A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

ARTICLES FOR FACULTY MEMBERS

Are digital trends driving corporate environmental, social, and governance practices? Evidence from China / Xiao, S., Xu, J., & Li, R.

Business Strategy and the Environment
Volume 33 Issue 6 (2024) 10990836 Pages 5366-5385
https://doi.org/10.1002/bse.3756
(Database: Wiley Online Library)

Assessing factors influencing ESG ratings in Malaysian companies: An empirical study / Samidi, N. S., & Kwan, J. H.

Paper Asia
Volume 40 Issue 6b (2024) Pages 280–288
https://doi.org/10.59953/paperasia.v40i6b.260
(Database: PaperASIA)

Can digital transformation improve market and ESG performance? Evidence from Chinese SMEs /Wang, S., & Esperança, J. P.

Journal of Cleaner Production
Volume 419 (2023) 137980 Pages 1-12
https://doi.org/10.1016/J.JCLEPRO.2023.137980
(Database: ScienceDirect)

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

ARTICLES FOR FACULTY MEMBERS

Digital transformation empowers ESG performance in the manufacturing industry: From ESG to DESG / Wang, J., Hong, Z., & Long, H.

SAGE Open
Volume 13 Issue 4 (2023) Pages 1-21
https://doi.org/10.1177/21582440231204158
(Database: SAGE Publications Inc.)

Environmental social governance (ESG) in digitalization research: A bibliometric analysis / Tan, Q. L., Hashim, S., & Zheng, Z.

SAGE Open
Volume 15 Issue 1 (2025) Pages 1-15
https://doi.org/10.1177/21582440241310953
(Database: SAGE Publications Inc.)

How digital leadership guides ESG sustainability / Qiao, P., Zhao, Y., Fung, A., & Fung, H. G.

Research in International Business and Finance
Volume 73 Part B (2025) 102644 Pages 1-17
https://doi.org/10.1016/j.ribaf.2024.102644
(Database: ScienceDirect)

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

ARTICLES FOR FACULTY MEMBERS

Technology empowerment: Digital transformation and enterprise ESG performance-Evidence from China's manufacturing sector / Wu, X., Li, L., Liu, D., & Li, Q.

PLoS ONE
Volume 19 Issue 4 (2024) 0302029 Pages 1-24
https://doi.org/10.1371/JOURNAL.PONE.0302029
(Database:PLoS ONE)

The AI ESG protocol: Evaluating and disclosing the environment, social, and governance implications of artificial intelligence capabilities, assets, and activities / Sætra, H. S.

Sustainable Development
Volume 31 Issue 2 (2023) 10991719 Pages 1027–1037
https://doi.org/10.1002/sd.2438
(Database:Wiley Online Library)

The impact of digital transformation on ESG performance / Li, Y., Zheng, Y., Li, X., & Mu, Z.

International Review of Economics & Finance
Volume 96 Part B (2024) 103686 Pages 1-16
https://doi.org/10.1016/j.iref.2024.103686
(Database:ScienceDirect)

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

Are digital trends driving corporate environmental, social, and governance practices? Evidence from China / Xiao, S., Xu, J., & Li, R.

Business Strategy and the Environment
Volume 33 Issue 6 (2024) 10990836 Pages 5366-5385
https://doi.org/10.1002/bse.3756
(Database: Wiley Online Library)

Received: 14 June 2023 | Revised: 23 February 2024 | Accepted: 6 March 2024

DOI: 10.1002/bse.3756

RESEARCH ARTICLE

Business Strategy and the Environment

WILEY

Are digital trends driving corporate environmental, social, and governance practices? Evidence from China

Suyang Xiao [1] | Jiajun Xu [2] | Rui Li [2]

[1]School of Marxism, China University of Geosciences (Wuhan), Wuhan, China

[2]School of Economics and Management, Wuhan University, Wuhan, China

Correspondence
Jiajun Xu, School of Economics and Management, Wuhan University, Wuhan 430072, China.
Email: jiajunxu@whu.edu.cn

Funding information
Research Results of China University of Geosciences (Wuhan) Marxist Theory Research and Discipline Construction Program Project, Grant/Award Number: MX2311; The Key Research Base of Humanities and Social Sciences in Hubei Ordinary Institutions of Higher Education–Research Center of College Student Development and Innovative Education of China University of Geosciences, Grant/Award Number: DXS20150012

Abstract

This paper aims to explore whether the trend of digital transformation is driving companies to engage in environmental, social, and governance (ESG) practices. The impact of strategic transformation on firms is all-encompassing, making it difficult to capture the mechanisms of impact on corporate ESG practices. To this end, we construct a new theoretical framework that combines slack resources and stakeholder theory. This framework attributes the heterogeneity of ESG practices to differences in the ability and willingness of companies. Using data from Chinese listed companies, we find that the digital transformation is improving ESG performance. The mechanism is that digital transformation increases the availability of long-term slack resources and strengthens the connection with stakeholders. However, there is insufficient evidence that digital transformation contributes to greater transparency in corporate disclosure. We also find that this effect is larger for firms with less risk-responsiveness and firms with international connections, but smaller for firms with political connections. Our findings affirm the advantages of contemporary trends in corporate digital transformation for ESG practices and offer a new theoretical framework to investigate the factors influencing ESG practices.

KEYWORDS
digital transformation, ESG practices, slack resources theory, stakeholder theory, sustainable development

1 | INTRODUCTION

In recent decades, environmental pollution, global warming, poor employee well-being, and corporate scandals have raised public expectations for companies to take responsibility for environmental, social, and governance (ESG) issues (Arvidsson & Dumay, 2022; Lokuwaduge & Heenetigala, 2017). This has led to an increasing focus on socially responsible activities and has encouraged companies to combine the pursuit of operating profits with social responsibility. ESG investments are seen as an important way for the public to voice that demand (Cheng et al., 2014; Meira et al., 2023). Unlike traditional investments, ESG investors do not seek high investment returns but rather consider the positive environmental and social impact of a company as their primary criteria. The criteria for this investment are ESG performance and are designed to motivate companies to engage in socially responsible activities.

From a corporate perspective, however, unlike the innate desire for financial performance, corporations do not always make every effort to pursue ESG performance. Because the pursuit of ESG performance is costly, its economic benefits usually take time to materialize and, in many cases, are highly uncertain (Gatignon, 2022; Tang et al., 2018). In this respect, ample evidence has been presented by a large number of studies discussing the relationship between ESG performance and corporate financial performance (CFP). Theoretically,

Abbreviations: CFP, Corporate Financial Performance; DID, Differences-in-differences; ESG, Environmental, Social, and Governance; MD&A, Management Discussion and Analysis; NGOs, Non-Governmental Organizations; RBT, Resource-based theory; *TFP*, Total Factor Productivity.

Aguilera et al. (2007) argued that because business organizations are embedded in different national systems, they will experience divergent degrees of internal and external pressures to engage in social responsibility initiatives. In addition, the findings of Schaltegger and Horisch (2017) suggested that the search for legitimacy rather than profit dominates corporate sustainability management practices. The limiting power of legitimacy on corporate behavior varies depending on the characteristics of the corporate and institutional environment, which leads to heterogeneity in corporate ESG practices.

Along this line, previous literature has examined the factors influencing ESG practices at the country and corporate levels. The corporate level has mainly focused on exploring the impact of firm financial performance (Baldini et al., 2018; Branco & Rodrigues, 2008; Reverte, 2009) and management characteristics (Li, Zhang, & Ding, 2023; Park et al., 2023). Scholars argued that we are still far from explaining the heterogeneity of ESG performance among firms and call for a comprehensive theoretical and empirical study of the reasons behind the observed differences (Ioannou & Serafeim, 2012; Zaman et al., 2022).

Under the impetus of government and market forces, many companies are actively embracing digital technology, considering digital transformation a pivotal growth strategy (Zeng et al., 2022). According to Verhoef et al. (2021), digital transformation is the ownership of digital assets, with capabilities related to digital agility, digital networks, and big data analytics, among others, which entails going through three stages, introducing digital resources (or digital assets), establishing connections with customers through digital technologies to change existing production and business processes, adding digital components to products or services, using digital platforms and data to drive business model transformation, and so on. With the trend toward digitalization, existing literature has identified that Industry 4.0, blockchain, and the circular economy are playing an increasingly important role in promoting corporate social responsibility (Agrawal et al., 2022; Laing et al., 2019; Mukhuty et al., 2022; Srivastava et al., 2022; Upadhyay et al., 2021). Digital transformation is being used as a potential catalyst for sustainable practices (Sahoo et al., 2023; Sharma et al., 2022). Furthermore, the literature has found that digital transformation improves firms' ESG performance. For example, Chen and Hao (2022) found that firms' digital transformation significantly contributes to corporate environmental performance and that board characteristics have an important moderating role. Lu et al. (2023) found that digital transformation enhances firms' ESG performance by strengthening internal control and green innovation. Another strand of literature has argued that digital transformation also poses challenges for ESG practices, such as resource crowding, short-term profit orientation, and issues of legality, compliance, and ethics (Cappa et al., 2021; Vial, 2021; Zhong & Ren, 2023). The research is still inconclusive as to whether the digital transformation of an organization can effectively contribute to its ESG performance.

In addition, despite the comprehensive impact of digital transformation on companies, the complexity arises when attempting to identify the specific mechanisms influencing corporate ESG practices. Existing literature mostly selects two or three indicators as mediating variables for mechanism testing, with each emphasizing different aspects, including green innovation, information disclosure quality, internal controls, and media attention (Wu & Li, 2023; Zhong et al., 2023). However, this selective approach fails to fully capture the crucial channels through which digital transformation affects corporate ESG performance. Currently, there is still a lack of a comprehensive theoretical framework to encapsulate the complete transmission mechanisms of digital transformation on corporate ESG performance. This is crucial for a profound understanding of how digital transformation significantly influences corporate ESG performance.

The previous academic literature explored the influencing factors of ESG practices and identified various theoretical approaches, such as widely used institutional theory and legitimacy theory (Baldini et al., 2018; Schaltegger & Horisch, 2017). Furthermore, in the context of digital transformation, resource slack theory and stakeholder theory seem to be most relevant to corporate ESG practices. The former suggests that companies with abundant financial, managerial, and/or technological resources are more likely to engage in ESG practices compared to their peers with limited slack resources (Julian & Ofori-dankwa, 2013). The latter emphasizes that companies have a responsibility to not only serve shareholders but also to meet the expectations of various stakeholders regarding corporate ESG performance (Perez-Batres et al., 2012). However, these studies overlook the concurrent application of resource slack theory and stakeholder theory in explaining ESG differences among companies.

Resource slack theory and stakeholder theory should not be considered mutually exclusive. Given the non-mandatory nature of ESG practices and the long-term nature and uncertainty of returns, a company's capability and willingness jointly determine ESG practices. By applying resource slack theory, we argue that digital transformation may increase the availability of slack resources, thereby enhancing the "capability" of corporate ESG. Additionally, by applying stakeholder theory, we hypothesize that the closer connections with stakeholders brought about by digital transformation may elevate the "willingness" of companies to improve ESG performance. Therefore, our research aims to integrate resource slack theory and stakeholder theory to construct a new theoretical framework, filling gaps in existing literature. Using this framework, we provide a comprehensive overview of the impact channels of digital transformation on ESG performance, primarily covering both "capability" and "willingness" aspects.

This study makes the following two original contributions: First, our study contributes to the growing literature on the factors influencing corporate ESG. To date, research has examined firm and management characteristics (Borghesi et al., 2014) as well as national laws and culture (Ioannou & Serafeim, 2012) on the impact of corporate ESG practices. However, few studies have analyzed the causal effect of digital transformation on ESG practices, and current research has not yet reached a unified view on whether digital

transformation promotes ESG practices. We demonstrate that digital transformation is improving enterprise ESG performance after considering endogeneity and robustness. Second, we integrate slack resources and stakeholder theory into a new theoretical framework that attributes the influences of corporate ESG practices to the availability of slack resources and the connection with stakeholders. We adopt this framework to fill the theoretical gap in the impact of digital transformation on ESG practices. This framework is general and can be used to explore the impact of other strategic management strategies on ESG practices.

In the next section, the developed theoretical hypotheses are presented. This is followed by a section on methodological and empirical results. Finally, some conclusions are drawn.

2 | THEORETICAL HYPOTHESIS

Digital transformation is impacting every aspect of a business, thus influencing ESG practices from various channels. However, this also makes it challenging to identify mechanisms. This study attributes the heterogeneity of companies' ESG practices to two reasons, namely, differences in ability and willingness. On the one hand, investing in environmental and social responsibility can be a drain on corporate resources but the benefits of ESG practices to companies are uncertain. Companies with more technology, and human and financial resources available are better positioned to improve ESG performance, while being in financial distress can limit ESG practices. On the other hand, even if companies are well positioned to engage in ESG practices, short-sightedness, and information asymmetry with stakeholders can undermine companies' willingness to practice ESG. Specifically, we analyze below how digital transformation affects ESG performance using slack resources theory and stakeholder theory as mechanisms of ability and willingness. In addition, based on this theoretical framework, we explore the role of firms' social connections and risk responsiveness in the relationship between digital transformation on ESG performance. The conceptual framework in Figure 1 depicts the relationship between corporate digital transformation and ESG performance. The model is based on four hypotheses derived from our analysis.

2.1 | Potential mechanisms

2.1.1 | Slack resources mechanism

The assumption of slack resource theory is that having a certain level of resource slack is beneficial to the organization (Bourgeois Iii, 1981). Such slack resources provide flexibility and resilience, enabling the organization to respond more effectively to unexpected challenges or opportunities. Companies can accumulate slack resources in the form of financial resources, experienced management and technical staff, and advanced technology. The availability of slack resources allows companies to act and compete more boldly and confidently (Nohria & Gulati, 1996). Companies with sufficient slack resources are less likely to have to make painful trade-offs than those that must pursue multiple goals with fairly limited slack resources (Xiao et al., 2018). In the specific context of corporate sustainability, several scholars have put forward a consistent set of theoretical arguments that the presence of slack resources can facilitate corporate participation in sustainable development (Daniel et al., 2004; Waddock & Graves, 1997).

The availability of slack resources also profoundly affects the ESG practices of companies. First, the availability of slack resources frees companies from the pursuit of short-term profits. The literature suggests that strategies to profitably improve ESG performance are more likely to be lagging and highly uncertain (Gatignon, 2022; Tang et al., 2018). Clearly, financially distressed companies may not have the ability to make discretionary investments in traditional ESG practices (such as philanthropy), while financially sound companies have the resources to spend in ways that may have a longer-term strategic impact, such as investing in improving local schools or community conditions to improve the workforce. Second, firms with sufficient slack resources can make substantial rather than symbolic efforts to improve their social and environmental

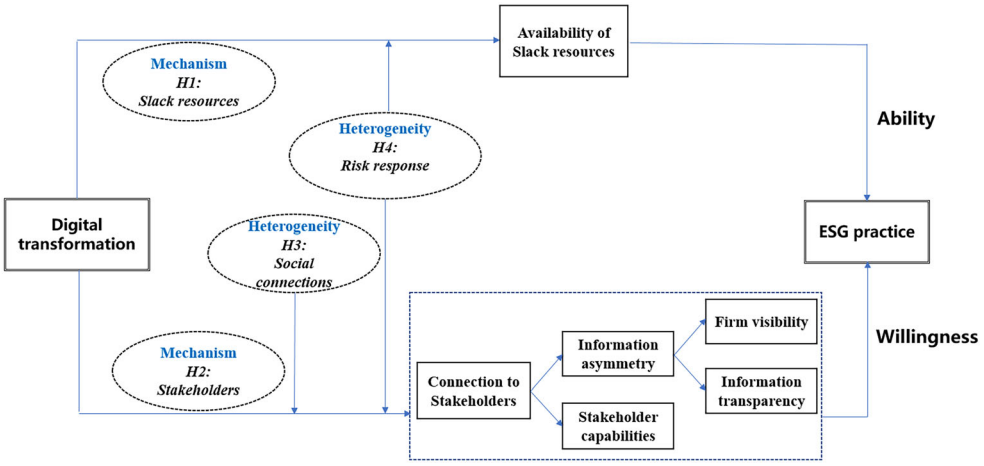


FIGURE 1 Conceptual framework.

performance (Perez-Batres et al., 2012). For example, companies can purchase expensive equipment and develop new technologies to reduce energy consumption, pollution, and/or waste. In summary, when faced with similar stakeholder pressure, companies with sufficient slack resources are more capable of responding to stakeholder ESG demands than their peers with limited slack resources.

Companies are digitally transforming to stay competitive (Chatterjee & Mariani, 2022), which can impact the availability of slack resources. Martinez-Caro et al. (2020) found that enterprise digital transformation can facilitate value activities when a digital organizational culture is integrated. Hautala-Kankaanpaa (2022) showed that the digital transformation of enterprises can optimize 13 business operations, including cost and output. The literature suggests that enhanced firm value and operational performance are key factors in the increased availability of slack resources (Panwar et al., 2017; Sun & Govind, 2022). However, previous studies are not unified on whether digital transformation will facilitate or hinder the corporate availability of slack resources. Some evidence suggests that the benefits of digital transformation often do not cover the costs they incur, thus worsening their operational performance (Cappa et al., 2021; Ekata, 2012). Digital transformation requires companies to invest heavily in digital devices or technology infrastructure to collect, analyze, and manage data resources (Bresciani et al., 2021). The short-term significant increase in these costs may reduce the slack resources of the company. In addition, irrational digital transformation tends to disrupt organizational functions, leading to discomfort and conflict in the short term and weakening the funds available to the transforming company (Vial, 2021). Zhong and Ren (2023) argued that the short-term benefits of digital transformation are insufficient to offset the costs incurred. However, the long-term advantages of reducing operational costs will outweigh the initial expenses. In conclusion, digital transformation may affect the availability of slack resources, but its direction needs to be further tested. On the basis of these arguments, we hypothesize the following:

> **Hypothesis 1.** Digital transformation has changed the slack resources available to companies, further impacting the ability of their ESG practices.

2.1.2 | Stakeholder mechanism

ESG practices of a company do not depend only on the availability of slack resources. Due to the non-mandatory nature of ESG practices, firms with slack resources may invest resources in long-term financial goals rather than non-financial goals. According to stakeholder theory, a company's business decisions must take into account the interests of stakeholders or accept their constraints (Freeman et al., 2004). Stakeholders comprise pressure groups such as shareholders, employees, government, NGOs, customers, environmentalists, etc. In recent years, with the public's concern about social and environmental issues, companies have asked their stakeholders to take social responsibility (McWilliams & Siegel, 2001). ESG practices are used by companies as a tool to demonstrate social awareness and to engage in acceptable behavior in accordance with stakeholder expectations (Cheng et al., 2014). As a result, companies facing stakeholder pressure will be more willing to improve their ESG performance.

However, information asymmetry exists between stakeholders and companies, and the degree varies from company to company. On the one hand, companies face different levels of attention. Companies with higher exposure tend to be under greater stakeholder pressure and thus more direct scrutiny (Baldini et al., 2018; Reverte, 2009). This will motivate companies to commit to improving their ESG performance to maintain their reputation or seize the opportunity to attract more ESG investments (Bansal & Clelland, 2004; Bansal & Roth, 2000; Reverte, 2009). On the other hand, to avoid stakeholder pressure, some companies have learned how to strategically pretend their ESG behavior rather than substantively implement it (Walker & Wan, 2012). This type of strategy is known in management research as "greenwashing" by disclosing false ESG performance while meeting stakeholder expectations at a low cost (Font et al., 2012; Lee & Raschke, 2023).

In addition, the attitude of a company's management toward sustainability can influence the company's response to its stakeholders. A wide range of stakeholders is constantly asking companies to be transparent in providing ESG disclosures (Herremans et al., 2016). However, companies' strategic responses to stakeholder requests for sustainability disclosures vary (Hess, 2008; Sweeney & Coughlan, 2008). Enterprises have vastly different perceptions of the business and sustainability value of ESG practices. Zakhem (2008) argued that the "stakeholder capability" to understand and exploit stakeholder relationships varies between firms. The success of a business's strategy is largely dependent on activating stakeholder cooperation (Waligo et al., 2014). Short-sighted management's disdain for the needs of stakeholders will lead to a reduction in the company's sustainability.

The digital transformation of the enterprise leads to a deeper connection between the enterprise and its stakeholders. First, digital technology will alleviate the information asymmetry between companies and stakeholders. From a stakeholder perspective, companies undergoing digital transformation will receive more attention. Stakeholders will pay more attention to companies undergoing transformation to assess the effectiveness of their strategies. Evidence also suggests that digital technologies promote organizational transparency, which in turn increases the visibility of the company to stakeholders (Reischauer & Ringel, 2023). From the perspective of enterprises, the digital transformation of enterprises, especially the application of big data and blockchain technology, makes the activities of enterprises recordable and traceable and enhances the transparency of information within enterprises.

Second, the digital transformation of enterprises may make them more sustainable. Enterprise digitalization can improve the efficiency and agility of all aspects of internal control, which helps to achieve dynamic feedback and assessment of risk capture and identification as well as management decisions in the enterprise's interaction with the environment (Sharma et al., 2022). This improves the efficiency of

communication with external stakeholders and the dynamics of decision-making interactions, enhances the company's stakeholder capabilities, and makes managers more far-sighted. This leads us to the following hypotheses:

> **Hypothesis 2.** Digital transformation enhances the connection between companies and stakeholders, which in turn makes companies more willing to improve ESG performance.

2.2 | Heterogeneous effects

2.2.1 | Social connection

Businesses must obtain resources from various stakeholders to ensure survival and growth, and in the process, they must assume corresponding social responsibilities to meet the concerns and demands of stakeholders. Previous research has indicated that businesses with political and international affiliations face different pressures from stakeholders (Lucea & Doh, 2012; Mbalyohere & Lawton, 2018). This means that when there are distinctions in the social relationships of a business, there are differences in the financial and non-financial purposes of digital transformation. The stance of businesses in political and international relations may influence their attitude toward ESG practices in digital transformation. This perspective provides an interesting angle for our research to explore the interactive impact of different social relationships on corporate digital transformation and ESG practices. In the following, we will discuss the heterogeneity of firms' social connections in the relationship between digital transformation and ESG performance based on the stakeholder mechanism (willingness mechanism) outlined in our theoretical framework.

The literature suggests that establishing long-term political relationships can assist businesses in obtaining more subsidies and welfare policies (Faccio et al., 2006). One significant benefit is that government officials protect businesses with political relationships, shielding them from strict environmental regulations and social pressures for personal gain. Correia (2014) found that companies with political relationships face fewer enforcement actions and lower penalties for misconduct. For example, Xiao and Shen (2022) discovered that companies losing political relationships experience a significant increase in environmental ratings. This implies that businesses with political relationships face less pressure from stakeholders themselves. In the process of digital transformation, businesses with political relationships are protected by the government on social issues and are more likely to use digital technology for non-ESG projects, thus lacking the willingness to improve ESG performance. In contrast, non-politically affiliated businesses, during digitalization, are more likely to compensate for their lack of stakeholder connections.

International connections of businesses may also lead to heterogeneity in the impact of digital transformation on ESG performance. Multinational corporations place greater emphasis on ESG performance as they operate globally and need to comply with regulations and standards in multiple countries (Branco & Rodrigues, 2008). Subsidiaries of multinational corporations, if they wish to maintain business relationships with these corporations, must also meet these requirements, as multinational corporations often incorporate these requirements into their supply chain management standards (Bansal & Clelland, 2004). Additionally, many multinational corporations require their suppliers or partners to meet certain standards in ESG, reducing their business risks and enhancing their reputation (Branco & Rodrigues, 2008). As mentioned earlier, digital transformation reduces the asymmetry between businesses and stakeholders, allowing them to transparently showcase their ESG performance. Due to the high standards of multinational corporations in ESG, internationalized businesses are more likely to seize the opportunity to improve ESG performance during the digital transformation process compared to non-internationalized businesses. Therefore, we hypothesize that digitalization has a more positive impact on the ESG performance of businesses with international affiliations.

Therefore, we hypothesize the following:

> **Hypothesis 3.** There is heterogeneity in the impact of digital transformation on the ESG practices of companies with different social connections.

2.2.2 | Risk response

The level of internal control and environmental uncertainty are important factors that affect an enterprise's ability to respond to risk. Internal control is a series of strategies, plans, policies, procedures, and measures developed by an enterprise to achieve its business objectives, and the process of monitoring their effectiveness. Insufficient internal control capabilities may lead to a lack of effective risk assessment and management mechanisms, increasing the likelihood of facing potential issues. Additionally, a company's investments and strategic decisions are consistently influenced by the external environment. When environmental uncertainty is high, companies tend to decrease their preference for risky activities, opt for more stable investment approaches in projects, and exercise greater caution in project reviews (Li & Zhang, 2017). There is also heterogeneity in the relationship between risk response capabilities and digital transformation as well as ESG performance. In the following, we will analyze this based on the slack resource mechanism (ability mechanism) and stakeholder mechanism (willingness mechanism) in our theoretical framework.

First, when a company has a weaker risk response capability, digital transformation is more likely to enhance its ability to engage in ESG practices. Feng et al. (2024) argued that in situations of higher environmental uncertainty, companies with a higher degree of digital transformation are better positioned to demonstrate advantages in moving toward technological frontiers. Through the use of digital tools, companies can rapidly access and analyze market trends, policy changes, and social feedback, allowing them to adjust strategies with agility and flexibility, thus creating more corporate value. Alshourah

et al. (2023) pointed out that in dynamically changing environments, especially in markets undergoing rapid technological changes, digital transformation is more likely to help companies stand out in intense competition, achieve innovation, and gain sustainable competitive advantages. Similarly, in situations where a company lacks internal control capabilities, digital transformation provides solutions for automation and efficiency improvement. Through digital management systems, companies can achieve more precise monitoring and management of internal processes, and automated data collection and processing contribute to increased financial transparency, reducing internal errors caused by human factors (Sharma et al., 2022). In summary, compared to companies with better risk response capabilities, these companies with weaker capabilities can leverage digital transformation to overcome limitations in risk response capabilities, thereby enabling them to be more capable of engaging in ESG practices.

Second, digital transformation is also more likely to leverage stakeholder channels and increase willingness to engage in ESG practices when firms have poor risk response capabilities. Weak internal control capabilities can lead to inadequate disclosure, depriving stakeholders of key information and affecting their trust in the firm (Agyei-Mensah, 2016). High environmental uncertainty can make companies hesitant to engage in ESG practices in the face of uncertain returns (Wang et al., 2023). Digital transformation can help companies by enabling them to collect more comprehensive and accurate data, improving their ability to manage sustainably (Sahoo et al., 2023). When companies face risks, having accurate data to support them can help them make more far-sighted decisions. This, in turn, can enhance a company's engagement with stakeholders by helping them improve the disclosure of ESG practices and enhancing their stakeholder management capabilities. In summary, digital transformation is more helpful for less risk-responsive firms to increase stakeholder connectivity than for firms that are more risk-responsive on their own, thus promoting willingness to engage in ESG practices.

Accordingly, we hypothesize the following:

> **Hypothesis 4.** Digital transformation is more effective in improving ESG performance for firms with poor risk response capabilities.

3 | METHODOLOGY

3.1 | Reggression model design

Based on the above analysis, this paper constructs an econometric model to explore the effect of digital transformation on corporate ESG performance, and the benchmark regression model is as follows.

$$ESG_{i,t} = a_1 + \beta_{11} Lndigit_{i,t} + \beta_{12} Z_{i,t} + \Sigma year + \Sigma Firm + \varepsilon_{i,t} \quad (1)$$

In equation (1), $ESG_{i,t}$ is the firm's ESG rating score representing the level of ESG performance. i and t denote firm and year, respectively. To control for possible effects caused by time and individual factors, $\Sigma year$ and $\Sigma Firm$ are added in this paper to control the year and firm fixed effects, respectively. $Z_{i,t}$ represents the control variables; $\varepsilon_{i,t}$ represents the random disturbance term; a_1 represents the constant term.

3.2 | Variable selection

3.2.1 | Dependent variable

The rating data of ESG performance of Chinese companies in this paper are obtained from the Sino-securities Index Information Service (Shanghai) Co. Ltd, which has measured the ESG performance of Chinese listed companies based on their combined performance in three areas: environment, society, and governance. Focusing on sustainable development concepts such as green development, safe development, and corporate governance, the ESG index incorporates more indicators that are in line with China's national conditions, such as sponge city construction, business ethics, and credibility of information disclosure, and focuses more on non-financial indicators of enterprises while considering their financial performance, so as to evaluate the long-term development value of enterprises, which has been widely adopted in previous studies. It has been widely adopted in previous studies (Xie & Lyu, 2022). According to the index system, ESG performance is divided into nine levels (C, CC, CCC, B, BB, BBB, A, AA, AAA), to which we assign a score of 1–9, and a higher score indicates a better overall ESG performance of the company. The advantage of the ESG index disclosed by the Sino-securities Index lies in its construction of a framework that is more aligned with the actual developmental context of China. It encompasses the positive efforts and achievements made by companies in pollution prevention, environmental friendliness, and other relevant aspects. In terms of social responsibility, it incorporates distinctive Chinese goals such as a company's contributions to community service and rural revitalization. On the corporate governance front, it includes indicators related to the corporate governance structure and the evaluation of information disclosure quality. The comprehensive and objective nature of the evaluation framework makes it well-suited for assessing ESG disclosure practices of Chinese listed companies.

3.2.2 | Independent variable

The digital transformation includes the use of advanced digital technologies and digital devices to change the enterprise's data processing capabilities, decision analytics, and platforms and ecosystems, triggering an organizational strategic response and bringing about a comprehensive change in the enterprise's organizational structure, value propositions, production processes, business decisions, and partnerships, which can be reflected in the change of consumer behavioral expectations, disruption of the competitive landscape, and the improvement of data accessibility (Vial, 2021). The digital

transformation of enterprises not only involves converting factors of production and raw materials into digital information but also entails the flexible use of digital devices and technologies to integrate them into the production and operation processes of enterprises. This process thoroughly disrupts the inherent technological systems and production and operation models of enterprises, ultimately achieving more sustainable development goals (Verhoef et al., 2021; Wu et al., 2021).

Previous research predominantly utilized methods such as questionnaire surveys, investments in enterprise informatization, and the application of ICT technologies to measure the degree of penetration of the digital economy into enterprises or as a measure of enterprise digital transformation (Khin & Ho, 2018; Nylén & Holmström, 2015). However, these studies faced limitations in terms of the subjective nature of survey methods, lack of timeliness in financial disclosures, and the lack of comprehensiveness in measurement indicators.

In recent years, text analysis based on corporate annual reports has been widely applied in studies on enterprise digital transformation. The annual report is a window that reflects the enterprise's judgment and disclosure of its past performance evaluation and external environment information such as future industry development. The textual information in annual reports can reveal when a company started focusing on digitization, initiated its digital transformation, or outlined future strategic development plans and prospects. Rigorously reviewed annual reports possess authenticity and reliability. Furthermore, due to their disclosure coherence and standardization, they facilitate horizontal and vertical comparisons of information across companies (Tian et al., 2022; Wu et al., 2021; Zhu et al., 2022).

Therefore, following previous research (Wu et al., 2021), this study employs Python web scraping technology to extract key words related to digital transformation from annual reports of listed companies, China's local government reports, and authoritative institutions such as Tsinghua University published research reports related to the digital transformation of Chinese enterprises, including "artificial intelligence", "blockchain", "cloud computing", "big data", "Industrial Internet" etc. (more than 100 digital transformation keywords). The degree of enterprise digital transformation is then measured based on the frequency of these characteristic words. The frequency of words related to digital transformation mentioned in the annual reports of companies is used as a measure of the degree of digitalization (*Indigit*). Due to the right-skewed nature of the data, a logarithmic transformation is applied after adding 1 to the word frequency.

