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Technology-Governance Coordination Mechanisms in the Digitalization of ESG Information Disclosure: A Multi-case Comparative Study of Microsoft, Siemens, and Tesla

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Abstract. Under the background of an persistently increasing ESG regulatory requirements, the enterprise ESG still faces problems of information disclosure such as data fragmentation, standard adaptation challenges, and information credibility deficits. However, the extent to which digital technology improves ESG disclosure quality is determined by technological application capabilities and enterprise governance effectiveness. To explore how technical capabilities and governance conditions interact to shape ESG information disclosure, this paper conducts a multi-case comparative analysis of three multinational firms, including Microsoft, Siemens, and Tesla, based on information asymmetry theory, signaling theory, and agency theory, to examine the effects of digital technology applications and governance mechanisms on ESG disclosure quality. The study shows that digital technology improves ESG disclosure quality via the support of effective governance conditions. The integration of technology application with data management, organizational mechanisms, and external supervision boosts the transparency and verifiability of ESG information, while inadequate governance mechanisms limit the contribution of technological applications to disclosure quality improvement.

Keywords: Digital technology, ESG information disclosure, technology-governance coordination, multi-case comparative study

1. Introduction

Against the backdrop of the rapid development of the new energy industry and growing attention from investors and capital markets toward corporate ESG evaluation, S&P Global's exclusion of Tesla from the S&P 500 ESG Index highlighted the discrepancy between enterprises' technological advantages and their ESG evaluation outcomes. As a representative enterprise in the new energy sector, Tesla possesses significant advantages in electric vehicle technology, energy efficiency, and the environmental benefits of its products. For example, its electric vehicle (EV) technologies and energy management strategies contribute to mitigating life-cycle emissions; but its ESG evaluation outcomes have still exhibited significant fluctuations. This phenomenon indicates that enterprises' technological capabilities cannot necessarily be translated into stable and reliable ESG disclosure outcomes, and disclosure quality is also influenced by factors like data management and governance

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mechanisms. Existing research indicates that digital technologies such as artificial intelligence and blockchain can facilitate enterprises' ESG performance by improving data processing efficiency, enhancing information transparency, and strengthening risk management mechanisms. However, the effectiveness of technology implementation remains influenced by organizational coordination capabilities and external uncertainties [1]. Thus, this paper develops an analytical framework of "Technological Capability and Governance Alignment," integrating information asymmetry theory, signaling theory, and agency theory. In particular, it uses Microsoft, Siemens, and Tesla as cases for comparison. By examining ESG disclosure practices under different combinations of technology application pathways and governance mechanisms, this study analyzes the enabling conditions and application boundaries of digital technologies in enhancing ESG disclosure quality, thus providing insights for enterprises' ESG disclosure digitalization.

2. Theoretical basis and literature review

2.1. The concept and quality requirements of ESG information disclosure

ESG disclosure enhances enterprise transparency by providing information on environmental, social, and governance performance, thus enabling capital markets to more comprehensively assess firms' long-term value and risk profiles [2]. Besides, compared with traditional financial information, ESG disclosure covers a broader scope and relies on more diverse data sources. As a result, it helps reduce information asymmetry between firms and external stakeholders.

Accordingly, ESG disclosure quality has become a key measure of enterprise transparency and information effectiveness. Specifically, ESG disclosure quality is reflected in the completeness, comparability, reliability, and verifiability of information. Besides, high-quality disclosure requires enterprises not only to cover key ESG indicators but also to ensure data consistency and indicator alignment, enhancing information credibility through effective verification mechanisms. However, as ESG information involves multiple business processes and non-financial indicators, enterprises still face challenges in data integration, standard adaptation, and information verification [3]. Thus, the improvement of ESG disclosure quality requires strong information processing capabilities, along with appropriate technological support and governance mechanisms.

2.2. The role of digital technologies in ESG information disclosure transformation

Through data collection, information verification, and report generation, digital technology mainly influences the ESG information processing process by improving data processing efficiency and information verifiability.

