent upon the institutional circumstances and materiality decisions were explained. The study showed that the relationship between the volume of ESG information disclosed and the

degree of disagreement between rating agencies was not necessarily negative. These studies cast doubt on the notion that transparency would naturally result from the disclosure of new information. The reporting incentives for disclosure continued to vary. Accordingly, in the current framework, ESG transparency was defined as the accessibility and inspectability of evidence of underlying claims. It stood out as an abstraction from a high sustainability rating, or a positive environmental result (Khan et al., 2022; Khanfar et al., 2021).

Block chain had been grabbing the attention due to its ability to provide a common ledger of transactions that would be visible if the transactions were altered later on in the chain under a properly managed network. This could link a reported claim to a supplier certificate, shipment event, or documented approval in supply chains. Khanfar et al. (2021) discussed applications in sustainable manufacturing and highlighted possible contributions in terms of traceability and information sharing. Centobelli et al. (2022) linked trust, traceability and transparency in circular supply chains. This type of research served as a foundation for predicting a positive connection between the substantive implementation of block chain and the availability of information for inspection of ESG. But, the relevant capability was actual use, not an announcement that a firm had embraced an innovative technology for reporting activities (Centobelli et al., 2022; Joo & Han, 2021).

Reporting requirements under ESG frameworks were increasingly placing pressure on organizations to support their ESG reporting and statements, which in many cases were based on partial supplier records and different definitions (Hair & Alamer, 2022; Ringle et al., 2023). These limitations had been suggested to be remedied with a technology called block chain, but its usefulness required more than just the durability of the digital entries. Most importantly, where the participants did not trust the implementation or lacked institutional guidance, the implementation would not have achieved useful transparency in reporting. On the other hand, positive trust might have stemmed from an existing clear culture, but not due to block chain. These rival theories called for a model that would distinguish the technological predictor, the mediator, the contextual moderator, and the informational outcome (Berg et al., 2022; Christensen et al., 2021).

The study sought to investigate the relationship between block chain implementation and ESG transparency, evaluate the potential mediating role of trust in the ESG reporting system in the relationship, and assess the impact of regulatory backing on the direct relationship between block chain implementation and ESG transparency. It also aimed to differentiate between inspect able disclosure and sustainability performance, to provide transparency to the industry regarding the quantitative analysis process and to use synthetic observations to identify the measurement and research design needs for a future field investigation.

The study examined that whether block chain implementation was positively associated with ESG transparency after controlling for the level of regulatory support and synthetic organizational controls. While there was a positive indirect association between block chain implementation and ESG transparency through trust, and whether the relationship between block chain implementation and ESG transparency became stronger as the level of regulatory support increased.

The methodological contribution was the complete identification of an example of mediation with moderation of the direct path. Not all interactions were defined as moderated mediation in the model. The indirect associations remained the same across the three levels of support due to the absence of interactions in the two pathways of the mediated pathway. Schuler et al. (2025) had identified three practical mediation challenges: temporal ordering, measurement error, and confounding. The analysis also showed that the bootstrapping of confidence intervals, robust standard errors, and explicit variable scaling were important. These decisions made the manuscript useful as a template for analysis, and the strong labeling of the manuscript as a simulation retained the distinction between statistical illustration and the evidence of research. This focus on transparent reporting was guided by methodological suggestions from the present day on model specification and interpretation of results.

2. Literature Review and Hypothesis Development

2.1ESG Transparency and the Quality of Sustainability Evidence

ESG transparency went beyond just releasing environmental and social data. It was about whether relevant users could find reported measures, the extent to which they could comprehend the boundaries, be able to examine supporting records, and determine if there were follow-up corrections. These attributes were found to be different from organizational sustainability performance. A company could have high emissions and another company could have good scores on some of the indicators with poor supporting documentation. As Berg et al. (2022) showed, some divergent ESG assessments were partly a result of the decisions on what was measured and how. Similarly, they demonstrated that disclosure had not led to interpretive consensus. The current system thus did not consider inspect ability as a positive assessment of the organization, but rather as a helpful piece of information.

The link between disclosure and accountability was further complicated by research on green washing. Montgomery et al. (2024) investigated the evolution of green wash, and Huang et al. (2025) reviewed the general

literature. These contributions helped to bring attention to the gap between the words and the actions. A digital evidence trail might have been able to limit some such misstatements but it could also have enhanced the sense of legitimacy of unsupported statements. The study, therefore, did not include any items asking if the firm looked green. Rather, the content related to access to records and the ability to recreate an ESG from the known source.

The measurement problem was followed by the measurement challenge of empirical proxies. Bernini et al. (2024) and Lublóy et al. (2025) had examined the extent to which researchers accounted for communication and the impact of proxi choices on the results. The intention of using a rating disagreement measure, a disclosure score and verified emissions discrepancy was to measure different phenomena. This observation was important because the eventual result was a perceptual composite in the simulation. It helped participants assess inspectability, but did not provide any objective assessment of document completeness or reporting accuracy. For a field application, there was a need for an independently scored evidence checklist and clear definitions of the environmental, social and governance boundaries to which each reported measure applies.