3.2.3 | Mechanism variables

Slack Resources. To distinguish the short- and long-term effects of digital transformation on slack resources, this paper uses two types of variables to represent the availability of slack resources. Short-term slack resources are measured by retained earnings per share (*eps*) and equity ratio (*eqr*), which are commonly used in the literature (Sun & Govind, 2022; Zhang et al., 2022). In addition, we measure the availability of long-run slack resources by total factor productivity (*TFP*). TFP denotes the efficacy of a firm's factor development and utilization, commonly employed to gauge the firm's sustainability. Firms boasting high TFP effectively leverage production factors such as labor, capital, and raw materials over the long term, resulting in increased output. Literature suggests that enterprises with elevated total factor productivity expend fewer resources to yield higher outputs, thereby playing a pivotal role in accumulating long-term slack resources (George, 2005). As opposed to using OLS to estimate the total factor productivity of a firm, the Levinsohn-Petrin (LP) and Olley-Pakes (OP) methods allow for the possibility of converting unobservable productivity to observable under certain assumptions (Levinsohn & Petrin, 2003; Olley & Pakes, 1996). Since the LP method can take into account the interdependence of production factors and the non-linear relationship between inputs and outputs, this allows the LP method to more accurately identify potential bottlenecks and opportunities for efficiency improvement in the production process. In addition, the LP method improves on the OP method by substituting intermediate goods input indicators instead of using investment amount as a proxy variable (Ackerberg et al., 2015). In this paper, the LP method is adopted to measure the total factor productivity of firms due to the lack of data on the amount of investment in many samples.

Connection to stakeholders. Based on the analysis in the theoretical section, we use analyst attention (*attention*), management myopia (*myopia*), and the quality of information disclosure (*quality*) to measure the degree to which the firm is connected to its stakeholders. First, this paper uses the total number of analysts (teams) who have followed a company within a year to measure the analyst attention of listed companies, which is logarithmically processed by adding 1 in the empirical analysis. Second, in line with previous research (Hu et al., 2021), textual analysis is used to capture the set of Chinese words in the MD&A of listed companies that reflect the "short term" of managers, such as "within the year, immediately" and other direct meanings. The ratio of the total word frequency of "short-sightedness" to the total word frequency of MD&A of the company is used to measure the degree of management short-sightedness, and the larger the ratio, the more serious the management short-sightedness. Third, referring to Yi et al. (2010), we adopt the evaluation of enterprise information disclosure by the Shenzhen Stock Exchange (and Shanghai Stock Exchange) in China. The evaluation is divided into four levels: A-D, which corresponds to excellent, good, qualified, and unqualified, respectively. We assign a value of 4, 3, 2, and 1 to them, with a higher score indicating a higher quality of company information disclosure.

3.2.4 | Control variables

First, it has been shown in the literature that some basic characteristics of firms affect ESG performance (Lu et al., 2023). In this paper, we control for firm size (*size*), firm age (*age*), and property right (*property*)

TABLE 1 Measurement of control variables.

Type	Variables	Symbol	Measures
Firm level	Firm size	*Size*	Firm revenues
	Firm age	*Age*	Difference between the year of incorporation and the current year
	Property right	*Property*	Takes the value of 1 if the listed company is a state-owned enterprise, and 0 otherwise
	Leverage	*Lev*	Ratio of total liabilities to total assets
	Cash ratio	*Cash*	Ratio of net cash flow from operating activities to total assets at the end of the year
	Audited by a big 4 accounting firm	*Audit*	Audited by a big 4 international accounting firm, assigned a value of 1, otherwise 0
	Return on assets	*Roa*	Net profit after tax as a percentage of total assets
	Shareholding structure	*Herf*	Number of shares held by the largest shareholder as a percentage of total shares
	Ownership concentration	*Er*	Proportion of the number of shares held by the largest shareholder to the number of shares held by the second-largest shareholder
	Size of directors	*Director*	Number of current independent directors
	Independence of the board of directors	*Indepen*	Number of independent directors
Regional level	Level of economic development	*Gdp*	Real GDP per capita
	Level of government intervention	*Gov*	Ratio of government expenditure to GDP
	Population density	*Pop*	Ratio of the population of prefecture-level cities to the size of their administrative areas
	Human capital	*Hum*	Ratio of the number of people with general undergraduate degrees and above to the city's resident population
	Industrial structure	*Ind*	Share of secondary sector in GDP

TABLE 2 Descriptive statistics.

Variables	N	Mean	SD	Min	Max
ESG	21,383	6.511	1.124	1	9
Lndigit	21,383	1.159	1.334	0	6.084
Size	21,383	21.63	1.474	13.40	28.72
Age	21,383	2.266	0.653	1.099	3.434
Property	21,383	0.411	0.492	0	1
Lev	21,383	0.428	0.197	0.007	0.998
Cash	21,383	−0.044	1.032	−112.4	17.46
Audit	21,383	0.060	0.238	0	1
Roa	21,383	0.038	0.093	−1.648	8.441
Herf	21,383	34.51	14.93	0.290	89.99
Er	21,383	25.02	17.67	0	88.87
Director	21,383	10.24	2.680	4	26
Indepen	21,383	3.874	1.220	1	13
Gdp	21,383	11.42	0.680	8.640	12.72
Gov	21,383	0.156	0.0565	0.0439	0.693
Pop	21,383	914.1	631.5	5.093	2,654
Hum	21,383	430.8	322.0	3.238	1,311
Ind	21,383	41.51	11.27	12.08	89.75

to represent the basic firm characteristics. Second, based on the literature examining the relationship between financial performance and ESG (Friede et al., 2015; Waddock & Graves, 1997), this paper controls for a series of indicators of firms' financial condition and operating performance, including leverage (*lev*), cash flow (*cash*), audited by a Big 4 accounting firm (*audit*), and return on assets (*roa*). Third, this paper controls for shareholding structure (*herf*), ownership concentration (*er*), size of directors (*director*), and independence of the board of directors (*indepen*) to take out the interference of the degree of firm equity balance and governance structure on ESG performance. In addition, the paper controls for a series of regional factors that may affect ESG performance, including the level of economic development (*gdp*), the degree of government intervention (*gov*), population density (*pop*), human capital (*hum*), and industry structure (*ind*). Detailed measures of the firm-level and regional-level control variables are shown in Table 1.

3.3 | Research sample and data sources

Since the ESG index was grossly undersampled in 2009, this paper uses 2010 as the initial sample. This study uses data from listed

companies in China from 2010 to 2020. In addition, we excluded the following samples: (i) companies lacking primary research data; (ii) companies in the financial industry; (iii) ST, *ST, and PT companies; (iv) some samples have abnormal asset return data, and the samples of enterprises with total assets less than total liabilities are deleted. After the above processing, 21,383 samples are obtained, and the descriptive statistics of the variables are shown in Table 2. The disclosure data of listed enterprises used in this paper are obtained from the China Stock Market & Accounting Research (CSMAR) database and the China Research Data Service (CNRDS) database. The ESG rating data are from the Wind database.

4 | EMPIRICAL RESULTS

4.1 | Benchmark regression results

To ensure that the experimental results are true and credible, this paper adopts a stepwise regression model to test the impact effect of digital transformation on corporate ESG performance. The empirical results are shown in Table 3. Columns (1) and (2) in Table 3 represent the regression results of the OLS model without controlling for individual fixed effects and the two-way fixed effects (FE) model controlling for both time and individual effects, respectively. In columns (3) and (4), a series of control variables are included in this paper, and all regression results are significantly positive at least at the 5% level, indicating that the digital transformation of firms promotes corporate ESG performance.

4.2 | Robustness tests

4.2.1 | Differences-in-differences (DID) model and parallel trend analysis

In addition, the paper distinguishes between firms that have or have not undergone a digital transformation to examine the impact on corporate ESG performance and its long-term effects. We divide the sample data into two groups, and if a company starts to adopt a digital transformation strategy in a certain year, we use this year as the base year, assign a value of 1 to the year after that year, and otherwise assign a value of 0. We construct the variable Treat*Time, and use a multi-period differences-in-differences (DID) model to test whether digital transformation can affect the ESG performance of a company.

The ex-ante years are defined as −4, −3, −2, and −1, and the subsequent years as 1, 2, and so on. The interaction dummy variables

TABLE 3 Baseline regression results.

Variables	(1) ESG	(2) ESG	(3) ESG	(4) ESG
Lndigit	0.061*** (4.86)	0.028*** (2.60)	0.072*** (6.25)	0.025** (2.31)
Size			0.213*** (14.32)	0.136*** (6.52)
Age			0.090*** (3.14)	−0.305*** (−4.88)
Property			0.391*** (8.99)	0.038 (0.65)
Lev			−0.687*** (−6.61)	−0.349*** (−3.83)
Cash			−0.012*** (−2.73)	−0.012** (−2.19)
Audit			0.216*** (3.11)	0.072 (0.97)
Roa			0.617* (1.78)	0.143* (1.76)
Herf			0.003 (1.24)	0.008** (2.28)
Er			−0.002 (−1.13)	−0.006** (−2.21)
Director			−0.007 (−0.97)	−0.017*** (−3.39)
Indepen			0.012 (0.91)	0.003 (0.29)
Hum			0.000 (0.15)	−0.000*** (−3.31)
Gdp			−0.019 (−0.53)	−0.043 (−0.22)
Ind			−0.005*** (−2.77)	−0.004 (−1.48)
Gov			0.024 (0.06)	−0.198 (−0.44)
Pop			0.000 (0.33)	−0.000** (−2.48)
_cons	6.353*** (261.05)	6.123*** (212.06)	2.020*** (3.94)	4.972** (2.35)
Firm fixed effects	NO	Yes	NO	Yes
Year fixed effects	Yes	Yes	Yes	Yes
N	21,383	21,383	21,383	21,383
Adj. R^2	0.015	0.030	0.165	0.048

Note: The t-statistic is in parentheses. ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively.

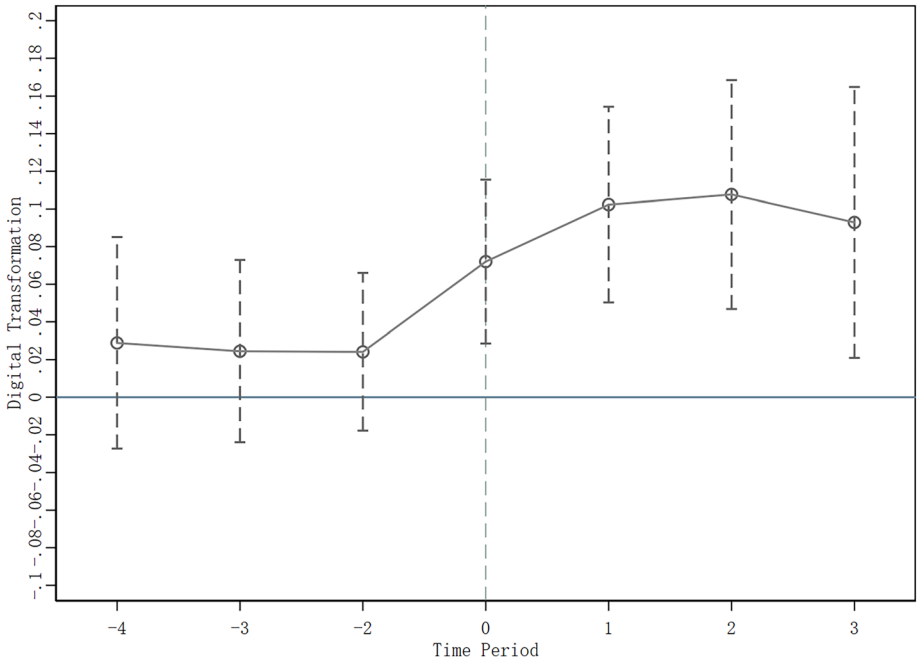


FIGURE 2 Parallel trend hypothesis testing.

corresponding to the above periods are constructed for comparative analysis and parallel trend test results, as shown in Figure 2. Following the usual practice in the previous literature, the previous period is excluded as a control in this paper. The effect of digital transformation on ESG performance is not significant in ex-ante periods 2–4, but its effect on ESG performance is significantly positive after adopting a digital transformation strategy. Moreover, this positive effect is persistent and the coefficient tends to increase, and digital transformation still contributes to corporate ESG performance within 3 periods.

4.2.2 | Replacing variables

(1) Digital transformation index. To prevent potential manipulation of annual reports by companies for purposes such as manipulating stock prices, leading to artificially inflated frequencies of digitalized vocabulary and consequently affecting the accurate measurement of the degree of digital transformation, this study has replaced the core independent variable. In this paper, the Digital_Index, a corporate digital transformation index measured by the Digital Transformation Research Database of Chinese Listed Companies, jointly developed by the CSMAR team and East China Normal University, is selected to measure the degree of enterprises' digital transformation. The index measures the degree of enterprise digital transformation by collecting data and assigning sovereign values from six dimensions: strategic leadership, technology drive, organizational empowerment, environmental support at the mid-macro level, digital achievements, and digital applications, which can reflect the actual situation of enterprise digital transformation in a more comprehensive way. The regression results, as shown in column (1) of Table 4, show that the enhancement of digital transformation on enterprise ESG performance is significantly positive at the 5% level.

(2) Bloomberg ESG index. Due to the fact that different organizations focus on different perspectives in their evaluation systems for ESG, there may be differences between the ratings of the organizations, which may result in estimation errors. In this study, the ESG index evaluated by Bloomberg based on the quality and transparency of corporate disclosure of ESG information is used as a proxy for the core dependent variable for robustness testing. The results, as shown in column (2) of Table 4, show that the enhancing effect of digital transformation on ESG performance is significantly positive at the 5% level. This suggests that, even after substituting the dependent variable, the regression results continue to support the key findings of this study.

4.2.3 | Changing the estimation model

Since the dependent variable in this paper is categorical and ordinal, we further use an ordered logit model for robustness testing. Controlling for fixed effects and time effects, the regression results, as presented in column (3) of Table 4, indicate that the contribution of digital transformation to firms' ESG performance is significantly positive at the 5% level. This suggests that the core findings of this paper are robust.

4.2.4 | Controlling for multidimensional fixed effects

Based on the baseline regression, this paper further tests the model by controlling for multidimensional fixed effects. City, industry, and year interaction fixed effects are added to the model to exclude possible effects of city and industry-level characteristics on firm ESG

TABLE 4 Robustness test.

Variables	(1) FE	(2) FE	(3) FE-OLogit	(4) FE	(5) IV
Lndigit		0.206** (2.15)	0.084** (2.34)	0.025*** (2.895)	0.209** (2.335)
Digital_Index	0.004** (2.05)				
_cons	3.327 (1.51)	17.124 (0.79)	/	3.910*** (13.047)	/
			/		/
Ind*year	/	/	/	/	/
Pro*year	/	/	/	/	/
K-P rk LM	/	/	/	/	88.763
K-P rk Wald F	/	/	/	/	56.312
Hansen J	/	/	/	/	0.3825
Control	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	NO	YES
City#year#Ind	/	/	/	Yes	/
N	20,267	8,241	17,468	20,440	21,242
Adj. R2	0.035	0.680	/	0.719	/

Note: The t-statistic or Z-statistic values are in parentheses and ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

performance over time. Due to the inclusion of city-year interaction fixed effects, control variables at the city level are automatically omitted, leaving only firm-level control variables, as shown in column (4) of Table 4. After controlling more stringently for fixed effects in the model, the coefficients of the core explanatory variables are significantly positive at the 1% level, indicating that the main findings of this paper are robust.

4.2.5 | Endogeneity treatment

Since companies with better ESG performance tend to perform better financially and thus are more likely to undergo digital transformation, there may be a bidirectional causal relationship between digital transformation and ESG performance. In addition, unobservable omitted control variables and measurement errors for ESG performance may also lead to endogeneity. Therefore, we use the instrumental variables approach to rule out the possibility of a spurious relationship due to endogeneity.

(1) Prior researches suggest the presence of a peer effect in the adoption of corporate digital transformation strategies, wherein firms within the same industry may tend to follow and imitate the actions of other firms, leading to a convergence in the digitalization levels across the entire group (Chen et al., 2021; Ning et al., 2023). However, corporate ESG performance is not directly influenced by the digitalization levels of other firms. Therefore, using the average digital transformation level within the same industry as an instrumental variable is reasonably grounded. Referring to Fisman and Svensson (2007), we take the mean value (except for that firm) of digital transformation at the industry level of the firm as an instrumental variable. Whether a firm adopts a digital transformation strategy and the way it adopts digital transformation may be influenced by other firms in the industry and can satisfy the correlation requirement with the explanatory variables. Meanwhile, the digital transformation of other firms does not affect the ESG performance of this firm through other paths, satisfying the exclusivity of the instrumental variables.

(2) It has also been shown in the literature that there are spatial spillover effects in the development of the digital economy. Hangzhou, as one of the earliest and most vibrant regions in China's digital economy industry (Hu et al., 2023; Qin et al., 2022), hosts numerous enterprises engaged in core digital economy sectors. These enterprises provide digital solutions or platform services to surrounding areas. Proximity to Hangzhou increases accessibility to digital resources such as technology, talent, or platforms. Moreover, closer proximity enhances opportunities for business collaborations with digital economy enterprises, resulting in a higher degree of corporate digitization. Therefore, this paper uses the inverse of the spherical distance of the enterprise office location from Hangzhou calculated by GIS as the second instrumental variable. Since geographical distance is cross-sectional data and not suitable as a direct instrumental variable, this study uses the Internet investment amount in the previous year for the city where the company is located as a time trend variable and multiplies it with geographic distance as a panel instrumental variable.

The regression results obtained using two-stage least squares are shown in column (5) of Table 4. The Kleibergen-Paap rk LM statistic of 88.763($P = 0.000 < 0.05$) rejects the hypothesis that the instrumental variable is not identifiable at the 1% level. The Kleibergen-Paap rk Wald F statistic of 56.312 is much larger than the critical value of 19.93 at the 10% significance level, indicating that there is no weak instrumental variable problem. Hansen J statistic overidentification test of all instruments gives a Chi-square statistic value of 0.763 ($P = 0.3825 > 0.05$). All tests indicate that the selection of

instrumental variables in this paper is valid and the posterior effect of digital transformation on ESG is still significantly positive at the 5% level after excluding potential endogeneity issues.

4.3 | Mechanism test

4.3.1 | Slack resource mechanism

Columns (1) and (2) in Table 5 demonstrate that corporate digital transformation does not significantly contribute to retained earnings per share and equity ratio. This indicates that digital transformation does not provide immediate financial performance returns to the enterprise. In other words, digital transformation does not improve the availability of corporate slack resources in the short term. This may be due to the two-sided impact of digital transformation on the firm in the short term. On the one hand, the adoption of digital technology leads to overall efficiency improvements in the enterprise, but on the other hand, the cost of digital devices or technology infrastructure takes away from the available resources of the enterprise. Column (3) shows that digital transformation significantly contributes to the total factor productivity of a company. Despite the investment cost of digital transformation, however, it facilitates the long-term slack resource availability of the firm. This contributes to the sustainability of the company and makes the company more capable of engaging in ESG practices. In short, digital transformation does not promote the availability of short-term slack resources but enhances ESG performance by increasing the availability of long-term slack resources.

4.3.2 | Stakeholder mechanism

Previous research has argued that when firms are subjected to more pressure from outside investors, short-sighted opportunistic behaviors can arise, affecting their long-term performance and sustainability (Cadman & Sunder, 2014). This study discusses whether digital transformation strategies can have a dampening effect on short-sighted opportunism, promote sustainable growth, and enhance firms' ESG performance from three perspectives: firms' external attention pressure, managerial myopia, and disclosure quality.

The results in column (1) of Table 6 show that digitally transformed companies receive more analyst attention at the 1% significance level. This indicates that digitally transformed companies will be under greater stakeholder pressure and in turn, will have to work on improving ESG performance. In contrast, the results in column (2) show that digital transformation has a significant negative impact on managerial short-sightedness at the 1% level of significance. Digital transformation strengthens managers' focus on sustainability and is accompanied by an increase in stakeholder management capabilities. This suggests that digital transformation also promotes the willingness of companies to engage in ESG practices. The above results show that digital transformation exposes firms to more pressure from outside stakeholders but effectively curbs managers' short-sighted opportunism, suggesting that digital transformation may be an important driver in transforming firms' external pressures into ESG enhancement. Enterprises with more knowledge and capabilities of digital technology, such as improved data analytics, can make their activities of processing, transferring, and servicing resources, such as knowledge and information, more flexible and convenient. Moreover,

TABLE 5 Slack resource mechanism test results.

Variables	(1) eps	(2) eqr	(3) tfp
Lndigit	0.002 (0.07)	0.057 (0.49)	0.007*** (2.68)
_cons	−30.408* (−1.94)	15.969 (0.89)	−8.226*** (−15.90)
Control	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
N	21,383	21,383	19,974
Adj. R2	0.133	0.042	0.921

TABLE 6 Stakeholder mechanism test results.

Variables	(1) attention	(2) myopia	(3) quality
Lndigit	0.057*** (5.22)	−0.003*** (−3.81)	0.006 (0.80)
_cons	−5.045** (−2.37)	0.518*** (2.84)	−0.217 (−0.12)
Control	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
N	21,383	21,383	16,155
Adj. R^2	0.192	0.049	0.041

Note: The t-statistic or Z-statistic values are in parentheses and ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

through the introduction of digital resources applied to diversified digital scenarios and solutions, enterprise digital transformation can correct the short-sighted opportunistic behavior of managers and alleviate the short-sightedness of managers in their behavioral decisions.

Column (3) demonstrates that digital transformation contributes to the quality of disclosure, but is not statistically significant. This suggests that digital transformation is mainly effective in improving corporate stakeholder relations by increasing external monitoring pressure and reducing management short-sightedness, but may not be effective in preventing corporate "greenwashing". This is because not all firms have sufficient incentives to utilize digital technologies to improve the quality of disclosure. The widespread use of digital technologies and digital platforms provides a powerful channel for firms to publicize their performance, which can effectively increase their visibility and reputation. The use of digital technologies by firms to publicize their good ESG performance has a positive impact on attracting investment, increasing consumer trust, and attracting talent. However, companies may not want to use digital transformation to increase the transparency of their information when their ESG performance is poor. What's more, digital platforms may also be used by some companies for fake disclosures. This may be motivated by a company's intentional exaggeration or misrepresentation of its ESG performance in order to portray a better image or obtain more resources, which is known as greenwashing. Therefore, there may be disparities in the impact of digital transformation on disclosure quality across different types of firms, leading to an overall insignificance.

To account for this, we also do a complementary test. We regress groups of firms with different ESG performance. Due to sample limitations, we are unable to regress firms with ESG scores of 1 and 2. As shown in Table 7, we find that firms' digital transformation promotes disclosure quality only when their ESG scores are greater than 7. The coefficients are insignificant when the firm's ESG score is 4–7. And when the firm's ESG score is 3, the coefficient is even negative.

4.4 | Heterogeneity analysis

4.4.1 | Social connection

According to Chizema et al. (2015), a company is considered to be politically connected if its chairman or managing director is or was a government official, a deputy to the National People's Congress, or a member of the Chinese People's Political Consultative Conference. We test heterogeneity by grouping regression of firms based on whether there is a political connection. Similarly, grouping regression is conducted based on whether the firm has overseas affiliates to test the heterogeneity of international connections.

The results in columns (1) and (2) of Table 8 show that digital transformation does not significantly contribute to the ESG

TABLE 7 Results of digital transformation on disclosure quality grouped by ESG performance.

Variables	(1) ESG = 3	(2) ESG = 4	(3) ESG = 5	(4) ESG = 6	(5) ESG = 7	(6) ESG = 8	(7) ESG = 9
Lndigit	−0.658*** (−3.97)	−0.011 (−0.14)	0.008 (0.24)	0.002 (0.18)	−0.015 (−0.79)	0.040** (2.01)	0.117** (2.10)
_cons	−713.843*** (−15.59)	40.301 (1.02)	6.235 (1.60)	0.497 (0.22)	4.453 0.96	−8.328* (−1.87)	28.122* (1.84)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	143	483	1,633	7,555	3,217	2,689	402
Adj. R^2	0.002	0.337	0.051	0.057	0.039	0.069	0.215

Note: The t-statistic or Z-statistic values are in parentheses and ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

TABLE 8 Results of the heterogeneity test for social connection.

Variables	(1) PC-no	(2) PC-yes	(3) internet -no	(4) internet -yes
Lndigit	0.041*** (3.25)	0.002 (0.13)	0.009 (0.61)	0.036** (2.37)
_cons	2.404 (0.95)	11.126** (2.44)	1.478 (0.47)	7.467* (2.34)
Control	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
N	14,529	6,854	10,819	10,564
Adj. R2	0.050	0.048	0.035	0.069

Note: The t-statistic or Z-statistic values are in parentheses and ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. PC-No refers to the grouping of companies with no political connection, and Internet-No refers to the grouping of companies with no international connection.

performance of politically connected companies. This suggests that political connections may have a "resource curse" effect in the way that firms' digital transformation affects ESG performance. During digital transformation, politically connected firms are protected by the government on social issues and are more likely to use digital technologies for non-ESG projects, thus lacking the willingness to improve ESG performance. Our findings provide evidence for the previous study, that political connections can enable firms to avoid stakeholder pressures from poor corporate social responsibility performance during digital transformation (Muttakin et al., 2018).

The regression results in columns (3) and (4) show that setting up branches overseas and pursuing an internationalization strategy is an important way to promote ESG disclosure in the context of digital transformation, which enhances overseas investors' trust in corporate governance capabilities, environmental friendliness, and corporate social responsibility. This finding further supports resource-based theory (RBT) related research on the positive effects of firms' digital transformation and internationalization on firm performance or competitiveness (Kotha et al., 2001). In terms of the ability to allocate slack resources, investments in digital technology can enhance the dynamic capabilities of firms and partners in international subcontracting relationships (i.e., the ability of firms to integrate, build, and reconfigure internal and external resources in response to rapidly changing environments) (Eisenhardt & Martin, 2000; Teece et al., 1997). Firms will also be better able to fulfill their ESG responsibilities when they have abundant redundant resources and are able to allocate resources more efficiently and flexibly with dynamic capabilities. Another potential reason is that ESG has become a key indicator of "soft power" for companies competing in overseas investments (Baker et al., 2021). The strategic goals of digitalization, globalization, and openness have provided companies with more opportunities to exchange information and to adopt stricter standards of social responsibility to govern their behavior.

4.4.2 | Risk response

This paper uses the internal control index of listed companies released by Diebold as a proxy variable for the quality of internal control, and the higher the index, the better the internal governance mechanism of the company. Specifically, we use the median grouping method to divide the level of internal control into two groups for regression. In addition, following Shen et al. (2012), an industry-adjusted uncertainty index is used to measure environmental uncertainty. Similarly, a grouped regression using the median method was conducted to examine the heterogeneity of the impact of digital transformation on corporate ESG performance when industry environmental uncertainty levels vary.

The results in columns (1) and (2) of Table 9 indicate that the promoting effect of digital transformation on corporate ESG performance is stronger at lower levels of internal corporate governance capabilities. The application of digital technology can help companies to obtain external information promptly and to make quick decisions, improve the efficiency of internal information communication and transmission, and thus better improve the performance in ESG. The regression results in columns (3) and (4) show that the effect of digital transformation on the ESG is only significant in the high environmental uncertainty group and its coefficient is significantly higher than that in the low environmental uncertainty group. This indicates that the effect of digital transformation on the ESG performance of firms is more significant when the environmental uncertainty in the industry is high. The results in Table 9 point to the fact that digital transformation can help companies with low-risk response capabilities improve their ESG performance.

4.5 | Further study: digital resources and digital interaction of investors

Under the framework of slack resource theory and stakeholder theory, we further examine the impact of digital transformation on firms' ESG performance from the dimensions of firms' digital resource inputs and firms' digital interactions with investors, respectively.

In the process of digital transformation, intangible assets become an important strategic resource for enterprises (Kouhizadeh et al., 2021). Digital intangible assets, as a new and key production factor for enterprises, play a key role in improving enterprise productivity (Brynjolfsson et al., 2021), which can bring important

TABLE 9 Results of the heterogeneity test for risk response capacity.

Variables	(1) control-low	(2) control-high	(3) Uncer-low	(4) Uncer-high
Lndigit	0.031** (2.01)	0.021 (1.60)	0.016 (0.95)	0.032** (2.42)
_cons	0.881 (0.32)	10.865*** (3.98)	6.570* (1.85)	3.826 (1.45)
Control	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
N	10,421	10,962	9,000	12,383
Adj. R^2	0.049	0.076	0.048	0.056

Note: The t-statistic or Z-statistic values are in parentheses and ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Control-Low refers to the grouping of companies with low internal control levels, and Uncer-Low refers to the grouping of companies with low environmental uncertainty levels.

information resources to enterprises, help improve the risk prediction ability of strategic decision-makers, improve the planning of goals (Guo et al., 2023), and thus improve the governance ability and social responsibility of enterprises. At the same time, it can mutually empower the traditional production factor resources of enterprises, fully activate slack resources, and help enterprises explore the potential value of slack resources (Verhoef et al., 2021). Referring to Li et al. (2023), we define the intangible assets associated with digital transformation as a measure of an enterprise's digital resources and use the ratio of the amount of the digitization-related portion of an enterprise's intangible asset's line item to the total amount of intangible assets (*ass_dig*) to measure the intensity of an enterprise's investment in digitized intangible assets.

Investors usually face many information and cost issues when choosing companies to invest in, and how to conveniently and quickly integrate public information resources to provide an in-depth understanding and assessment of listed companies' strategies and development prospects is a major concern for stakeholders (Lee & Zhong, 2022). Previous studies have mostly analyzed the role of investor attention on corporate ESG performance from the perspectives of investor sentiment, news coverage, and search volume on social platforms (Lee & Zhong, 2022; Zhao et al., 2023). Our study on the mechanisms of analyst attention also validates the positive effect of digital transformation on firms' ESG through increased external attention. However, in this section, we provide a new analytical perspective on investors' digital concerns and digital interactions between investors and firms. Starting in 2010, China's Shenzhen Stock Exchange (SZSE) formally launched the "Listed Company Investor Interactive Platform" (IIP), which is a new, direct platform communication method that is of great value. According to the interactive content of the platform, investors are paying more and more attention to the digital transformation of listed companies, and companies need to respond to investors in a timely manner according to their own development status. The company's response to investors can reflect the level of listed companies' awareness of the current status and future strategic direction of their own digital transformation, which may be a strong positive signal for companies to increase their ESG practice activities. Therefore, this paper takes the response rate of listed companies' questions about digital transformation, i.e., the ratio of the number of companies' responses to questions about digital transformation to the number of investors' questions about digitalization, as a measure of companies' digital interaction with investors (*rep_dig*).

The regression results are shown in Table 10. We find that increased investment in digital resources and digital interaction between firms and investors play an important role in enhancing ESG performance. In the context of Industry 4.0, the value and role of digital resources, such as digital intangible assets, are not only reflected in the sales, production, and management of enterprises, but also in the connectivity of the entire organization, information network, and value chain (Qiao et al., 2024). The input of industrial IoT, APPs, and various intelligent software and technologies can help enterprises monitor and control production processes, customer information, and energy consumption in real-time, promote stakeholder-oriented value creation, optimize and reorganize slack resources, and provide more opportunities for enterprises to create more social value, as well as provide important technical support for green and low-carbon development of enterprises (Alkaraan et al., 2022), thus enhancing corporate sustainability performance in terms of environmental, social and governance. In addition, the findings on the digital interactions between firms and investors further support the research related to the fact that firms' digital transformation and investor focus can contribute to firms' ESG performance. Interactions about digital transformation can strengthen the communication link between firms and investors, which is conducive to building a positive image of firms and enhancing investor confidence in firms' digital transformation, and the importance of digital transformation development is well absorbed and fed back in the process of firms responding to investor expectations as well as in the process of improving firms' ESG performance. This further supports the core findings of this study.

TABLE 10 Further study test.

