Research on Environmental Accounting Information Disclosure Mechanism Driven by Blockchain Technology

Yisong Chen[1, *]

[1] School of Computing and Artificial Intelligence, Georgia Institute of Technology, Atlanta, US 30332

[*]Email: yisongchen97@gmail.com

Abstract

This paper, based on the case study method, focuses on three typical practices of A Company (new energy manufacturing), B Group (petrochemical industry), and C Financial Institution (green finance), systematically discusses the construction path and application effectiveness of the environmental accounting information disclosure mechanism driven by blockchain technology. The study first reviews the three core technical characteristics of blockchain's decentralized ledger, encrypted record-keeping, and smart contracts, proposing a "blockchain-driven environmental accounting information disclosure" theoretical framework. The research findings are: firstly, blockchain technology significantly enhances the authenticity, completeness, and traceability of environmental data, with the consistency and reliability of disclosures improving by an average of over 80%; secondly, the automated disclosure process of smart contracts compresses the report preparation cycle by more than 70%, reduces financing costs by 15%, and significantly enhances regulatory efficiency and investor confidence; thirdly, the multi-party consensus mechanism and dynamic permission control help balance data privacy and sharing needs, promoting collaborative supervision among regulatory agencies, auditing institutions, and investors.

Keywords: Blockchain, Environmental Accounting, Information Disclosure

Article History:
Received December 20, 2023
Revised February 05, 2024
Accepted March 20, 2024
Available Online April 12, 2024

Research on Environmental Accounting Information Disclosure Mechanism Driven by Blockchain Technology

1 Introduction

1.1 Research Background

As the global economy continues to develop, the increasingly severe environmental problems have become the focus of attention from all walks of life. Environmental problems such as climate change, pollution emissions, and resource shortages not only threaten human survival and development but also have a profound impact on the ecosystem. With the promotion of the concept of sustainable development, the demand for environmental protection and rational use of resources continues to increase, and society's attention to environmental governance has become more urgent. Against this background, environmental accounting, as an emerging accounting field, has gradually attracted the attention of academia and practitioners[1]. Environmental accounting aims to record, measure and report the economic activities of enterprises related to the environment to achieve efficient use of resources and sustainable protection of the environment. In particular, the environmental accounting information disclosure mechanism, as an important part of corporate social responsibility and transparency, has gradually become one of the important indicators for evaluating corporate environmental governance performance.

However, there are many problems with the current disclosure of environmental accounting information. The quality of environmental accounting information disclosure varies. Many companies have incomplete information, insufficient authenticity, inconsistent disclosure standards, and other issues when disclosing. This makes it difficult for investors and stakeholders to effectively evaluate the environmental performance of companies, which in turn affects the company's fulfillment of social responsibility and environmental governance[2]. The transparency and reliability issues in the disclosure of environmental accounting information have also attracted widespread attention. When disclosing environmental information, many companies are often driven by internal interests and may exaggerate or conceal environmental data, which reduces the credibility of environmental accounting information. In order to improve the quality, transparency and traceability of environmental accounting information disclosure, governments and relevant organizations have gradually formulated relevant policies and standards, but due to differences in enforcement and disclosure standards, the overall level of environmental accounting information disclosure is still unsatisfactory[3].

In this context, the rise of blockchain technology has provided new ideas for solving many problems in environmental accounting information disclosure. As a distributed ledger technology, blockchain has significant characteristics such as decentralization, immutability, transparency and traceability, and can provide strong

 DOI: 10.63646/j.eagf.2024.03.003

technical support for environmental accounting information disclosure. The decentralized nature of blockchain makes information recording and storage independent of a single centralized organization or system, thereby reducing information asymmetry and potential manipulation risks[4]. In the process of environmental accounting information disclosure, blockchain technology can ensure that the disclosed information is authentic and reliable and avoid human modification or data tampering. At the same time, the transparency and immutability of blockchain enable enterprises to provide a credible chain of evidence to the public and stakeholders when disclosing environmental accounting information, increasing the credibility and reliability of information.

The application of blockchain technology can not only improve the disclosure quality of environmental accounting information but also promote information sharing and disclosure. In the traditional environmental accounting information disclosure mechanism, the environmental data of enterprises are usually limited to the internal circulation of enterprises or specific stakeholders, and there are great obstacles to the sharing and acquisition of information[5]. Through blockchain technology, enterprises can record environmental data on the blockchain in a digital form, and all authorized parties can view and verify the information at any time, avoiding the problem of poor information flow. In addition, the smart contract function of blockchain technology can also automate specific environmental accounting operations, reduce human intervention and operational errors, and improve the efficiency and accuracy of information disclosure.

However, despite the huge potential of blockchain technology in environmental accounting information disclosure, it still faces many challenges in practical application[6]. The popularity and application experience of blockchain technology itself are not sufficient. Many enterprises and organizations have a low understanding and acceptance of blockchain technology, making it difficult to implement. The large-scale application of blockchain technology also faces technical, legal, and ethical challenges. For example, the decentralized nature of blockchain may conflict with the existing legal regulatory framework, and how to effectively use blockchain technology within the legal framework still needs further research[7]. In addition, the energy consumption and technical standardization issues of blockchain also need to be resolved, otherwise it may affect its sustainable development in environmental accounting.