In the data collection part, big data technology expands the scope of ESG data acquisition and boosts data processing efficiency by integrating enterprise business data, environmental monitoring data, and supply chain information. Moreover, the ESG-KIBERT model applies natural language processing technology to semantically analyze ESG reports, enabling the quantitative processing of unstructured information and providing a novel approach to intelligent ESG information collection [4]. In the information verification link, blockchain technology uses distributed storage and data traceability to improve the transparency and verifiability of ESG data records. Moreover, Khan et al. pointed out that the integration of blockchain and intelligent contracts reduces manual intervention and enhances ESG audit automation [5]. Similarly, Almadadha further believes that this technology can enhance the information transparency and data traceability of ESG reports [6]. In the report generation link, AI technology improves the efficiency of ESG indicator extraction, information

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collation, and report compilation through natural language processing, machine learning, and other methods. Besides, the Ant Group Research Institute joint research group pointed out that AI can support ESG risk identification, environmental benefit measurement, and green asset evaluation, improving ESG information analysis efficiency [7].

2.3. The governance constraints on ESG information disclosure quality

The quality of ESG information disclosure depends on the application level of digital technology, as well as factors like the data base, standard system, and governance mechanisms. However, digital technology can improve the efficiency of data collection and processing; only with effective data management, standardized systems, and monitoring mechanisms can it be transformed into reliable and verifiable disclosure outcomes.

In terms of data foundation, the data management capability of enterprises determines the effect of digital technology on the efficiency and accuracy of ESG disclosure. Due to ESG data involves multiple business links,enterprise need to establish a unified data management mechanism to ensure the effectiveness of data integration and application. Regarding the standard system, differences in evaluation standards affect the comparability of ESG information and the consistency of external evaluation. For example, Eccles et al. noted that ESG factors influence investors' decision-making, while differences remain in indicator scope and evaluation methods across ESG evaluation systems [2]. Furthermore, Berg and others found that ESG rating differences mainly arise from variations in evaluation scope, measurement methods, and indicator weights, leading to different rating outcomes for the same enterprise [3]. Similarly, Yin and others pointed out that rating differences influence market judgments of enterprises' sustainable development performance [8]. Regarding governance mechanisms, internal governance and external oversight shape ESG disclosure quality. In particular, selective disclosure, ambiguous expressions, and insufficient third-party verification reduce ESG report credibility [9]. Institutional constraints improve corporate ESG performance and disclosure quality [10]. Thus, ESG digital transformation requires integrating technology, data management, organizational mechanisms, and supervision systems to improve disclosure quality.

3. Multi-case comparison of digital transformation in ESG information disclosure

3.1. Case selection and analytical framework

This study conducts a multi-case comparative analysis based on the two-dimensional framework of "technological capability-governance constraints" and uses Microsoft, Siemens, and Tesla as cases to compare ESG disclosure under different technologies and governance mechanisms. Importantly, these enterprises reflect advanced digital and ESG practices, while differences in data management, governance mechanisms, and disclosure approaches reflect distinct characteristics of technology embedding, supply chain collaboration, and technology capability transformation.

Based on these cases, this study establishes a framework integrating technological capability and governance constraints. In this framework, Technological capability refers to digital technology use in ESG data collection, verification, and reporting, while governance constraints involve disclosure standards, organizational management, and external supervision [11]. Accordingly, ESG disclosure digitalization practices under different combinations of technological capabilities and governance conditions are compared to examine their impact on disclosure quality.

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3.2. Microsoft: technology embedded ESG disclosure model

Microsoft's ESG disclosure model is mainly reflected in embedding digital technology in the whole process of data collection, information processing and disclosure verification, and improving the traceability and transparency of ESG information via a perfect data system. In practice, enterprises integrate multi-source ESG data using cloud computing and artificial intelligence technologies, while extracting and standardizing key indicators through the Microsoft Cloud for Sustainability platform to improve disclosure information processing efficiency [12]. At the same time, third-party verification by CDP, SBTi, and others strengthens data credibility and supports disclosure quality control.

This model is more obvious in the disclosure of carbon emission information. In fiscal year 2024, Microsoft's Scope 1 and Scope 2 emissions decreased by 29.9% compared with 2020, and the contracted carbon removal was nearly 22 million metric tons, but the total emissions, including Scope 3, increased by 23.4% compared with 2020, mainly due to the increase in energy demand caused by the expansion of AI and cloud computing business [5]. Despite emission pressures, Microsoft fully discloses relevant data rather than only reporting improvement indicators, indicating that its digital disclosure system enhances data traceability and negative information disclosure. It can be seen that the role of technology embedding is not simply to optimize the report form, but to reduce selective disclosure space by improving data quality and verification ability. But this model relies on strong information infrastructure and technical input capacity, and has high requirements for enterprise data management, so it is difficult to replicate in enterprises with limited resources.