Variables	(1) FE	(2) FE
ass_dig	0.205** (2.13)	
rep_dig		0.321*** (2.96)
_cons	−3.051 (−0.73)	2.608 (0.52)
Control	YES	YES
Firm fixed effects	YES	YES
Year fixed effects	YES	YES
N	13,444	9,328
Adj. R2	0.041	0.064

Note: The t-statistic or Z-statistic values are in parentheses and ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.
[Correction added on 09 April 2024, after first online publication: In Table 10, (2)FE column, '0.321* (2.96)' was changed to '0.321*** (2.96)' in this version.]

5 | CONCLUSION AND DISCUSSION

In recent years, public attention has been increasingly focused on the social and environmental ethical issues generated by corporations. At the same time, as digital technologies continue to evolve and become more widely used in business, companies are undergoing digital transformation to remain competitive. Our research aims to explore how this important trend in business is impacting ESG practices. We develop hypotheses on the causality, channel, and heterogeneity effects of digital transformation on ESG and test them using a sample of Chinese-listed companies from 2010 to 2020. The empirical results indicate that corporate digital transformation promotes corporate ESG performance, and the findings hold after a series of robustness tests. The mechanism test finds that the digital transformation of companies promotes corporate ESG practices by increasing the availability of long-term slack resources and strengthening stakeholder linkages. In addition, we find that the effect of digital trends in promoting ESG practices is heterogeneous across different types of enterprises. Moreover, in further analysis, we find

that increased investment in digital resources and digital interactions between firms and investors play an important role in improving ESG performance.

5.1 | Theoretical implications

We make three essential theoretical contributions to the existing literature. First, this study enriches the literature on the relationship between digital transformation and ESG. In the context of the digital transformation of firms, relevant studies have focused on exploring the impact of digitalization on firm performance (Agrawal et al., 2022; Guo et al., 2023). This particular focus is justified but has led to insufficient research on corporate social responsibility performance. This paper finds that digital transformation promotes corporate ESG performance, and further validates that digital transformation affects ESG performance by improving the availability of long-term slack resources and stakeholder connections in firms. This provides a novel perspective to deconstruct how digital transformation affects ESG performance.

Second, this paper emphasizes that the impact of digitalization trends on firms is all-encompassing, which poses the challenge of clarifying the mechanisms of their impact on ESG practices. Previous literature has tended to be one-sided in analyzing the mechanisms of digital transformation and ESG performance, selecting only one or a few perspectives to explore the channels through which digital transformation affects ESG performance (Wu & Li, 2023; Zhong et al., 2023). Our theoretical analysis applies slack resource theory and stakeholder theory in a holistic manner, and attributes the mechanisms of digital transformation on ESG practices to "ability" and "willingness". This is a new theoretical framework with generalizability. It is applicable to other studies of the ESG impact of strategic transformation that have a comprehensive impact on firms.

Finally, our study provides a more nuanced analytical perspective on the impact of digital transformation on firms' ESG performance. Based on the "ability" and "willingness" frameworks, we consider the impact of digital transformation on firms' ESG performance when firms have different social relations and risk-coping capabilities. We find that political connections can enable firms to avoid stakeholder pressure during digital transformation, providing evidence for a neo-pluralist perspective (Muttakin et al., 2018). Instead, internationalized firms are more likely to strengthen ties with stakeholders and improve ESG performance during digital transformation. We also find that firms with poorer corporate risk response capabilities need more help from digital transformation to improve ESG performance.

5.2 | Practical implications

These findings confirm the benefits of the current trend of corporate digital transformation for social responsibility engagement and add knowledge not only to existing academic gaps but also to policy and regulation. In the examination of the mechanism of slack resources, we find that the digital transformation of firms does not promote the availability of slack resources in the short run, but increases the availability of slack resources in the long run and leads firms to improve ESG performance. This helps eliminate the government's concerns about whether to drive the digital transformation of the enterprise. Although the digital transformation of enterprises may not increase the slack resources in the short term, it can be beneficial in the long run. The government can alleviate the financial pressure on enterprises in the early stages of digital transformation by implementing incentive measures such as tax incentives, funding subsidies, or technical support programs. This can assist enterprises in better navigating the initial challenges of transformation, leveraging the increased long-term slack resources to enhance ESG performance.

The test results of the stakeholder mechanism suggest that digitally transformed companies will receive more stakeholder attention and that digital transformation will reduce the short-sightedness of the company's management and thus value the relationship with stakeholders. However, there is insufficient evidence that digital transformation facilitates increased transparency of corporate disclosures. Enterprises may simply use digital technology to advertise their good social performance, but digital technology may not be effective in reducing green fraud. In response, governments can develop norms and standards for digital transformation to ensure that companies fully consider stakeholder concerns in the digital transformation process and provide transparency in ESG performance reporting. These norms could include requiring companies to disclose the goals of digital transformation, the level of stakeholder engagement, and data reporting related to ESG performance.

The heterogeneity test results distinguish the enterprises that receive more benefits from digital transformation and those that are ineffective. In social connection, the digital transformation of politically connected companies has not been successful in improving ESG performance. In China, firms with politically connected companies face less pressure from stakeholders. And companies with overseas connections are better positioned to leverage digital transformation than companies without international connections. This is because companies with international connections are more focused on ESG performance and better prepared to take advantage of digital trends. In this regard, governments should strengthen their efforts to regulate politically connected companies to ensure compliance and transparency in their digital transformation process so that stakeholders can monitor and evaluate their performance. In addition, the government can encourage companies to expand their international connections and promote international exchanges and cooperation to improve their ESG performance levels.

In addition, there is a greater role for digital transformation for companies that are less able to cope with risk. Companies with poor risk response capabilities may have the will to engage in ESG, but the practice is hindered by their own inadequate internal control capabilities or a highly uncertain external environment. Digital transformation of companies will improve their ability to respond to risks and help these companies overcome their hesitation in making socially responsible decisions. The government can further incentivize businesses to

leverage digital technology innovation, developing and applying tools and platforms related to risk management, to enhance their capabilities in risk identification, assessment, and response, thereby improving ESG performance.

5.3 | Limitations and future research

Our study also has some limitations that can be improved in the future. First, we investigate the impact of digital transformation on ESG performance over a relatively short 10-year period. The impact of digital transformation on the enterprise is likely to be long-term, so future research could complement our study by expanding the sample period. Second, while the strength of the Chinese sample provides a valuable platform, ESG practices vary considerably across countries with different institution and cultures. Future research could exploit the cross-country sample to explore whether the contribution of digital transformation to ESG performance is universal. In addition, there may be significant differences in the impact on ESG performance depending on the pace of digital transformation in the industry, especially in traditional industry sectors where digital transformation has been slower and more challenging. In the future, the impact of digital transformation on ESG can also be further explored based on different industries. Third, as discussed above, digital transformation can help companies advertise their ESG performance and thus receive more attention, but it does not improve the quality of their disclosures. This raises an interesting direction: do companies instead use digital technologies and digital platforms to overly embellish the social responsibility they have undertaken? In other words, are companies increasing their "greenwashing" behavior under the digital trend? Although this is not the focus of this paper, it is interesting and worth exploring further in the future.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Suyang Xiao, Jiajun Xu and Rui Li. The first draft of the manuscript was written by Suyang Xiao, Jiajun Xu and Rui Li, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial supports by "Research Results of China University of Geosciences (Wuhan) Marxist Theory Research and Discipline Construction Program Project" (MX2311) and "The Key Research Base of Humanities and Social Sciences in Hubei Ordinary Institutions of Higher Education–Research Center of College Student Development and Innovative Education of China University of Geosciences" (DXS20150012). In addition, the authors are grateful to the anonymous referees who provided valuable comments and suggestions to significantly improve the quality of the paper.

DECLARATIONS

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is also no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled.

ORCID

Suyang Xiao https://orcid.org/0009-0000-3908-2099
Jiajun Xu https://orcid.org/0000-0002-4084-6743
Rui Li https://orcid.org/0000-0001-5547-0040

REFERENCES

Ackerberg, D. A., Caves, K., & Frazer, G. (2015). Identification properties of recent production function estimators. *Econometrica*, *83*(6), 2411–2451. https://doi.org/10.3982/ECTA13408

Agrawal, R., Wankhede, V. A., Kumar, A., Upadhyay, A., & Garza-Reyes, J. A. (2022). Nexus of circular economy and sustainable business performance in the era of digitalization. *International Journal of Productivity and Performance Management*, *71*(3), 748–774. https://doi.org/10.1108/IJPPM-12-2020-0676

Aguilera, R. V., Rupp, D. E., Williams, C. A., & Ganapathi, I. (2007). Putting the S back in corporate social responsibility: A multilevel theory of social change in organizations. *Academy of Management Review*, *32*(3), 836–863. https://doi.org/10.5465/amr.2007.25275678

Agyei-Mensah, B. K. (2016). Internal control information disclosure and corporate governance: Evidence from an emerging market. *Corporate Governance: the International Journal of Business in Society*, *16*(1), 79–95. https://doi.org/10.1108/CG-10-2015-0136

Alkaraan, F., Albitar, K., Hussainey, K., & Venkatesh, V. (2022). Corporate transformation toward industry 4.0 and financial performance: The influence of environmental, social, and governance (ESG). *Technological Forecasting and Social Change*, *175*, 121423. https://doi.org/10.1016/j.techfore.2021.121423

Alshourah, S., Altawalbeh, M., Mansour, M., Alharaiza, Y., & Al-Kharabsheh, A. (2023). Digital strategic orientation and FIRM'S performance: The moderating effect of environmental uncertainty. *Polish Journal of Management Studies*, *28*(2), 7-27.

Arvidsson, S., & Dumay, J. (2022). Corporate ESG reporting quantity, quality and performance: Where to now for environmental policy and practice? *Business Strategy and the Environment*, *31*(3), 1091–1110. https://doi.org/10.1002/bse.2937

Baker, E. D., Boulton, T. J., Braga-Alves, M. V., & Morey, M. R. (2021). ESG government risk and international IPO underpricing. *Journal of Corporate Finance*, *67*, 101913. https://doi.org/10.1016/j.jcorpfin.2021.101913

Baldini, M., Dal Maso, L., Liberatore, G., Mazzi, F., & Terzani, S. (2018). Role of country- and firm-level determinants in environmental, social, and governance disclosure. *Journal of Business Ethics*, *150*(1), 79–98. https://doi.org/10.1007/s10551-016-3139-1

Bansal, P., & Clelland, I. (2004). Talking trash: Legitimacy, impression management, and unsystematic risk in the context of the natural environment. *Academy of Management Journal*, *47*(1), 93–103. https://doi.org/10.2307/20159562

Bansal, P., & Roth, K. (2000). Why companies go green: A model of ecological responsiveness. *Academy of Management Journal*, *43*(4), 717–736. https://doi.org/10.2307/1556363

Borghesi, R., Houston, J. F., & Naranjo, A. (2014). Corporate socially responsible investments: CEO altruism, reputation, and shareholder interests. *Journal of Corporate Finance*, *26*, 164–181. https://doi.org/10.1016/j.jcorpfin.2014.03.008

Bourgeois Iii, L. J. (1981). On the measurement of organizational slack. *Academy of Management Review*, *6*(1), 29–39. https://doi.org/10.2307/257138

Branco, M. C., & Rodrigues, L. L. (2008). Factors influencing social responsibility disclosure by Portuguese companies. *Journal of Business Ethics*, *83*(4), 685–701. https://doi.org/10.1007/s10551-007-9658-z

Bresciani, S., Huarng, K. H., Malhotra, A., & Ferraris, A. (2021). Digital transformation as a springboard for product, process and business model innovation. *Journal of Business Research*, *128*, 204–210. https://doi.org/10.1016/j.jbusres.2021.02.003

Brynjolfsson, E., Rock, D., & Syverson, C. (2021). The productivity J-curve: How intangibles complement general purpose technologies. *American Economic Journal: Macroeconomics*, *13*(1), 333–372.

Cadman, B., & Sunder, J. (2014). Investor horizon and CEO horizon incentives. *The Accounting Review*, *89*(4), 1299–1328. https://doi.org/10.2308/accr-50719

Cappa, F., Oriani, R., Peruffo, E., & McCarthy, I. (2021). Big data for freating and capturing value in the digitalized environment: Unpacking the effects of volume, variety, and veracity on firm performance*. *Journal of Product Innovation Management*, *38*(1), 49–67. https://doi.org/10.1111/jpim.12545

Chatterjee, S., & Mariani, M. (2022). Exploring the influence of exploitative and explorative digital transformation on organization flexibility and xompetitiveness. *IEEE Transactions on Engineering Management*, *11*, 1-11.

Chen, P., & Hao, Y. (2022). Digital transformation and corporate environmental performance: The moderating role of board characteristics. *Corporate Social Responsibility and Environmental Management*, *29*(5), 1757–1767. https://doi.org/10.1002/csr.2324

Chen, Q., Wang, Y., & Wan, M. (2021). Research on peer effect of enterprise digital transformation and influencing factors. *Chinese Journal of Management*, *18*(5), 653–663.

Cheng, B. T., Ioannou, I., & Serafeim, G. (2014). Corporate social responsibility and access to finance. *Strategic Management Journal*, *35*(1), 1–23. https://doi.org/10.1002/smj.2131

Chizema, A., Liu, X. H., Lu, J. Y., & Gao, L. (2015). Politically connected boards and top executive pay in Chinese listed firms. *Strategic Management Journal*, *36*(6), 890–906. https://doi.org/10.1002/smj.2253

Correia, M. M. (2014). Political connections and SEC enforcement. *Journal of Accounting and Economics*, *57*(2–3), 241–262. https://doi.org/10.1016/j.jacceco.2014.04.004

Daniel, F., Lohrke, F. T., Fornaciari, C. J., & Turner, R. A. (2004). Slack resources and firm performance: A meta-analysis. *Journal of Business Research*, *57*(6), 565–574. https://doi.org/10.1016/S0148-2963(02)00439-3

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: What are they? *Strategic Management Journal*, *21*(10–11), 1105–1121. https://doi.org/10.1002/1097-0266(200010/11)21:10/11<1105::AID-SMJ133>3.0.CO;2-E

Ekata, G. E. (2012). The IT productivity paradox: Evidence from the Nigerian banking industry. *Electronic Journal of Information Systems in Developing Countries*, *51*(1), 1–25. https://doi.org/10.1002/j.1681-4835.2012.tb00361.x

Faccio, M., Masulis, R. W., & McConnell, J. J. (2006). Political connections and corporate bailouts. *The Journal of Finance*, *61*(6), 2597–2635. https://doi.org/10.1111/j.1540-6261.2006.01000.x

Feng, T., Dong, X., & Wang, Y. (2024). Assessing the impact of digital transformation on capital market information efficiency under environmental uncertainty: Evidence from China. *PLoS ONE*, *19*(1), e0295187. https://doi.org/10.1371/journal.pone.0295187

Fisman, R., & Svensson, J. (2007). Are corruption and taxation really harmful to growth? Firm level evidence. *Journal of Development Economics*, *83*(1), 63–75. https://doi.org/10.1016/j.jdeveco.2005.09.009

Font, X., Walmsley, A., Cogotti, S., McCombes, L., & Hausler, N. (2012). Corporate social responsibility: The disclosure-performance gap. *Tourism Management*, *33*(6), 1544–1553. https://doi.org/10.1016/j.tourman.2012.02.012

Freeman, R. E., Wicks, A. C., & Parmar, B. (2004). Stakeholder theory and "the corporate objective revisited". *Organization Science*, *15*(3), 364–369. https://doi.org/10.1287/orsc.1040.0066

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, *5*(4), 210–233. https://doi.org/10.1080/20430795.2015.1118917

Gatignon, A. (2022). The double-edged sword of boundary-spanning corporate social responsibility programs. *Strategic Management Journal*, *43*(10), 2156–2184. https://doi.org/10.1002/smj.3403

George, G. (2005). Slack resources and the performance of privately held firms. *Academy of Management Journal*, *48*(4), 661–676. https://doi.org/10.5465/amj.2005.17843944

Guo, X., Li, M., Wang, Y., & Mardani, A. (2023). Does digital transformation improve the firm's performance? From the perspective of digitalization paradox and managerial myopia. *Journal of Business Research*, *163*, 113868. https://doi.org/10.1016/j.jbusres.2023.113868

Hautala-Kankaanpaa, T. (2022). The impact of digitalization on firm performance: Examining the role of digital culture and the effect of supply chain capability. *Business Process Management Journal*, *28*(8), 90–109. https://doi.org/10.1108/BPMJ-03-2022-0122

Herremans, I. M., Nazari, J. A., & Mahmoudian, F. (2016). Stakeholder relationships, engagement, and sustainability reporting. *Journal of Business Ethics*, *138*(3), 417–435. https://doi.org/10.1007/s10551-015-2634-0

Hess, D. (2008). The three pillars of corporate social reporting as new governance regulation: Disclosure, dialogue, and development. *Business Ethics Quarterly*, *18*(4), 447–482. https://doi.org/10.5840/beq200818434

Hu, D., Guo, F., & Zhai, C. (2023). Digital finance, entrepreneurship and the household income gap: Evidence from China. *Information Processing & Management*, *60*(5), 103478. https://doi.org/10.1016/j.ipm.2023.103478

Hu, N., Xue, F., & Wang, H. (2021). Does managerial myopia affect long-term investment? Based on text analysis and machine learning. *Management World*, *37*, 139–156.

Ioannou, I., & Serafeim, G. (2012). What drives corporate social performance? The role of nation-level institutions. *Journal of International Business Studies*, *43*(9), 834–864. https://doi.org/10.1057/jibs.2012.26

Julian, S. D., & Ofori-dankwa, J. C. (2013). Financial resource availability and corporate social responsibility expenditures in a sub-Saharan economy: The institutional difference hypothesis. *Strategic Management Journal*, *34*(11), 1314–1330. https://doi.org/10.1002/smj.2070

Khin, S., & Ho, T. C. (2018). Digital technology, digital capability and organizational performance: A mediating role of digital innovation. *International Journal of Innovation Science*, *11*(2), 177–195.

Kotha, S., Rindova, V. P., & Rothaermel, F. T. (2001). Assets and actions: Firm-specific factors in the internationalization of US internet firms. *Journal of International Business Studies*, *32*, 769–791. https://doi.org/10.1057/palgrave.jibs.8490994

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics*, *231*, 107831. https://doi.org/10.1016/j.ijpe.2020.107831

Laing, T., Upadhyay, A., Mohan, S., & Subramanian, N. (2019). Environmental improvement initiatives in the coal mining industry: Maximisation of the triple bottom line. *Production Planning and Control*, *30*(5–6), 426–436. https://doi.org/10.1080/09537287.2018.1501813

Lee, C. M., & Zhong, Q. (2022). Shall we talk? The role of interactive investor platforms in corporate communication. *Journal of Accounting and Economics*, *74*(2–3), 101524.

Lee, M. T., & Raschke, R. L. (2023). Stakeholder legitimacy in firm greening and financial performance: What about greenwashing temptations? *Journal of Business Research*, *155*, 113393. https://doi.org/10.1016/j.jbusres.2022.113393

Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, *70*(2), 317–341. https://doi.org/10.1111/1467-937X.00246

Li, C., Huo, P., Wang, Z., Zhang, W., Liang, F., & Mardani, A. (2023). Digitalization generates equality? Enterprises' digital transformation, financing constraints, and labor share in China. *Journal of Business Research*, *163*, 113924. https://doi.org/10.1016/j.jbusres.2023.113924

Li, W. Q., Zhang, J. Z., & Ding, R. (2023). Impact of Directors' network on corporate social responsibility disclosure: Evidence from China. *Journal of Business Ethics*, *183*(2), 551–583. https://doi.org/10.1007/s10551-022-05092-3

Li, Z., & Zhang, T. (2017). Internal control, nature of property right and social responsibility information disclosure: Evidence from Chinese listed companies. *Accounting Research*, *10*, 86–92.

Lokuwaduge, C. S. D. S., & Heenetigala, K. (2017). Integrating environmental, social and governance (ESG) disclosure for a sustainable development: An Australian study. *Business Strategy and the Environment*, *26*(4), 438–450. https://doi.org/10.1002/bse.1927

Lu, Y., Xu, C., Zhu, B., & Sun, Y. (2023). Digitalization transformation and ESG performance: Evidence from China. *Business Strategy and the Environment*, *33*(2), 352-386. https://doi.org/10.1002/bse.3494

Lucea, R., & Doh, J. (2012). International strategy for the nonmarket context: Stakeholders, issues, networks, and geography. *Business & Politics*, *14*(3), 1–30. https://doi.org/10.1515/bap-2012-0018

Martinez-Caro, E., Cegarra-Navarro, J. G., & Alfonso-Ruiz, F. J. (2020). Digital technologies and firm performance: The role of digital organisational culture. *Technological Forecasting and Social Change*, *154*, 119962. https://doi.org/10.1016/j.techfore.2020.119962

Mbalyohere, C., & Lawton, T. C. (2018). Engaging stakeholders through corporate political activity: Insights from MNE nonmarket strategy in an emerging African market. *Journal of International Management*, *24*(4), 369–385. https://doi.org/10.1016/j.intman.2018.04.006

McWilliams, A., & Siegel, D. (2001). Corporate social responsibility: A theory of the firm perspective. *Academy of Management Review*, *26*(1), 117–127. https://doi.org/10.2307/259398

Meira, E., de Souza Cunha, F. A. F., Orsato, R. J., Miralles-Quirós, M. M., & Miralles-Quirós, J. L. (2023). The added value and differentiation among ESG investment strategies in stock markets. *Business Strategy and the Environment*, *32*(4), 1816–1834. https://doi.org/10.1002/bse.3221

Mukhuty, S., Upadhyay, A., & Rothwell, H. (2022). Strategic sustainable development of industry 4.0 through the lens of social responsibility: The role of human resource practices. *Business Strategy and the Environment*, *31*(5), 2068–2081. https://doi.org/10.1002/bse.3008

Muttakin, M. B., Mihret, D. G., & Khan, A. (2018). Corporate political connection and corporate social responsibility disclosures: A neo-pluralist hypothesis and empirical evidence. *Accounting, Auditing & Accountability Journal*, *31*(2), 725–744. https://doi.org/10.1108/AAAJ-06-2015-2078

Ning, J., Jiang, X., & Luo, J. (2023). Relationship between enterprise digitalization and green innovation: A mediated moderation model. *Journal of Innovation & Knowledge*, *8*(1), 100326. https://doi.org/10.1016/j.jik.2023.100326

Nohria, N., & Gulati, R. (1996). Is slack good or bad for innovation? *Academy of Management Journal*, *39*(5), 1245–1264. https://doi.org/10.2307/256998

Nylén, D., & Holmström, J. (2015). Digital innovation strategy: A framework for diagnosing and improving digital product and service innovation. *Business Horizons*, *58*(1), 57–67. https://doi.org/10.1016/j.bushor.2014.09.001

Olley, G. S., & Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, *64*(6), 1263–1297. https://doi.org/10.2307/2171831

Panwar, R., Nybakk, E., Hansen, E., & Pinkse, J. (2017). Does the business case matter? The effect of a perceived business case on small firms' social engagement. *Journal of Business Ethics*, *144*(3), 597–608. https://doi.org/10.1007/s10551-015-2835-6

Park, J., Kim, S., & Tsang, A. (2023). CEO personal hedging and corporate social responsibility. *Journal of Business Ethics*, *182*(1), 199–221. https://doi.org/10.1007/s10551-021-05021-w

Perez-Batres, L. A., Doh, J. P., Miller, V. V., & Pisani, M. J. (2012). Stakeholder pressures as determinants of CSR strategic choice: Why do firms choose symbolic versus substantive self-regulatory codes of conduct? *Journal of Business Ethics*, *110*(2), 157–172. https://doi.org/10.1007/s10551-012-1419-y

Qiao, W., Ju, Y., Dong, P., & Tiong, R. L. (2024). How to realize value creation of digital transformation? A system dynamics model. *Expert Systems with Applications*, *244*, 122667. https://doi.org/10.1016/j.eswa.2023.122667

Qin, X., Wu, H., & Li, R. (2022). Digital finance and household carbon emissions in China. *China Economic Review*, *76*, 101872. https://doi.org/10.1016/j.chieco.2022.101872

Reischauer, G., & Ringel, L. (2023). Unmanaged transparency in a digital society: Swiss army knife or double-edged sword? *Organization Studies*, *44*(1), 77–104. https://doi.org/10.1177/01708406221106329

Reverte, C. (2009). Determinants of corporate social responsibility disclosure ratings by Spanish listed firms. *Journal of Business Ethics*, *88*(2), 351–366. https://doi.org/10.1007/s10551-008-9968-9

Sahoo, S., Upadhyay, A., & Kumar, A. (2023). Circular economy practices and environmental performance: Analysing the role of big data analytics capability and responsible research and innovation. *Business Strategy and the Environment*, *32*, 6029–6046. https://doi.org/10.1002/bse.3471

Schaltegger, S., & Horisch, J. (2017). In search of the dominant rationale in sustainability management: Legitimacy- or profit-seeking? *Journal of Business Ethics*, *145*(2), 259–276. https://doi.org/10.1007/s10551-015-2854-3

Sharma, M., Kumar, A., Luthra, S., Joshi, S., & Upadhyay, A. (2022). The impact of environmental dynamism on low-carbon practices and digital supply chain networks to enhance sustainable performance: An empirical analysis. *Business Strategy and the Environment*, *31*(4), 1776–1788. https://doi.org/10.1002/bse.2983

Shen, H., Yu, P., & Wu, L. (2012). State ownership, environment uncertainty and investment efficiency. *Economic Research Journal*, *7*, 113–126.

Srivastava, D. K., Kumar, V., Ekren, B. Y., Upadhyay, A., Tyagi, M., & Kumari, A. (2022). Adopting industry 4.0 by leveraging organisational factors. *Technological Forecasting and Social Change*, *176*, 121439. https://doi.org/10.1016/j.techfore.2021.121439

Sun, W. B., & Govind, R. (2022). A new understanding of marketing and "doing good": Marketing's power in the TMT and corporate social responsibility. *Journal of Business Ethics*, *176*(1), 89–109. https://doi.org/10.1007/s10551-020-04662-7

Sweeney, L., & Coughlan, J. (2008). Do different industries report corporate social responsibility differently? An investigation through the lens of stakeholder theory. *Journal of Marketing Communications*, *14*(2), 113–124. https://doi.org/10.1080/13527260701856657

Tang, Y., Mack, D. Z., & Chen, G. L. (2018). The differential effects of CEO narcissism and hubris on corporate social responsibility. *Strategic Management Journal*, *39*(5), 1370–1387. https://doi.org/10.1002/smj.2761

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533.

https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Tian, G., Li, B., & Cheng, Y. (2022). Does digital transformation matter for corporate risk-taking? *Finance Research Letters*, *49*, 103107. https://doi.org/10.1016/j.frl.2022.103107

Upadhyay, A., Kumar, A., Kumar, V., & Alzaben, A. (2021). A novel business strategies framework of do-it-yourself practices in logistics to minimise environmental waste and improve performance. *Business Strategy and the Environment*, *30*(8), 3882–3892. https://doi.org/10.1002/bse.2846

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, *122*, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022

Vial, G. (2021). Understanding digital transformation: A review and a research agenda. *Managing Digital Transformation*, *28*(2), 13–66. https://doi.org/10.4324/9781003008637-4

Waddock, S. A., & Graves, S. B. (1997). The corporate social performance - financial performance link. *Strategic Management Journal*, *18*(4), 303–319. https://doi.org/10.1002/(SICI)1097-0266(199704)18:4<303::AID-SMJ869>3.0.CO;2-G

Waligo, V. M., Clarke, J., & Hawkins, R. (2014). The 'leadership-stakeholder involvement Capacity' nexus in stakeholder management. *Journal of Business Research*, *67*(7), 1342–1352. https://doi.org/10.1016/j.jbusres.2013.08.019

Walker, K., & Wan, F. (2012). The harm of symbolic actions and greenwashing: Corporate actions and communications on environmental performance and their financial implications. *Journal of Business Ethics*, *109*(2), 227–242. https://doi.org/10.1007/s10551-011-1122-4

Wang, W., Sun, Z., Wang, W., Hua, Q., & Wu, F. (2023). The impact of environmental uncertainty on ESG performance: Emotional vs. rational. *Journal of Cleaner Production*, *397*, 136528. https://doi.org/10.1016/j.jclepro.2023.136528

Wu, F., Hu, H., Lin, H., & Ren, X. (2021). Enterprise digital transformation and capital market performance: Empirical evidence from stock liquidity. *Management World*, *37*(7), 130–144.

Wu, S., & Li, Y. (2023). A study on the impact of digital transformation on corporate ESG performance: The mediating role of green innovation. *Sustainability*, *15*(8), 6568. https://doi.org/10.3390/su15086568

Xiao, C. Y., Wang, Q., van Donk, D. P., & van der Vaart, T. (2018). When are stakeholder pressures effective? An extension of slack resources theory. *International Journal of Production Economics*, *199*, 138–149. https://doi.org/10.1016/j.ijpe.2018.03.002

Xiao, G., & Shen, S. (2022). To pollute or not to pollute: Political connections and corporate environmental performance. *Journal of Corporate Finance*, *74*, 102214. https://doi.org/10.1016/j.jcorpfin.2022.102214

Xie, H., & Lyu, X. (2022). Responsible multinational investment: ESG and Chinese OFDI. *Economic Research Journal*, *68*, 83–99.

Yi, Z., Jiang, F., & Qin, Y. (2010). The market competition in products, the corporate governance and the quality of information disclosure. *Management World*, *1*, 133–141.

Zakhem, A. (2008). Stakeholder management capability: A discourse-theoretical approach. *Journal of Business Ethics*, *79*(4), 395–405.

Zaman, R., Jain, T., Samara, G., & Jamali, D. (2022). Corporate governance meets corporate social responsibility: Mapping the interface. *Business & Society*, *61*(3), 690–752. https://doi.org/10.1177/0007650320973415

Zeng, H., Ran, H., Zhou, Q., Jin, Y., & Cheng, X. (2022). The financial effect of firm digitalization: Evidence from China. *Technological Forecasting and Social Change*, *183*, 121951. https://doi.org/10.1016/j.techfore.2022.121951

Zhang, F., Chen, J. W., Zhu, L., & Liu, L. L. (2022). Does resource slack promote or constrain firm environmental management investment? Moderating roles of technology sources. *Total Quality Management & Business Excellence*, *33*(5–6), 590–613. https://doi.org/10.1080/14783363.2021.1882843

Zhao, X., Fang, L., & Zhang, K. (2023). Online search attention, firms' ESG and operating performance. *International Review of Economics and Finance*, *88*, 223–236. https://doi.org/10.1016/j.iref.2023.06.025

Zhong, X., & Ren, G. (2023). Independent and joint effects of CSR and CSI on the effectiveness of digital transformation for transition economy firms. *Journal of Business Research*, *156*, 113478. https://doi.org/10.1016/j.jbusres.2022.113478

Zhong, Y., Zhao, H., & Yin, T. (2023). Resource bundling: How does Enterprise digital transformation affect Enterprise ESG development? *Sustainability*, *15*(2), 1319. https://doi.org/10.3390/su15021319

Zhu, Z., Song, T., Huang, J., & Zhong, X. (2022). Executive cognitive structure, digital policy, and firms' digital transformation. *IEEE Transactions on Engineering Management*, *71*, 2579-2592.

How to cite this article: Xiao, S., Xu, J., & Li, R. (2024). Are digital trends driving corporate environmental, social, and governance practices? Evidence from China. *Business Strategy and the Environment*, *33*(6), 5366–5385. https://doi.org/10.1002/bse.3756

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

Assessing factors influencing ESG ratings in Malaysian companies: An empirical study / Samidi, N. S., & Kwan, J. H.