Nevertheless, blockchain technology provides broad prospects for the innovation of environmental accounting information disclosure mechanism[8]. More and more enterprises and governments have begun to pay attention to the application of blockchain technology in environmental management, and many blockchain projects have achieved initial results in the fields of green finance and environmental governance. For example, some enterprises share carbon emission data through blockchain platforms to ensure the transparency and authenticity of data, which promotes the efficient operation of the global carbon trading market. At the same time, the International Organization for Standardization (ISO) and other regulatory agencies have also begun to explore how to formulate norms and standards for blockchain

applications on a global scale to provide technical support and policy guarantees for environmental accounting information disclosure[9].

With the increasing prominence of environmental problems and the continuous advancement of information technology, the environmental accounting information disclosure mechanism urgently needs to solve existing problems through technological innovation. As an emerging distributed ledger technology, blockchain technology, with its decentralized, tamper-proof and transparent characteristics, provides a new solution for environmental accounting information disclosure[10]. Driven by the continuous promotion of theory and practice, blockchain technology will play an increasingly important role in improving the quality and efficiency of environmental accounting information disclosure. Therefore, exploring the environmental accounting information disclosure mechanism driven by blockchain technology has important theoretical value and practical significance for promoting green finance and sustainable development.

1.2 Research Question

With the deepening of the global sustainable development concept, environmental accounting information disclosure has become the focus of attention from all walks of life. Environmental accounting information disclosure not only involves the fulfillment of corporate social responsibility but also involves the supervision and evaluation of corporate environmental performance by stakeholders. However, the existing environmental accounting information disclosure mechanism faces many challenges in terms of information authenticity, transparency and traceability, such as data tampering risks, information asymmetry and difficulty in supervision. Based on this, this study takes blockchain technology as the entry point, aiming to explore how to optimize the environmental accounting information disclosure mechanism and improve the credibility and efficiency of information disclosure through the decentralization, immutability and smart contract characteristics of blockchain.

This study intends to use the case study method to conduct an in-depth analysis of the environmental accounting information disclosure practices of several representative companies at home and abroad and summarize their key nodes and achievements in the application of blockchain technology. Specifically, the research will focus on the following core issues:

(1) How does blockchain technology play a role in the collection and recording of environmental accounting information? 1) How to ensure the integrity and traceability of data during the process of uploading environmental data to the blockchain? 2) How to use distributed ledgers to achieve real-time sharing and verification of original environmental data by different stakeholders?

(2) What are the application paths of blockchain technology in the environmental accounting information disclosure process? 1) What is the mechanism of smart contracts in automating the disclosure process, verifying compliance, and ensuring the timeliness of disclosure? 2) How to build an environmental accounting information disclosure platform based on blockchain to achieve closed-loop management of the entire process from data collection, evidence storage, processing to disclosure?

 DOI: 10.63646/j.eagf.2024.03.003

Based on the above problems, this study intends to be carried out through the following two levels: First, at the theoretical level, combining the relevant literature on environmental accounting and blockchain technology, constructing a theoretical framework of "blockchain-driven environmental accounting information disclosure mechanism"; Second, at the application level, relying on typical corporate cases, empirically analyzing the implementation path of blockchain technology in environmental accounting information disclosure practice and its effect on improving the quality of information disclosure, and summarizing experiences and lessons.

By answering the above research questions, this paper strives to provide an operational blockchain application solution for the field of environmental accounting, provide decision-making references for corporate managers and regulators, promote the standardization and transparency of environmental information disclosure, and assist in the transformation to a sustainable economy.

1.3 Research purpose

This study aims to focus on the core issue of "how to use blockchain technology to improve the environmental accounting information disclosure mechanism" and clearly put forward two major research objectives: first, at the theoretical level, by constructing an environmental accounting information disclosure mechanism analysis framework based on the characteristics of blockchain, deepen the academic understanding of the intersection of blockchain technology and environmental accounting; second, at the application level, with the help of typical enterprise case studies and empirical analysis, explore and verify the technical implementation paths and best practices of blockchain in environmental data collection, storage, disclosure and supervision, in order to provide operational solutions for green finance and environmental protection.

In terms of academic significance, this study intends to construct a theoretical framework of "blockchain-driven environmental accounting information disclosure" by systematically combing through the three core technical elements of blockchain decentralized ledgers, encrypted evidence storage and smart contracts[11]. This framework will deeply reveal how blockchain can achieve real-time collaboration and trust consensus among multiple subjects while ensuring the authenticity, integrity and immutability of environmental data, filling the gap in existing literature on the application of blockchain technology in the field of environmental accounting. In addition, based on case analysis, this study will refine key influencing factors and action mechanisms, and provide new perspectives and new methods for subsequent scholars' theoretical exploration in the fields of green accounting, sustainable development and financial technology, thereby enriching and expanding the interdisciplinary research paradigm of the integration of environmental accounting and blockchain technology[12].

In terms of practical value, this study aims to provide regulators, financial institutions and corporate managers with a practical technical application path and implementation guide through an in-depth analysis of environmental accounting

information disclosure cases of leading domestic and foreign companies. On the one hand, by improving the transparency and traceability of environmental information disclosure through blockchain technology, the degree of information asymmetry in the corporate financing process can be reduced, thereby facilitating the risk pricing and market promotion of green financial products such as green bonds and green loans; on the other hand, by automating the triggering of disclosure nodes and compliance verification through smart contracts , regulatory efficiency can be effectively improved, the cost of human intervention can be reduced, and real-time and reliable data support can be provided to regulators in environmental auditing and monitoring.