The concept of a direct relationship was grounded on the possibility of a reduction in the fragmentation of the reporting records due to application of the block chain. If two or more events had been reported by a number of parties that were equally consistent with the same rules, a reviewer might be able to determine the order of the events behind any event reported for a specific measure. For instance, a materials claim might have been linked to a supplier declaration, a receipt record and an approved conversion factor. Khanfar et al. (2021) discussed the applications in the manufacturing industry and Parmentola et al. (2022) discussed the relation of block chain with environmental sustainable goals. Their reviews set out to identify potential usage and restrictions, rather than a blanket statement of performance. The present argument was thus one of the inspectable records under certain conditions, rather than improvements in all ESG dimensions automatically.

Empirical studies also indicated that it was relevant to pay attention to intermediate organizational processes. Khan et al. (2022) studied the supply chain mapping and integration and found that block chain technologies had an indirect relationship with supply chain sustainability. This outcome demoralized a transfer of positive claims from one outcome to another. The mapping of the supply chain might have increased the awareness of the sources of the records, but still, there was a need for operational decisions to be made in order to sustain the performance. The current study suggested that a direct pathway of transparency be considered since the evidence retrieval might have been better even if there was no increase in trust. It did not eliminate the mediated path as participation and disclosure behaviour might have introduced an organisational path over and above technical recordkeeping.

The anticipated relationship was weakened via a number of implementation decisions. There may be loopholes between suppliers due to selective participation. Records may not have been connected across systems if there were inconsistencies in the identifiers. If a network administrator had restricted access to unfavorable evidence, it would have been a case of network oligarchy.If a network administrator had limited access to bad evidence, it would have been network oligarchy. The trade-off between traceability and sustainability was studied by Biswas et al. (2023), and the study by Zhou et al. (2023) had explored consumer skepticism in block chain disclosure decisions. The direct hypothesis thus implied an average positive association, given the relevant implementation quality. It didn't presume that all block chain projects were superior to a properly governed traditional database system.

H1 Block chain implementation was positively associated with ESG transparency.

2.2Block chain Implementation and Trust

Confidence in the ESG reporting arrangement was influenced by the ability of responsible parties to keep records effectively, ensure agreed procedures are followed consistently and resolve issues if they are identified in a truthful manner. This confidence might have been bolstered by the ability to access block chain and see a history that is stable and reviewable. If a supplier was put in a position of having to deal with a certificate that is disputed, they could have looked into who submitted it, and whether or not any documentation changed. Centobelli et al. (2022) studied the relationship between trust, traceability and transparency in circular supply chains. Their work did offer a related foundation, but circular supply chain coordination was not the full extent of the governance challenges faced by corporate ESG reporting.

Joo and Han (2021) provided a more detailed description of the distributed trust in a food supply chain. Yavaprabhas et al. (2023) identified different types of trust relationships in the literature and identified opposing perspectives on whether block chain would be a replacement or reinforcement for interpersonal trust. The current model did not presume the absence of trust from software. Participants still relied on the skill of the data providers, honesty of system administrators, and fairness of dispute resolution. It was hoped that implementation would help to clarify some of the uncertainty, making conduct easier to police, but keeping these organisational dependencies visible.

An alternative plausible explanation was also found to be a possible explanation for the relationship. Sharing of systems could have been more applied by organizations with higher trust in the first place since the participants had already agreed on the common rules. Furthermore, there might have been a loss in trust due to discrepancies that became apparent during implementation. Zhang et al. (2023) found that the negative trust coefficient was context-dependent in a block chain adoption model in Pakistan, warning against generalizing results from research contexts. The study was left with a positive hypothesis to test.

H2 Block chain implementation was positively associated with trust in the ESG reporting arrangement.

2.3Trust and ESG Transparency

Transparency could have been achieved by the willingness to share information, which would have brought an organisation into scrutiny. Participants who had previously thought that the records were being fairly evaluated might have been more willing to produce measurements that were not complete, to report exceptions, and to cooperate with assurance requests. Defensive withholding may have also been dampened because of an increase in the reporting structure that would give more confidence. But this self-assurance demanded a "bounded object. Trust of the business reliability of a trading partner did not mean trust of the trading partner's labor data. The existing structure thus placed the mediator under the control of ESG reporting governance and not of organizational goodwill in general.

Trust and transparency had a possible two-way relationship. Greater confidence may have encouraged wider disclosure and more accessible records would have led to more confidence. Research linking trust and transparency like Joo and Han (2021) validated the plausibility of this bi-directional relationship without independently testing the directionality towards transparency that was used here. The current study recognized this limitation in the development of the hypotheses. It suggested that the confidence in the arrangement allowed the subsequent disclosure behavior to occur, and recommended to conduct the measurement at a separate time in a field test. This separation meant that there would not be any conceptual association presented as evidence of temporal sequence.