Paper Asia
Volume 40 Issue 6b (2024) Pages 280–288
https://doi.org/10.59953/paperasia.v40i6b.260
(Database: PaperASIA)

Assessing Factors Influencing ESG Ratings in Malaysian Companies: An Empirical Study

Nurulhuda Syahiirah Samidi, Jing-Hui Kwan*
Faculty of Management, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia

*Corresponding author email: jhkwan@mmu.edu.my

ABSTRACT
This study explores the determinants of Environmental, Social, and Governance (ESG) ratings within the Malaysian corporate sector. Employing panel regression analysis on data collected from 40 companies listed on Bursa Malaysia between 2018 and 2022, this research investigates the roles of company size, board diligence, digital transformation, Shariah compliance, and gender diversity in influencing ESG performance. The results indicate that larger firms are generally associated with lower ESG ratings, suggesting that achieving sustainability at scale remains a significant challenge. In contrast, gender diversity on corporate boards emerges as a robust positive predictor of ESG ratings, highlighting the essential role of inclusive governance in enhancing sustainability outcomes. Contrary to expectations, the study finds no significant direct impact of board diligence and digital transformation on ESG outcomes, suggesting the need for a critical reassessment of these factors within existing sustainability frameworks. By identifying key drivers and uncovering unexpected findings, this research contributes to the ongoing discourse on ESG practices, offering valuable insights for policymakers, corporate leaders, and stakeholders committed to advancing sustainable business practices. The study not only maps the landscape of ESG performance drivers in Malaysia but also sets a direction for future research aimed at developing more nuanced and effective sustainability strategies in similar emerging market contexts.

KEYWORDS: Corporate sustainability, ESG ratings, Board diversity, Digital transformation, Shariah compliance.

Received 27 August 2024; Revised 16 September 2024; Accepted 27 November 2024
Doi: https://doi.org/10.59953/paperasia.v40i6b.260

1. INTRODUCTION

The growing emphasis on Environmental, Social, and Governance (ESG) practices has become a central focus for organizations worldwide as they recognize the necessity of integrating sustainable practices into their operations. Despite this increasing attention, there remains a significant gap in understanding how the scale of a corporation impacts its ESG performance, particularly in emerging markets like Malaysia. This study aims to address this gap by examining the relationship between company size, board diligence, digital transformation, and other factors influencing ESG ratings within the Malaysian corporate sector. By doing so, it seeks to provide valuable insights that can help firms enhance their ESG performance.

The lack of standardization in ESG ratings across different data providers, as highlighted by the OECD (2020), poses a challenge for investors seeking to use these metrics as reliable investment criteria. Understanding the potential differences in ESG performance between larger and smaller firms can offer critical insights into the scalability of sustainable practices. According to Bissoondoyal-Bheenick et al. (2023), larger companies are generally more inclined to engage in ESG activities to efficiently meet stakeholder expectations, benefiting from economies of scale. However, some studies, such as Friede et al., (2015), have found no significant correlation between company size and ESG ratings. This lack of consensus calls for further investigation into the factors that might influence the relationship between company size and ESG ratings in Malaysia.

The convergence of board diligence and ESG ratings has emerged as a crucial aspect in modern corporate governance. The degree of board diligence, which refers to the board's active engagement and proactive oversight of the company's performance, has been recognised as a potential factor influencing Environmental, Social, and Governance (ESG) ratings. Nevertheless, the present field of research, exemplified by studies like Garcia et al., 2017), does not possess a comprehensive comprehension of the precise governance practices and procedures that support the favourable correlation between board diligence and ESG ratings. This study seeks to fill this knowledge gap by conducting an in-depth analysis of the relationship

between board diligence and ESG ratings, aiming to uncover the mechanisms that underlie this association. In addition, the ongoing process of digital transformation has significantly impacted various industries, altering structures, processes, and strategies for stakeholder engagement. The adoption of digital technologies such as big data, artificial intelligence, and cloud computing has become a catalyst for economic growth, driving the global economy towards a digital era (Ferreira et al., 2019; Vial, 2019; Verhoef et al., 2021; Jiang et al., 2022; Meng et al., 2022). Companies that have embraced digital transformation are likely to possess the tools and capabilities necessary for the effective implementation of ESG policies and practices.

ESG ratings have become vital indicators in today's corporate environment, extensively used by investors, businesses, and society to assess a company's commitment to sustainability and ethical business practices. It is imperative for companies to understand the fundamental factors that influence their ESG ratings, as this knowledge is crucial for refining their operational frameworks and promoting sustainable and responsible business practices. Despite the growing interest in ESG ratings, there is still a considerable gap in understanding how specific factors such as company size, board diligence, and digital transformation influence ESG ratings within the Malaysian context. This research aims to address this gap by thoroughly investigating the interactions between these critical factors and ESG ratings, contributing to the current discourse on corporate sustainability.

2. LITERATURE REVIEW

This section reviews the key factors influencing Environmental, Social, and Governance (ESG) ratings, focusing on company size, board diligence, digital transformation, and gender diversity on corporate boards. These variables have been widely studied in the literature, and this review will explore their roles in shaping ESG performance, providing context for the hypotheses developed in this study.

2.1 Company Size and ESG Ratings

The relationship between firm size and ESG ratings has been extensively debated in academic literature, revealing a complex interaction between organizational characteristics and sustainability efforts. Larger firms are often perceived as having inherent advantages in adopting sustainable practices due to their substantial resources, which enable them to invest in eco-friendly technologies, comprehensive governance frameworks, and socially responsible activities (Barney, 1991; Kraus et al., 2020). This perspective aligns with the resource-based view, suggesting that firms with greater resources are better positioned to implement effective sustainability initiatives.

However, the relationship between firm size and ESG ratings is not straightforward. Grewal et al. (2021) identified a non-linear correlation, noting that medium-sized firms often outperform both smaller and larger firms in ESG performance. This finding suggests that while large firms have more resources, the complexities introduced by their scale might hinder the optimal implementation of ESG practices. These complexities may include bureaucratic inefficiencies, higher coordination costs, and potential misalignment of sustainability goals across different divisions.

Conversely, other studies have found a positive correlation between firm size and ESG ratings. For instance, Clarkson et al. (2011) and Kuznetsova et al. (2021), argue that larger firms are more likely to engage in environmental and social responsibility practices, leading to higher ESG ratings. This is often attributed to the greater organizational legitimacy and stakeholder expectations faced by larger firms, particularly in terms of transparency and accountability. Additionally, Hawn et al. (2019) and Kim et al. (2021) observed that this positive relationship is more pronounced in companies with significant institutional ownership, where investors may exert pressure to adopt more rigorous ESG practices.

Moreover, Flammer (2015) highlighted the role of organizational slack—excess resources that firms can allocate to non-core activities—in mediating the relationship between firm size and ESG ratings. Drempetic et al. (2020) further explored this by examining the impact of company size on the availability and quality of ESG data, finding that larger firms are better equipped to provide comprehensive ESG disclosures, which positively influences their ratings.

Given these mixed findings, this study proposes that larger firms, despite their potential challenges, are generally positioned to achieve higher ESG ratings due to their resource advantages and the external pressures they face.

H1: There is a positive relationship between company size and ESG ratings.

2.2. Board Diligence and ESG Ratings

Board diligence, defined as the active involvement, well-informed decisions, and proactive supervision by a company's board of directors, has emerged as a critical factor influencing ESG ratings. Strong corporate governance not only enhances ESG performance but also provides protection during economic downturns or crises, as evidenced by research demonstrating that well-governed companies experienced less severe stock price crashes during the COVID-19 pandemic (Oh & Shin, 2018). The effectiveness of a board in overseeing ESG initiatives is often linked to the frequency and quality of

board meetings, diversity in board composition, and the independence of its members (García Martín & Herrero, 2020). Research has shown that board characteristics, such as board size and independence, are significant determinants of sustainability disclosures, particularly within financial industries, which emphasizes the role of board diligence in enhancing ESG transparency and performance (Lo et al., 2019).

Vafeas (1999) posited that more frequent board meetings indicate closer monitoring and better alignment with shareholder interests. This is particularly relevant in today's complex and unpredictable business environment, where corporate boards must frequently convene to address diverse stakeholder concerns and manage various risks (Hussain et al., 2018). This idea is supported by stakeholder theory, which emphasizes the need for diligent governance in managing the multifaceted demands of various stakeholders.

Empirical evidence further supports this relationship. Studies by Liao et al. (2015) and Nuhu and Alam (2024) demonstrated that industries under stringent regulatory scrutiny benefit from frequent board meetings, which are positively associated with enhanced environmental performance. Birindelli et al. (2018) emphasized that frequent board meetings not only facilitate critical decision-making but also ensure that strategic and operational issues are thoroughly deliberated, leading to higher-quality decisions. These meetings provide a platform for directors to discuss and deliberate on ESG initiatives, ensuring that they are aligned with the company's broader strategic objectives. This, in turn, reinforces stakeholder relationships and enhances the firm's reputation in the eyes of investors and the public. Given this evidence, it is expected that boards that engage more diligently with ESG issues, as evidenced by frequent and substantive meetings, will positively influence the company's ESG ratings.

H2: There is a positive relationship between board diligence and ESG ratings.

2.3. Digital Transformation and ESG Ratings

The advent of digital transformation has become a powerful catalyst for transforming the business landscape across several industries. This paradigm shift is defined by the extensive incorporation of digital technologies, which fundamentally transform the way organisations function, engage with stakeholders, and generate value. Concurrently, ESG ratings have become increasingly important as crucial measures evaluating a company's dedication to sustainability, ethical business practices, and corporate governance. Scholars have shown great interest in examining the complex interplay between digital transformation and ESG ratings.

According to a study done by Wu and Li (2023), digital transformation can enhance corporate ESG performance by fostering green innovation. Additionally, the study revealed that the impact of digital transformation on ESG performance is more pronounced in larger-scale organisations. There is also a study that revealed how digital transformation can improve ESG performance by utilising dynamic skills like green innovation, social responsibility, and operational management (Zhang et al., 2023). Hence, these studies done proved that the implementation of digital transformation has a beneficial influence on the environmental, social, and governance (ESG) performance and its subsequent impact on ESG ratings of its corporations, particularly in larger-scale organisations since it is heavily influenced by the presence of green innovation.

Vial (2019) emphasized that improving ESG performance through digital transformation involves the rapid identification, collection, and analysis of stakeholder value demands. By aligning business decisions with these demands, companies can enhance their ESG performance, leading to higher ESG ratings. This process not only improves operational efficiency but also helps companies build stronger relationships with their stakeholders, which is crucial for long-term sustainability.

Zhao and Cai (2023) noted that companies undergoing digital transformation are more likely to have a sustainability strategy in place, which positively influences their ESG ratings. The relationship between digital transformation and ESG ratings is further reinforced by the idea that companies effectively implementing environmental, social, and governance standards are more likely to achieve higher ESG ratings.

The evidence from the literature strongly suggests that digital transformation has a positive impact on ESG performance by enhancing a company's ability to innovate and meet stakeholder demands. Therefore, it is hypothesized that there is a positive relationship between digital transformation and ESG ratings, particularly as firms that effectively leverage digital technologies are likely to achieve higher ESG outcomes.

H3: There is a positive relationship between digital transformation and ESG ratings.

2.4. Women On Board and ESG Ratings

The influence of gender diversity on corporate boards, particularly the presence of women, has garnered significant attention in relation to ESG ratings. Research consistently shows that gender-diverse boards contribute positively to sustainability disclosures and overall corporate governance (Wasiuzzaman & Mohammad, 2020; Zahid et al., 2020a; Zahid et al., 2020b). Adams & Ferreira (2009) linked these outcomes to the diverse perspectives and oversight capabilities that female

directors bring to board decision-making, particularly in areas such as risk management, social responsibility, and ethical governance. The inclusion of women on boards is argued to enrich the decision-making process, leading to more comprehensive and inclusive strategies for addressing sustainability challenges.

A meta-analysis by Post & Byron (2015), covering 140 studies, found a positive correlation between the participation of women on corporate boards and accounting returns. Similarly, Abdullah (2014) suggested that the qualifications and decision-making influence of female directors justify their positive impact on corporate governance. These findings indicate that gender diversity is not only beneficial for financial performance but also for broader governance outcomes, including those related to ESG.

Further studies by Adams et al. (2009) demonstrated that businesses with higher proportions of female board members perform better financially and socially, with gender diversity on boards being associated with improved governance practices, social responsibility, and environmental sustainability. This broader influence aligns with the factors evaluated in ESG ratings, suggesting that companies with more women on their boards are likely to achieve higher ESG scores.

The literature provides substantial evidence supporting the positive impact of gender diversity on corporate boards, particularly in terms of enhancing governance and sustainability practices. Therefore, it is hypothesized that there is a positive relationship between women on boards and ESG ratings, as gender-diverse boards are likely to drive better ESG outcomes.

H4: There is a positive relationship between women on board and ESG ratings

3. METHODOLOGY

3.1 Sample and Data

This study examines the factors influencing ESG ratings among companies listed on Bursa Malaysia, the primary stock exchange in Malaysia. ESG ratings quantify a company's environmental, social, and governance performance, and are increasingly utilized by investors, regulators, and consumers to evaluate corporate sustainability. The study's sample includes companies listed on Bursa Malaysia, covering the period from 2018 to 2022, which provides the most recent five years of available data.

The initial dataset comprised 1,023 companies listed on Bursa Malaysia, sourced from secondary data providers, including Bloomberg and the annual reports of the selected companies. A rigorous data cleaning and validation process was employed to ensure the reliability and completeness of the dataset. This process involved identifying and correcting missing or conflicting data points, addressing outliers and anomalies, and ensuring the integrity of the dataset for subsequent analysis. Upon careful examination, it was noted that a substantial proportion of the companies (about 98.1%) did not reveal their ESG ratings for the stipulated period. Subsequently, a rigorous screening process was carried out, resulting in the inclusion of 40 companies in the final dataset. These chosen companies not only offered thorough ESG rating data but also showed transparency in their reporting within the given timeframe. The data cleaning process entailed identifying and correcting missing or conflicting data points to ensure the correctness and integrity of the information. In addition, outliers and anomalies were dealt with to improve the reliability of the dataset for further analysis.

To summarize, the data collection process involved the following steps. (1) a comprehensive identification process was constructed to determine all the companies that were listed on Bursa Malaysia as of December 31, 2022. This meticulous procedure yielded a total of 1,023 entities. (2) Companies that failed to provide any necessary information like board diligence, number of women on board and company size for any year from 2018 to 2022 were omitted from the analysis. As for the result, the sample size was further decreased to 120 firms. (3) This analysis excluded organisations that lacked an ESG rating from Bloomberg from the year 2018 to 2022. This is because the ESG rating serves as the dependent variable in this research. This resulted in a reduction of the sample size to 40 firms. This carefully selected sample is sufficient for robust statistical analysis, as it includes firms with consistent ESG data over five years, ensuring reliable and valid findings.

3.2 Variables Measurement

This study focuses on the intricate relationships between various independent variables—specifically, company size, board diligence, digital transformation, Shariah compliance, and the number of women on the board—and their impact on the dependent variable, ESG ratings. The ESG rating, which serves as the dependent variable, measures a company's performance across environmental, social, and governance dimensions. These ratings are used by investors to assess the ethical and sustainable implications of their investments. ESG ratings are calculated by various rating organisations, including Refinitiv, MSCI, and Sustainalytics, compute ESG ratings using publicly accessible data regarding the performance, policies, and operations of a company.

For example, the FTSE4GOOD BURSA MALAYSIA INDEX evaluates companies using an open and unbiased methodology that considers the degree of material ESG risk they face in relation to their business operations as well as publicly revealed risk management measures.

The list of variables and their measurement are summarized in **Table 1**.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Table 2 presents the descriptive statistics. The mean is a statistical measure that represents the central tendency of a dataset, The calculation involves summing all the values (scores or observations) and subsequently dividing by the total count of values. Firstly, the mean for ESG_SCORE of 3.1762 indicates that, on average, the entities, or observations in the study (n=200) demonstrate a moderate level of dedication to ESG principles. This offers a fundamental comprehension of the whole ESG performance within the dataset. The mean market for CUR_MKT_CAP is 18687.64. The average market value of the companies included in the study is approximately RM18687.64. Next, the mean for BOARD_MEETING_ATTENDANCE_PCT is 96.75293 which indicates that the average attendance rate of board members attending meetings is roughly 96.75%. The mean digitalization score is 54.295 which means on average, companies exhibit a moderate degree of digitalization in their operations. Finally, the average Shariah Compliance mean of 0.675 suggests that organizations generally demonstrate partial adherence to Shariah standards.

4.2 Panel Regression Analysis

4.2.1 Diagnostic Tests

As the p-value for the Breusch-Pagan test for cross-section and time elements is less than 0.05, reject the null hypothesis. A significant result indicates the presence of heteroscedasticity. Thus, the Fixed Effect Model or Random Effect Model should be considered in this regression. The Hausman test was the next step in choosing between the fixed effect model and the random effect model. **Table 3** illustrates the results of the Hausman test, which was employed to determine whether the fixed effect model or random effect model is more appropriate for this study. The significant p-value of 0.0003 confirms that the fixed effect model is a better fit for the data, as it rejects the null hypothesis.

Table 1: *Variable Definition*

Variable Type	Variable Name	Variable symbol	Variable Measure
Dependent Variable	ESG rating	ESG_score	ESG score from Bloomberg
Independent Variables	Company Size	Cur_Mkt_cap	Total current market value of a company outstanding shares stated in the pricing currency (RM)
	Board diligence	Board_meeting_ Attendance_pct	Board meeting attendance percentage for each company
	Digital transformation	Digitalization	Frequency of digital-related words in the annual report
	Shariah-compliance	Shariah Compliance	Binary variable that equals 1 if a shariah compliance company and 0 otherwise
	Number of women on board	Number_of_women _on_board	Determines how many female directors there are on a company's board of directors in absolute terms
Control Variables	Board size	Board_size	Total number of directors on a company's board
	Independent directors	Independent_directors	The count of independent directors on a corporate board
	Financial leverage	Fncl_Lvrg	The extent to which a company relies on debt financing
	Return on asset	Return_on_asset	Financial indicator that evaluates how well, a business uses its assets to generate profits.

Source: Bloomberg (2024) and ISI Emerging Markets (2024)

Table 2: *Descriptive Statistics*

Variable	Mean	Std. Dev	Min	Max	Skewness	Kurtosis
ESG_SCORE	3.18	0.92	1.14	5.53	0.19	2.84
CUR_MKT_CAP	18687.60	19280.10	559.27	96121.80	1.62	5.36
BOARD_MEETING_ATTENDANCE_PCT	96.75	7.39	5.00	100.00	-9.80	120.52
Digitalization	54.30	93.51	0.00	583.00	3.27	15.50
Shariah Compliance	0.68	0.47	0.00	1.00	0.75	1.56
NUMBER_OF_WOMEN_ON_BOARD	2.34	1.22	0.00	5.00	0.38	2.41
BOARD_SIZE	9.17	1.65	5.00	13.00	0.07	2.20
INDEPENDENT_DIRECTORS	5.09	1.36	2.00	10.00	0.56	3.67
FNCL_LVRG	3.31	2.74	1.10	13.84	2.32	7.76
RETURN_ON_ASSET	6.42	12.47	-46.73	83.96	2.22	16.96

4.2.2 Fixed Effect Model

To analyse the determinants of ESG ratings among companies listed on Bursa Malaysia, a fixed-effect regression model was deployed. The analysis utilized data from 40 companies over the period 2018 to 2022, with a total of 200 observations. **Table 4** presents the coefficient estimates from the fixed effect regression analysis. The results show that the size of the company (CUR_MKT_CAP) and the number of women on the board (NUMBER_OF_WOMEN_ON_BOARD) are significant predictors of ESG ratings, with larger companies generally associated with lower ESG ratings and more women on the board positively impacting ESG performance.

Significantly, the size of the company (CUR_MKT_CAP) and the number of women on board (NUMBER_OF_WOMEN_ON_BOARD) were identified as important predictors. Greater companies generally displayed poor ESG ratings, indicating a possible obstacle for larger entities in obtaining higher sustainability ratings. It demonstrated a substantial negative relationship between the size of the company (CUR_MKT_CAP) and the ESG_SCORE. Larger companies generally have lower ESG ratings. The study's findings enhance our comprehension of how firm size can influence ESG performance within the Malaysian setting. The favourable relationship between the number of women on the board and ESG ratings confirms the beneficial impact of gender diversity on sustainable and responsible company operations.

Nevertheless, there were no statistically significant correlations found between ESG_SCORE and board meeting attendance percentage (BOARD_MEETING_ATTENDANCE_PCT), digitalization (Digitalization), and Shariah compliance (Shariah Compliance). These findings indicate that, in the specific context of our investigation, these variables may not significantly contribute to explaining the variability in ESG ratings. Additional investigation is necessary to determine the precise effects of board diligence and the extent of digital transformation on ESG performance. The coefficients obtained from the regression model offered valuable information regarding the size and direction of the impact of each variable. Specifically, a reduction in the size of a company was projected to result in a rise in ESG_SCORE (ESG ratings) which suggests that bigger companies may find it more difficult to achieve higher sustainability scores. On the other hand, a substantial rise in ESG_SCORE was linked to the participation of women on the board, highlighting the beneficial impact of gender diversity on sustainability measures.

The utilisation of fixed and random effect models provided additional evidence to support the favourable influence of the number of women on the board on ESG_SCORE. The findings demonstrated a significant rise in the ESG_SCORE, highlighting the significance of gender diversity in governance frameworks in attaining higher ESG ratings. This validates the idea that having a variety of perspectives, particularly in positions of power, has a beneficial impact on the implementation of sustainable and ethical business strategies. The likelihood-ratio test supported the fixed effect model, indicating that the inclusion of women on the board makes a significant contribution to explaining the variation in ESG_SCORE. This highlights the significance of employing a consistent approach when assessing the impact of gender diversity on environmental, social, and governance (ESG) ratings. The selection of the fixed effect model is motivated by the distinct influence of the number of women on the board on ESG evaluations, facilitating a clearer comprehension of this correlation.

Table 3: *The Hausman Test*

Test Summary	**Chi-Sq. Statistic**		**Chi-Sq. d.f.**	**Prob**
Cross Section Random	21.0220		4.0000	0.0003
	Fixed Effect	**Random Effect**	**Var. (Diff)**	**Prob**
CUR_MKT_CAP	0.0000	0.0000	0.0000	0.0266
BOARD_MEETING_ATTENDANCE_PCT	0.0009	0.0022	0.0000	0.0997
Digitalization	0.0063	0.0026	0.0000	0.0000
NUMBER_OF_WOMEN_ON_BOARD	0.1593	0.2099	0.0008	0.0694

Table 4: *Fixed Effect Regression*

Variable	**Coefficient**	**Std. err.**	**t**	**P>|t|**
CUR_MKT_CAP	0.0000	0.0000	-0.5100	0.0413
BOARD_MEETING_ATTENDANCE_PCT	0.0009	0.0053	0.1700	0.8690
Digitalization	0.0063	0.0013	4.9600	0.0000
Shariah Compliance	0.0000			
NUMBER_OF_WOMEN_ON_BOARD	0.1593	0.0585	2.7200	0.0070
_cons	2.4530	0.5473	4.4800	0.0000
sigma_u	0.9803			
sigma_e	0.4970			
rho	0.7956			

In addition, the analysis of BOARD_MEETING_ ATTENDANCE_PCT revealed a statistically significant and modestly favourable correlation with ESG_SCORE. This aligns with the research purpose, suggesting that active participation by the board may lead to higher ESG ratings. The study's findings offer concrete evidence supporting the correlation between board diligence and ESG ratings. The correlation analysis further emphasised the influence of digital transformation and adherence to Shariah principles on the ESG_SCORE. The regression analysis of Digitalization found a statistically significant and minor negative correlation with ESG_SCORE. Consequently, firms that are undergoing larger digital evolves may, to some extent, have lower ESG scores. The findings clearly correspond to the research objective, providing valuable insights into the influence of digitalization on ESG ratings. The correlation coefficients, particularly those related to CUR_MKT_CAP, BOARD_MEETING_ ATTENDANCE_PCT, Digitalization, Shariah Compliance, and NUMBER_OF_ WOMEN_ON_ BOARD, are directly related to the research objective of investigating the correlation between specific factors and ESG ratings. The findings enhance our thorough comprehension of the relationship between different company attributes and ESG performance within the Malaysian context.

5. CONCLUSION

This study provides critical insights into the factors influencing ESG ratings among companies listed on Bursa Malaysia. The findings reveal a significant negative relationship between company size and ESG ratings, suggesting that larger companies may encounter challenges in achieving high sustainability scores due to the complexities inherent in managing large-scale operations. Conversely, gender diversity on corporate boards is positively associated with ESG ratings, emphasizing the crucial role of inclusive governance practices in enhancing sustainability outcomes.

The research also highlights the importance of board diligence, particularly as reflected in board meeting attendance, in shaping a company's ESG performance. Active and engaged boards contribute significantly to the effectiveness of a company's sustainability initiatives, underscoring the need for corporations to prioritize and strengthen board engagement in their ESG strategies.

The analysis of digital transformation's influence on ESG ratings uncovers complex dynamics. Companies undergoing substantial digital transformations may experience a decline in their ESG ratings if these initiatives are not aligned with sustainability principles. This finding suggests that firms must carefully evaluate the ESG implications of their digital strategies to ensure they contribute positively to their overall sustainability goals.

Additionally, the study identifies a significant influence of Shariah compliance on ESG ratings. Companies that adhere to Shariah principles generally exhibit lower ESG ratings, indicating a need for these firms to reassess and potentially enhance their policies to better align with ESG criteria. This insight is particularly valuable for Shariah-compliant companies aiming to improve their sustainability practices and meet broader ESG standards.

Furthermore, the positive correlation between the presence of women on company boards and higher ESG scores supports the promotion of gender diversity in corporate leadership. The increase in the number of women on boards is linked to improved ESG performance, highlighting the beneficial impact that gender diversity can have on an organization's sustainability efforts. This finding underscores the importance of fostering and maintaining gender-inclusive leadership structures for companies seeking to enhance their ESG policies.

Despite the valuable insights provided by this study, several limitations must be acknowledged. The reliance on publicly available ESG ratings may introduce selection bias, as companies with stronger ESG practices are more likely to disclose such ratings. Additionally, the relatively small sample size of 40 companies, constrained by data availability, may limit the generalizability of the findings. Future research should aim to include a larger and more diverse sample, and explore additional factors that might influence ESG ratings, such as industry-specific variables and regional differences.

The findings of this study have important implications for corporate leaders, policymakers, and investors. Companies striving to improve their ESG performance should focus on enhancing gender diversity in leadership and leveraging digital transformation to advance sustainability initiatives. Policymakers could use these insights to develop frameworks that support and incentivize sustainable practices, particularly for larger firms that may face challenges in scaling their ESG efforts.

Future research should delve deeper into the mechanisms through which company size influences ESG outcomes, exploring aspects such as organizational complexity, resource allocation, and stakeholder management. Additionally, examining the impact of board diversity on other facets of corporate governance and performance could yield further valuable insights. Research across different geographic regions and industry contexts would also help to validate and extend the findings of this study.

In conclusion, this study underscores the complexity of achieving high ESG performance, particularly for larger firms, while also highlighting the critical importance of gender diversity and digital transformation in driving sustainability. As the global emphasis on corporate sustainability continues to grow, understanding these dynamics will be crucial for companies seeking to align with evolving stakeholder expectations and regulatory standards.

REFERENCES

Abdullah, S. N. (2014). The causes of gender diversity in Malaysian large firms. *Journal of Management & Governance, 18*(4), 1137–1159. https://doi.org/10.1007/s10997-013-9279-0

Adams, R. B., & Ferreira, D. (2009). Women in the boardroom and their impact on governance and performance. *Journal of Financial Economics, 94*(2), 291–309. https://doi.org/10.1016/j.jfineco.2008.10.007

Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Birindelli, G., Dell'Atti, S., Iannuzzi, A. P., & Savioli, M. (2018). Composition and activity of the board of directors: Impact on ESG performance in the banking system. *Sustainability, 10*(12), 4699. https://doi.org/10.3390/su10124699

Bissoondoyal-Bheenick, E., Brooks, R., & Do, H. X. (2023). ESG and firm performance: The role of size and media channels. *Journal of Cleaner Production, 391*, 136193. https://doi.org/10.1016/j.jclepro.2023.136193

Bloomberg. (2024). Data retrieved from Bloomberg Terminal.

Clarkson, P. M., Li, Y., Richardson, G. D., & Vasvari, F. P. (2011). Does it really pay to be green? Determinants and consequences of proactive environmental strategies. Journal of Accounting and Public Policy, 30(2), 122–144. https://doi.org/10.1016/j.jaccpubpol.2010.09.013

Drempetic, S., Klein, C., & Zwergel, B. (2020). The influence of firm size on the ESG score: Corporate sustainability ratings under review. *Journal of Business Ethics, 167*(2), 333–360. https://doi.org/10.1007/s10551-019-04164-1

Ferreira, J. J., Fernandes, C. I., & Ferreira, F. A. (2019). To be or not to be digital that is the question: Firm innovation and performance. *Journal of Business Research, 101*, 583–590. https://doi.org/10.1016/j.jbusres.2018.11.013

Flammer, C. (2015). Does corporate social responsibility lead to superior financial performance? A regression discontinuity approach. *Management Science, 61*(11), 2549–2568. https://doi.org/10.1287/mnsc.2014.2038

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment, 5*(4), 210–233. https://doi.org/10.1080/20430795.2015.1118917

García Martín, C. J., & Herrero, B. (2020). Do board characteristics affect environmental performance? A study of EU firms. *Corporate Social Responsibility and Environmental Management, 27*(1), 74–94. https://doi.org/10.1002/csr.1775

Garcia, A. S., Mendes-Da-Silva, W., & Orsato, R. J. (2017). Sensitive industries produce better ESG performance: Evidence from emerging markets. *Journal of Cleaner Production, 150*, 135–147. https://doi.org/10.1016/j.jclepro.2017.02.180

Grewal, J., Hauptmann, C., & Serafeim, G. (2021). Material sustainability information and stock price informativeness. *Journal of Business Ethics, 171*(3), 513–544. https://doi.org/10.1007/s10551-019-4398-y

Hawn, O., Chatterji, A. K., & Mitchell, W. (2019). Do investors actually value sustainability? New evidence from investor reactions to the Dow Jones Sustainability Index (DJSI). *Strategic Management Journal, 39*(4), 949–976. https://doi.org/10.1002/smj.2752

Hussain, N., Rigoni, U., & Orij, R. P. (2018). Corporate governance and sustainability performance: Analysis of triple bottom line performance. *Journal of Business Ethics, 149*, 411–432. https://doi.org/10.1007/s10551-016-3099-5

ISI Emerging Markets. (2024). Data retrieved from ISI Emerging Markets Database: https://www.emis.com

Jiang, K., Du, X., & Chen, Z. (2022). Firms' digitalization and stock price crash risk. *International Review of Financial Analysis, 82*, 102196. https://doi.org/10.1016/j.irfa.2022.102196

Kim, Y., Park, M. S., & Wier, B. (2021). Is earnings quality associated with corporate social responsibility? *The Accounting Review, 87*(3), 761–796. https://doi.org/10.2308/accr-10209

Kraus, S., Rehman, S. U., & García, F. J. S. (2020). Corporate social responsibility and environmental performance: The mediating role of environmental strategy and green innovation. *Technological Forecasting and Social Change, 160*, 120262. https://doi.org/10.1016/j.techfore.2020.120262

Kuznetsova, S., Zavyalova, E., & Shelepova, E. (2021). Corporate social responsibility and financial performance: The role of size, industry, and national context. *Journal of Cleaner Production, 320*, 128823. https://doi.org/10.1016/j.jclepro.2021.128823

Liao, L., Luo, L., & Tang, Q. (2015). Gender diversity, board independence, environmental committee and greenhouse gas disclosure. *The British Accounting Review, 47*(4), 409–424. https://doi.org/10.1016/j.bar.2014.01.002

Lo, K. Y., Ramos, T. B., & Rogelja, T. (2019). Impact of

financial performance and board characteristics on sustainability disclosure: Evidence from the Taiwanese financial industry. *Journal of Business Ethics, 158*(1), 217–240. https://doi.org/10.1007/s10551-017-3707-2

Meng, S., Su, H., & Yu, J. (2022). Digital transformation and corporate social performance: How do board independence and institutional ownership matter? *Frontiers in Psychology, 13*, 915583. https://doi.org/10.3389/fpsyg.2022.915583

Nuhu, Y., & Alam, A. (2024). Board characteristics and ESG disclosure in energy industry: Evidence from emerging economies. *Journal of Financial Reporting and Accounting, 22*(1), 7–28. https://doi.org/10.1108/JFRA-02-2023-0107

OECD. (2020). Environmental, social and governance (ESG) investing: Practices, progress and challenges. *OECD Publishing*. https://doi.org/10.1787/e9ed300b-en

Oh, W. Y., & Shin, H. (2018). Can strong corporate governance protect companies from stock price crash during the COVID-19 pandemic? *Finance Research Letters, 45*, 102087. https://doi.org/10.1016/j.frl.2021.102087

Post, C., & Byron, K. (2015). Women on boards and firm financial performance: A meta-analysis. *Academy of Management Journal, 58*(5), 1546–1571. https://doi.org/10.5465/amj.2013.0319

Vafeas, N. (1999). Board meeting frequency and firm performance. *Journal of Financial Economics, 53*(1), 113–142. https://doi.org/10.1016/S0304-405X(99)00018-5

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research, 122*, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems, 28*(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Wasiuzzaman, S., & Mohammad, N. M. N. (2020). Environmental, social, and governance (ESG) disclosure, competitive advantage, and performance of firms in Malaysia. *Cleaner Environmental Systems, 2*, 100015. https://doi.org/10.1016/j.cesys.2021.100015

Wu, Z., & Li, X. (2023). Digital transformation and ESG performance: Evidence from global firms. *Journal of Business Research, 151*, 452–463. https://doi.org/10.1016/j.jbusres.2022.10.011

Zahid, M., Ghazali, Z., & Faisal, M. (2020a). Gender diversity and corporate sustainability: The moderating role of family ownership. *Sustainability, 12*(7), 2877. https://doi.org/10.3390/su12072877

Zahid, M., Ghazali, Z., Faisal, M., & Ibrahim, M. (2020b). The impact of board gender diversity on corporate social responsibility: Evidence from Malaysia. *Journal of Cleaner Production, 244*, 118704. https://doi.org/10.1016/j.jclepro.2019.118704

Zhang, X., Jin, Y., & Liu, C. (2023). Digital transformation and corporate ESG performance: Evidence from Chinese listed companies. *Journal of Cleaner Production, 398*, 136339. https://doi.org/10.1016/j.jclepro.2023.136339

Zhao, X., & Cai, L. (2023). Digital transformation and corporate ESG: Evidence from China. *Finance Research Letters, 58*, 104310. https://doi.org/10.1016/j.frl.2023.104310

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

Can digital transformation improve market and ESG performance? Evidence from Chinese SMEs /Wang, S., & Esperança, J. P.