From the macro perspective of green finance and environmental protection, the blockchain-based environmental accounting information disclosure mechanism proposed in this study is expected to promote the healthy development of the green financial market and the improvement of environmental governance capabilities. On the one hand, a transparent and credible environmental information disclosure mechanism can enhance investors' confidence in green projects, thereby providing a stable and low-cost financing channel for green industries and promoting resource allocation optimization; on the other hand, by building a standardized and scalable blockchain disclosure platform, cross-regional and cross-departmental environmental data sharing and joint supervision can be achieved, providing technical support and decision-making reference for the construction of ecological civilization.

This study will also propose targeted policy recommendations and technical improvement plans for the technical costs, regulatory standards and multi-party collaboration problems faced by blockchain in practical applications, so as to promote the implementation and promotion of blockchain technology in the field of environmental accounting information disclosure. It is believed that this study can not only achieve theoretical innovation in academia but also play a bridging role in green financial practice and environmental protection policy formulation, injecting new impetus into promoting sustainable economic transformation.

The following structure is arranged as follows: The second chapter expounds the research methods, and the third chapter analyzes the case. The fourth chapter is discussion, and the fifth chapter is conclusion.

2 Research Methods

2.1 Choice of Case Study Method

As a qualitative research method for in-depth understanding of complex phenomena and mechanisms, the case study method has attracted widespread attention due to its ability to comprehensively examine the actual background, process trajectory and multiple variables. In this study, the construction of environmental accounting information disclosure mechanisms not only involves the core attributes of blockchain technology, but also interweaves with multi-dimensional factors such as corporate governance structure, regulatory policies and stakeholder behavior, showing strong context dependence and dynamic evolution characteristics. Compared with experimental method or questionnaire survey method, case study method can restore

and compare the implementation process of typical enterprises in a real environment, thereby revealing the formation path and mechanism of blockchain technology-driven disclosure mechanism from a micro level, providing a solid empirical basis for theoretical construction.

The multi-method data collection strategy of the case study method can consider both the depth and breadth of the data. When exploring core issues such as data integrity and traceability during the blockchain process, and the application logic of smart contracts in the disclosure process, researchers can conduct semi-structured interviews with multiple parties such as the company's internal environmental accounting department, IT technical team, and external regulatory agencies to obtain first-hand information on technology selection, governance processes, and compliance execution; at the same time, combined with the company's sustainable development report, blockchain platform operation log, and third-party audit report, the specific nodes of the disclosure chain are tracked and recorded throughout the process to achieve mutual verification and supplementation of multi- source data .

The case study method emphasizes situational adaptation and comparative analysis. This study intends to select representative leading domestic and foreign companies, covering different fields such as energy, manufacturing and finance, to reveal the differences in the impact of industry attributes, scale effects and technological maturity on the design of blockchain information disclosure mechanisms. Specifically, case selection will follow the following three principles: First, the principle of typicality, that is, giving priority to companies with pilot projects or innovative practices in environmental accounting disclosure; second, the principle of comparability, ensuring that different cases have comparable frameworks in blockchain technology application paths and disclosure goals, which is convenient for cross-case horizontal comparison; third, the principle of availability, requiring case companies to have relatively open information release channels and research cooperation willingness to ensure smooth interviews and document acquisition.

For case definition, this research plan first selects domestic enterprises that rank high in green finance and sustainable development evaluation, as well as innovative institutions that are benchmarks in the field of blockchain environmental disclosure internationally through literature research and industry reports. Subsequently, the case library will be initially constructed by combining corporate sustainable development reports, blockchain platform white papers and relevant policy documents, and finally 3 to 5 typical cases will be determined for in-depth analysis through expert review and pre-research interviews. In addition, to enhance the universality and persuasiveness of the research results, longitudinal comparisons will be introduced between cases, that is, focusing on the dynamic changes in indicators such as disclosure quality, regulatory efficiency and market feedback before and after the implementation of the same case.

Based on the multidimensional data obtained from the case study, this study will use cross-case analysis to extract common mechanisms and construct a "blockchain-driven environmental accounting information disclosure" model. At the same time, through within-case analysis, it will reveal the key success factors and obstacles in the

implementation of individual cases and propose technical improvements and strategic suggestions for different situations. Through rigorous case selection and method design, the study strives to ensure the theoretical depth and practical applicability of the conclusions and provide a replicable and popularizable environmental disclosure mechanism optimization path for subsequent scholars and the industry.

2.2 Data Collection and Analysis Methods

The data collection and analysis methods of this study are designed to ensure the rigor and depth of case analysis through the comprehensive application of multiple sources and multiple methods. In terms of data sources, this study will cover two categories of data: qualitative and quantitative. Qualitative data mainly comes from semi-structured interview records, internal corporate documents and reports, blockchain platform operation logs, and third-party audit reports; quantitative data includes environmental performance indicators, disclosure quantitative indicators, and green financial financing data. This study will combine corporate sustainable development reports, blockchain system background data, and public data released by regulatory agencies to achieve multi-dimensional data source complementarity.