Too much trust also may have led to a decrease in inspections. Those who not only assumed that partners had acted appropriately but also had not detected discrepancies or received less than adequate documentation. The use of corporate communication had already been problematic in the context of "green washing" research, which was still limited at the time. It was not an account of the "passive acceptance" of managerial claims. This reading was a reading that positioned the mediator as ones who cooperate, not believers.

H3 Trust in the ESG reporting arrangement was positively associated with ESG transparency after adjustment for block chain implementation and regulatory support.

2.4The Mediating Role of Trust

The mediation role of trust argument which is drew from the above relationships, an organizational mechanism. Reporting conduct might have been more observable because of substantive implementation, and this could have fostered confidence in the arrangement (Qureshi et al., 2025; Zaczyk & Semrau, 2026). This would have allowed participants to give more supporting information if they had had higher confidence. This sequence was not the direct path that was followed in record retrieval. The direct route was based on the capacity for documentation within the system, the indirect route was based on the response to the documentation capacity within the system. The framework thus permitted both relationships to continue without suggesting that, as a result of that, trust accounts for all of the benefits of implementation (Centobelli et al., 2022; Joo & Han, 2021; Yavaprabhas et al., 2023).

In addition, statistical mediation was more narrowly constructed than causal mediation. If both omission reporting culture and trust were explained by an estimated product of the coefficients, then zero could have been excluded. A positive covariance pattern could have been established by simultaneous self-reports in absence of the sequence. The association was indirect and deliberately created to be compatible with the model simulation; thus, this association represents model behavior under the assumption (Khanfar et al., 2021; Munir et al., 2022; Parmentola et al., 2022).

H4 Trust statistically mediated a positive association between block chain implementation and ESG transparency.

2.5Regulatory Support as a Moderator

Regulatory support was measured as clarity and help from regulators on the use of digital evidence for ESG reporting. It included clear instructions, resources on implementation support, reasonable expectations, and practical processes for addressing reporting confusion. The following features were not caused by regulatory pressure. The issue of pressure was about the costs of noncompliance, whereas support was about the circumstances whereby organizations would be compliant with reporting. Chittipaka et al. (2023) have been incorporating environmental influences in a block chain adoption model, have been emphasizing the

implementation environment of sustainability reporting. These streams, when added together, warranted an analysis of institutions beyond the background (Huang et al., 2025; Santos et al., 2024; Berg et al., 2022; D. M. Christensen et al., 2022; Christensen et al., 2021).

When participants knew what evidence was accepted and who was responsible for any incorrect inputs, and how reporting borders were used, it would have been helpful to have been documented on the block chain (Bernards et al., 2024; Huang et al., 2025; Montgomery et al., 2024). If an organization was not well supported, it could have been keeping a lot of records, but not understand if the records meet reviewers' needs. The same level of implementation ability would have been matched with a bigger improvement in reporting that was inspected. It was a foretelling of the interaction between implementation and transparency rather than just of an increased level of transparency in all organisations in a supportive setting (Arshad et al., 2023; Qureshi et al., 2025; Sahoo et al., 2024).

Other possibilities continued to be viable. Detailed rules could have fostered a template that would have diminished the block chain's added value. Detailed rules could have facilitated uniform templates, lowering the added value of the block chain. Conventional reporting systems also could have gained from additional support to bring technologies closer together. Liu et al. (2023) had found decision rights and accountability to be unsettled issues of governance in sustainability and Bernards et al. (2024) had doubted whether better documentation is always the right thing for better sustainability governance. The positive interaction continued to be a possibility that had to be tested.

H5 Regulatory support positively moderated the direct association between block chain implementation and ESG transparency, such that the association became stronger at higher levels of support.