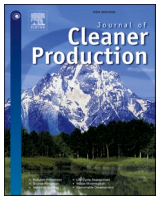
Journal of Cleaner Production
Volume 419 (2023) 137980 Pages 1-12
https://doi.org/10.1016/J.JCLEPRO.2023.137980
(Database: ScienceDirect)

Journal of Cleaner Production 419 (2023) 137980

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro



Can digital transformation improve market and ESG performance? Evidence from Chinese SMEs

Shaofeng Wang [a,*], José Paulo Esperança [b]

[a] School of Logistics and e-Commerce, Zhejiang Wanli University, Ningbo, 315000, China
[b] ISCTE Business School, BRU-IUL, University Institute of Lisbon, Lisbon, Portugal

ARTICLE INFO

Handling Editor: Govindan Kannan

Keywords:
Digital transformation
ESG
Firm competitiveness
Firm market performance
PLS-SEM
fsQCA

ABSTRACT

Promoting the digital transformation of businesses and ESG (Environmental, Social, and Governance) performance can significantly benefit from research on the impact of small and medium-sized enterprise (SME) digitalization on firm market performance and ESG. This study presents a theoretical framework for the impact of digitization on small firms' commercial and social performance. It examines the relationships among digital resources, digital organization, digital adoption, digital innovation culture, firm competitiveness, digital management, market performance, and ESG performance. This study examines the influence of digital transformation on market and ESG performance in Chinese small and medium-sized enterprises (SMEs). Utilizing 331 valid questionnaires, we conducted a comprehensive modeling and empirical analysis through the application of fsQCA and PLS-SEM methodologies, revealing the following: 1) Digital resources, organizing, adoption, management, and firm competitiveness indirectly and positively affect ESG through the intermediary variable (firm market performance). 2) There is no precondition for establishing ESG; firm competitiveness is sufficient for ESG. 3) Firm market performance positively affects ESG, which is also a sufficient condition for ESG. 4) Innovatively discovering the moderator variable (digital innovation culture) positively modulates two paths (digital adoption and firm competitiveness, digital adoption and digital management). It provides theoretical, practical, and policy references to helping SMEs improve their competitiveness, performance, and practice of ESG.

1. Introduction

Digital technologies such as artificial intelligence, big data, blockchain, and virtual reality hold great potential for advancing society (Guerra et al., 2023; Wang et al., 2023). The firm's digital transformation is a hot topic in academia (Andersen et al., 2022), and promoting the ESG (environmental, social, and firm governance) performance of firms (Liang et al., 2022) has become increasingly important. ESG refers to the three central factors in measuring an investment's sustainability and ethical impact in a firm or business, encompassing environmental, social, and governance dimensions (Lee et al., 2022). Understanding ESG is crucial for both field-related and non-expert readers, as it helps contextualize the role and significance of ESG in business operations and societal development (Puriwat and Tripopsakul, 2022).

Digital transformation refers to integrating digital technologies into every facet of a business, fundamentally altering the firm's operation and value delivery to customers (Vial, 2019). The digital strategy aligns business objectives with digital technologies to create a competitive edge (Correani et al., 2020). Digital resources are a firm's digital assets and capabilities, including hardware, software, data, and digital skills (Mikalef and Gupta, 2021). Digital organizing involves structuring and coordinating a firm's digital resources and activities to achieve business goals (Yu et al., 2021). Digital adoption measures the extent a firm embraces and utilizes digital technologies to enhance its operations and customer experiences (Fonseka et al., 2022). Digital marketing leverages digital channels for more effective customer reach and engagement (Varadarajan et al., 2022). A digital innovation culture nurtures a culture that welcomes new technologies and ideas to drive business growth and sustainability (Chatterjee et al., 2021b). Digital management efficiently plans, organizes, and controls digital resources and processes within a firm to achieve strategic goals (Bag et al., 2021).

Small and medium-sized enterprises (SMEs), as a critical mainstay of the digital economy (Reim et al., 2022), contribute to social development by creating employment opportunities, reducing poverty, narrowing the urban-rural gap, promoting sustainable development,

* Corresponding author.
E-mail addresses: vipwhsl@hotmail.com (S. Wang), jose.esperanca@iscte-iul.pt (J.P. Esperança).

https://doi.org/10.1016/j.jclepro.2023.137980
Received 7 February 2023; Received in revised form 8 June 2023; Accepted 1 July 2023
Available online 10 July 2023

boosting exports, and fostering technological innovation (Yu and Zhu, 2022). The rise of digital technologies and transformation has reshaped the volatile business environment while providing SMEs with unique new development opportunities (Marcysiak and Pleskacz, 2021). Integrating ESG into digital transformation is essential for fostering sustainable and responsible business practices.

The current research on the digital transformation of SMEs mainly focuses on influential factors, support systems, transformation strategies, innovation, policy environment, high-quality development, performance, and competitiveness (Yang et al., 2022a). Digital skills in SMEs positively impact organizational agility and firm market performance (Rozak et al., 2021). Family harmony positively affects small and medium family firm performance, and IT governance and strategy positively mediate this relationship (Dutot et al., 2021). SMEs can use digital technologies such as artificial intelligence to improve their marketing processes and procedures, enhancing market performance (Fonseka et al., 2022). ESG researchers have analyzed the impact of third-party distribution, innovation, economic growth, and sustainable development (Cristea et al., 2022). Many scholars emphasize technology and the digital revolution relating to firm digitalization. Still, related research needs to pay more attention to the mixed-method research of SME digitalization and ESG (Cristea et al., 2022). The digital innovation culture is an important driving factor of digital transformation (Yang et al., 2022b), and digital management needs further attention. More research should be done on SME digitalization, firm market performance, and ESG (Lee et al., 2022). To fill in the gaps, the main research questions of this study are as follows:

Q1. How does digital transformation affect the market performance and ESG performance of SMEs?

Q2. Which digital factors indirectly impact the ESG performance of SMEs?

Q3. How does digital innovation culture moderate the relationship between digital factors and the competitiveness of firms?

Based on these research questions, the objectives of this study are: to explore the impact of digital transformation on the market performance and ESG performance of SMEs, to analyze how digital factors, such as digital resources, digital organization, digital adoption, and digital management, indirectly affect ESG performance through firm market performance; and to investigate the moderating role of digital innovation culture in the relationship between digital factors and firm competitiveness. This research considers new variables such as digital resources, digital organization, digital adoption, and digital management to explore the connection between firm digitalization and ESG while constructing explanations and predictions. The research model of SME ESG explores the moderating role of a digital innovation culture and the mediating role of firm competitiveness and market performance and uses PLS-SEM to identify the degree of influence and critical paths of different factors and fsQCA to find the impact of firm ESG configuration. This research includes an introduction followed by a literature review. Section 3 presents the research methods, followed by the PLS-SEM (section 4) and fsQCA (section 5) analyses. To conclude, section 6 provides a discussion as well as the limitations and conclusions of the research.

2. Literature review and hypotheses development

2.1. Environmental, Social, and Governance (ESG) performance

In recent years, there has been a growing interest in Environmental, Social, and Governance (ESG) performance in the business and academic communities (Wang et al., 2023b). Several studies have investigated the impact of these factors on firm performance, risk management, and stakeholder relationships (Broadstock et al., 2021). To comprehensively understand the current state of research in this area, we have included a table of recent literature on ESG performance below (Table 1).

By incorporating this table and literature review into our study, we aim to provide a more comprehensive understanding of the current research landscape on ESG performance and demonstrate how our research contributes to the ongoing academic conversation in this area.

2.2. Research hypotheses

2.2.1. Firm market performance and ESG performance

Firm market performance (FP) is a comprehensive evaluation of a firm's benefits and performance within a specific operating period (Fonseka et al., 2022). Enterprise ESG performance emphasizes evaluating sustainable development effectiveness in the environment, firm, and society (Liang et al., 2022). Promoting ESG is to expand the market size and improve market performance. Enterprises are also responsible for contributing to the development of social well-being (Navickas et al., 2021). Enterprises provide most jobs in society, and their high-quality development is a powerful boost to ESG. It can also help eliminate poverty, promote equity (Losa-Jonczyk, 2020), and improve employee job satisfaction (Kim et al., 2022), as well as environmental protection (Cristea et al., 2022). Enterprises are value creators in the social economy (Liang et al., 2022). The financial performance of firms is closely related to the practice of ESG (Laguir et al., 2021), and high-performance firms tend to have high firm CSR (Villalba-Ríos et al., 2022) and ESG rankings (Puriwat and Tripopsakul, 2022). Based on the above analysis, the research hypotheses put forward in this study are:

H1. Firm market performance has a positive effect on firm ESG performance.

2.2.2. Digital adoption, firm competitiveness and market performance

Digital adoption (DA) is how firms adopt digital technologies to carry out digital transformation (Zhang et al., 2021a). Firm competitiveness (FC) refers to the comprehensive ability of firms to realize their value creation through digital transformation (Ghasemaghaei, 2021; Rahman et al., 2021). The digital transformation enabling SMEs to implement intelligent manufacturing improves their market performance. The four dimensions of digital technology, strategy, capability, and culture included in digital transformation positively affect firms' market performance. Enterprise digitization facilitates more flexible and competitive operations and benefits developing firm expansion (Emara and Zhang, 2021). Digital technology can reduce the impact of time and space, allowing employees to join work anytime, anywhere to improve firm market performance. Adopting and mastering extensive data capabilities in digital transformation help firms improve performance (Ciampi et al., 2021). Early adoption of digital technologies (such as artificial intelligence, big data, cloud computing, etc.) can allow firms to gain sustainable competitive advantages, which is essential to survive in a harsh business environment (Martínez-Caro et al., 2020). Enterprises' adoption and mastery of extensive data capabilities in digital transformation play a crucial role in maintaining business competitiveness (Ciampi et al., 2021). Digitalization of business can lead to improved market performance and competitiveness (Martínez-Caro et al., 2020). Based on the above analysis, the research hypotheses put forward in this study are:

H2. Digital adoption has a positive effect on market performance.

H3. Enterprise competitiveness has a positive effect on firm market performance.

H4. Digital adoption has a positive effect on firm competitiveness.

2.2.3. Digital adoption, digital management, and firm market performance

Digital management (DM) refers to the supporting management activities implemented by firms to adopt digital transformation (Khattak et al., 2021). The emergence of digital technology no longer requires simple information management but requires firms to carry out a series

Table 1
Summary of recent literature on ESG performance.

Author(s)	Title	Key Findings
Alkaraan et al. (2022)	Corporate transformation toward Industry 4.0 and financial performance: The influence of environmental, social, and governance (ESG)	The corporate transformation toward Industry 4.0 (CTTI4.0) disclosure positively impacts financial performance, with environmental, social, and governance (ESG) practices strengthening this relationship.
Bătae et al. (2021)	The relationship between environmental, social, and financial performance in the banking sector: A European study	Emission and waste reductions are positively related to bank profitability. However, increased corporate governance quality negatively affects financial performance, with market investors not valuing social responsibility initiatives or best governance practices.
Bilyay-Erdogan et al. (2023)	ESG performance and dividend payout: A channel analysis	Companies with higher ESG performance tend to pay higher dividends, with "earnings" and "risk" identified as the two possible channels through which ESG performance influences dividend payouts.
Broadstock et al. (2021)	The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China	During the COVID-19 financial crisis, high-ESG portfolios generally outperformed low-ESG portfolios, and ESG performance helped mitigate financial risk, highlighting its incremental importance during crisis periods.
Camodeca and Almici (2021)	Digital transformation and convergence toward the 2030 agenda's sustainability development goals: evidence from Italian listed firms	The positive relationship between digitalization and Sustainable Development Goals, emphasizing the importance of digital technology in implementing the sustainability agenda for Italian FTSE MIB listed firms.
Chen et al. (2022)	Impacts on the ESG and financial performances of companies in the manufacturing industry based on the climate change related risks	The degree of disclosure of climate change-related risks and opportunities (CCR risks) and different ownership structures had a positive but negative moderating effect on manufacturing companies' financial performance, with the positive impact of environmental performance on financial performance diminishing as investments in environmental performance indicators increased.
Fang et al. (2023)	Can enterprise digitization improve ESG performance?	Enterprise digitization significantly improves ESG performance, particularly for non-politically affiliated companies and regions with high-quality institutions, by reducing agency costs and improving goodwill. However, it does not impact environmental scores.
Fatemi et al. (2018)	ESG performance and firm value: The moderating role of disclosure	ESG strengths increase firm value, while ESG weaknesses decrease it. ESG disclosure plays a crucial moderating role, mitigating the negative effect of weaknesses and attenuating the positive effect of strengths on firm value.
Garcia et al. (2017)	Sensitive industries produce better ESG performance: Evidence from emerging markets	Subject to social, moral, and political pressures, sensitive industries exhibit superior environmental performance in emerging markets, even when controlling for firm size and country.
Hu et al. (2023)	Research on the Effect of ESG Performance on Stock Price Synchronicity: Empirical Evidence from China's Capital Markets	Higher corporate ESG performance improves stock price synchronicity by reducing information asymmetry, with a more significant "noise reduction" effect observed in state-owned companies and those with high investor trust.
Liu et al. (2022)	ESG and financial performance: A qualitative comparative analysis in China's new energy companies	China's new energy companies, two configurations generate high corporate financial performance (CFP), with the social pillar being a determinant for high CFP outcomes and maintaining stability in its configuration over time.
Pozzoli et al. (2022)	The impact of audit committee characteristics on ESG performance in the European Union member states: Empirical evidence before and during the COVID-19 pandemic	Audit committee independence and expertise positively impact ESG performance, while audit committee tenure negatively affects it, with these relationships becoming statistically more substantial during the COVID-19 pandemic among European listed companies.
Rahman et al. (2023)	ESG and firm performance: The rarely explored moderation of sustainability strategy and top management commitment	ESG and its dimensions positively impact firm performance (ROA and Tobin's Q), with sustainability strategy and top management commitment further enhancing these associations in a developing country, specifically Pakistan.
Wang et al. (2023a)	Digital Technology for Good: Path and Influence—Based on the Study of ESG Performance of Listed Companies in China	Digital transformation improves ESG performance for Chinese listed companies. However, this effect is not observed in highly monopolistic industries, while the concept of technological goodness spreads through network relationships, supporting other market enterprises.
Wang et al. (2023b)	The impact of environmental uncertainty on ESG performance: Emotional vs. rational	The environmental uncertainty weakens ESG performance, with investor sentiment and green innovation mediating this relationship. At the same time, mature companies and those in "small market, big

(*continued on next page*)

Table 1 (*continued*)

Author(s)	Title	Key Findings
		government" scenarios experience a more pronounced dampening effect on ESG performance.

of digital operations that support the performance of digital technology (Chen et al., 2022). The value of digital technology needs to be integrated through the transformation of business processes, and a series of digital management activities are essential prerequisites for firms to enjoy the dividends of digital technology (Yang et al., 2022b). Digital technologies can help firms exchange information with their partners in real-time, improving communication efficiency (Khattak et al., 2021). Enterprises can reduce management costs by expanding or purchasing digital technology services (Wang et al., 2022). Digital technologies help firms gain market intelligence by becoming an effective medium for collecting high-quality market information and communicating with customers and partners, thereby improving decision-making (Pergelova et al., 2019). Enterprises can also use digital technology to quickly find new partners, improve internal and external resource integration capabilities, and optimize operational efficiency (Yu et al., 2021). The rapid replacement of digital technology also requires firms to monitor the progress of digital technology. Firms continuously update digital technology to ensure that digital technology can support firm development (Bag et al., 2021). Digital technologies have brought new opportunities for business development, and realizing digital innovation requires adopting digital technologies (Fonseka et al., 2022). Firms must also manage and fully utilize digital technologies in the innovation process (Rahman et al., 2022); firms can accelerate the innovation process by integrating and mobilizing human and technological resources (Khin and Ho, 2019). Based on the above analysis, the research hypotheses put forward in this study are:

H5. Digital management has a positive effect on firm market performance.

H6. Digital adoption has a positive effect on digital management.

2.2.4. Digital resources, digital organization, and adoption

Digital resources (DR) are the sum of hardware, software, technology, capital, and other resources firms need to adopt digital transformation (Chen et al., 2022). Digital organizing (DO) refers to business activities such as formulating strategies, collecting resources, and internal promotion to support the firm's digital transformation (Chatterjee et al., 2021a). The digital transformation process is full of challenges, and it is necessary to adequately prepare the resources required for digital transformation (Mikalef and Gupta, 2021). Storage, software for performing calculations, and high-speed networks are primary resources for firm digitization (Chen et al., 2022). It requires that firms maintain high capabilities, talents, and expertise to manage digital technologies and develop new products (Khin and Ho, 2019). The efficient integration and reconfiguration of firms' existing resources are pivotal in implementing digital transformation (Martínez-Caro et al., 2020). Integrating digital technology will change business processes, business models, and value creation (Yang et al., 2022b). This process is inseparable from establishing digital transformation strategies for firms to achieve goals (Rahman et al., 2021). Enterprises display various performances to support digital transformation helping them reduce costs and increase efficiency (Pinheiro et al., 2022). In the digital transformation process, firms should adjust their vision, strategy, organizational structure, function, and culture through digital technology to adapt to the development of the digital age (Zhang et al., 2021a). Based on the above analysis, the research hypotheses put forward in this study are:

H7. Digital resources have a positive effect on digital adoption.

H8. Digital organization has a positive effect on digital adoption.

2.2.5. The moderating effect of digital innovation culture

Digital innovation culture (DIC) can drive firms to implement digital transformation by creating an inclusive and innovative cultural atmosphere (Khattak et al., 2021). It helps them run businesses under digital innovation (Chatterjee et al., 2021b), enhancing firm competitiveness and market performance (Kumar et al., 2021). An excellent digital culture is a source of firm innovation and a booster to help firms gain market competitiveness (Martínez-Caro et al., 2020). By aligning business objectives with digital transformation efforts and fostering a supportive corporate culture, firms can better leverage digital technologies to achieve their strategic goals (Chatterjee et al., 2021b). The impact of digital culture on firm market performance is particularly prominent. Digital culture has a moderating effect on the path that affects firm market performance. Different cultural backgrounds will have differences in adopting and managing digital technology. Due to the uncertainty of digital transformation, firms must instill a digital innovation culture that suits their characteristics (Rahman et al., 2021). Firm culture is an essential key factor affecting the application of digital technology to transform firms (Zhang et al., 2021a). Incorporating business objectives and corporate culture into digital transformation strategies allows firms to create a cohesive approach, enhancing the overall effectiveness of their digital efforts (Chatterjee et al., 2021b). Based on the rapidly changing market environment of digital technology, firms should develop a digital innovation culture to support them in continuously improving their products and services. It helps them gain a more favorable market position (Chatterjee et al., 2021b). Developing an innovative firm culture can facilitate the business digitization process and generate value from digital tools, aiming to improve organizational performance (Chen et al., 2022). Based on the above analysis, the research hypotheses put forward in this study are:

H9. Digital innovation culture positively moderates the relationship between digital adoption and firm competitiveness.

H10. Digital innovation culture positively moderates the relationship between digital adoption and management.

2.3. Theoretical basis and research model

The Resource-Based View (RBV) and Dynamic Capabilities View (DCV) provide a suitable theoretical foundation for this study, as they emphasize the role of internal resources and capabilities in shaping firm performance (Soh and Wong, 2021). RBV posits that firms can achieve a competitive advantage and superior performance by leveraging their unique resources and capabilities (Barney, 1991). On the other hand, DCV highlights the importance of a firm's ability to adapt, integrate, and reconfigure its resources and capabilities in response to changes in the external environment (Teece et al., 1997). Both perspectives are particularly relevant to understanding how digital transformation can impact firms' market and ESG performance (Mardani et al., 2020).

This study considers digital resources, organization, adoption, and management as valuable resources and capabilities contributing to a firm's competitiveness and performance (Dubey et al., 2018). Furthermore, digital innovation culture can be viewed as a dynamic capability that enables firms to continuously adapt and innovate in response to the changing market and ESG requirements (Pagoropoulos et al., 2017).

Given the importance of firm age and size in shaping market performance and ESG (Banerjee and Campbell, 2009), these variables are included as control variables in the research model. The model of this study, grounded in RBV and DCV, is depicted in Fig. 1.

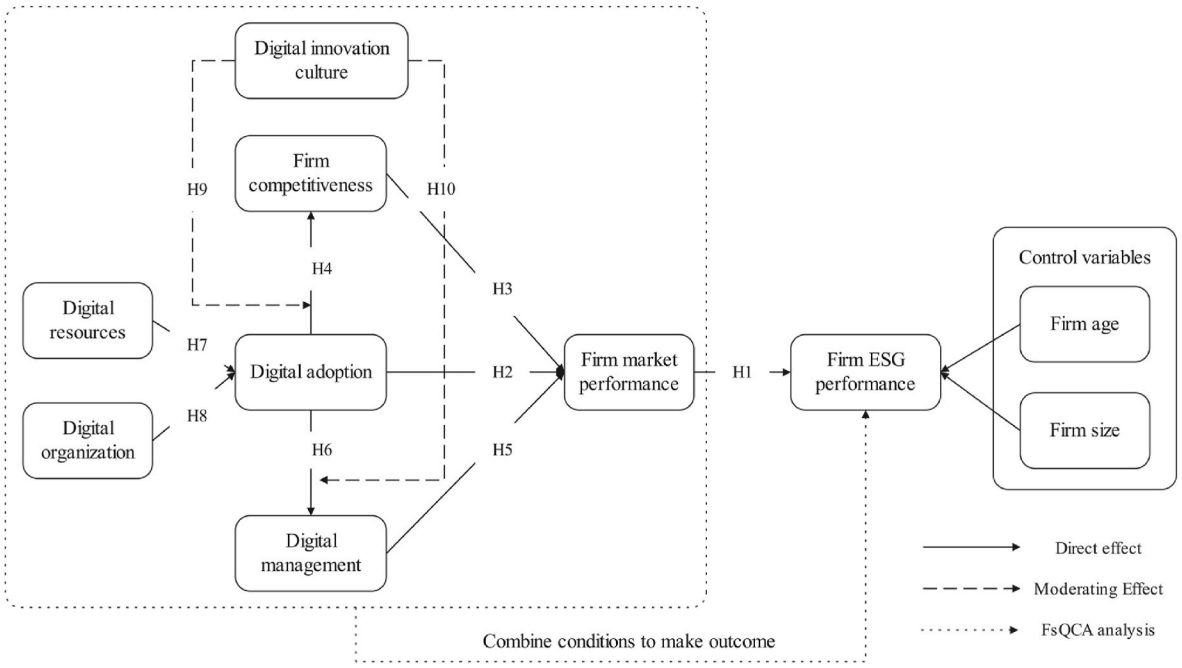


Fig. 1. Research model & Configuration model.

3. Research methods

3.1. Variables and measures

This study used a rigorous method to develop and validate the measurement instruments, strictly following a three-step process (Soh and Wong, 2021). These adjustments aim to ensure that the constructs and measurement tools are more closely aligned with the actual needs of the research context, thus enhancing the study's accuracy (Dubey et al., 2018). Firstly, we adapted all measurement questions based on relevant scholars' research findings to ensure the scales' quality and guarantee content validity (Liszbinski et al., 2023). Secondly, we engaged in discussions with researchers and entrepreneurs to optimize and refine the initial version of the questionnaire, ensuring expert validity (Moroni et al., 2022). Thirdly, after completing the preliminary design, we conducted a pilot study with 25 entrepreneurs to test the reliability of the scales. The data passed the reliability and validity tests (Cronbach's Alpha >0.7, KMO>0.7***), confirming that the developed measurement tools were suitable for formal surveys. After carefully reviewing the suggestions from the pilot study, we cautiously improved the scales (Moroni et al., 2022).

The paper used a questionnaire to collect research data (Dutot et al., 2021; Malik et al., 2021). The questionnaire contains basic statistical information about the firm and the measurement scale of the research model. Each latent variable consists of 3–5 measurement items, measured using a 5-point Likert scale (Rozak et al., 2021) (values 1–5 indicate strongly disagree to agree strongly). All measurement items were adapted from published literature to ensure content validity (Fonseka et al., 2022). The questionnaire for this study is shown in Table 2.

3.2. Sample and data collection

After the initial completion of the questionnaire, expert scholars and middle and senior managers of firms were invited to provide a pre-test (Fonseka et al., 2022; Malik et al., 2021). After collecting feedback from the pre-test, the questionnaire was carefully revised. The official survey was distributed to WeChat groups such as the Entrepreneurs Association and the Professional Managers Association. The members of these WeChat groups are entrepreneurs from Zhejiang Province, China. Because the criteria for joining these WeChat groups are the middle and senior managers of the firm, respondents can choose whether to voluntarily participate in this survey after receiving the invitation. The survey started in July 2022 and lasted one month, and 331 valid questionnaires were recovered. The basic information of the sample data is shown in Table 3.

To ensure consistency in the research subjects, we have referred to similar studies on SMEs (Aboelmaged, 2018; Biggeri et al., 2023; Pizzi et al., 2021; Xiang et al., 2022) to guarantee the applicability of our research methods and scope. We explicitly targeted SMEs during the survey and introduced them in the questionnaire title and research purpose. Moreover, by selecting the data, we followed the relevant legal regulations in the survey area, ensuring that the number of employees in the sampled firms met the SMEs criteria. According to the legal regulations in the survey area, most industries define SMEs as firms with fewer than 300 employees. The standard for industries like information transmission can be relaxed to less than 1000 employees (Ministry of Industry and Information Technology of China, 2011). Compared to other data collection methods, questionnaires allow for a larger sample size to obtain more generalizable results (Gosling et al., 2004); online questionnaires minimize data loss as we require respondents to complete the entire questionnaire before submission; this approach also directly generates data for quantitative analysis, avoiding issues in data encoding and conversion (Moroni et al., 2022). Surveying groups where research subjects are concentrated improves the theoretical relevance of the research results (Malhotra and Grover, 1998).

Furthermore, this method has been used in similar studies in the field, demonstrating its relevance and applicability (Jabbour et al., 2015; Kazancoglu et al., 2022; Liszbinski et al., 2023). Considering these reasons, our study employs online questionnaires distributed to entrepreneur-focused, authenticated WeChat groups for data collection. Based on these measures and criteria, most of the firms in our sample met the conditions, and we believe that the data has good consistency in research subjects (Baah et al., 2023; Reyes-Rodríguez, 2021; Simmou et al., 2023).

Table 2
Survey variables and measures.

Variable	ID	Items	Sources
Digital resources	DR1	Our firm has the hardware equipment (computers, etc.) required for digital transformation.	Mikalef and Gupta (2021) and Pinheiro et al. (2022)
	DR2	Our firm has access to the data they need for digital transformation.	
	DR3	Our firm owns the software for digital transformation.	
	DR4	Our firm has the technical resources for digital transformation.	
	DR5	Our firm is well-funded for digital transformation.	
Digital organization	DO1	Our firm should develop strategies to advance digital transformation.	Chatterjee et al. (2021a) and Yu et al. (2021)
	DO2	Our firm should collect empirical data to implement digital transformation.	
	DO3	Our firm should integrate digital transformation into its business strategies.	
	DO4	Our firm should promote a digitally driven culture to advance digital transformation.	Fonseka et al. (2022), Rahman et al. (2021), and Zhang et al. (2021a)
Digital adoption	DA1	Our firm's product/service innovation is based on digital technology.	
	DA2	Digital technologies can help the firm make accurate decisions.	
	DA3	Adopting digital technologies can help improve firm operational efficiency.	
	DA4	A sound implementation plan is essential for adopting digital technologies.	
	DA5	Our firm is integrating digital technologies to advance digital transformation.	
Digital innovation culture	DIC1	Our firm culture encourages digital innovation.	Chatterjee et al. (2021b)
	DIC2	Our firm culture encourages employees to share knowledge.	
	DIC3	Our firm culture focuses on teamwork and innovation.	
	DIC4	Digital technology plays a vital role in new product development.	
	DIC5	Digital technologies play an important role in process improvement.	
Digital management	DM1	Our firm uses digital technology to exchange information with partners in real-time.	Bag et al. (2021) and Yu et al. (2021)
	DM2	Our firm can easily find new partners with the help of digital technology.	
	DM3	Our firm can extend new applications or capabilities with the help of digital technologies.	
	DM4	Our firm continuously monitors the progress of digital technologies.	

Table 2 (*continued*)

Variable	ID	Items	Sources
Firm market performance	FP1	Our firm's market share has steadily increased.	Fonseka et al. (2022) and Kumar et al. (2021)
	FP2	Our firm is not currently experiencing financial difficulties.	
	FP3	Our firm continues to launch new products and services.	
	FP4	Our firm's profitability has increased.	
Firm ESG performance	ESG 1	Our firm focuses on and continuously improves employee job satisfaction.	Cristea et al. (2022) and Liang et al. (2022)
	ESG 2	Our firm provides outstanding support for talent development.	
	ESG 3	Our firm participates in social welfare activities.	
	ESG 4	Our firm has a business philosophy of sustainable development.	
Firm competitiveness	FC1	Digital transformation can help improve the competitiveness of our firm.	Ghasemaghaei (2021) and Rahman et al. (2021)
	FC2	Digital transformation helps our firm reduce costs and increase efficiency.	
	FC3	Digital transformation helps improve our firm's reputation.	
	FC4	Digital transformation is part of our firm strategy.	