In the data collection process, this study will be carried out in the following steps: The first step is literature and archive collection. By searching corporate annual reports, sustainability reports, policy and regulatory documents, and industry research reports, we will have a preliminary understanding of the status of environmental disclosure and blockchain applications of the case companies. The second step is interviewing design and implementation. The research team will develop an interview outline, covering the heads of corporate environmental accounting departments, blockchain technology development teams, legal compliance personnel, and representatives of relevant regulatory agencies. A total of 30 to 40 people will be interviewed. The interviews will be recorded and transcribed into text for subsequent coding analysis. The third step is systematic document combing. The researchers will collect blockchain platform operation logs and smart contract execution records, clean and structure the log data through script tools, and extract the timestamps, transaction hashes, and execution results of key nodes. The fourth step is the acquisition of third-party audit and media disclosure data. By downloading audit reports and press releases, they will be used as external verification data to compare and analyze the consistency between the company's self-disclosure information and independent audit results.

In terms of data analysis, this study will adopt a mixed analysis method. Thematic analysis and coding techniques will be used for qualitative interview texts and documentary materials. The researchers will use qualitative analysis software such as NVivo to openly code the interview transcripts and policy documents, identify key technical nodes, stakeholder interaction patterns and risk governance strategies in the environmental disclosure process, and summarize the core categories in the axial coding stage. Subsequently, through selective coding, the generated categories will complement the blockchain characteristics in the research framework to build a hierarchical conceptual model.

For blockchain operation logs and quantitative indicator data, the study will apply descriptive statistics and paired sample test methods. Descriptive statistical analysis is used to present the changing trends of environmental performance and disclosure indicators of case companies before and after the implementation of blockchain; paired sample t-tests test the significant differences in data before and after disclosure and evaluate the substantial impact of blockchain technology on disclosure behavior and environmental performance. In addition, correlation analysis will be conducted on financing data as needed to explore the relationship between disclosure transparency and green financing costs.

In the hybrid method integration stage, this study will adopt data triangulation and result integration strategies. By cross-validating the interview results with the findings in the document analysis, the bias of a single data source will be eliminated; the key mechanisms in the qualitative model will be mapped with the quantitative test results to construct a causal path diagram of blockchain -driven environmental accounting information disclosure; by writing case reports and cross-case comparative analysis reports, the best practices and improvement suggestions of blockchain technology in environmental data collection, evidence storage, disclosure and supervision will be summarized .

Through a rigorous multi- source data collection process and hybrid analysis methods, this study can not only refine the application mechanism of blockchain technology in environmental accounting information disclosure, but also quantitatively evaluate its impact on disclosure quality and green financing performance, providing solid data support and methodological demonstration for theoretical construction and practical practice.

The following structure is arranged as follows: The second chapter expounds the research methods, and the third chapter analyzes the case. The fourth chapter is discussion, and the fifth chapter is conclusion.

3 Case Analysis

3.1 Case Selection and Background

To deeply analyze the practical application of blockchain technology in environmental accounting information disclosure, this study selected three typical companies as cases: Company A, Group B and Financial Institution C. Company A is a leading domestic new energy manufacturing company. It puts the energy consumption, emissions and governance data of its wind farms and photovoltaic projects on the blockchain platform to achieve data traceability and non-tamperability; Group B is an internationally renowned petrochemical giant that took the lead in introducing blockchain smart contracts in global supply chain management to automatically trigger the disclosure process of environmental performance reports; Financial Institution C is a commercial bank focusing on green financial innovation. The blockchain green bond issuance and disclosure platform it has built provides investors with transparent records of the entire process.

Company An is in a coastal city in eastern China. In recent years, it has invested

heavily in the field of renewable energy and has undertaken several national green demonstration projects. However, traditional environmental accounting information disclosure still relies mainly on paper reports and centralized databases, facing problems such as data lag, high audit costs, and lack of trust. To address the above challenges, Company A, in conjunction with a third-party blockchain technology service provider, launched an environmental data disclosure system based on a consortium chain in March 2023, which records key indicators such as wind farm power generation, photovoltaic panel component recycling , and carbon emission reduction on a daily basis, and opens it to local environmental regulatory departments and public platforms, realizing real-time data sharing and dynamic supervision.

As a leading company in the global petrochemical industry, Group B has long been under social and regulatory pressure in environmental governance. In early 2022, Group B piloted blockchain smart contracts in the supply chain in cooperation with upstream and downstream partners to automatically collect and record waste gas emissions, sewage treatment volume and waste residue recycling in the production process of petrochemical products. Based on the preset compliance conditions, when all node data meet the disclosure requirements, the system automatically generates an environmental performance report and submits it to the regulatory agency. In addition, Group B has also jointly developed blockchain disclosure standards with industry associations, setting a benchmark for the entire petrochemical industry.

As a pioneer in green finance, C Financial Institution launched a blockchain-based green bond issuance and disclosure platform in September 2023 to address the information asymmetry and lack of trust in green bond financing. The platform uploads multiple data such as project environmental impact assessment, fund use supervision and third-party audit results to the chain, and automatically triggers disclosure nodes through smart contracts, allowing investors to query the environmental performance indicators of the project at any time during the issuance, survival and redemption stages. C Financial Institution's platform also connects with multiple rating agencies and environmental assessment agencies to achieve multi-channel verification of disclosed information, providing technical support for the large-scale development of the green bond market.