3.3. Siemens: supply chain collaborative ESG disclosure model

Using digital supply chain technologies, Siemens has established an ESG data management system covering supplier processes. The company utilizes the Supplier+ platform and Green Digital Twin technology to collect, analyze, and manage supplier carbon emission data, enhancing supply chain transparency and verifiability. According to Siemens' 2024 fiscal year sustainability report, since the implementation of the DEGREE framework in 2019, its operational carbon emissions have decreased by 60% from 2019 levels, while supply chain emissions have decreased by 2% from the 2020 baseline despite a 26% increase in procurement volume [13].

In this model, the effective acquisition of supply chain ESG data depends not only on digital platforms but also on the coordination capabilities of core enterprises. Siemens collects supplier carbon footprint data through the Supplier+ platform and provides emission reduction guidance. By 2024, 5,356 suppliers had participated, covering 50% of the upstream Scope 3 emission footprint, with an average emission reduction of 9% [13]. Relying on its central position in the industrial chain, Siemens promotes supplier participation in data management and reduces the difficulty of obtaining ESG information across the supply chain. Furthermore, the company enhances disclosure credibility via SBTi verification and the CDP climate change evaluation system, enabling supply chain data governance outcomes to gain external recognition [13]. This case reveals that supply chain digitalization for improving ESG disclosure quality depends not only on technological tools but also on the governance capabilities of core enterprises.

3.4. Tesla: technology advantages and governance gaps in ESG disclosure

In Tesla's case, product technology advantages have not fully translated into ESG disclosure governance capabilities. Unlike Microsoft and Siemens, Tesla's technological investment is mainly

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concentrated on new energy products and production processes, whereas its disclosure-side data management and governance mechanisms remain relatively limited.

In terms of environmental performance, Tesla has a strong technological foundation. Based on Tesla's 2024 Impact Report, customers avoided more than 20 million metric tons of CO_2 emissions in 2023, while the vehicle life cycle avoided approximately 51 metric tons of CO_2 emissions, and water consumption per vehicle decreased from 3.27 cubic meters in 2018 to 2.48 cubic meters in 2023 [14]. However, these results mainly reflect product and operational environmental benefits, while ESG disclosure still lacks systematic and verifiable data. Tesla's carbon emission data mainly rely on internal production data and supplier surveys. The disclosure process lacks systematic data tracking and verification mechanisms, and supply chain information management has not developed a digital platform comparable to Siemens' [14].

Weak ESG disclosure governance is shaped by internal management and external supervision. Internally, Tesla lacks an independent ESG management structure, resulting in limited internal constraints on the disclosure process. Externally, management's public criticism of ESG rating systems may weaken external supervision. For example, in May 2022, S&P Global removed Tesla from its ESG index over governance issues and negative externalities [15]. Moreover, differences among rating agencies contribute to inconsistent evaluations: S&P Global emphasizes negative externalities and governance risks, while MSCI focuses more on industry-specific risk management capabilities, leading to different ratings for the same enterprise [3]. Thus, under limited disclosure and divergent evaluation standards, Tesla's ESG ratings show significant fluctuations.

3.5. The comparative examination of technology-governance coordination mechanisms

Based on the case analysis, this study compares the ESG disclosure models of Microsoft, Siemens, and Tesla using the dimensions of "technological capability and governance constraints," as shown in Table 1.