Table 3
Demographic characteristics (n = 331).

Characteristics	Category	Number	Percentage (%)
Firm age	≤3	60	18.1
	4~8	173	52.3
	9~15	71	21.5
	≥16	27	8.2
Firm size	≤20	128	38.7
	21~299	159	48.0
	≥300	44	13.3
Ownership	State-owned firm	66	19.9
	Private firm	231	69.8
	Other	34	10.3

3.3. Common method bias and non-response bias test

In this study, Harman's one-factor test was used to test for common method bias. It concluded that the variance explained by the first factor was 28.0% (<40%), so the conclusion illustrates that common method bias would not significantly affect the results of this study (Chen et al., 2022).

We examined the presence of non-response bias (NRB) by comparing the data collected in the survey (top 50% and bottom 50%) (Rahman et al., 2021), using SPSS analysis, finding no statistically significant difference between the two groups ($p > 0.05$) (Bag et al., 2021). Therefore, non-response bias will not affect the analysis results.

3.4. Statistical modeling technique

This study aims to establish a model to explain and predict firm digitization and ESG, which can influence current and future studies. The research model is a complex model with mediating and moderating effects, and the analysis data of this study is derived from

questionnaires. Therefore, we adopted the PLS-SEM analysis as it focuses more on predictive capabilities and explaining causal relationships compared to OLS (Cepeda-Carrion et al., 2018; Mardani et al., 2020), which better aligns with the objectives of our research (Hair et al., 2022; Malik et al., 2021). Data analysis techniques were used, and tests were performed using SmartPLS 3.0 software (Rozak et al., 2021; Dutot et al., 2021).

Furthermore, to gain a deeper understanding of the causal relationships in different contexts and reveal the configuration of factors influencing ESG, we employed fuzzy set qualitative comparative analysis (fsQCA) as a complementary method to PLS-SEM analysis (Ciampi et al., 2021; Dahms, 2020; Hayajneh et al., 2022). This approach allows us to uncover the distinct configurations of causal conditions and their impact on firm performance. It provides valuable insights into the influencing factors and their combinations that are of practical significance for businesses and policymakers (Abbasi et al., 2022; Yin and Yu, 2022).

4. PLS-SEM analysis

4.1. Assessment of measurement model

This research tested the model by assessing reliability, discriminant, and convergent validity (Hair et al., 2022). The reliability can be judged by testing the combined reliability and Cronbach's coefficient. From Table 4, both values are greater than 0.8 (>0.7), so the measurement model has good reliability. Convergent validity is judged by verifying the average extracted variation (AVE) value. Table 4 shows that each AVE exceeds 0.5, indicating good convergent validity. The discriminant validity can be obtained by comparing the correlation coefficient between the AVE square root of each latent variable and the other latent variables. Table 5 shows that the correlation coefficient between each latent variable and the other latent variables is smaller than the latent variable's AVE square root. Hence, the measurement model's discriminant validity is relatively high.

Factor loadings between each latent variable and its measurement items are more significant than the cross-factor loadings between the latent variable and other latent variables. The measurement model has ideal convergent and discriminant validity. The Heterotrait-monotrait ratio (HTMT) of the measurement models was all less than 0.662, further indicating that the discriminant validity of the measurement models was good (Hair et al., 2022).

4.2. Structural model test

Structural model checking was performed using Bootstrap in SmartPLS 3 software, as suggested by Hair et al. (2022). The structural model test results are shown in Fig. 2.

According to the PLS-SEM results, the hypotheses H1, H3, H4, H5, H6, H7, H8, and H9 were supported. However, H2 was not be supported, suggesting that digital adoption does not directly lead to improved firm market performance. Firm market performance has become a critical factor that directly affects ESG performance. Digital resources and digital organizations indirectly affect ESG through intermediary variables (digital adoption, digital management, and firm competitiveness). In addition, digital innovation culture (moderating variables) positively regulates the two paths of digital adoption, firm competitiveness and digital management. The coefficients of determination (R2) of firm competitiveness, firm market performance, and ESG are 42%, 46%, and 30%, respectively, indicating that the model has more than moderate explanatory power (Hair et al., 2022). The standardized root means square residual (SRMR) of the model was 0.05 (<0.8), indicating a good model fit (Hair et al., 2022). The data analysis results show that the maximum VIF value is 3.148 (<10), so there is no multicollinearity problem, and the model results are more reliable (Hair et al., 2022).

Table 4
Reliability and convergent validity.

Variable	Cronbach's Alpha	rho_A	Composite Reliability	AVE
DR	0.905	0.907	0.930	0.726
DO	0.868	0.869	0.910	0.715
DA	0.845	0.847	0.890	0.618
DIC	0.866	0.872	0.903	0.650
DM	0.847	0.848	0.897	0.685
FP	0.819	0.821	0.881	0.649
ESG	0.828	0.831	0.879	0.592
FC	0.833	0.834	0.889	0.666

4.3. Mediating effect test

This study used the bootstrap method to test the mediation effect (Hair et al., 2022). Table 6 displays that digital resources, digital organization, digital adoption, digital management, and firm competitiveness indirectly impact ESG through firm market performance; There is a mediation effect on the relationship.

4.4. Moderating effect test

This study utilizes SmartPLS 3 to use PLS Algorithm and Bootstrap to test the moderating effect of digital innovation culture (Hair et al., 2022). Table 7 shows the results of the moderating effect test. The path coefficient from the moderating effect term (DIC × DA) to FC is 0.132, and the T value is 2.032, showing that digital innovation culture positively moderates the relationship between digital adoption and firm competitiveness. The path coefficient of the moderating effect term (DIC × DA) to DM is 0.299, and the T value is 9.572, indicating that digital innovation culture positively moderates the relationship between digital adoption and digital management. When a digital innovation culture exists, the influence between digital adoption, firm competitiveness, and digital leadership is enhanced (Hair et al., 2022; Chen et al., 2022).

5. fsQCA analysis

5.1. Calibration procedure

Fuzzy Set Qualitative Comparative Analysis (fsQCA) can complement PLS-SEM analysis by detecting the effects of heterogeneity, helping researchers identify combinations of causal conditions for ESG practice (Hayajneh et al., 2022; Zhang et al., 2021a). The first stage of fsQCA transforms the data into degree indices of full membership, crossover point, and full non-membership. The calibration results are shown in Table 8.

5.2. Analysis of necessary conditions

The second stage of fsQCA is Necessary Condition Analysis (NCA) to explore whether there are preconditions for deriving the generation of dependent variables (Dahms, 2020; Yang et al., 2022b). This condition is necessary if the agreement exceeds 0.90 (Ciampi et al., 2021). Table 9 shows the conditions required for the absence of ESG.

5.3. Analysis of sufficient conditions

The fsQCA analysis aims to verify that 7 prerequisites are included in the presence of ESG results (Dahms, 2020). This study used a raw consistency threshold of 0.80 and a PRI consistency threshold of 0.60 and set the frequency to 3. Table 10 shows the 5 groups of configurations for sufficient condition analysis, the solution consistency is 0.856 (>0.8), and the solution coverage rate is 0.510 (>0.5). The results above show that the 5 groups have acceptable reliability and explanatory power (Hayajneh et al., 2022; Zhang et al., 2021a).

Robustness tests were performed in this study, increasing the PRI

Table 5
Discriminant validity.

	ESG	DA	DIC	DM	DO	DR	FC	FP
ESG	**0.770**							
DA	0.294	**0.786**						
DIC	0.193	0.121	**0.806**					
DM	0.341	0.541	0.182	**0.828**				
DO	0.085	0.470	0.056	0.237	**0.846**			
DR	0.157	0.467	0.163	0.280	0.025	**0.852**		
FC	0.358	0.522	0.415	0.407	0.232	0.316	**0.816**	
FP	0.464	0.437	0.249	0.542	0.149	0.239	0.547	**0.806**

Note: The bold diagonal lines indicate the square root of the AVE.

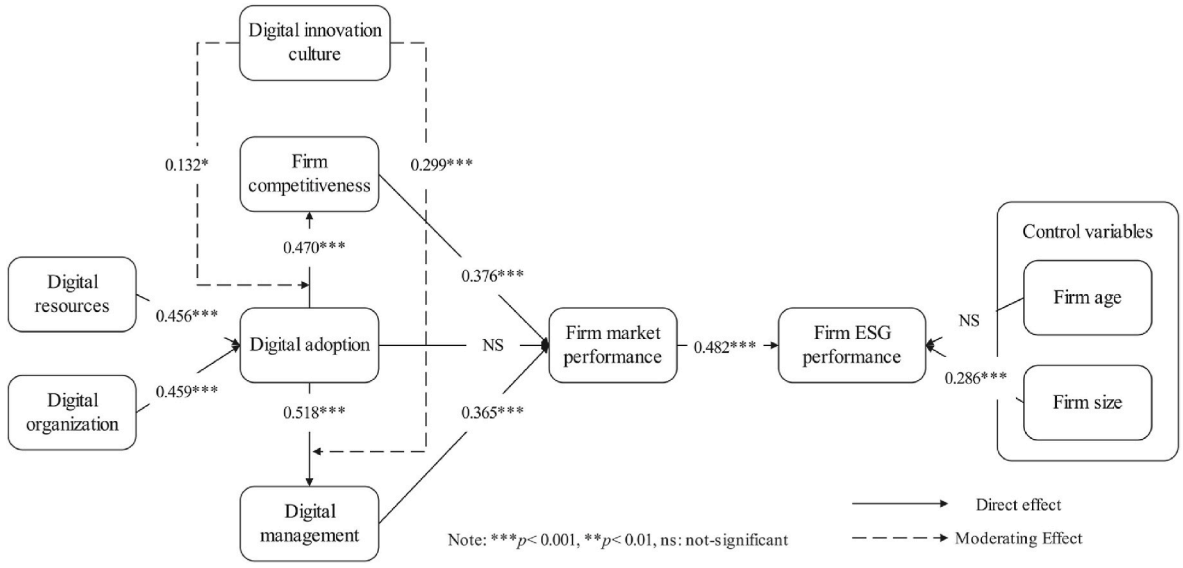


Fig. 2. PLS-SEM results.

Table 6
Mediated effect test results.

Path	95% confidence intervals	P-value	Significance
DA → FC → FP → ESG	[0.054, 0.119]	0.000	Yes
DA → DM → FP → ESG	[0.060, 0.126]	0.000	Yes
DO → DA → FP → ESG	[-0.016, 0.036]	0.464	No
DO → DA → DM → FP → ESG	[0.026, 0.060]	0.000	Yes
DO → DA → FC → FP → ESG	[0.025, 0.056]	0.000	Yes
DR → DA → FP → ESG	[-0.015, 0.035]	0.462	No
DR → DA → DM → FP → ESG	[0.026, 0.059]	0.000	Yes
DR → DA → FC → FP → ESG	[0.024, 0.056]	0.000	Yes
DM → FP → ESG	[0.119, 0.236]	0.000	Yes
FC → FP → ESG	[0.124, 0.248]	0.000	Yes

Table 7
Moderated effect test results.

Path	No moderating variable			With moderating variable		
	B	T-value	Significance	β	T-value	Significance
DA → FC	0.522	13.067	***	0.470	12.941	***
DA → DM	0.541	14.043	***	0.518	14.062	***
DIC → FC				0.364	9.731	* **
DIC → DM				0.147	3.284	***
DIC × DA → FC				0.132	2.032	*
DIC × DA → DM				0.299	9.572	***

Note: ***p < 0.001; **p < 0.01; *p < 0.05; ns: not-significant.

consistency threshold from 0.60 to 0.65 and increasing the case frequency from 3 to 4, resulting in consistent configuration results. Therefore, the findings are robust (Ciampi et al., 2021; Yang et al., 2022b; Zhang et al., 2021a).

6. Discussion and conclusions

6.1. Discussion and theoretical implications

This study offers several implications that enrich our comprehension of the interplay among digital transformation, firm market performance, and ESG, in line with the Resource-Based View (RBV) and Dynamic Capabilities View (DCV) theories. These implications, founded on our research outcomes, provide valuable perspectives for academics and industry professionals. Previous research concerning corporate digital transformation has primarily focused on either market performance (for instance, Fang et al., 2023; Rahman et al., 2023: Peng and Tao, 2022; Zhou et al., 2022) or ESG performance (for instance, Camodeca and Almici, 2021; Ren et al., 2023; Wang et al., 2023a; Zhong et al., 2023). The paper is the first to employ multiple theories, specifically RBV and DCV, to enhance our understanding of how digital transformation influences market and ESG performance (Alkaraan et al., 2022; Chen et al., 2022). In addition, our research delves deeper into the relationships between digital innovation culture and the adoption of digitalization, firm competitiveness, and digital management by examining the moderating role of a digital innovation culture. Furthermore, by applying symmetric (PLS-SEM) and asymmetric (fsQCA) methodologies, our study offers a more comprehensive and nuanced exploration of the methods used in studying digital transformation and ESG performance,

Table 8
Calibration positioning points of case variables.

	Variables							
	DR	DO	DA	DIC	DM	FC	FP	ESG
Full membership	1.800	1.750	2.200	2.000	1.750	1.900	2.250	2.000
Crossover point	3.600	3.750	3.800	3.600	3.250	3.500	3.750	3.400
Full non-membership	4.800	5.000	4.800	4.800	4.750	4.750	4.750	4.600

Table 9
Analysis of necessary conditions.

Conditional variable	High-level ESG		Conditional variable	High-level ESG	
	Consistency	Coverage		Consistency	Coverage
DR-JZ	0.661	0.638	~DIC-JZ	0.585	0.567
~DR-JZ	0.592	0.577	DM-JZ	0.686	0.696
DO-JZ	0.647	0.620	~DM-JZ	0.564	0.524
~DO-JZ	0.601	0.589	FC-JZ	0.720	0.694
DA-JZ	0.706	0.685	~FC-JZ	0.546	0.533
~DA-JZ	0.568	0.551	FP-JZ	0.713	0.741
DIC-JZ	0.669	0.650	~FP-JZ	0.567	0.516

Note: the symbol (~) demonstrates the condition is null.

Table 10
Sufficiency analysis of conditional configuration.

	Configurations				
	1	2	3	4	5
DA	Θ	Θ	O	O	
DIC			Θ	Θ	Θ
DM	●	●		●	●
DO	Θ		⊗	⊗	⊗
DR		Θ	O		Θ
FC	●	●	●	●	●
FP	●	●	●	●	●
Raw coverage	0.392	0.401	0.225	0.247	0.258
Unique coverage	0.048	0.023	0.019	0.000	0.000
Consistency	0.873	0.872	0.911	0.908	0.901
Solution coverage	0.510				
Solution consistency	0.856				

Note: ●core condition present; ⊗ opposite core condition present; Θ contributing condition present; O opposite contributing condition present. An empty cell represents an irrelevant condition.

thereby enriching the research approach in these fields.

Firstly, our research reveals that firm market performance positively impacts ESG ($Path_{FP\rightarrow ESG} = 0.482$, $p < 0.001$) and is present in all five antecedent configurations of ESG establishment (in Table 10). Many firms have embarked on digital transformation initiatives in the context of digital reform. By leveraging digital technology to enhance their market performance, they acquire the tools necessary for more substantial engagement in ESG practices. This result suggests that firms' engagement in ESG practices can be enhanced through improved market performance, leading to an increased societal impact. This finding aligns with RBV, as firms use their unique resources and capabilities to achieve a competitive advantage, leading to improved market performance and ESG outcomes (Barney, 1991). High-quality development of firms allows them to increase market share and profitability, providing numerous jobs for society. It is crucial in eradicating poverty and promoting social equity (Losa-Jonczyk, 2020). Moreover, improved firm market performance contributes to employees' psychological well-being by fostering investments in workforce development, material resources, and funds to enhance the working environment and job satisfaction (Kim et al., 2022). Such investments support employee training and continuing education, facilitating the joint sustainable development of employees and firms (Cristea et al., 2022; Kim et al., 2022).

Secondly, our study proposes and validates a research model linking firm digitization, firm market performance, and ESG based on the RBV and DCV theories. Our findings confirm that digital resources ($Path_{DR\rightarrow DA} = 0.456$, $p < 0.001$), digital organization ($Path_{DO\rightarrow DA} = 0.459$, $p < 0.001$), digital adoption ($Path_{DA\rightarrow DM} = 0.518$, $p < 0.001$), digital management ($Path_{DM\rightarrow FP} = 0.365$, $p < 0.001$), and firm competitiveness ($Path_{DM\rightarrow FP} = 0.376$, $p < 0.001$) all indirectly and positively affect ESG through firm market performance. Furthermore, we observe that digital management and firm competitiveness are key factors influencing ESG, as they appear in four groups in the antecedent configuration of ESG (in Table 10). This finding underscores the strategic role of digital transformation in enhancing firms' ESG practices, thereby contributing to sustainability. It is consistent with DCV, which emphasizes adapting and reconfiguring resources and capabilities in response to external changes (Teece et al., 1997).

Thirdly, our study observes that a digital innovation culture positively moderates the relationship between digital adoption ($Path_{DIC\times DA\rightarrow FC} = 0.132$, $p < 0.05$), digital management ($Path_{DIC\times DA\rightarrow DM} = 0.299$, $p < 0.001$), and firm competitiveness, which aligns with the DCV perspective in Section 2.3, as it demonstrates the role of dynamic capabilities in fostering adaptability and innovation (Teece et al., 1997). A digital innovation culture integrates digital technology (Yang et al., 2022b) and condenses public social opinion and government guidance on digitalization from the external environment into a cultural atmosphere. Firms that incorporate this digital innovation culture into their organization can experience significant benefits in implementing digital transformation, which can improve their market performance and ESG practices (Khattak et al., 2021). A digital innovation culture helps remove the ideological burden associated with implementing digital management and enables firm managers and employees to reach a consensus that promotes smooth digital transformation. Digital technology has demonstrated remarkable potential in product R&D design, process optimization, and transformation (Zhang et al., 2022b).

Fourth, our study sheds light on the specific implications of digital transformation for small and medium-sized enterprises (SMEs) in enhancing both market performance and ESG performance and enriches the research achievements in this field (in Table 1). The rise of digital technology and digital transformation has provided SMEs with unique development opportunities (Marcysiak and Pleskacz, 2021). To seize the digital dividend, firms should pay attention to the impact of technology, organization, and the environment (Xu et al., 2021). Digital transformation requires the consideration of digital resource reserves (human, material, and financial resources), adequate preparation of resources, strategy formulation and implementation, and digital

organization and management. These elements are vital for enhancing competitiveness and market access. Thus, firms should combine digital resources and personnel training to support digital technology applications and transformation. This process requires strong leadership and strategies to overcome resistance from internal and external stakeholders. Digital management aims to mitigate this resistance and facilitate efficient, engaging digital transformation, ultimately improving SMEs' competitiveness, market performance, and ESG outcomes, highlighting the importance of addressing the unique challenges and opportunities these enterprises face in the digital era. Our results suggest that the benefits of digital transformation extend beyond improving efficiency and competitiveness to enhancing ESG performance, highlighting a new dimension of the impact of digital transformation on SMEs.

In conclusion, by integrating and applying the Resource-Based View and Dynamic Capabilities View theories, our study makes several significant theoretical contributions to the literature on digital transformation, firm market performance, and ESG. We provide a validated research model that elucidates the relationships between these constructs and offers insights into the role of digital innovation culture in fostering successful digital transformation. Our findings serve as a foundation for future research and have practical implications for businesses seeking to enhance their market performance and ESG outcomes through digital transformation initiatives.

6.2. Practical implications

Our research, substantiated by fsQCA and PLS-SEM analysis findings, offers implementable and practical recommendations for practitioners and policymakers grounded in our results.

Firstly, applying Digital Solutions should take precedence, especially those that align with particular ESG objectives. For instance, SMEs could consider investing in energy management systems to streamline energy consumption and reduce greenhouse gas emissions. Alternatively, implementing supply chain management software could ensure responsible sourcing and fair labor practices. When digital transformation efforts are tied to ESG goals, technology can be effectively leveraged to enhance sustainability performance.

Secondly, the Strategic Integration of ESG objectives into the firm's overarching strategy is essential. To facilitate this, ESG leaders should be appointed to guide and oversee sustainability initiatives. Alongside this, firms should prioritize fostering digital competencies and sustainability awareness in employee training and development programs, empowering their workforce to contribute to ESG objectives.

The third recommendation is to encourage Cross-functional Synergy. By fostering cross-departmental collaboration and information exchange, firms can ensure that their digital transformation and ESG initiatives are coordinated and mutually reinforcing. An example could be IT and sustainability departments partnering to identify digital solutions that optimize resource use and minimize waste.

Fourthly, the implementation of Continuous Monitoring is essential. By applying a comprehensive ESG performance measurement framework, firms can track the progress of their digital transformation and sustainability initiatives. Regular review and adjustment of ESG strategy based on performance data will enable continuous improvement and flexibility in response to changing market conditions and stakeholder expectations.

It is also necessary to consider Industry-specific considerations for digital adoption. Digital adoption's impact varies across industries, each facing unique digital transformation opportunities and challenges. By recognizing these industry-specific nuances, practitioners can tailor their digital transformation strategies to address their field's unique challenges and opportunities, optimizing the benefits of digital adoption.

Lastly, the alignment of Business Objectives and Firm Culture is crucial. Companies must ensure that digital transformation efforts harmonize with business goals and foster a supportive corporate culture promoting digital innovation. In doing so, companies can maximize the use of digital technologies to achieve strategic objectives and create a comprehensive approach to digital transformation. Clear communication and support for employees throughout the digitalization process can ensure a smooth transition and encourage active engagement in digital initiatives.

By integrating these practical suggestions, companies can cultivate a cohesive approach to digital transformation and ESG performance enhancement, placing themselves in a position of competitive advantage and setting the stage for sustainable success.

6.3. Limitations and future research

This research has produced specific results, but there is room for improvement. The research sample is mainly derived from the cross-sectional data of firm respondents. The different impacts on ESG before and after the digital transformation would provide powerful lessons for the transformation process due to the adoption of digital tools and help in designing smoother paths; subsequent research can consider adopting a phased follow-up study and a Multigroup analysis (MGA) to explore differences in ESG practice between two data samples. One limitation of this study is that the second hypothesis, H2 (Digital adoption has a positive effect on market performance), was found unsupported in some cases, indicating that digital adoption might have different effects on market performance in specific situations or industries. As a result, we have added a discussion on how the impact of digital adoption may differ across various industries and scenarios, emphasizing the need for future research to explore this issue further. Future research could identify the conditions under which digital adoption leads to varying outcomes and further examine these relationships in different contexts. The measurement of the selected variables is derived from the subjective judgment of the respondents, which may lead to cognitive biases; in future research, various information and data collection methods can be considered, including case study methods, to obtain the expanded conclusions of this study. The samples in this study are all from China, and the regions and systems of different countries may have other impacts; an international comparative study would provide exciting lessons. Furthermore, future studies can also examine the potential moderating role of industry-specific factors, firm size, or market conditions in the relationship between digital adoption and market performance to better understand the findings' generalizability.

6.4. Conclusions

This research investigates the impact of digital transformation on firm market performance and ESG performance in Chinese small and medium-sized enterprises (SMEs). It establishes that digital transformation positively influences both aspects. The PLS-SEM analysis demonstrates that digital resources, organizational structure, technology adoption, management practices, and firm competitiveness all indirectly and positively impact ESG performance through the mediating effect of firm market performance. Furthermore, firm market performance has a direct positive influence on ESG performance. The fsQCA analysis reveals no singular precondition for establishing ESG performance; however, firm competitiveness and market performance are sufficient conditions for achieving strong ESG performance. It emphasizes the importance of fostering a competitive business environment and leveraging digital transformation to enhance market performance, ultimately driving improvements in ESG performance. This study also uncovers the moderating role of digital innovation culture, which positively influences the relationships between digital adoption and firm competitiveness, as well as digital adoption and digital management. Based on our findings, we provide theoretical, practical, and policy references to help SMEs improve their

competitiveness, market performance, and ESG practices. By incorporating these insights, SMEs can better leverage digital transformation to achieve sustainable growth and long-term success.

Ethics approval

Not applicable.

Funding

This work was supported by the Zhejiang Provincial Philosophy and Social Sciences Planning Project (45); Major Humanities and Social Sciences Research Projects in Zhejiang higher education institutions Grant Number (2023QN115); Zhejiang Soft Science Project (2023C35032); Ningbo Philosophy and Social Science Planning Project (G2023-2-55); Key Research Institute of Philosophy and Social Sciences of Zhejiang Province-Modern Port Service Industry and Creative Culture Research Center (2023); Zhejiang Federation of Humanities and Social Sciences Circles Research Project (2023N073); A Project Supported by Scientific Research Fund of Zhejiang Provincial Education Department (Y202248756); and Zhejiang Wanli University Project (HX2022154).

CRediT authorship contribution statement

Shaofeng Wang: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **José Paulo Esperança:** Visualization, Project administration, Funding acquisition, All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in,or the review of,the manuscript entitled “Can Digital Transformation Improve Market and ESG Performance? Evidence from Chinese SMEs”.

Data availability

Data will be made available on request.

Acknowledgment

Thanks to Liangwei Tu for their assistance in the language expression of the article.

References

Abbasi, G.A., Keong, K.Q.C., Kumar, K.M., Iranmanesh, M., 2022. Asymmetrical modelling to understand purchase intention towards remanufactured products in the circular economy and a closed-loop supply chain: an empirical study in Malaysia. J. Clean. Prod. 359, 132137.

Aboelmaged, M., 2018. The drivers of sustainable manufacturing practices in Egyptian SMEs and their impact on competitive capabilities: a PLS-SEM model. J. Clean. Prod. 175, 207–221.

Alkaraan, F., Albitar, K., Hussainey, K., Venkatesh, V.G., 2022. Corporate transformation toward Industry 4.0 and financial performance: the influence of environmental, social, and governance (ESG). Technol. Forecast. Soc. Change 175, 121423.

Andersen, T.C.K., Aagaard, A., Magnusson, M., 2022. Exploring business model innovation in SMEs in a digital context: organizing search behaviours, experimentation and decision-making. Creativ. Innovat. Manag. 31 (1), 19–34.

Baah, C., Agyabeng-Mensah, Y., Afum, E., Kumi, C.A., 2023. Do circular economy practices accelerate CSR participation of SMEs in a stakeholder-pressured era? A network theory perspective. J. Clean. Prod. 394, 136348.

Bag, S., Dhamija, P., Pretorius, J.H.C., Chowdhury, A.H., Giannakis, M., 2021. Sustainable electronic human resource management systems and firm performance: an empirical study. Int. J. Manpow. 43 (1), 32–51.

Banerjee, P.M., Campbell, B.A., 2009. Inventor bricolage and firm technology research and development. R&d Management 39 (5), 473–487.

Barney, J., 1991. Firm resources and sustained competitive advantage. J. Manag. 17 (1), 99–120.

Bătae, O.M., Dragomir, V.D., Feleagă, L., 2021. The relationship between environmental, social, and financial performance in the banking sector: a European study. J. Clean. Prod. 290, 125791.

Biggeri, M., Borsacchi, L., Braito, L., Ferrannini, A., 2023. Measuring the compliance of management system in manufacturing SMEs: an integrated model. J. Clean. Prod. 382, 135297.

Bilyay-Erdogan, S., Danisman, G.O., Demir, E., 2023. ESG Performance and Dividend Payout: A Channel Analysis. Finance Research Letters, 103827.

Broadstock, D.C., Chan, K., Cheng, L.T., Wang, X., 2021. The role of ESG performance during times of financial crisis: evidence from COVID-19 in China. Finance Res. Lett. 38, 101716.

Camodeca, R., Almici, A., 2021. Digital transformation and convergence toward the 2030 agenda’s sustainability development goals: evidence from Italian listed firms. Sustainability 13 (21), 11831.

Cepeda-Carrion, G., Cegarra-Navarro, J.G., Cillo, V., 2018. Tips to use partial least squares structural equation modelling (PLS-SEM) in knowledge management. J. Knowl. Manag. 23 (1), 67–89.

Chatterjee, S., Rana, N.P., Tamilmani, K., Sharma, A., 2021a. The effect of AI-based CRM on organization performance and competitive advantage: an empirical analysis in the B2B context. Ind. Market. Manag. 97, 205–219.

Chatterjee, S., Chaudhuri, R., Vrontis, D., 2021b. Does data-driven culture impact innovation and performance of a firm? An empirical examination. Ann. Oper. Res. 1–26.

Chen, D., Esperança, J.P., Wang, S., 2022. The impact of artificial intelligence on firm performance: an application of the resource-based View to e-commerce firms. Front. Psychol. 13, 884830.

Ciampi, F., Demi, S., Magrini, A., Marzi, G., Papa, A., 2021. Exploring the impact of big data analytics capabilities on business model innovation: the mediating role of entrepreneurial orientation. J. Bus. Res. 123, 1–13.

Correani, A., De Massis, A., Frattini, F., Petruzzelli, A.M., Natalicchio, A., 2020. Implementing a digital strategy: learning from the experience of three digital transformation projects. Calif. Manag. Rev. 62 (4), 37–56.

Cristea, M., Noja, G.G., Thalassinos, E., Cîrciumaru, D., Ponea, C.Ş., Dură̆u, C.C., 2022. Environmental, social and governance credentials of agricultural companies—the interplay with company size. Resources 11 (3), 30.

Dahms, S., 2020. Power, CSR strategy, and performance in foreign-owned subsidiaries. Can. J. Adm. Sci. Rev. Canad. Sci. Adm. 37 (3), 315–333.

Dubey, R., Gunasekaran, A., Childe, S.J., Luo, Z., Wamba, S.F., Roubaud, D., Foropon, C., 2018. Examining the role of big data and predictive analytics on collaborative performance in context to sustainable consumption and production behaviour. J. Clean. Prod. 196, 1508–1521.

Dutot, V., Bergeron, F., Calabrò, A., 2021. The impact of family harmony on family SMEs’ performance: the mediating role of information technologies. J. Fam. Bus. Manag.

Emara, N., Zhang, Y., 2021. The non-linear impact of digitization on remittances inflow: evidence from the BRICS. Telecommun. Pol. 45 (4), 102112.

Fang, M., Nie, H., Shen, X., 2023. Can enterprise digitization improve ESG performance? Econ. Modell. 118, 106101.

Fatemi, A., Glaum, M., Kaiser, S., 2018. ESG performance and firm value: the moderating role of disclosure. Global Finance J. 38, 45–64.

Fonseka, K., Jaharadak, A.A., Raman, M., 2022. Impact of E-commerce adoption on business performance of SMEs in Sri Lanka; moderating role of artificial intelligence. Int. J. Soc. Econ. (ahead-of-print).

Garcia, A.S., Mendes-Da-Silva, W., Orsato, R.J., 2017. Sensitive industries produce better ESG performance: evidence from emerging markets. J. Clean. Prod. 150, 135–147.

Ghasemaghaei, M., 2021. Understanding the impact of big data on firm performance: the necessity of conceptually differentiating among big data characteristics. Int. J. Inf. Manag. 57, 102055.

Gosling, S.D., Vazire, S., Srivastava, S., John, O.P., 2004. Should we trust web-based studies? A comparative analysis of six preconceptions about internet questionnaires. Am. Psychol. 59 (2), 93.

Guerra, J.M.M., Danvila-del-Valle, I., Suárez, M.M., 2023. The impact of digital transformation on talent management. Technol. Forecast. Soc. Change 188, 122291.

Hair, J.F., Hult, G.T.M., Ringle, C.M., Sarstedt, M., 2022. A Primer on Partial Least Squares Structural Equation Modelling (PLS-SEM), third ed. Sage.