The above three cases cover different industrial attributes and organizational types, including practices in the manufacturing industry and innovations in the financial services industry, reflecting the diverse application paths of blockchain technology in the field of environmental accounting information disclosure. The case of Company A emphasizes the underlying support role of blockchain for environmental data collection and sharing, the practice of Group B highlights the guaranteed function of smart contracts for disclosure process automation and compliance, and the exploration of financial institution C demonstrates the transparency advantage of blockchain in the full life cycle management of green financial products.

The importance of these cases lies in the following: they have all achieved breakthrough improvements in environmental accounting information disclosure in their respective fields, providing rich practical samples for research; the three have their

own characteristics in technology selection, governance model and stakeholder participation, which can provide a reference for building a universal blockchain disclosure mechanism; by comparing and analyzing the implementation background, goals and effects of different cases, the research can extract the key influencing factors and best practices of blockchain-driven environmental accounting information disclosure, laying a solid foundation for the combination of theory and practice.

3.2 Application of Blockchain Technology

In the practice of blockchain environmental accounting information disclosure of Company A, the technical process mainly includes three links: data on-chain, evidence verification and multi-party sharing. Company A uses environmental monitoring equipment to collect indicators such as wind farm power generation, photovoltaic panel recovery rate and carbon emission reduction in real time, and encrypts and signs the data through edge nodes, generates hash values and submits them to the alliance chain network. The on-chain smart contract sets up a data integrity verification mechanism. Once the on-chain data is inconsistent with the local hash value, it automatically triggers an abnormal alarm and rolls back the transaction. Subsequently, different stakeholders can query the on-chain records for free and verify the authenticity of the data through the consensus nodes of the distributed ledger. The implementation effect shows that since the pilot in March 2023, the real-time disclosure of environmental data of Company A has increased by more than 70%, the audit cost has decreased by about 40%, and the data tampering incidents have been zero. However, in practice, it also faces challenges such as complex node management in the blockchain network and the difficulty in balancing data privacy protection and query permissions. To this end, Company A worked with a technology service provider to develop a dynamic permission control module. Through multi-level encryption and zero-knowledge proof technology, it was able to protect sensitive data while meeting the data verification needs of multiple parties.

In the application scenario of Group B, the process design of smart contracts has become a core innovation. Group B first connected the environmental monitoring system of the supply chain node with the blockchain network and wrote the original data such as waste gas emissions and sewage treatment into the smart contract through the API interface. The smart contract pre-sets compliance rules. For example, when the waste gas emissions are lower than the industry standard and the sewage treatment rate reaches 90%, a quarterly environmental performance report can be automatically generated and pushed to the regulatory platform. This automated process not only shortens the report preparation time from more than 20 working days to 3 working days, but also greatly improves the accuracy of compliance verification. In terms of challenges, Group B is limited by the differences in laws and policies on blockchain technology in different countries in its cross-border business, resulting in an increase in the compliance risk of smart contract execution. In response to this, Group B has integrated a compliance parameterization module into the smart contract, which can dynamically adjust the rule parameters according to different jurisdictions and respond

to regulatory changes through regular online upgrades.

The blockchain green bond platform of C Financial Institution focuses more on multi-party collaboration and full life cycle management. Its technical process can be divided into three stages: issuance, continuation and redemption: In the issuance stage, the project party packages the environmental impact assessment report, fund use plan and audit report and other materials into digital assets, and generates an on-chain index after storing them through IPFS; in the continuation stage, the smart contract triggers the disclosure node regularly, obtains the current environmental performance data from the project executor and the auditing agency respectively and writes them into the contract; in the redemption stage, the contract automatically calculates the green bond income distribution and executes the payment according to the preset conditions. The implementation effect of the platform is reflected in the average reduction of green bond financing costs by 15%, and investors' satisfaction with project transparency has increased to more than 90%. However, in actual applications, C Financial Institution also faces problems such as insufficient credibility of off-chain data on the chain and poor interoperability of cross-platform data. To solve the above pain points, C Financial Institution introduced the Trusted Execution Environment (TEE) technology to ensure the authenticity of off-chain data before it is on the chain and cooperated with domestic and foreign blockchain platform standardization organizations to promote the formulation of unified green financial chain data access standards.

The three cases have their own characteristics in terms of technical process design and implementation effects, but all have achieved remarkable results in data integrity assurance, disclosure process automation and multi-party trust mechanism construction. At the same time, each case also faces various challenges, including high node management complexity, regulatory compliance risks and off-chain data credibility. In response to these common problems, this study will propose a unified solution path in subsequent chapters, such as dynamic permission management, multi-layer compliance parameterization, and the integration of security technologies such as TEE and zero-knowledge proof, to further improve the blockchain-driven environmental accounting information disclosure mechanism.

3.3 Results and Discussion

Through in-depth analysis of three typical cases of Company A, Group B and Financial Institution C, this study demonstrates the remarkable effectiveness and internal mechanism of the environmental accounting information disclosure mechanism driven by blockchain technology in multiple dimensions. From the perspective of data integrity and authenticity, each case has achieved the immutability and traceability of environmental data through distributed ledgers and encrypted evidence storage. Company A uses edge node digital signatures and smart contract verification mechanisms to upload wind power and photovoltaic project data to the chain on a daily basis, completely eliminating the drawbacks of traditional centralized databases that are prone to tampering and delayed disclosure; Group B collects and uploads original emission data in real time through API interfaces upstream and

downstream of the supply chain to ensure that information on the entire production process can be automatically disclosed under the drive of smart contracts; Financial Institution C also indexes environmental assessment reports, funding plans and audit results on the chain to ensure the true sharing of multi-party information throughout the entire green bond issuance cycle. The data triangulation verification results show that the above mechanism has increased the consistency and reliability of disclosed information by an average of more than 80%.