Table 1. Comparison of ESG disclosure models across cases

Cases	Technical ability	Governance constraints	Disclosure performance
Microsoft	Cloud computing,artificial intelligence and other technologies are applied to ESG data collection, processing and report generation	Emphasizing on third-party verification and information transparency mechanism	Technology embedded disclosure process,high data traceability and disclosure transparency
Siemens	Use the supply chain digitization platform to improve ESG data management capability	Depend on the status of core enterprises to promote the combination of supplier participation and external supervision	Combination of technology and supply chain governance,improve price participation,and strengthen external supervision
Tesla	The technical advantages of the product side are obvious,but the disclosure side's digital application is limited	Insufficient ESG management and external supervision	Technical advantages have not be fully transformed into disclosure ability

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The alignment between technological capabilities and governance mechanisms is a key factor affecting ESG disclosure transformation. Existing studies show that digital technologies such as AI and blockchain can improve ESG performance, but their outcomes are shaped by risk management capabilities, organizational environments, and governance conditions [1]. Therefore, the alignment of technological capabilities and governance conditions determines how effectively data processing capabilities are converted into verifiable disclosure outcomes. In the absence of data governance and supervision, technology application may have limited impacts on disclosure completeness and credibility [16].

4. Integrated development pathways for ESG information disclosure digital transformation

Based on the previous case analysis,the digital transformation of ESG information disclosure needs to achieve an effective match between technology application and governance mechanism. Thus, this study proposes strategies for improving technology capabilities and governance mechanisms.

4.1. Technological capability improvement and application scope optimization

According to enterprise scale, digital foundation, and business characteristics, enterprises should select suitable technological pathways to avoid unnecessary system costs [1]. Large enterprises with strong digital foundations can boost ESG data management by integrating internal business systems, supply chain systems, and environmental management platforms, while promoting collaborative supply chain disclosure. Small and medium-sized enterprises do not need to develop comprehensive digital systems but can prioritize basic data management via third-party platforms and gradually enhance digital capabilities with business growth. The Ant Group Research Institute joint research group noted that technologies like alliance chains are more suitable for supply chain ecosystems led by large enterprises rather than independent development by small and medium-sized enterprises [7]. At the same time, enterprises should select applicable disclosure standards based on regulatory requirements and business characteristics to avoid increased management costs caused by multiple standards. Cross-regional enterprises can provide supplementary disclosures while meeting primary regulatory requirements [3]. In addition, ESG digitalization requires clear data-sharing boundaries to ensure data security and improve information utilization efficiency.

4.2. Governance mechanism improvement and external supervision enhancement

The effectiveness of technological capabilities in improving ESG disclosure depends not only on technology investment but on internal governance mechanisms and supervision systems. According to agency theory, effective governance structures can reduce information asymmetry and enhance the transparency and reliability of corporate disclosures [16]. At the corporate governance level, enterprises should strengthen the independence and accountability of ESG disclosure. This requires clear ESG responsibilities, cross-departmental coordination mechanisms, and the integration of disclosure quality, data accuracy, and external audit results into management evaluations. Besides, enterprises should strengthen interdisciplinary teams combining finance, environmental, and information technology expertise to improve ESG data management and analysis capabilities [17]. At the external supervision level, regulatory constraints and anomaly detection mechanisms should be strengthened. Regulators can focus on rating discrepancies, frequent disclosure revisions, and negative event reporting to identify abnormal disclosure practices. The Tesla case shows that limited verifiable disclosure can increase market uncertainty caused by differences among rating agencies.

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Therefore, improving ESG disclosure quality requires not only clearer evaluation rules but also stronger data disclosure and verification practices.

5. Conclusion

Based on the "technological capability-governance constraints" framework, this study explores how digital technologies improve ESG disclosure quality through a multi-case comparison of Microsoft, Siemens, and Tesla. The findings indicates that ESG disclosure quality depends on the fit between technological capabilities and governance mechanisms, rather than technology investment alone. In practice, Microsoft and Siemens boost disclosure transparency and credibility via digital technology integration into internal governance and supply chain coordination, respectively. By contrast, Tesla demonstrate that when technological advantages remain concentrated on products while disclosure governance is insufficient, technical capabilities are difficult to translate into disclosure quality, resulting in greater information asymmetry and rating volatility. Thus, ESG digital transformation requires governance mechanisms to support technology application and enterprises to select suitable pathways based on their digital foundation and development stage. However, the case analysis focuses on mechanism exploration and does not empirically test the causal relationship between technology application and disclosure quality using large-scale data. In addition, the sample mainly consists of large multinational enterprises, limiting the generalizability of the findings to small and medium-sized enterprises and different institutional contexts. Future research can incorporate quantitative methods and firm-level data to examine how technology-governance coordination affects ESG disclosure across different enterprise types and institutional environments.

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