Hayajneh, J.A.M., Elayan, M.B.H., Abdellatif, M.A.M., Abubakar, A.M., 2022. Impact of business analytics and π-shaped skills on innovative performance: findings from PLS-SEM and fsQCA. Technol. Soc. 68, 101914.

Hu, J., Zou, Q., Yin, Q., 2023. Research on the Effect of ESG Performance on Stock Price Synchronicity: Empirical Evidence from China’s Capital Markets. Finance Research Letters, 103847.

Jabbour, C.J.C., Jugend, D., de Sousa Jabbour, A.B.L., Gunasekaran, A., Latan, H., 2015. Green product development and performance of Brazilian firms: measuring the role of human and technical aspects. J. Clean. Prod. 87, 442–451.

Kazancoglu, I., Ozbiltekin-Pala, M., Mangla, S.K., Kazancoglu, Y., Jabeen, F., 2022. Role of flexibility, agility and responsiveness for sustainable supply chain resilience during COVID-19. J. Clean. Prod. 362, 132431.

Khattak, A., Tabash, M.I., Yousaf, Z., Radulescu, M., Nassani, A.A., Haffar, M., 2021. Towards innovation performance of SMEs: investigating the role of digital platforms, innovation culture and frugal innovation in emerging economies. Journal of Entrepreneurship in Emerging Economies.

Khin, S., Ho, T.C., 2019. Digital technology, digital capability and organizational performance. Int. J. Innovat. Sci. 11 (2), 177–195.
Kim, H.S., Kim, M., Koo, D., 2022. From teamwork to psychological well-being and job performance: the role of CSR in the workplace. Int. J. Contemp. Hospit. Manag. (ahead-of-print).
Kumar, P., Dwivedi, Y.K., Anand, A., 2021. Responsible artificial intelligence (AI) for value formation and market performance in healthcare: the mediating role of patient's cognitive engagement. Inf. Syst. Front 1–24.
Laguir, I., Stekelorum, R., Laguir, L., Staglianò, R., 2021. Managing corporate social responsibility in the bank sector: a fuzzy and disaggregated approach. Corp. Soc. Responsib. Environ. Manag. 28 (4), 1324–1334.
Lee, M.T., Raschke, R.L., Krishen, A.S., 2022. Signaling green! firm ESG signals in an interconnected environment that promote brand valuation. J. Bus. Res. 138, 1–11.
Liang, Y., Lee, M.J., Jung, J.S., 2022. Dynamic capabilities and an ESG strategy for sustainable management performance. Front. Psychol. 13, 887776.
Liszbinski, B.B., Brizolla, M.M.B., Patias, T.Z., 2023. Driving factors for the involvement of agroindustries in the sustainable development goals. J. Clean. Prod., 137279
Liu, P., Zhu, B., Yang, M., Chu, X., 2022. ESG and financial performance: a qualitative comparative analysis in China's new energy companies. J. Clean. Prod. 379, 134721.
Losa-Jonczyk, A., 2020. Communication strategies in social media in the example of ICT companies. Information 11 (5), 254.
Malhotra, M.K., Grover, V., 1998. An assessment of survey research in POM: from constructs to theory. J. Oper. Manag. 16 (4), 407–425.
Malik, S., Chadhar, M., Vatanasakdakul, S., Chetty, M., 2021. Factors affecting the organizational adoption of blockchain technology: extending the technology–organization–environment (TOE) framework in the Australian context. Sustainability 13 (16), 9404.
Marcysiak, A., Pleskacz, Ż., 2021. Determinants of digitization in SMEs. Entrepreneurship and Sustainability Issues 9 (1), 300–318.
Mardani, A., Kannan, D., Hooker, R.E., Ozkul, S., Alrasheedi, M., Tirkolaee, E.B., 2020. Evaluation of green and sustainable supply chain management using structural equation modelling: a systematic review of the state of the art literature and recommendations for future research. J. Clean. Prod. 249, 119383.
Martínez-Caro, E., Cegarra-Navarro, J.G., Alfonso-Ruiz, F.J., 2020. Digital technologies and firm performance: the role of digital organisational culture. Technol. Forecast. Soc. Change 154, 119962.
Mikalef, P., Gupta, M., 2021. Artificial intelligence capability: Conceptualization, measurement calibration, and empirical study on its impact on organizational creativity and firm performance. Inf. Manag. 58 (3), 103434.
Moroni, I.T., Seles, B.M.R.P., Lizarelli, F.L., Guzzo, D., da Costa, J.M.H., 2022. Remanufacturing and its impact on dynamic capabilities, stakeholder engagement, eco-innovation and business performance. J. Clean. Prod. 371, 133274.
Navickas, V., Kontautiene, R., Stravinskienė, J., Bilan, Y., 2021. Paradigm shift in the concept of corporate social responsibility: COVID-19. Green finance 3 (2), 138–152.
Pagoropoulos, A., Maier, A., McAloone, T.C., 2017. Assessing transformational change from institutionalising digital capabilities on implementation and development of Product-Service Systems: learnings from the maritime industry. J. Clean. Prod. 166, 369–380.
Pergelova, A., Manolova, T., Simeonova-Ganeva, R., Yordanova, D., 2019. Democratizing entrepreneurship? Digital technologies and the internationalization of female-led SMEs. J. Small Bus. Manag. 57 (1), 14–39.
Pinheiro, M.A.P., Jugend, D., Lopes de Sousa Jabbour, A.B., Chiappetta Jabbour, C.J., Latan, H., 2022. Circular economy-based new products and company performance: the role of stakeholders and Industry 4.0 technologies. Bus. Strat. Environ. 31 (1), 483–499.
Pizzi, S., Corbo, L., Caputo, A., 2021. Fintech and SMEs sustainable business models: reflections and considerations for a circular economy. J. Clean. Prod. 281, 125217.
Pozzoli, M., Pagani, A., Paolone, F., 2022. The impact of audit committee characteristics on ESG performance in the European Union member states: empirical evidence before and during the COVID-19 pandemic. J. Clean. Prod. 371, 133411.
Puriwat, W., Tripopsakul, S., 2022. From ESG to DESG: the impact of DESG (digital environmental, social, and governance) on customer attitudes and brand equity. Sustainability 14 (17), 10480.
Rahman, M.S., Hossain, M.A., Fattah, F.A.M.A., 2021. Does marketing analytics capability boost firms' competitive marketing performance in data-rich business environment? J. Enterprise Inf. Manag. 35 (2), 455–480.
Rahman, M.S., AbdelFattah, F.A., Bag, S., Gani, M.O., 2022. Survival strategies of SMEs amidst the COVID-19 pandemic: application of SEM and fsQCA. J. Bus. Ind. Market.
Rahman, H.U., Zahid, M., Al-Faryan, M.A., 2023. ESG and firm performance: the rarely explored moderation of sustainability strategy and top management commitment. J. Clean. Prod., 136859
Reim, W., Yli-Viitala, P., Arrasvuori, J., Parida, V., 2022. Tackling business model challenges in SME internationalization through digitalization. Journal of Innovation & Knowledge 7 (3), 100199.
Reyes-Rodríguez, J.F., 2021. Explaining the business case for environmental management practices in SMEs: the role of organisational capabilities for environmental communication. J. Clean. Prod. 318, 128590.
Rozak, H.A., Adhiatma, A., Fachrunnisa, O., Rahayu, T., 2021. Social media engagement, organizational agility and digitalization strategic plan to improve SMEs' performance. IEEE Trans. Eng. Manag.
Simmou, W., Govindan, K., Sameer, I., Hussainey, K., Simmou, S., 2023. Doing good to be green and live clean!-Linking corporate social responsibility strategy, green innovation, and environmental performance: evidence from Maldivian and Moroccan small and medium-sized enterprises. J. Clean. Prod. 384, 135265.
Soh, K.L., Wong, W.P., 2021. Circular economy transition: exploiting innovative eco-design capabilities and customer involvement. J. Clean. Prod. 320, 128858.
Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strat. Manag. J. 18 (7), 509–533.
Varadarajan, R., Welden, R.B., Arunachalam, S., Haenlein, M., Gupta, S., 2022. Digital product innovations for the greater good and digital marketing innovations in communications and channels: evolution, emerging issues, and future research directions. Int. J. Res. Market. 39 (2), 482–501.
Vial, G., 2019. Understanding digital transformation: a review and a research agenda. J. Strat. Inf. Syst. 28 (2), 118–144.
Villalba-Ríos, P., Barroso-Castro, C., Vecino-Gravel, J.D., 2022. The influence of CEO profile on corporate social responsibility companies. A qualitative comparative analysis. Corp. Soc. Responsib. Environ. Manag. 29 (2), 356–366.
Wang, S., Paulo Esperança, J., Wu, Q., 2022. Effects of live streaming proneness, engagement and intelligent recommendation on users' purchase intention in short video community: take TikTok (DouYin) online courses as an example. Int. J. Hum. Comput. Interact. 1–13.
Wang, S., Esperança, J.P., Yang, W., Zhang, J.Z., 2023. Investigating the determinants of new technology entrepreneurial performance: an empirical study with PLS-SEM and MGA. Journal of the Knowledge Economy 1–26.
Wang, J., Song, Z., Xue, L., 2023a. Digital technology for good: path and influence—based on the study of ESG performance of listed companies in China. Appl. Sci. 13 (5), 2862.
Wang, W., Sun, Z., Wang, W., Hua, Q., Wu, F., 2023b. The impact of environmental uncertainty on ESG performance: emotional vs. rational. J. Clean. Prod. 397, 136528.
Xiang, D., Zhao, T., Zhang, N., 2022. How can government environmental policy affect the performance of SMEs: Chinese evidence. J. Clean. Prod. 336, 130308.
Xu, J., Pero, M.E.P., Ciccullo, F., Sianesi, A., 2021. On relating big data analytics to supply chain planning: towards a research agenda. Int. J. Phys. Distrib. Logist. Manag. 51 (6), 656–682.
Yang, W., Wang, S., Chen, C., Leung, H.H., Zeng, Q., Su, X., 2022a. Knowledge mapping of enterprise network research in China: a visual analysis using CiteSpace. Front. Psychol. 13, 898538.
Yang, Z., Likai, Z., Ruoyu, L., 2022b. The impact of network ties on SMEs' business model innovation and enterprise growth: evidence from China. IEEE Access 10, 29846–29858.
Yin, S., Yu, Y., 2022. An adoption-implementation framework of digital green knowledge to improve the performance of digital green innovation practices for industry 5.0. J. Clean. Prod. 363, 132608.
Yu, J., Zhu, L., 2022. Corporate ambidexterity: uncovering the antecedents of enduring sustainable performance. J. Clean. Prod. 365, 132740.
Yu, F., Jiang, D., Zhang, Y., Du, H., 2021. Enterprise Digitalisation and Financial Performance: the Moderating Role of Dynamic Capability. Technology Analysis & Strategic Management, pp. 1–17.
Zhang, J., Long, J., von Schaewen, A.M.E., 2021a. How does digital transformation improve organizational resilience?—findings from PLS-SEM and fsQCA. Sustainability 13 (20), 11487.
Zhang, T., Shi, Z.Z., Shi, Y.R., Chen, N.J., 2022b. Enterprise digital transformation and production efficiency: mechanism analysis and empirical research. Economic Research-Ekonomska Istraživanja 35 (1), 2781–2792.
Zhou, H., Chen, Y., Liu, Y., Wang, Q., Liang, Y., 2022. Farmers' adaptation to heavy metal pollution in farmland in mining areas: the effects of farmers' perceptions, knowledge and characteristics. J. Clean. Prod. 365, 132678.

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

Digital transformation empowers ESG performance in the manufacturing industry: From ESG to DESG / Wang, J., Hong, Z., & Long, H.

SAGE Open
Volume 13 Issue 4 (2023) Pages 1-21
https://doi.org/10.1177/21582440231204158
(Database: SAGE Publications Inc.)

Original Research

SAGE Open
October-December 2023: 1–21

DOI: 10.1177/21582440231204158
journals.sagepub.com/home/sgo
Sage

Digital Transformation Empowers ESG Performance in the Manufacturing Industry: From ESG to DESG

Jin Wang[1], Zihan Hong[1], and Hai Long[2]

Abstract

Digital transformation (DT) is a long-term strategy for economic sustainability, particularly for manufacturing-oriented economies. This study proposes a digital ESG (DESG) theoretical framework to investigate how DT empowers ESG performance in the manufacturing industry. Using Python, we collected data from Chinese manufacturing firms from 2009 to 2020. This study used the ordinary least squares method to examine the relationships among DT, ESG performance, and manufacturing ESG heterogeneity. The results suggest that big companies and growing firms pay more attention to their ESG performance than others and that state-owned enterprises are keen on ESG performance but underperform. Additionally, DT may contribute to manufacturing ESG performance in general; labor-intensive and non-state-owned enterprises benefit more from DT than their counterparts; and manufacturers in economically developed regions show more significant ESG performance thanks to DT. These findings support the use of a DESG theoretical framework in the manufacturing industry whereby digital technologies facilitate business production and improve the business profits of manufacturing firms, so that manufacturers have sufficient profits to conduct ESG investments for sustainable development in a virtuous cycle.

JEL Classification: O32, O44, Q56

Keywords

digital transformation, ESG performance, digital ESG, ESG heterogeneity, manufacturing ESG

Introduction

The United Nations announced in 2015, "The 2030 Agenda for Sustainable Development", which called for sustainable development in all countries. To achieve this goal, the performance associated with sustainability of any organization is assessed using the ESG (environmental, social, and governance) approach (Naffa & Fain, 2020). Since then, ESG has become a complex but very crucial strategy for sustainable development across the world, particularly in the post-COVID-19 era, during which business development was interrupted; each enterprise should have strong environmental awareness, take more social responsibility, and establish a sound governance system to initiate a sustainable business ecosystem.

The ESG concept has attracted a wide range of studies since then, including research in the institutional context (Baldini et al., 2018), on investor preference (Jiang et al., 2022), customer benefits (Akram et al., 2021), digital finance (Mu et al., 2023), etc. The systematic literature review by Daugaard (2020) documents five key strands of research on ESG, including the heterogeneous nature of ESG investment, ESG investment costs, ESG investment motivations, ESG contributions to business management, and ESG performance measurement. It also shows five emerging themes: emerging non-Western investors, human-associated elements, fund flow-oriented perspectives, climate change-based factors, and fixed income-specific factors. In addition, more recent studies discuss ESG disclosure (E. P. Yu & Luu, 2021), the ESG effect on stock markets (Baker et al., 2021; Luo et al., 2022), and the relationship between ESG performance and corporate governance (Agnese & Giacomini, 2023; Z. Chen & Xie, 2022; Gigante & Manglaviti, 2022). All

[1]Guangdong Polytechnic Normal University, Guangzhou, China
[2]International College, Krirk University, Bangkok, Thailand

Corresponding Author:
Hai Long, International College, Krirk University, No. 3 Soi Ramindra 1, Bangkok 10220, Thailand.
Email: soholonghai@163.com

in all, the published research dominantly investigates ESG characteristics and prefers to examine ESG effects on some other factors.

However, little research has shed light on solutions for the improvement of manufacturing ESG, although a comprehensive review study by Gillan et al. (2021) uncovers some factors from various perspectives, such as market characteristics, executive compensation, firm performance and value, ownership, and firm risk. Additionally, Du and Jiang (2022) support the existence of a positive relationship between digital transformation (DT) and firm productivity in Chinese enterprises. Saxena et al. (2023) suggest that advanced technologies empower ESG performance from an Industry 4.0 perspective. The advanced e-learning technologies may contribute to sustainability in the new normality era (Fülöp et al., 2022, 2023). Nevertheless, the baseline theoretical framework of DT as an ESG solution in the specific manufacturing industry has been investigated less often.

This is a vital topic because the economy of developing countries is mostly driven by the manufacturing industry, and economic sustainability in merging nations depends on sustainable manufacturing. Additionally, developing economies are characterized by industrialization, so ESG investment in the manufacturing industry is crucial for economic sustainability in developing countries. Empirical evidence shows that during the COVID-19 outbreak, poorly digitized institutions were fragile, while high-level-digitization organizations were quite flexible (Fletcher & Griffiths, 2020). Accordingly, this study bridges this gap and proposes upgrading ESG to digital ESG (DESG) as a solution for sustainable development in the manufacturing industry. By sampling Chinese manufacturing firms, it further examines how digitization contributes to ESG performance in the manufacturing industry.

Studies investigating the heterogeneity of DT effects on ESG performance are few and far between (no related research could be found in Google Scholar by searching for "ESG spatial heterogeneity"), although the digitization contribution to economic growth from a macro-perspective and to ESG performance from a micro-perspective has been extensively discussed in general. This study bridges the gap to investigate how DT differently contributes to ESG performance in the manufacturing industry in different manufacturing aspects, such as ownership, labor intensity, and spatial heterogeneity. Manufacturers from different regions with different economic and business contexts have various DT demands and ESG awareness, so the general findings from existing studies may not address heterogeneity.

China, as the global leader in manufacturing operations, has achieved remarkable development over recent decades (L. Li, 2013). China's manufacturing industry consists of 31 categories with 609 sub-categories, fully covering the whole industrial chain of the major categories. Thus, this study, which is based on China's manufacturing industry, has reference value for other manufacturing-oriented countries. Since the concept of Industry 4.0 transforming machine-dominant into digitization-driven manufacturing was introduced in Germany in 2011 (Aceto et al., 2020), DT has been encouraged by the majority of manufacturing firms, because it can boost enterprise profitability (Du & Jiang, 2022). Additionally, emerging environmentally friendly technologies, such as the Internet of Things (IoT) and cloud computing, may also facilitate sustainable development with less pollution in the long run. Especially during the outbreak of the COVID-19 pandemic, DT facilitated working from home, online teaching, and online meeting; thus, its advantages are prominent and have attracted extensive discussions. On this basis, it is proposed that DT could contribute to the ESG performance of manufacturing firms in developing countries. This study aims to address this question.

Building on the argument above, this study proposes a digital ESG (DESG) theoretical framework to investigate how DT empowers ESG performance in the manufacturing industry. Using Python, we collected data from Chinese manufacturing firms from 2009 to 2020, and we employed the ordinary least squares (OLS) method to examine the relationships among DT, ESG performance, and manufacturing ESG heterogeneity. The results show that DT may contribute to manufacturing ESG performance in general, that labor-intensive and non-state-owned enterprises benefit more from DT than their counterparts, and that manufacturers in economically developed regions show more significant ESG performance thanks to DT. This research presents a DESG theoretical framework whereby digital technologies facilitate business production and improve the business profits of manufacturing firms, so that manufacturers have sufficient profits to invest in ESG for sustainable development in a virtuous cycle.

The research contributions are threefold: First, this study demonstrates a baseline theoretical framework whereby DT contributes to manufacturing ESG performance in developing counties, called DESG theory. This theory can be viewed as a favorable solution for ESG improvement in the manufacturing industry. Second, it uncovers the heterogeneity of DT effects on manufacturing ESG performance in terms of ownership, labor intensity, and spatial aspects. This research also expands the relevant research on the economic spillover effects of DT. Third, as China has the vast majority of industrial chains, this study, which is based on China's manufacturing industry, has reference value for the sustainable development of manufacturing-driven developing

economies. The findings are helpful for policy makers and enterprise managers in developing countries to use DT to promote energy conservation and emission reduction in enterprises, and provide a certain theoretical reference and method reference for realizing green transformation and low-carbon goals.

Theoretical Framework and Hypotheses

From a macro-perspective, digital infrastructures significantly facilitate economic growth in developed and developing countries (Shiu & Lam, 2008), and their contribution penetrates the industry in the Industry 4.0 era as the manufacturing industry upgrades from an equipment-dominated model to a digitization-oriented model (Aceto et al., 2020), namely, it undergoes digital transformation. DT refers to using new digital technologies to improve major businesses by, for example, creating new business models, satisfying customer demands, increasing firm performance, etc. (Fitzgerald et al., 2014).

As Route 1 in Figure 1 shows, these novel technologies include artificial intelligence (AI), data mining, cloud computing, the IoT, block chain, etc., and may contribute to ESG improvement. These digital technologies play a crucial role in accurate ESG reporting, and ESG investment is associated with AI capabilities (Saxena et al., 2023). In addition, Sætra (2023) argues that the AI ESG protocol is a solution for ESG assessment and disclosure. D'Amato et al. (2022) employed a machine learning approach to assess the effect of financial balance sheets on the ESG score. Furthermore, Big Data have been widely used for ESG reporting (Lee & Kang, 2016). Landaluce et al. (2020) suggest that IoT devices facilitate the collection of real-time data for ESG assessment. Liu et al. (2021) assert that a block chain-based framework can be helpful for ESG evaluation. Thus, ESG improvement is significantly related to digital technology development.

Route 2 in Figure 1 shows that some literature studies document the relationship between DT and ESG performance from the perspectives of the environment, social responsibility, and corporate governance. P. Chen and Hao (2022) evidence that DT may remarkably promote the corporate environment in Chinese listed firms and that DT willingness is determined by various firm board structures promoting national diversity, different political connections, age diversity, etc. Burritt and Christ (2016) argue that the technological process of Industry 4.0 has motivated a comprehensive digital revolution in general, which could eventually contribute to environmental conservation. Furthermore, Gupta et al. (2020) demonstrate that cloud computing technology such as cloud ERP systems could optimize resource utilization and accordingly contribute to environmental performance. Furthermore, DT may not only cultivate environmental awareness of consumers in terms of shopping activities (D. Li & Shen, 2021) but also motivate environmental innovation, because personalized products cater to customer demands and accordingly maximize product value for both consumers and manufacturers (Varadarajan, 2020).

In terms of social responsibility, Baker et al. (2021) document that green innovation and technological improvement motivate enterprises to take more social responsibility, because DT facilitates recognizing and acquiring information from shareholders, consequently promoting information disclosure quality. Consistently, employees in social responsibility-engaged firms are more motivated to improve new production processes and look for new technologies and methods (Broadstock et al., 2020). Especially during the COVID-19 lockdown period, digital technologies played a remarkable role in social responsibility within business sustainability, as in the cases of working from home, online shopping (Wade & Shan, 2020), and online studying (Fülöp et al., 2022). Accordingly, the association between DT and social responsibility has been strengthened.

Regarding corporate governance, digital transformation contributes to the operating performance of manufacturing firms, because DT facilitates manufacturers in dynamically monitoring the production process and ultimately improving firm operating performance. Jabbour et al. (2018) discuss some crucial determinants for the integration of DT and environmentally sustainable manufacturing and support the existence of a positive relationship between them, because digital technologies could provide firm managers with real-time information about production, logistics, and customer services; thus, this efficient business environment could promote sustainable development. Additionally, excellent ESG performance not only can maximize shareholder value, but it can also maximize firm lawsuits, so that firms have more capital for corporate governance (Albuquerque et al., 2019). On the contrary, underperformance indicates an unsound governance system that may damage the interests of both internal and external stakeholders and result in a range of negative effects, such as decrease in firm value and interruption of firm sustainability (Jones, 1995).

Furthermore, DT contributions to corporate governance have been extensively discussed in other aspects. For instance, DT could contribute to productivity (Du & Jiang, 2022), financial performance (Hajli et al., 2015), competitiveness advantages (Benner & Waldfogel, 2023; Bruce et al., 2017), and innovation performance (Ferreira et al., 2019; Usai et al., 2021). Therefore, outstanding governance performance may promote firm profit and value, resulting in firms having more capital to pursue

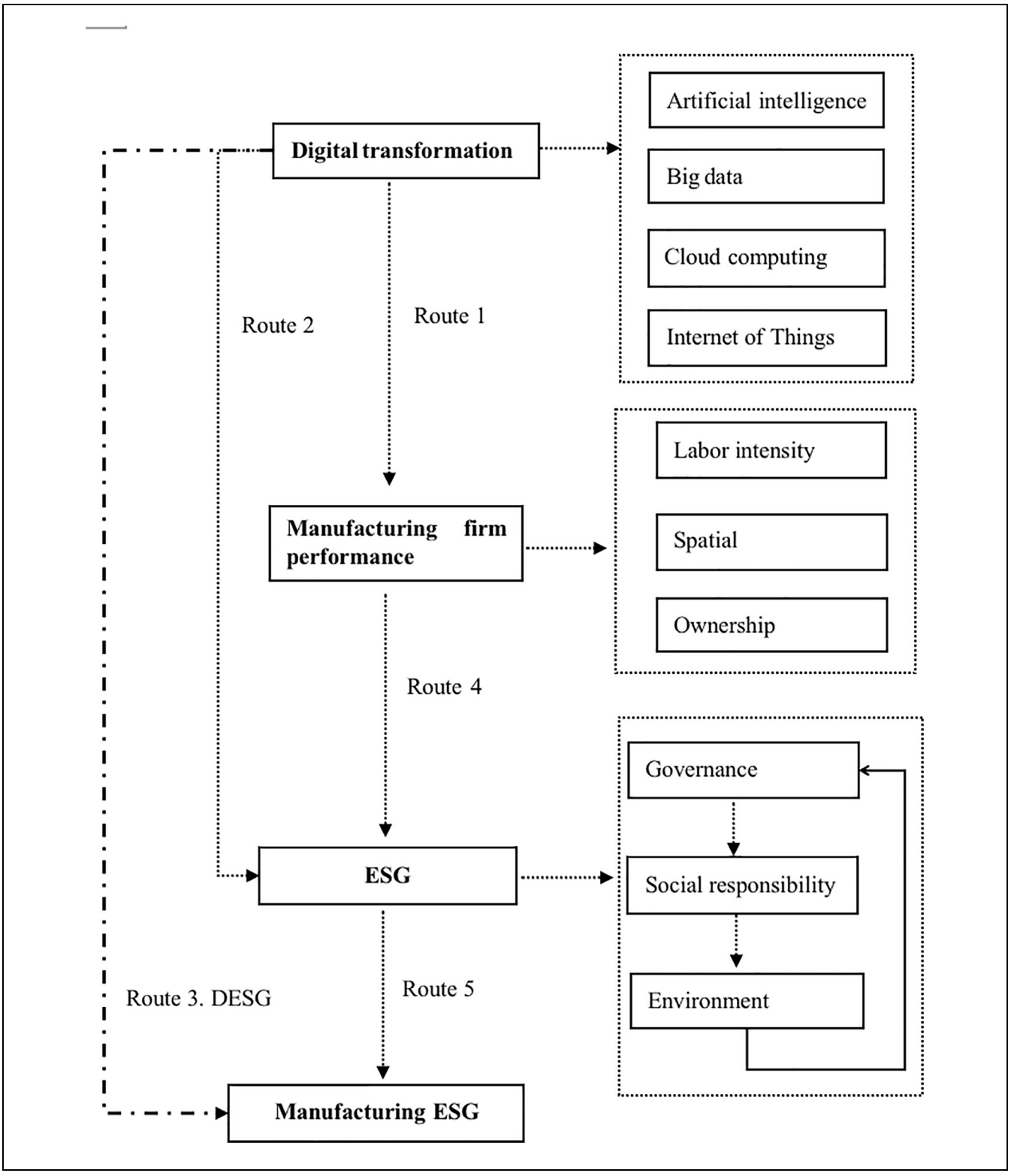


Figure 1. A route map of DT contributions to digital ESG in the manufacturing industry.

ESG investment. Therefore, this development concept calls for managers to pursue the upgrading of technologies in the digitalization era.

However, specific studies discussing how DT improves the ESG performance of manufacturing firms are scarce (Route 3 in Figure 1), and there are no existing literature

studies directly theorizing the relationship between digital transformation and manufacturing ESG. The indirect relationship can be theorized through Route 1, Route 4, and Route 5, respectively. As discussed above, DT upgrades manufacturing technologies that improve business performance (Du & Jiang, 2022), so that outstandingly performing manufacturers have sufficient money for ESG investment (Aich et al., 2021), as indicated by Route 4; furthermore, economic returns motivate stakeholders to consider ESG performance for sustainable development in the long run.

Based on the above, a DESG theoretical framework for the manufacturing industry is inferred for Route 3 and investigated in this paper. Digital technologies facilitate business production and improve the business profits of manufacturing firms, so that manufacturers have sufficient profits to invest in ESG for sustainable development. Such ESG performance may promote manufacturers' social reputation and strengthen firm competitiveness, consequently increasing firm value. This virtuous cycle facilitates the sustainable development of manufacturers. This study proposes the below hypothesis.

H1: The greater the digital transformation is, the better the ESG performance of manufacturing firms in developing economies is.

The heterogeneity of DT effects on ESG performance manifests as labor intensity, spatial differences, and ownership. Manufacturing, as an economic driver in developing countries, has characteristic heterogeneity in terms of labor intensity, spatial characteristics, and ownership (Huang et al., 2021). Heterogeneity can result in different effects of DT on ESG performance, so general findings that lack heterogeneity analyses would be unable to address these aspect-specific issues. This study conducted an in-depth analysis to investigate heterogeneity in terms of labor intensity, spatial characteristics, and ownership.

In terms of labor intensity, labor is the most important advantage for manufacturing firms in developing countries, as economic growth may benefit from labor-intensive industries (Banerji, 1975). With the gradually growing labor cost, DT is an optimum option to address labor cost-related issues, through which manufacturers can save more money to invest in productivity and governance performance (Du & Jiang, 2022), which accordingly improves ESG performance. On the contrary, the effect of DT on ESG performance in less labor-intensive industries may be different. Additionally, DT application has remarkably increased labor wage in the manufacturing industry, but it has also reduced the employment rate, and this effect varies across industries (Dai et al., 2022). Graetz and Michaels (2018) report a similar finding, indicating that low-skill-based positions are more easily replaced by AI. This significant unemployment rate challenges the social responsibility of DT-orientated manufacturers; however, some studies suggest a positive relationship between DT and employment rates. Pissarides (2000) asserts that upgrading technologies drives economic growth, which generates a number of new jobs, which in turn increases employment demands (labor intensity).

Furthermore, in labor-intensive manufacturing firms, digital technologies facilitate assessing employee working performance with accuracy, which motivates their innovative potentials and increases their job satisfaction (Leonardi & Contractor, 2018); accordingly, this improves the firm ESG performance, because DT optimizes corporate governance, making insider information transparent, drawing attention to job performance, and making incomes fair (Marler & Dulebohn, 2005). Based on the above discussion, this study proposes a second hypothesis, reported below.

H2: The DT effects on ESG performance are more significant in labor-intensive manufacturing firms than in others.

From the spatial heterogeneity perspective, uneven regional development disparity manifests in many forms in the long run, such as economic, institutional, cultural, and social aspects (Breinlich et al., 2014). As DT is a new technology-based business process, its application and development need a large number of advanced technicians; developed regions may attract more technical talents than others, which potentially leads to DT implementation heterogeneity. Additionally, the disparity is associated with firm performance heterogeneity. Manufacturing firms in developed regions have more transparent governance information, stronger environmental awareness, and more social responsibility than others, which attracts more outside investors and increases firm value (Zhou et al., 2022). Thus, these firms are more likely to invest in ESG and achieve technological innovation.

The ESG options for manufactures in different regions vary and are determined by local economic, institutional, and cultural factors. Furthermore, local digitization varies because of these factors. Accordingly, the spatial heterogeneity of DT effects on ESG performance occurs. South China's economy develops well with efficient institutions, where manufacturers regard public environmental awareness and social responsibility as important strategies. In addition, well-developed local economies support local fiscal expenditure on improving the business environment and funding manufacturers, which eases the financial pressure on firms, which consequently have more money to invest in ESG performance. Furthermore, manufacturers have more options to deal with their capital shortage in economically developed

regions. In contrast, manufacturers in North China have fewer advantages because of underperforming local economies; the majority of manufacturers have no digitization awareness but may want to invest in ESG. Presumably, the DT effect on ESG in South China is more significant than that in North China.

Digital infrastructure disparity may also result in spatial heterogeneity. Comparably, the digital infrastructure is well constructed in South China, where the integration of digitization and production optimizes the industrial structure in the long run, accelerates digital transformation, and eventually drives high-quality economy (Tian & Li, 2022). All these outcomes contribute to the potential of ESG. As North China lags in these aspects, manufacturers have no motivation in terms of technological inputs and ESG investment. Therefore, a hypothesis on spatial heterogeneity is proposed below.