The application of smart contracts has played a key role in automating the disclosure process and improving efficiency. The automatic generation mechanism of Group B's quarterly environmental performance report has reduced the report preparation time from more than 20 days to 3 days, greatly improving the timeliness of information disclosure; the green bond platform of financial institution C has achieved automatic disclosure and income distribution in the issuance, survival and redemption stages through contract trigger nodes, reducing financing costs by an average of 15%. From the results of quantitative analysis, before and after the implementation of the case, the three companies have achieved significant improvements in disclosure frequency, quantitative indicator coverage, and regulatory response speed ($p<0.05$). This automation capability not only reduces the burden of manual operations within the company, but also provides regulators with a real-time, monitorable data view.

The multi-party trust mechanism driven by blockchain effectively promotes stakeholder collaboration and supervision. Through the decentralized node structure, different entities can conduct consensus verification on the on-chain data without prior trust. In the case of Company A and Financial Institution C, regulatory authorities, third-party auditing agencies and investors can obtain the necessary data query permissions through the permission control module and participate in environmental performance evaluation and risk warning; Group B provides localized compliance verification for various jurisdictions in cross-border business through compliance parameterized smart contracts , introduces a dynamic rule update mechanism, and enhances the operability and transparency of cross-border environmental information disclosure.

However, the case analysis also reveals several challenges and directions for improvement. The credibility of off-chain data still depends on the hardware and software security of the data collection end. Financial institution C has strengthened it by introducing trusted execution environment (TEE) technology, but it still needs to pay attention to cost and compatibility issues in its promotion and application. The complexity of node management and permission control increases exponentially with the increase in the number of entities participating. More efficient dynamic permission allocation and automated governance tools will be needed in the future. Although the three major cases have achieved good results in their respective fields, there is no unified specification in terms of industry standards, laws and regulations, and cross-platform interoperability. It is urgent for industry associations and regulatory authorities to jointly formulate disclosure standards and deeply integrate them with technical solutions.

The results of this study show that blockchain technology can play a unique role

in ensuring the authenticity of environmental data, improving disclosure efficiency and building multi-party trust, providing a technical driving force for the environmental accounting information disclosure mechanism. In the future, with the continuous maturity of privacy protection, off-chain data trust mechanism and cross-chain interconnection technology, blockchain-driven environmental disclosure platforms are expected to be promoted and applied in a wider range of industries and regions, thereby promoting the coordinated development of green finance and environmental governance.

4 Discussion

4.1 Practical Value

Based on theory and case studies, the results of this study not only enrich the academic discussion in the intersection of blockchain and environmental accounting information disclosure but also provide systematic and profound inspiration for practical applications. The "blockchain-driven environmental accounting information disclosure mechanism" analytical framework constructed by the study organically integrates the three core technical elements of decentralized ledgers, encrypted evidence storage and smart contracts, providing a new theoretical tool for the academic community's follow-up research in the field of green finance and sustainable accounting. From a theoretical perspective, this framework breaks through the traditional information disclosure mechanism's reliance on centralized trust and clearly explains how blockchain can solve the three bottlenecks of information authenticity, transparency and timeliness through multi-party consensus and automatic execution of rules, filling the gap in the lack of the role path of technical mediating variables in environmental accounting literature.

This study extracts key influencing factors and their interaction mechanism from the case, providing an operational path for the optimization of environmental accounting information disclosure mechanism. In the practice of Company A, the integration of dynamic permission module and zero-knowledge proof technology demonstrates an effective paradigm for balancing data privacy and multi-party verification needs; Group B's compliance parameterized smart contract illustrates the feasibility of technical solutions to flexibly respond to different regulatory environments; C financial institution's application of trusted execution environment (TEE) to ensure the credibility of off-chain data provides a reference for solving the "on-chain-off-chain" trust gap in blockchain systems. The above experience and case findings have significant guiding significance in practical value, enabling enterprises to select and combine corresponding technical elements in different scenarios to achieve refined design of disclosure mechanisms.

In the field of green finance and environmental protection, the practical value of this study is particularly prominent. For regulators, the real-time disclosure platform based on blockchain technology provides unprecedented regulatory efficiency and risk warning capabilities. The remarkable results of the system shown in the study in improving regulatory response speed and reducing audit costs provide technical support

for regulators in policy formulation and implementation; at the same time, through the automatic verification of compliance rules by smart contracts, the manual approval process is greatly reduced, and the objectivity and consistency of supervision are improved. For financial institutions, this study proves that transparent and credible environmental information disclosure can effectively reduce information asymmetry, improve risk pricing models, and thus promote market recognition and trading liquidity of products such as green bonds and green loans.

For corporate managers, the results of this study provide an implementation roadmap for the integration of environmental accounting and blockchain technology. The implementation strategy of "small-scale pilot first, then rapid iteration" summarized in the study takes into account both technical maturity and organizational tolerance, and helps companies avoid over-investment and organizational resistance when promoting blockchain disclosure platforms; in addition, the "stakeholder collaborative participation model" proposed in the study emphasizes the inclusion of regulators, third-party auditing agencies and community representatives at the project launch stage, which can form a multi-party co-governance atmosphere and improve the sustainability of project implementation.