2.6Empirical Scope and Remaining Research Gaps

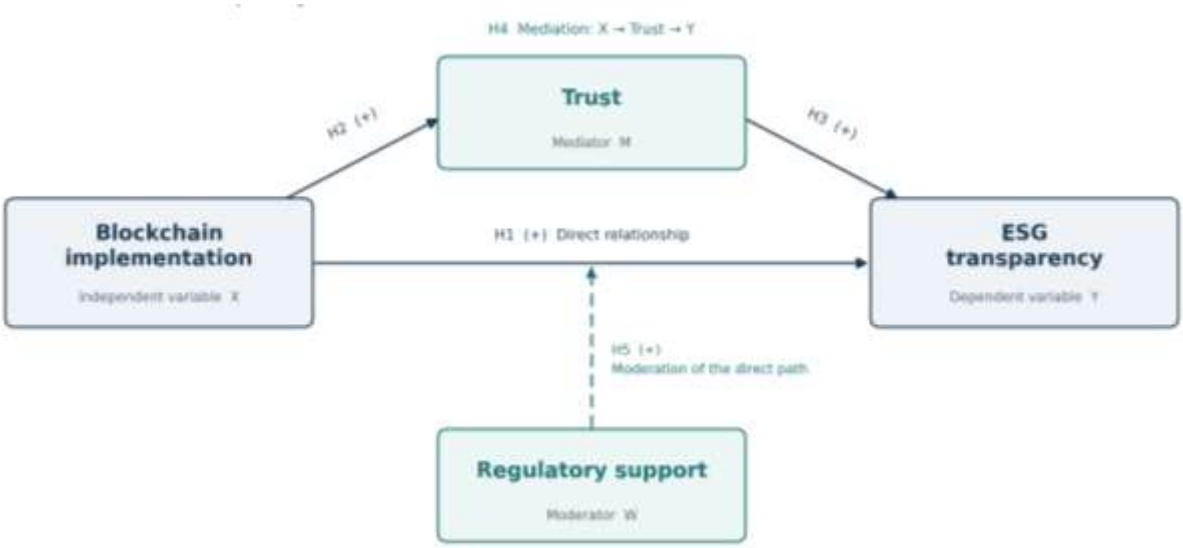
Park and Li (2021) had conducted literature review and cases to study block chain sustainability. Lohmer et al. (2022) had recognized that conceptual studies prevailed in the field of operations and supply chain studies. In terms of sustainability applications, Munir et al. (2022) had grouped the applications in the economic, environmental, and social perspectives, and Sahoo et al. (2024) had mapped the themes from different industries. These reviews helped to justify a specific outcome definition rather than general expectations being translated into a statement of transparency regarding ESG. Qureshi et al. (2025) had also pointed out implementation benefits, in addition to energy, standardization and integration issues. Arshad et al., (2023) had done a review of environmental sustainability research and theoretical and analytical approaches.

Another boundary came from buyer behavior. Vinayavekhin et al. (2024) had explored the preferences and willingness-to-pay of buyers for sustainability transparency on the block chain. This included preferences for the value users placed on information, rather than whether an organisation made the evidence available or not. Iranmanesh et al. (2023) had already studied transparency and other benefits of the supply chain as antecedents of adoption. This was a re-enforcement of the selection possibility, with the possibility that firms that already had a preference for clear coordination were more likely to be selected. The present model thus necessitates baseline transparency in a field design, instead of interpreting a cross-sectional coefficient as a field implementation effect (Bernini et al., 2024; Lublóy et al., 2025; Zioło et al., 2024).

Omitted dimensions were also identified in governance and with stakeholders through research. Werner (2023) had looked into block chain governance, and Mulligan et al. (2024) conducted a policy analysis of block chain sustainability research. Santos et al. (2024) have synthesized greenwashing in the context of stakeholders, Zioło et al. (2024) have looked at the general picture of greenwashing studies, and Liu, Li, Wang and Meng (2023) have studied the antecedents and consequences of greenwashing. These sources led to focus on who had the power to control reporting rules, who can check records, and who can have a complaint resolved that isn't considered within the system. Their work did not create the present configuration of trails, but it did help to spell out why technical effectiveness was not enough to make a credible reporting theory.

2.7Integration of the Conceptual Framework

The framework integrated a technical argument for capability with an institutional explanation for the use of information. Implementation was expected to be directly and indirectly facilitated by trust. The direct implementation slope was to be conditioned by regulatory support. There was no interaction indicated on the mediator equation or along the path of trust to transparency. Therefore in this model, the direct association was thus represented as being mediated in the presence of moderation. It didn't indicate a changing indirect relationship between levels of support. That distinction was important because support coefficient alone did not provide a test of moderated mediation.



3. Methodology

3.1Research Design and Analytical Scope

This study employed quantitative simulation design and cross sectional synthetic records. It had an organizational type of structure an organizational survey, but it did not involve survey administration. 400 independent cases were created using a fixed random seed of 20261022. There were four constructs associated with block chain implementation (technical, trust, regulation, transparency ESG). Two other random variables were hypothetical standardized organizational size and age controls. They provided an example of estimation, but it involved no actual organization. This design enabled a full demonstration of descriptive analysis, internal consistency, correlation, regression, mediation and moderation, while keeping a transparent account of the nature of the data being artificial.

3.2Population and Sampling

A follow-up field study was then structured by organizations that were responsible for the operation of ESG reporting and by varying degrees of block chain adoption. Eligible informants were those involved in sustainability data, sustainability compliance, internal audits or supply chain information systems. It was necessary for the sampling frame to be independently confirmed for both reporting responsibility and implementation status. Organizations that were not running a block chain use case were not at risk of being 'left out' as this would have shortened the predictor and restricted comparison. Announcement, token ownership, or cryptocurrency trading were not considered as proof of block chain implementation in ESG reporting.

A single primary informant per firm would have maintained the organizational unit of analysis, and other informants could have provided independent trust and transparency evaluations. There were multiple respondents from the same firm who needed aggregation evidence or a multilevel analysis. The number of 400 cases in the simulation was selected as a demonstration size (as in Lakens 2022).