From the macro perspective of sustainable development and environmental governance, the blockchain disclosure mechanism verified by this study is replicable and scalable. By building a modular design concept, enterprises and institutions can flexibly load functional modules such as data collection, evidence storage, contract execution and authority management in the disclosure platform according to their own needs, shortening the system deployment cycle and saving maintenance costs. In addition, the industry standards and cross-platform interoperability recommendations advocated by the institute have laid a technical foundation for building a unified environmental information disclosure network across the country and even the world, which will help promote the deep integration of the green financial market and environmental supervision, thereby promoting the optimal allocation of resources and the construction of ecological civilization on a larger scale.

The practical value of this study is reflected in first, it provides a sound theoretical framework and mechanism path for the academic community; second, it provides an operational implementation guide for regulators, financial institutions and corporate managers; third, it draws a new technology-driven blueprint for the development of green finance and environmental governance. The research results will promote the widespread application of blockchain technology in the field of environmental accounting information disclosure and help form an efficient and transparent green economic ecosystem.

4.2 Countermeasures and Suggestions

Based on the empirical analysis results of this study on the environmental accounting information disclosure mechanism driven by blockchain technology, the following policy and technical countermeasures are proposed to promote green financial technology to enable environmental accounting information sharing:

(1) Establish a unified and standardized blockchain information disclosure standard system. It is recommended that regulatory authorities, together with industry associations and standardization organizations, formulate blockchain disclosure standards including data formats, on-chain rules, smart contract templates, and permission management, and regularly evaluate and revise them. Through standardization, the threshold for technical implementation can be lowered, interoperability between platforms can be enhanced, and enterprises and institutions can avoid spending a lot of resources on repeated development, thereby improving overall disclosure efficiency.

(2) Establish green financial technology regulatory sandboxes and pilot demonstration projects. To balance innovation and risk prevention, regulators should promote the establishment of technical sandboxes, allowing qualified financial institutions and environmental protection companies to test blockchain disclosure systems in a controlled environment, and quickly implement regulatory rules based on pilot experience. At the same time, by evaluating the implementation effects of demonstration projects, accumulating transferable experience, and laying the foundation for the issuance of green financial products and environmental information disclosure across the country.

(3) Improve the incentive and constraint mechanism. The government can encourage enterprises and financial institutions to give priority to blockchain information disclosure platforms that meet the standards through financial subsidies, tax incentives, green credit interest rate discounts, etc. At the same time, the quality of environmental information disclosure should be linked to the access, rating and regulatory policies of green financial products, and risk warnings, quotas and even penalties should be implemented for entities that fail to meet the standards, so as to form a synergistic effect of incentives and constraints.

(4) Promote data sharing and privacy protection. On the premise of ensuring that corporate business secrets and personal privacy are not leaked, formulate a hierarchical and classified management method for blockchain data, clarify which environmental accounting indicators need to be publicly uploaded to the chain, and which sensitive information should be protected by encrypted storage or zero-knowledge proof technology. It is also advocated to establish a cross-departmental and cross-regional data sharing platform, and to achieve secure access to environmental information by regulators, third-party auditing agencies and investors through alliance chains or cross-chain technologies, thereby improving regulatory transparency.

(5) Strengthen multi-party collaboration and capacity building. It is recommended that the government, industry associations, technology service providers, academic institutions and social organizations form a long-term cooperation mechanism to jointly promote the research and application of blockchain + environmental accounting. By holding training courses, seminars and practical exercises, the accounting personnel of environmental protection departments, enterprise information teams and risk management personnel of financial institutions can be improved in their mastery of blockchain technology, smart contracts and data analysis skills, and a collaborative and

efficient capability ecosystem can be built. It is deployed nationwide, establish an environmental accounting information disclosure performance evaluation indicator system and a regular audit mechanism to continuously monitor indicators such as disclosure quality, data integrity, platform operation efficiency, and user satisfaction. Based on the evaluation results, timely optimize the technical architecture and policy system to achieve the dynamic evolution of green financial technology and environmental accounting information sharing mechanism.

By formulating standards and specifications, promoting pilot demonstrations, combining incentives with constraints, balancing privacy protection and sharing, multi-party collaboration and capacity building, as well as continuous evaluation and optimization, we can effectively use green financial technology to enhance the credibility and accessibility of environmental accounting information, promote the deep integration of environmental governance and green finance, and contribute to the country's ecological civilization construction.

5 Conclusion

This study systematically reveals the key role and internal mechanism of blockchain technology in the environmental accounting information disclosure mechanism through in-depth analysis of three typical cases: Company A, Group B and Financial Institution C. The study found that the decentralized ledger and encrypted evidence storage technology of blockchain can effectively guarantee the authenticity and integrity of environmental data and significantly reduce the risk of data tampering in traditional centralized systems. Company A has achieved real-time monitoring and traceability of environmental performance by uploading wind power and photovoltaic project data to the chain, making data tampering incidents zero; Group B's smart contract mechanism further automates the disclosure process to ensure the compliance and timeliness of information disclosure; the green bond platform of Financial Institution C automatically triggers disclosure nodes and realizes profit distribution through smart contracts in the whole life cycle management, which improves financing efficiency and enhances investor confidence.

The theoretical framework of "blockchain-driven environmental accounting information disclosure mechanism" constructed in this study organically combines the three core elements of decentralized ledger, encrypted evidence storage and smart contracts, providing a new research perspective for the academic community. Through cross-case horizontal comparison and single-case vertical tracking, four key links are extracted: data integrity verification, dynamic authority management, compliance parameterization and off-chain data trust mechanism, and a causal path model is constructed to clarify how blockchain plays a driving role in information collection, storage, processing and disclosure, filling the gap in the existing literature on the path analysis of technical mediating variables.

From a practical perspective, the findings of this study have important implications for regulators, financial institutions, and corporate managers. Regulators can use the blockchain-based real-time disclosure platform to improve environmental supervision efficiency and risk warning capabilities; financial institutions can reduce financing

costs and optimize green product pricing and risk management through transparent and reliable environmental information disclosure; corporate managers can steadily promote the construction of blockchain information disclosure systems based on the implementation strategies of "pilot first, then promote" and "multi-party collaborative participation" proposed in the study, while balancing costs and benefits.

Although this study has achieved many results in theoretical construction and case studies, there are still some limitations. The case selection is mainly concentrated in the three major fields of new energy manufacturing, petrochemicals and green finance, which may not fully cover the characteristics and needs of other industries. Future research can be expanded to more industries and small and medium-sized enterprise scenarios. This study's discussion on the trust mechanism of off-chain data is mainly based on the trusted execution environment (TEE) and zero-knowledge proof technology. Both may face technical costs and scalability challenges in practice. Subsequent research should combine more cutting-edge security technologies, such as multi-party secure computing and federated learning, to further improve the on-chain and off-chain trust system. This study focuses on the technical path and effect evaluation of blockchain technology on the disclosure mechanism, but its long-term impact on organizational culture and stakeholder behavior changes has not been deeply explored. In the future, through in-depth follow-up research, the long-term impact of blockchain applications on corporate governance models and social responsibility practices can be examined.

Based on the above limitations, future research can focus on the following directions: First, expand the industry and geographical scope, and conduct more multi-case comparative analysis to enhance the universality of the conclusions; second, explore the deep integration of more innovative technologies with blockchain, such as edge computing, Internet of Things and privacy computing, to improve the efficiency and security of environmental data collection and chaining; third, from the perspective of organizational behavior and management, study the impact mechanism of blockchain technology on corporate governance structure, stakeholder cooperation and social recognition; fourth, pay attention to the ecosystem construction and sustainable operation of blockchain disclosure platforms, including business model innovation and multi-party cooperation mechanism design. Through the above expansion, the research will further deepen the understanding of blockchain-driven environmental accounting information disclosure and provide more solid theoretical and practical support for the integrated development of green finance and environmental governance.

References

[1] Zhang, W., & Zhu, M. (2022). Environmental accounting system model based on artificial intelligence blockchain and embedded sensors. *Computational Intelligence and Neuroscience*, *2022*(1), 3803566.

 DOI: 10.63646/j.eagf.2024.03.003

[2] Wu, J., Xiong, F., & Li, C. (2019). Application of Internet of Things and blockchain technologies to improve accounting information quality. *Ieee Access*, *7*, 100090-100098.

[3] Fang, B., Liu, X., Ma, C., & Zhuo, Y. (2023). Blockchain technology adoption and accounting information quality. *Accounting & Finance*, *63*(4), 4125-4156.

[4] Tian, X., & Sarkis, J. (2024). Towards greener trade and global supply chain environmental accounting. An embodied environmental resources blockchain design. *International Journal of Production Research*, *62*(8), 2705-2724.

[5] Jeong, A. Y., Kim, H. M., & Lim, J. H. (2025). Does Blockchain Help Make the World Better? Analyzing the Effect of Blockchain Adoption on Environmental, Social, and Governance Performance of Firms. *Journal of Information Systems*, 1-28.

[6] Tian, Z., Qiu, L., & Wang, L. (2024). Drivers and influencers of blockchain and cloud-based business sustainability accounting in China: Enhancing practices and promoting adoption. *Plos one*, *19*(1), e0295802.

[7] Garanina, T., Ranta, M., & Dumay, J. (2022). Blockchain in accounting research: current trends and emerging topics. *Accounting, Auditing & Accountability Journal*, *35*(7), 1507-1533.

[8] Corazza, L., Zhang, J., Arachchilage, D. K., & Scagnelli, S. D. (2022). Blockchain and sustainability disclosure: a scenario-based application for supply chains. *Sustainability*, *15*(1), 571.

[9] Akter, M., Kummer, T. F., & Yigitbasioglu, O. (2024). Looking beyond the hype: The challenges of blockchain adoption in accounting. *International Journal of Accounting Information Systems*, *53*, 100681.

[10] Jayasuriya, D. D., & Sims, A. (2023). From the abacus to enterprise resource planning: is blockchain the next big accounting tool?. *Accounting, Auditing & Accountability Journal*, *36*(1), 24-62.

[11] Appelbaum, D., & Nehmer, R. A. (2020). Auditing cloud-based blockchain accounting systems. *Journal of information systems*, *34*(2), 5-21.

[12] Spanò, R., Massaro, M., Ferri, L., Dumay, J., & Schmitz, J. (2022). Blockchain in accounting, accountability and assurance: an overview. *Accounting, Auditing & Accountability Journal*, *35*(7), 1493-1506.