3.3Research Instrument

There were four original illustrative statements for each construct. The level of block chain implementation was assessed across the following areas: reporting events on a shared ledger; linking reports to documents; access to appropriate documents by authorized parties; and the use of block chain by routine ESG processes (Bernini et al., 2024; Lublóy et al., 2025; Hair & Alamer, 2022; Hair et al., 2021; Ringle et al., 2023). Participants' attendance at the reporting showed they had kept records competently, followed agreed rules, acknowledged errors honestly and dealt with disputed entries fairly. Trusting that participants were attending and keeping records competently, following agreed rules, acknowledging errors honestly, and dealing with disputed entries fairly. Regulatory support included whether guidance was clear, there was support to help implement the guidance, whether the expectations for reporting were compatible, and whether uncertainty was evidenced by workable procedures (Chittipaka et al., 2023; Mulligan et al., 2024; Zaczyk & Semrau, 2026).

Transparency included: accessibility of supporting evidence; source responsibility identifiable; selected figures reconstruct able from records; corrections visible. It is important to note that these item domains intentionally excluded the mediator's confidence language. They also refused to attribute improvements in transparency to improvements in environmental or social performance. The seven categories (strong disagreement, disagreement,

disagreement, neutrality, agreement, agreement, and strong agreement) were all used in illustrative responses. The synthetic procedure gave numbers from one to seven. For each construct four items were averaged, resulting in scores on the original response scale prior to being standardized for regression (Bernards et al., 2024; Montgomery et al., 2024).

The item domains were conceptually informed by the literature on block chain applications, block chain trust and block chain disclosure on sustainability such as Khanfar et al. (2021), Joo and Han (2021), and Yavaprabhas et al. (2023). The theoretical relevance rather than claimed inherited psychometric validity was outlined in those citations. An instrument used in the field had to undergo expert review, cognitive interviews and translation of the instrument (if needed), and be tested with the target population. Special care had to be taken to gauge if there was a lack of understanding amongst the nontechnical reporting personnel in relation to operational implementation, and if all respondents saw the reporting arrangement as being one and the same trust object.

3.4Data collection

The item responses were based on four underlying variables. The first draw of independent normals was correlated with implementation and was used to create an implementation variable as well as a regulatory support variable. Trust was then built up as a linear combination of implementation and support plus random disturbance. Implementation, trust, support, and implementation of support interaction, and another disturbance, were the causes of transparency. In particular, the equations underlying support = .20 implementation + √.96 u; trust = .55 implementation + .18 support + .78 v; and transparency = .25 implementation + .45 trust + .20 support + .18 implementation × support + .72 e. The disturbances were normally distributed and independent.

3.5Data Quality and Measurement Assessment

The 400 synthetic records included full item values from the onset. No recruitment was excluded, no questionnaires were incomplete, no one responded carelessly and no observations were imputed. The features detailed a clean simulation and were not the same as the missingness or the response behavior of a real survey. Descriptive statistics comprised the mean and standard deviation as well as the skewness and excess kurtosis of each of the composites. The internal consistency of each four item set was summarized using Cronbach's alpha. Alpha was not seen as evidence of a questionnaire having content validity or of the construct domain being fully represented, but rather as an indication of properties of responses generated by the questionnaire.

4. Results of the Simulated Quantitative Analysis

Table 1 Descriptive statistics and internal consistency of simulated composites

Construct	Mean	SD	Skew	Kurtosis	Alpha
Block chain implementation	4.022	0.938	0.013	-0.280	0.878
Trust	4.014	0.938	-0.022	-0.159	0.880
Regulatory support	3.923	0.928	0.080	0.023	0.873
ESG transparency	4.044	0.924	-0.067	-0.028	0.873

The four simulated composites were summarized in Table 1. For the seven-point response, the highest score was obtained for regulatory support (3.923) and the lowest score for transparency (4.044). Standard deviations did not vary significantly from .93. These values were not a reflection of the fact that a real sector had come to a moderate level of adoption or transparency, but the procedure by which they are generated. The simulated composite distributions were relatively symmetric and were fairly mesokurtic (with small amounts of excess kurtosis) and skewed. These descriptive patterns were not used to confirm the linear regression assumptions, namely the conditional relationships fitted and their residual behaviour, but not the marginal normality of each of the individual regressors. The internal consistency estimates were between .873 and .880.

Table 2 Correlations among simulated composite scores

Construct	1	2	3	4
1 Block chain implementation	1.000	—	—	—
2 Trust	0.458	1.000	—	—
3 Regulatory support	0.117	0.258	1.000	—
4 ESG transparency	0.466	0.559	0.365	1.000

Table 2 presented Pearson correlations. Implementation correlated with trust at r = .458 and with transparency at r = .466. Trust had the largest bivariate association with transparency, r = .559. Regulatory support correlated with transparency at r = .365 and with trust at r = .258. Its correlation with implementation was smaller, r = .117. This pattern provided sufficient predictor variation for the illustrative adjusted models. All correlations described

covariance among synthetic composite scores, and none established causal ordering or population-level association among actual organizations.

Table 3 Regression coefficients from simulated mediation and interaction models

Outcome	Predictor	b	HC3 SE	p	95% CI
Trust outcome	Implementation	0.434	0.042	< .001	0.351 to 0.517
Trust outcome	Support	0.208	0.041	< .001	0.127 to 0.288
Trust outcome	Synthetic size	0.014	0.043	0.751	-0.071 to 0.099
Trust outcome	Synthetic age	0.010	0.044	0.825	-0.077 to 0.096
Transparency outcome	Implementation	0.255	0.041	< .001	0.175 to 0.335
Transparency outcome	Trust	0.388	0.040	< .001	0.310 to 0.466
Transparency outcome	Support	0.237	0.040	< .001	0.159 to 0.315
Transparency outcome	Implementation × support	0.108	0.039	0.006	0.031 to 0.185
Transparency outcome	Synthetic size	0.033	0.037	0.381	-0.041 to 0.106
Transparency outcome	Synthetic age	-0.061	0.038	0.110	-0.135 to 0.014

The mediator equation accounted for 25.2% of the variance in trust. Implementation had a positive coefficient, a = .434, with HC3 SE = .042 and p < .001. There was also a positive adjusted coefficient for support, b = .208, p < .001. The synthetic size and age controls were not statistically significant. The mediator equation was reported along with the complete outcome equation in Table 3. Positive implementation coefficient was in agreement with H2 of the generated data. The result showed recovery of an assumed pattern, but not a technological influence on real reporting participants, as this relationship had been encoded in the generation procedure. The implementation conditional direct coefficient for the full outcome equation was .255 with HC3 SE = .041 and p < .001. Trust had a coefficient of .388, with SE = .040 and p < .001. Support had a coefficient of .237, p < .001. The interaction coefficient was .108, with SE = .039 and p = .006. Results obtained were similar to the simulation time levels H1, H3, and H5. The percentages of variance explained by the full equation were 43.6% and adjusted R^2 = .427. This was a variance for an outcome model without the interaction, which accounted for 42.6%. The additional of the product term added about 1% to the R^2. The interaction was thus a smaller addition to the total increments of the set of predictors explained together. The comparison was used to validate a proportional interpretation: the amount of simulated moderation was detectable, but did not overwhelm the outcome model. The synthetic size coefficients were .033 with a p value of .381 and the synthetic age coefficients were −.061 with a p value of .110. The vague controls did not suggest that the size or age of the organizations were not relevant to reporting transparency.

Table 4 Simulated indirect association through trust

Path component	Estimate	95% bootstrap CI
Implementation → trust	0.434	—
Trust → transparency	0.388	—
Indirect association a × b	0.168	0.125 to 0.216

The product of the implementation to trust coefficient and the trust to transparency coefficient was .168. Its 95% percentile bootstrap interval ranged from .125 to .216 and excluded zero. Table 4 therefore recorded a positive statistical indirect association consistent with H4 in the synthetic dataset. The direct implementation coefficient also remained positive. The combined pattern resembled complementary direct and indirect associations, but a causal claim about partial mediation remained unsupported. In particular, no observed time sequence established that implementation preceded trust or that trust preceded disclosure behavior.

Table 5 Conditional direct associations at simulated support levels

Support level	Slope	HC3 SE	95% CI
Low −1 SD	0.147	0.061	0.027 to 0.267
Mean 0	0.255	0.041	0.175 to 0.335

High +1 SD	0.363	0.052	0.261 to 0.465

Table 5 showed conditional implementation slopes at three support levels. At one standard deviation below mean support, the direct slope was .147, with a 95% interval of [.027, .267]. At mean support, the slope was .255, with [.175, .335]. At one standard deviation above mean support, it was .363, with [.261, .465]. The results illustrated the positive interaction: higher support accompanied a steeper implementation–transparency slope after adjustment. The estimates concerned conditional direct associations. They did not show that the indirect association through trust had changed across support levels. Variance inflation factors ranged from 1.008 to 1.351, indicating limited collinearity in the simulated specification. The Breusch–Pagan statistic was 6.043 on six degrees of freedom, p = .418. This test did not provide evidence against constant error variance under that auxiliary specification, although its nonsignificance did not prove homoskedasticity. HC3 standard errors remained the planned reporting basis. Independence had been imposed by generation rather than verified from an organizational sampling process. The diagnostics therefore described a comparatively simple artificial setting and did not anticipate all the complications of clustered firms, supplier networks, or repeated reports.

Table 6 Hypothesis evaluation within the simulated dataset

Hypothesis	Tested quantity	Estimate
H1	Direct slope at mean support	.255
H2	Implementation → trust	.434
H3	Trust → transparency	.388
H4	Indirect association	.168
H5	Implementation × support	.108

The results indicated that each of the five statistical questions led to different interpretations. H1 was a conditional direct slope, which meant that the estimate only applied on average, but not in all reporting environments. H2 was associated with implementation and H3 was associated with adjusted trust and transparency. H4 and H5 have merged these two fitted paths together in an indirect association, and H5 has estimated the change in the direct implementation slope. This separation helped to avoid the possibility of being misled into thinking that there was a significant correlation. It also helped to shield the positive interaction from the possible interpretation that the support to regulation had increased the trust mechanism. These distinctions have been maintained in the analysis of the numerical pattern when summarizing the pattern, as each conclusion was based on a different coefficient or interval.

5. Discussion

The positive conditional coefficient indicated a recordkeeping channel for linking entries that would have supported evidence retrieval if the assumptions made in the generation were met. Another consideration related to technology comparison. The model did not include an alternate database system nor a cost measure. The positive implementation coefficient it provided therefore did not provide any evidence to show that block chain was superior compared to a well designed traditional reporting platform. An equivalent reporting definitions, access rules, assurance effort, and organizational resources had to be used across technologies for an equivalent comparison to be made. If they were absent, the association observed might have been due to investment quality or managerial attention. The concern was made salient by Bernards et al. (2024) who doubted whether technologically mediated disclosure solved the underlying governance issues raised by its use (Berg et al., 2022).

The positive indirect association has been exemplified to show that confidence in the reporting arrangement could have been associated with the implementation – transparency association. The mechanism was in principle possible, as information-sharing could result in participants being made aware of the information to be reviewed, and perhaps be the subject of criticism. Participants likely might not have been as likely to withhold weak measurements or delay disclosure if they had believed that errors would be fairly handled. Yavaprabhas et al. (2023) identified some different forms of trust, which justified writing the name of the trust object explicitly. Current mediator focused on reporting competence and on fair procedure. It did not say that users' hearts had become attached to a technical platform or they had gained confidence in all participants of the supply chain (Qureshi et al., 2025; Zaczyk & Semrau, 2026).

There was an institutional complementarity in the positive interaction shown. The larger the implementation difference the larger the transparency difference was at higher support. This interpretation worked in an environment where there was clear guidance and accessible support to bridge the gap between technical records and the reporting requirements. It was not associated with the support main effect, which was about the association between support and transparency at the mean implementation. H.B. Christensen et al. (2021) had highlighted the need for implementation and enforcement in sustainability reporting, and Chittipaka et al. (2023)

had included the regulatory influences in adoption studies. These sources confirmed the institutional argument without providing an empirical measure of the current moderation effect (Centobelli et al., 2022; Joo & Han, 2021; Yavaprabhas et al., 2023).

The conceptual argument linked block chain research with issues of transparency and credibility. Ren et al. (2023) placed block chain in the context of sustainable finance, and Parmentola et al. (2022) discussed the possible environmental benefits in addition to the technological expenses. These streams collectively indicated that a reporting application needed to be evaluated more than just for its ease of being digitized. The relevance of an ESG measure, the incentive to report it honestly, and the potential for contestation of an entry still remained once it was put into practice. The study thus did not make the mistake of assuming that longevity of data was synonymous with honesty in corporate actions, but also introduced technical immutability into a larger evidence process. The study therefore didn't mistake the immutability of the technical evidence for the honesty of the companies' actions, but also brought the concept of technical immutability into a more comprehensive evidence process (Bernards et al., 2024; Huang et al., 2025; Montgomery et al., 2024).

Evidence was also sought for environmental, social and governance claims. Energy use might have been based on calibrated meters and conversion factors; labor conditions might have been based on workers' confidential testimony; governance events might have been based on approvals and accountability records. A ledger might have been useable for specific documentation tasks, but might not have been appropriate for specific evidence or context. An individual transparency composite could mask these differences. In their literature review, Zaczyk and Semrau (2026) have identified that attention to the applications of environmental, social and governance has been disproportionate. The general literature on the block chain application and measurement of greenwashing supported further analyses that have differentiated the three ESG fields and investigated if the same mechanism holds in each field (Hair & Alamer, 2022; Hair et al., 2021; Ringle et al., 2023).

The transferability was restricted by institutional variation. There were different participants and incentives studied in an emerging-market adoption study, food traceability study, and global supply chain governance critique. Although Zhang et al. (2023) and Chittipaka et al. (2023) had regionally relevant research on adoption; there was no direct link between adoption intentions and reporting outcomes. The present manuscript identified contextual considerations with the work of those studies and not as empirical replication. The sampling frame, the reporting context, the language used, and the verification of actual implementation of a study in Pakistan had to be locally-centric to make jurisdiction-specific conclusions (Chittipaka et al., 2023; Mulligan et al., 2024; Zaczyk & Semrau, 2026).

6. Methodological Implications

Finally, there was the need for an actual study of an organization that would distinguish between statistical adjustment and causal identification. There was no elimination of potential confounders, such as reporting culture, leadership commitment, prior transparency, and external scrutiny, after the inclusion of size and age. Both of the controls were synthetic and provided no real testing of confounding control. A future analysis required a causal basis for each of the adjustment variables, and did not attempt to control for the consequences of the implementation which were integral components of the implementation process. Even if a long list of controls was added, a significant coefficient for block chain use would not have resolved the issue of endogeneity if the question of selecting to use block chain had not been addressed (Bernini et al., 2024; Lublóy et al., 2025; Zioło et al., 2024).

The analysis spurred a recommendation to consider input verification before an expansion of shared ledgers. Appropriate procedures were carried out as identification of data owners, measurement methods, documentation of uncertainty, and recording of the way disputed evidence was addressed (Arshad et al., 2023; Qureshi et al., 2025; Sahoo et al., 2024). A supplier certificate needed to be confirmed by the supplier and was valid for a certain time period, and a calculated emissions figure needed to be supported by the activity measure and the conversion factor. These recommendations came out of conceptual distinction between record integrity and source accuracy. They did not show benefits of the "model" they had created (Khanfar et al., 2021).

Organizations were encouraged to create clear accountability for record entry, record approval, record corrections, and challenge of records. Builders of trust needed to see the procedures, not make claims about decentralization. Participants had to have a way to report mistakes without him/her being deprived of access and without being over-rewarded (Khanfar et al., 2021; Munir et al., 2022; Parmentola et al., 2022). Access arrangements also had to prioritize commercially sensitive information from information that external reviewers had a valid need for. Yavaprabhas et al. (2023) affirmed the attention given to the various relationships that the trust had been built on. The recommendation was thus about confidence based on responsible action and the need for independent inspection was not removed even with longstanding partners.

The framework provided for a recommendation that practical reporting support be considered for review in tandem with compliance requirements by policy and industry stakeholders. Technology neutral evaluation was necessary for such measures to allow organizations to choose an appropriate reporting system (Huang et al., 2025; Santos et al., 2024). The simulated interaction did not prove financial subsidies or new legal requirements led to improved transparency. It showed one possible complementary relationship. The policy discourse regarding sustainability reporting had already highlighted that the conditions for implementing the policy were important to consider because they influenced the policy's outcomes.

Companies were encouraged to make comparisons between reporting gains and costs for integration and training, maintenance and assurance. Evaluation also needed to show that when there was an improvement in inspectability, there was also an improvement in environmental or social outcomes. Although a system that exposed poor performance more clearly could be said to have greater transparency, this alone did not solve the problem. However, Parmentola et al. (2022) had already mentioned the environmental trade-offs of block chain and therefore the consideration of the architecture chosen should not be based on all block chain apps (Berg et al., 2022; Centobelli et al., 2022; Bernards et al., 2024). An explicit conventional-system comparator was required for any investment appraisal, as was an evaluation of the burden of supplier participation (Bernards et al., 2024; Montgomery et al., 2024).

6. Limitations and Directions for Future Research

The main constraint was that the observations were only simulated. There was no estimate that included a real organizational population, and for all supported paths, they were applied to intentional relationships in the generation. The one random seed also ruled out the possibility of testing the stability of the estimates with repeated samples. Other levels of noise, weaker interactions, missing common causes and nonlinear relationships might have resulted in other patterns.

The second restriction was furnished by measurement. The four items per construct provided a compact structure for the instrument, but there were no judgments by the participants and no factor models to determine the dimensionality of the items. It would have been better to have made the uniform items as the actual organizational survey would have provided less clean scales. Regulatory support is a collection of enabling conditions; interactions between these conditions could be different in real life. The information features that the ESG transparency reflects may have differed in the environmental, social and governance records. Future research is needed to determine whether these domains are suitable for being made as reflective scales or if there needs to be separate indicators and a separate definition.

7. Conclusion

The study created a quantitative model that correlates block chain adoption with ESG transparency based on trust and conditional on the regulatory environment. It was an analytical demonstration because it was based on 400 simulated cases. The conditional direct association between implementation and average support was positive, between implementation and trust was positive, and bootstrapped indirect association between implementation and trust was not equal to zero. The positive interaction showed a greater direct implementation slope at a higher support. These patterns were not a result of the relations that were coded in generation and not a validation of the hypotheses outside the simulation, nor were it a causal effect.

The conceptual contribution was based on well-defined distinctions. Operational use of block chain, confidence in accountable reporting procedures, enabling institutional conditions by regulatory support, and inspectable evidence by transparency, was the areas of concern associated with block chain implementation. These are constructs that did not associate disclosure with sustainability achievement. Previous studies on ESG ratings and block chain applications as well as critical governance perspectives had warranted this separation. The framework also clarified between moderation of a direct relationship and moderation of mediation, with consistency between theory, specification and the estimates reported.

The result of this research program was a focus on the importance of verified implementation, independent transparency assessment, temporal ordering, and explicit consideration of reporting incentives. Some organizational recommendations included source verification, fair correction procedures and access rules that will permit meaningful scrutiny. Practical clarity and interoperable evidence requirements were recommended in policies, subject to cost and alternative considerations. The research finally framed credible ESG transparency as an organizational and institutional achievement, underpinned by technology. Before any real firm could be said to have seen improvement in reporting results due to block chain, trust, or regulation, it was still necessary to do a field investigation.

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