H3: The DT effects on ESG performance in developed South China economies are more significant than those in underdeveloped North China economies.

Regarding ownership heterogeneity, SOEs have greater access to financial support from the government and state-owned institutions (Shih et al., 2021), so they have no short-term capital pressure on business operation and have sufficient money to invest in ESG. Additionally, the marginal effect of ESG improvement is very low in SOEs. Furthermore, SOEs take more social responsibility for media coverage and political promotion, such as employment and environment protection (Hsu et al., 2021). On the other hand, non-SOEs have no incentives; they pursue short-term business and market returns (Zhou et al., 2022), risk management (Wen et al., 2022), and better financial performance (Z. Chen & Xie, 2022) and reduce information asymmetry between managers and shareholders (He et al., 2022). To achieve this target, non-SOEs implement DT programs to improve ESG performance, showing stakeholders development potential in the long run (M. Yu & Pan, 2010).

On the other hand, L. Xu et al. (2020) suggest that SOEs have significant agency issues deriving from managers who engage in ESG investment for their personal reputation and political connections. For instance, SOE managers overdo ESG investments for their political performance when national elections approach. This attempt results in a negative relationship between ESG performance and firm financial performance (Brammer et al., 2006). From this point of view, ESG performance in non-SOEs is more likely to be better than that in SOEs.

SOEs and non-SOEs have different DT purposes. SOEs have dual roles, acting as governors and participants; thus, the DT and ESG strategy is more motivated by institutional and political factors than economic ones (B. Wang & Yang, 2022). On the other hand, non-SOEs, as pure market participants, engage in ESG projects to pursue growing economic returns and market value. Therefore, the relationship between DT and ESG is stronger in non-SOEs than in SOEs.

As Shih et al. (2021) suggest, SOEs have greater access to financial support from the government and state-owned institutions, and sufficient financial support may facilitate DT. They are less likely to improve ESG performance by means of DT. In addition, it is unlikely for SOEs to obtain more economic returns from capital markets by means of DT (Wu et al., 2021). Non-SOEs, on the other hand, do not have these financial privileges, and they seek to achieve sustainable development by means of ESG improvement and obtain more funding from financial institutions in consequence. Therefore, non-SOEs have strong DT incentives and improve ESG performance by upgrading technologies. Based on the above discussions, this study suggests the below hypothesis.

H4: Compared with SOEs, DT contributes to ESG performance in non-SOEs to a great extent.

Having the comprehensive review above, Table 1 demonstrates the literature gaps marked with ☑, which few studies shed light on. While the existing studies mainly concentrated on Route 1 to 2 and 4 to 5 in Figure 1, except Route 3, which this research contributes to.

Data and Methodology

Data

Data were collected from some of China's leading databases, including the China Stock Market & Accounting Research (CSMAR) database (https://cn.gtadata.com), the WIND database (https://www.wind.com.cn/portal/en/WDS/database.html), the MARK database (https://www.macrodatas.cn), and Shenzhen Securities Information Company (http://www.cninfo.com.cn/new/index). These databases have been extensively used by scholars (Cheung et al., 2013; X. Xu et al., 2018).

The initial 31,992 samples came from 2,816 manufacturing firms listed on China's A-share during 2009 to 2020, and 20,147 samples were ultimately considered valid after various data treatment methods were applied: (1) removal of variable-deficient samples; (2) removal of ST and ST* firms (because of financial deficit in 1 and 2 years, respectively); (3) given the influence of some extreme data values, tail shrinkage of extreme values of all major variables by 1% and 99%; (4) removal of firms with unclear ownership; (5) removal of firms with an asset–liability ratio over 1.

Table 1. Summary of Comprehensive Literature Review.

	Route 1	Route 2	Route 3	Route 4	Route 5
	DT to firm performance	DT to ESG	DT to ESG in manufacturing industry	Firm performance to ESG	ESG in Manufacturing
DT heterogeneity	Saxena et al. (2023), Sætra (2023), D'Amato et al. (2022), Lee and Kang (2016), Landaluce et al. (2020), Liu et al., 2021	P. Chen and Hao (2022), Burritt and Christ (2016), Gupta et al. (2020), Varadarajan (2020), D. Li and Shen (2021), Huang et al., 2021	☑	Aich et al. (2021)	Aich et al. (2021), Du & Jiang, 2022
Heterogeneity in firms	Du and Jiang (2022), Hajli et al. (2015), Benner and Waldfogel (2023), Bruce et al. (2017), Ferreira et al. (2019), Usai et al., 2021	Marler and Dulebohn (2005)	☑	*	Zhou et al. (2022)
Regional heterogeneity	*	Huang et al. (2021)	☑	Breinlich et al. (2014), Zhou et al. (2022), Tian & Li, 2022	*
Heterogeneity in ownership	Shih et al. (2021)	Wu et al. (2021), Huang et al., 2021	☑	L. Xu et al. (2020)	Hsu et al. (2021), M. Yu and Pan (2010), Shih et al., 2021

*There is no evidence to support the points upon the literature review for this study.

Methodology

Figure 2 indicates a methodology flowchart. This study conducts a univariate *T*-test to assess ESG performance. After that, it investigates further what extent digitization improves ESG performance, followed by a robustness test to confirm the relationship between DT and ESG performance. Upon the findings, this study employs mediated effect model to investigate the conductive effect of DT on ESG performance by firm performance. Finally, this study conducts a heterogeneity analysis to offer insights into it in terms of labor intensity, spatial characteristics, and ownership, respectively.

Based on Khalid et al. (2021), this study developed an OLS regression model to investigate Route 3, which concerns the DT effects on ESG performance.

$$\begin{aligned} ESG_{i,t}|lnESG_{i,t} = {} & \theta_0 + \theta_1 DTS_{i,t}|lndts_{i,t} + \theta_2 Size_{i,t} \\ & + \theta_3 Lev_{i,t} + \theta_4 Grow_{i,t} + \theta_5 PPE_{i,t} \\ & + \theta_6 Intang_{i,t} + \theta_7 Invent_{i,t} + \theta_8 Age_{i,t} \\ & + \theta_9 Dualpo_{i,t} + \theta_{10} Soe_{i,t} \\ & + \theta_{11} \sum_{i=1}^{12} Year_{i,t} + \varepsilon \end{aligned} \quad (1)$$

where DTS and lndts are the indicators measuring the degree of digital transformation of manufacturing companies, and ESG and lnESG are the indicators for measuring the ESG rating of manufacturing enterprises. Because of significant data dispersion, this study separately used logarithmic ESG (lnESG) and DTS (lndts) to address the research questions. Based on previous theoretical analysis, if θ1 is significantly positive, it means that the higher the degree of digital transformation is, the higher the ESG performance is, which in turn highlights that digital transformation is conducive to improving ESG performance.

Digital Transformation. Based on Wu et al. (2021), DTS was measured with the frequency of 76 digitally related words in five dimensions: artificial intelligence, Big Data, cloud computing, and blockchain, as shown in Figure 3. lndts is the result of taking the logarithm after adding 1 to DTS. Specifically, we used Python crawler to download the annual reports of the sample companies from 2009 to 2020, sorted the original report texts into panel data, and then counted and sorted out the length of the full text of the companies' annual reports. After that, we built a dictionary of corporate digital terms and

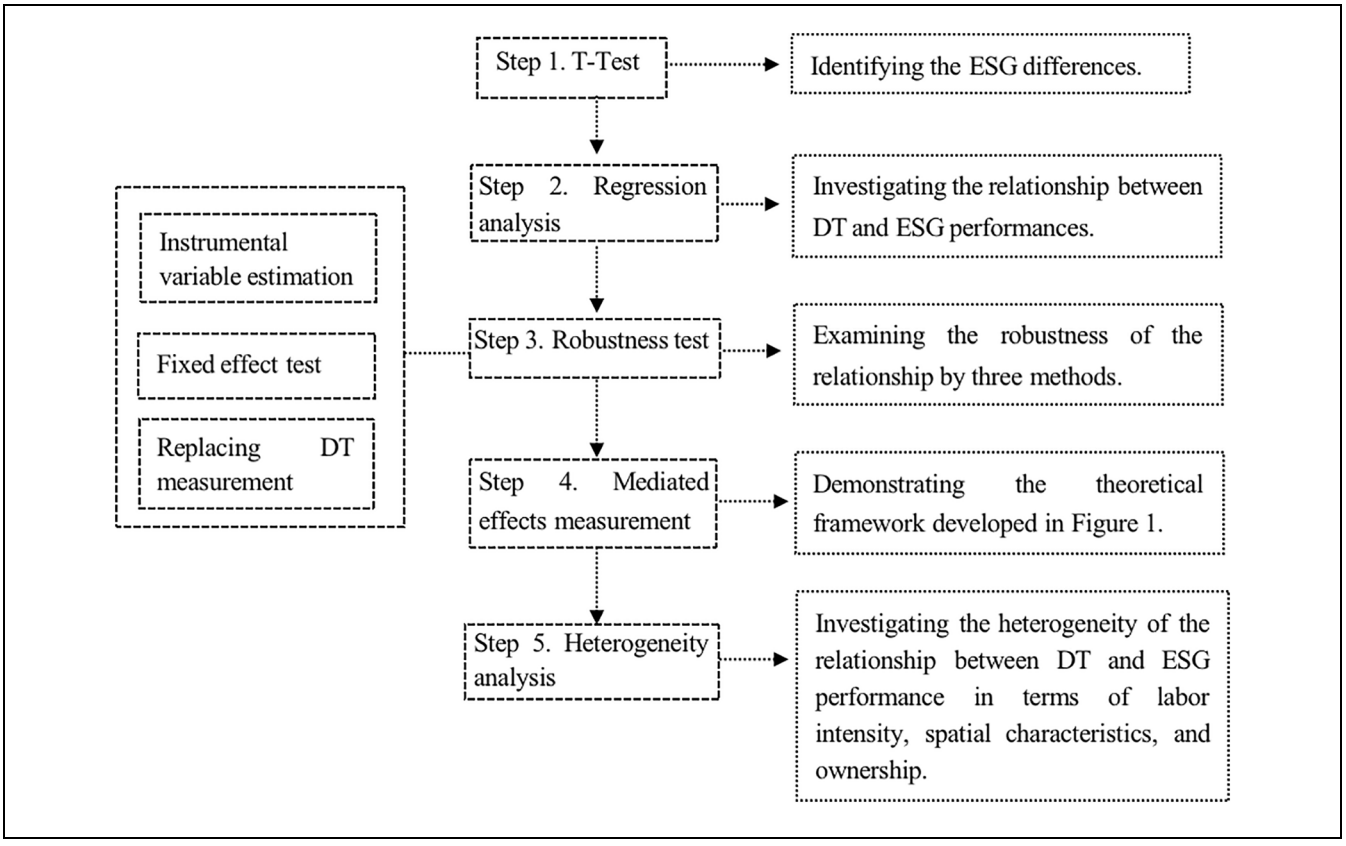


Figure 2. Methodology flowchart.

expanded the vocabulary to the Jieba database after removing stop words. After counting the frequency of these words in the full text of the annual reports, we finally constructed an index to measure the degree of digital transformation of the enterprises.

ESG Evaluation. Although there are many ways for evaluating ESG performance, considering data availability and referring to Shahab et al. (2020) and Khalid et al. (2021), this study employed the frequently used ESG scores from China's leading ESG assessment database (Sino-Securities Index). This method assesses three key indicators, that is, environment, social responsibility, and governance, including 80 plus ultimate indicators from some sub-indicators (climate change, resource utilization, environmental management, human capital, product liability, data security and privacy, shareholder interest, governance structure, etc.). The ESG ratings include nine tiers of ratings from AAA to C (AAA, AA, A, BBB, BB, B, CCC, CC, and C) scoring from 9 to 1, respectively. This method has been adopted by other researchers (Lin et al., 2021).

Following Khalid et al. (2021) and Zhou et al. (2022), this study included some control variables, whose description and measurement methods are reported in Table 2.

Instrumental Variable Estimation. In line with Breuer et al. (2018), this study used the 1-year-lagged average DT degree of other firms in the same industry and province where the sample firms were registered as an instrumental variable. After controlling for endogeneity, the interactive relationship between DT and ESG still showed a significant positive correlation. The models are expressed below.

$$DTS_{i,t}|lndts_{i,t} = \alpha_0 + \alpha_1 L.MDTS_{i,t-1}|L.Mlndts_{i,t-1} + \alpha_k Controls_{i,t} + \varepsilon \quad (2)$$

$$ESG_{i,t}|lnESG_{i,t} = \beta_0 + \beta_1 DTS_{i,t}|lndts_{i,t} + \beta_k Controls_{i,t} + \varepsilon \quad (3)$$

where $L.MDTS$ and $L.Mlndts$ represent the average DT values of other manufacturing firms in the province where the sample companies were registered.

To demonstrate the theoretical framework in Figure 1, this study employed mediated effects models to investigate the conductive effect of DT on ESG performance by firm performance. In line with Mackinnon et al. (1995), the mediated models were developed as shown below.

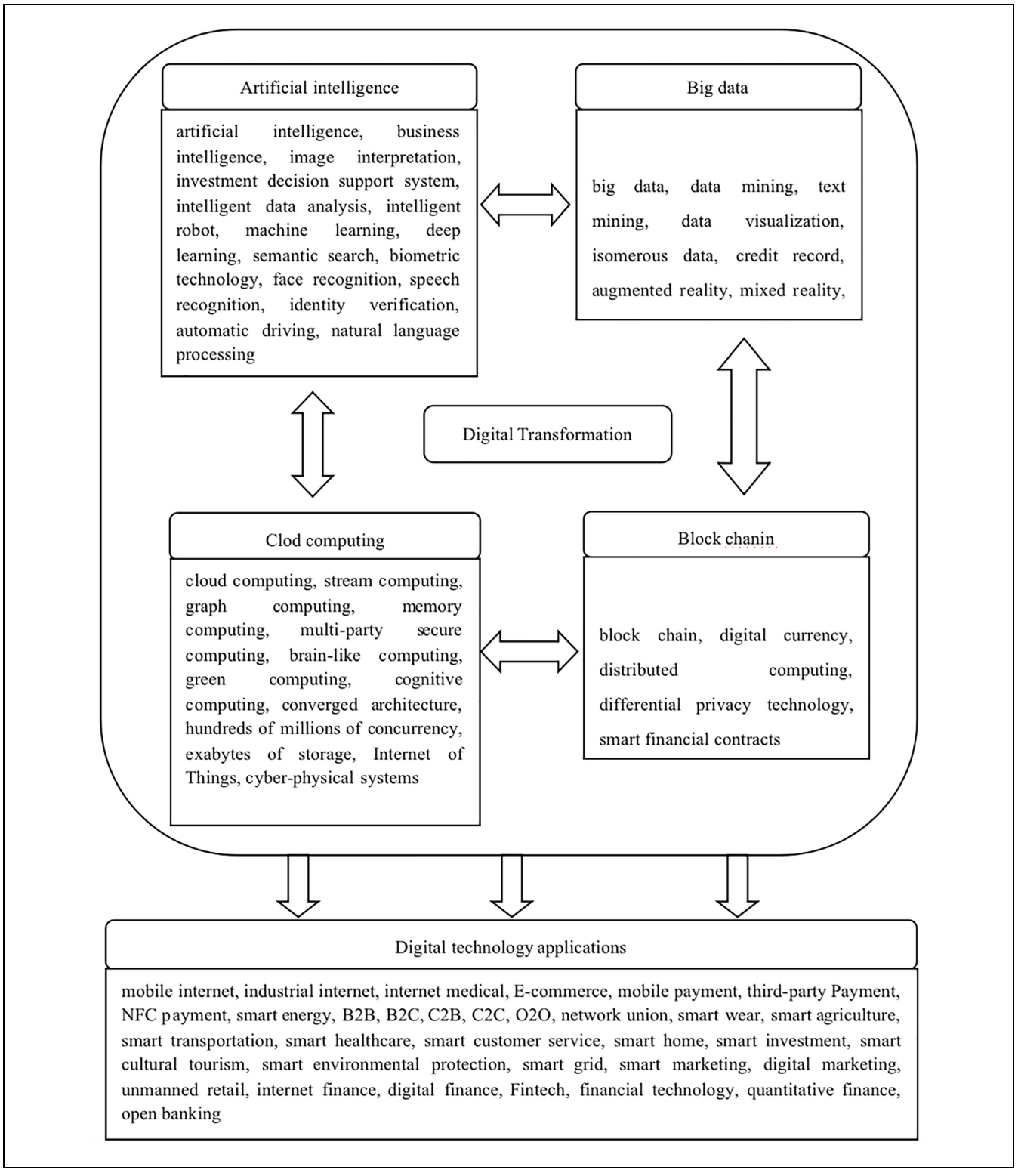


Figure 3. DT-related indicators searched for word frequency statistics in the manufacturing industry.

Table 2. Variable Definitions and Measurement Methods.

Variable			
Type	Name	Abbreviation	Measurement method
Dependent variables	ESG evaluation	*ESG*	Scores from 1 to 9 according to the ESG rating of Sino-Securities Index, greater values mean better ESG performance.
		LnESG	Logarithmic ESG = ln(ESG)
Independent variables	Digital transformation	*DTS*	Digitization keyword frequency of a firm (Wu et al., 2021)
		lndts	Logarithmic digitization keyword frequency plus 1 = ln(DTS + 1) (Wu et al., 2021)
		Dfreq	Digitized keyword frequency accounts for the total text length
		Cpnum	*Dfreq* multiplied by 100
	Dummy digital transformation	*Dum1*	DTS is 1 if it is higher than the industrial average value in the same year; otherwise, it is 0
		Dum2	lndts is 1 if it is higher than the industrial average value in the same year; otherwise, it is 0
Control variables	Firm size	*Size*	Logarithmic total assets at the end of a year = ln(assets)
	Financial leverage	*Lev*	Total debts/total assets at the end of a year
	Growth potential	*Grow*	Tobin's Q
	Fixed asset rate	*PPE*	Fixed assets/total assets at the end of a year
	Intangible asset rate	*Intang*	Intangible assets/total assets at the end of a year
	Inventory rate	*Invent*	Inventory/total assets at the end of a year
	IPO age	*Age*	Logarithmic (IPO year − the observed year) + 1
	Dual tenure as CEO and president	DualPo	Dual tenure as CEO and president = 1; otherwise, 0
	Equity ownership	*Soe*	A dummy variable that equals 1 if the major shareholder is from the government or government- affiliated institutions; otherwise, the scoring is 0
	Labor intensity	*Lint*	Logarithmic annual employee expenditure in cash/ firm revenue
	Firm performance	*ROA*	Net profits/total assets
	Year	*Year*	Dummy variables controlling the influence of macro-economic factors in different years

$$ROA_{i,t} = \alpha_0 + \alpha_1 DTS_{i,t} | lndts_{i,t} + \alpha_k Controls_{i,t} + \varepsilon \quad (4)$$

$$ESG_{i,t} | lnESG_{i,t} = \beta_0 + \beta_1 ROA_{i,t} + \beta_k Controls_{i,t} + \varepsilon \quad (5)$$

To obtain a general result on the relationship between DT and ESG in the manufacturing industry, this study conducted a heterogeneity analysis to offer insights into it from three perspectives: labor intensity, spatial characteristics, and ownership.

China's traditional manufacturing industry features labor-intensive companies (Thorbecke & Zhang, 2009), but gradually growing labor costs have pushed many manufacturing firms toward technological upgrading and transformed them into technology-intensive firms. F. Wang et al. (2020) discusses labor cost heterogeneity across industrial and firm-specific labor intensity levels. Furthermore, China's labor-intensive manufacturing firms have heterogeneous responses to the association between digitization and ESG performance, because the digitization of manufacturing firms may reduce employee quantity and labor costs in China (Yuan et al., 2021).

Results and Analysis

Descriptive Analysis

Table 3 outlines the distribution of the variables. The mean value of *ESG* was 6.306, ranking between A and BBB. The minimum value of 3.000, ranking as CCC, indicates that all sample firms had embarked on their *ESG* evaluations, but some of them did not pay attention to it. Furthermore, the minimum value (0.000) of *DTS* indicates that some companies had not yet initiated digital transformation, so they had other options for their *ESG*. This result is supported by the minimum value of *Dfreq*.

Figure 4 illustrates a remarkable upward trend of digital transformation from 2009 to 2020; this means that the manufacturing industry experienced a significant digitization process in China during this period and that Chinese manufacturing firms did not realize it before 2008.

Table 3. Descriptive Analysis of the Variables.

Variable	*N*	Mean	*SD*	Min	p50	Max
ESG	20,147	6.306	0.998	3.000	6.000	8.000
lnESG	20,147	1.979	0.144	1.099	1.946	2.303
DTS	20,147	4.608	9.609	0.000	1.000	53.00
lndts	20,147	0.914	1.134	0.000	0.693	3.989
Dfreq	20,147	0.0004	0.001	0.000	0.000	0.004
Cpnum	20,147	0.038	0.090	0.000	0.002	1.391
Size	20,147	21.90	1.159	19.29	21.76	25.25
Lev	20,147	0.397	0.201	0.052	0.385	0.998
Grow	20,147	2.140	1.356	0.903	1.704	8.952
PPE	20,147	0.229	0.139	0.010	0.203	0.658
Intang	20,147	0.045	0.036	0.000	0.037	0.225
Invent	20,147	0.138	0.087	0.009	0.120	0.477
Age	20,147	1.950	0.906	0.000	2.079	3.434
DualPo	20,147	0.307	0.461	0.000	0.000	1.000
Soe	20,147	0.298	0.457	0.000	0.000	1.000
ROA	20,147	0.046	0.065	−0.221	0.043	0.233

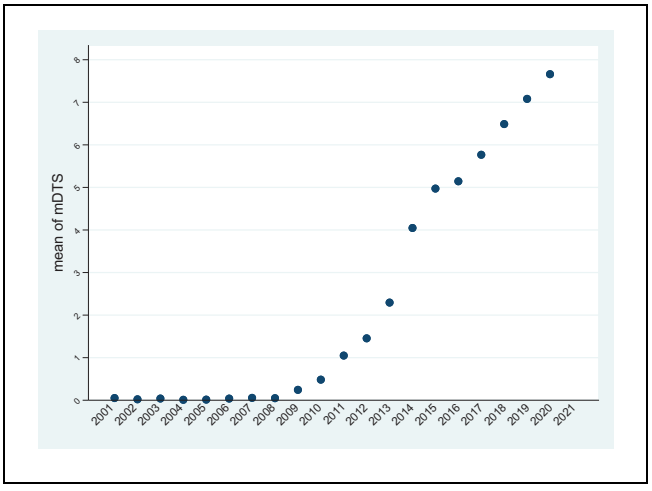


Figure 4. Changes in digital transformation from 2001 to 2020.

Univariate Analysis

Next, a univariate *T*-test was conducted to assess ESG performance by setting dummy variables of digital transformation. As Table 2 defines, Dum1 = 1 if the DTS values are greater than the mean values; otherwise, Dum1 = 0. A similar reasoning is adopted for Dum2, evaluated using lndts. As Table 4 shows, the mean values are greater than the counterpart when Dum1, −2 = 1 at a very significant level; this means that the better the digitization was, the better the ESG performance was. The preliminary results support H1.

Regression Analysis

The regression analysis presented in the following further investigated to what extent digitization improved firm ESG performance. The coefficients (0.0034 and 0.0445) in columns (1) and (2) indicate a significant positive relationship between firm digitization and ESG performance, which is consistent with the results in columns (3) and (4). These results significantly support H1.

However, there are many other factors associated with ESG performance. We found a positive relationship between ESG and firm size (*size*), growth potential (*Grow*), inventory (*Invent*), and equity ownership (*Soe*). On the contrary, a negative relationship was found between ESG and financial leverage (*Lev*), and between ESG and firm age (*Age*). This indicates that big companies and growing firms paid more attention to their ESG performance than others and that state-owned enterprises were keen on ESG performance. However, both aged firms and higher-leveraged firms were more numerous, regardless of their ESG, because of the negative relationships between *ESG* and *Age*, and between ESG and *Lev*.

To further investigate the digitization contribution to ESG performance, this study employed dummy variables (*Dum1* and *Dum2*) instead of *DTS* and *lndts* to further show significance between them. As indicated in Table 5, the coefficients of both *Dum1* (.0686 and .0101) and *Dum2* (.0662 and .0100) were found to be significantly greater than their counterparts (.0034 and .0005, and .0445 and .0068, respectively) shown in Table 6. This relationship becomes more significant when we consider firm digitization at a higher level, indicating that the greater the digitization was, the better the ESG performance was.

As digitization is a time-consuming strategy, it has lagged effects on firm ESG. This study next investigated the relationship between 1-year-lagged digitization and ESG. Table 7 shows a comparable positive relationship between lagged digitization and ESG compared with that

Table 4. *T*-test of ESG by Digitization Groups.

	Variable	Group	No.	Mean	Difference	*T*-value
Panel A	*ESG*	Dum1 = 0	15,413	6.2857	–0.08632	–5.2088***
		Dum1 = 1	4,734	6.3720		
	ESG	Dum2 = 0	12,664	6.2724	–0.09026	–6.2089***
		Dum2 = 1	7,483	6.3627		
Panel B	*lnESG*	Dum1 = 0	15,413	1.9760	–0.01212	–5.0548***
		Dum1 = 1	4,734	1.9881		
	lnESG	Dum2 = 0	12,664	1.9743	–0.01221	–5.8014***
		Dum2 = 1	7,483	1.9865		

Note. Two-tailed test.
***$p < .01$.

Table 5. Relationships Between Dummy Digitization and ESG Performance.

	(1) ESG	(2) ESG	(3) lnESG	(4) lnESG
Dum1 = 1	0.0686*** (2.71)		0.0101*** (2.84)	
Dum2 = 1		0.0662*** (2.97)		0.0100*** (3.18)
Size	0.3407*** (23.29)	0.3400*** (23.21)	0.0469*** (22.92)	0.0467*** (22.83)
Lev	–1.0097*** (–12.85)	–1.0097*** (–12.86)	–0.1510*** (–13.09)	–0.1510*** (–13.10)
Grow	0.0405*** (4.84)	0.0404*** (4.83)	0.0054*** (4.48)	0.0053*** (4.47)
PPE	0.0196 (0.20)	0.0198 (0.20)	–0.0007 (–0.05)	–0.0006 (–0.04)
Intang	–0.1424 (–0.41)	–0.1350 (–0.39)	–0.0229 (–0.43)	–0.0218 (–0.41)
Invent	0.7012*** (4.47)	0.6980*** (4.45)	0.1030*** (4.69)	0.1026*** (4.68)
Age	–0.0574*** (–3.69)	–0.0570*** (–3.67)	–0.0112*** (–5.05)	–0.0112*** (–5.04)
DualPo	–0.0235 (–0.99)	–0.0239 (–1.00)	–0.0039 (–1.15)	–0.0040 (–1.16)
Soe	0.3605*** (9.29)	0.3604*** (9.30)	0.0519*** (9.63)	0.0519*** (9.64)
Year	YES	YES	YES	YES
_cons	–0.9595*** (–3.11)	–0.9431*** (–3.05)	0.9951*** (23.17)	0.9977*** (23.20)
N	23,127	23,127	23,127	23,127
r2	0.1579	0.1580	0.1434	0.1435
r2_a	0.1571	0.1572	0.1426	0.1427

Note. *t*-Statistics in parentheses.
***$p < .01$.

shown in Table 6. This finding suggests that digitization not only contributed to firm ESG performance but also had a profound effect on it. Additionally, financial leverage had a very significant lagged side effect on ESG performance, given that the negative coefficients are greater than those in Table 6. Other factors (*Size, Grow, Age, Invent, and Soe*) also had comparable lagged effects on ESG performance. Therefore, digitization is a long-term strategy for ESG improvement.

Robustness Test

Table 8 shows the regression results of the instrumental variable estimation. The coefficients (0.9265 and 0.8291) of *L.MDTS* and *L.Mlndts* in columns (1) and (3), respectively, were found to be significantly positive, indicating that the DT degree of other companies was significantly positive with respect to the digital transformation of the sampled company. After the introduction of instrumental variables, the digital transformation *DTS* and *lndts* of manufacturing enterprises was found to be still positively correlated with ESG rating scores in the second stage (columns (2) and (4), respectively), compared with *DTS* and *lndts* in Table 6, respectively. After controlling for endogeneity, the relationship between the two resulted in being more significant, further demonstrating that a high DT degree promoted the ESG performance of manufacturing companies, which further supports research hypothesis 1.

Fixed Effect Test. The control year was further subjected to fixed effect regression for the robustness test. In

Table 6. Relationships Between Independent Variables and ESG Performance.

	(1) ESG	(2) ESG	(3) lnESG	(4) lnESG
DTS	0.0034*** (2.77)		0.0005*** (3.00)	
lndts		0.0445*** (3.93)		0.0068*** (4.23)
Size	0.3308*** (21.55)	0.3278*** (21.31)	0.0451*** (21.30)	0.0446*** (21.05)
Lev	–0.9602*** (–11.96)	–0.9571*** (–11.94)	–0.1419*** (–12.18)	–0.1414*** (–12.16)
Grow	0.0444*** (4.88)	0.0433*** (4.77)	0.0058*** (4.50)	0.0056*** (4.39)
PPE	0.0446 (0.43)	0.0757 (0.74)	0.0038 (0.27)	0.0085 (0.59)
Intang	–0.1756 (–0.50)	–0.1520 (–0.43)	–0.0286 (–0.53)	–0.0251 (–0.46)
Invent	0.6949*** (4.33)	0.6881*** (4.29)	0.0994*** (4.46)	0.0983*** (4.42)
Age	–0.0409** (–2.49)	–0.0415** (–2.53)	–0.0085*** (–3.65)	–0.0085*** (–3.69)
DualPo	–0.0251 (–1.01)	–0.0269 (–1.08)	–0.0043 (–1.21)	–0.0046 (–1.29)
Soe	0.3462*** (8.69)	0.3504*** (8.81)	0.0490*** (8.91)	0.0497*** (9.04)
_cons	–0.7915** (–2.44)	–0.7383** (–2.27)	1.0260*** (23.00)	1.0340*** (23.14)
Year	YES	YES	YES	YES
N	20,147	20,147	20,147	20,147
r2	0.1554	0.1564	0.1404	0.1415
r2_a	0.1545	0.1556	0.1395	0.1406

Note. Figures reported in brackets are *t*-values adjusted by heteroscedasticity.
*** and ** mean significance at 1%, 5%, and 10% levels, respectively.

Table 7. One-Year-Lagged Independent Variables and ESG Performance.

	(1) ESG	(2) ESG	(3) lnESG	(4) lnESG
L.DTS	0.0031** (2.28)		0.0005** (2.38)	
L.lndts		0.0406*** (3.38)		0.0060*** (3.51)
Size	0.3496*** (22.93)	0.3470*** (22.69)	0.0479*** (22.58)	0.0475*** (22.33)
Lev	–1.0193*** (–12.42)	–1.0170*** (–12.41)	–0.1517*** (–12.66)	–0.1513*** (–12.65)
Grow	0.0406*** (4.73)	0.0399*** (4.65)	0.0053*** (4.33)	0.0052*** (4.24)
PPE	0.0267 (0.25)	0.0553 (0.53)	0.0000 (0.00)	0.0042 (0.29)
Intang	–0.1723 (–0.48)	–0.1485 (–0.42)	–0.0243 (–0.45)	–0.0208 (–0.38)
Invent	0.6769*** (4.12)	0.6716*** (4.09)	0.0980*** (4.28)	0.0972*** (4.25)
Age	–0.0727*** (–3.78)	–0.0735*** (–3.82)	–0.0130*** (–4.78)	–0.0132*** (–4.82)
DualPo	–0.0333 (–1.30)	–0.0347 (–1.36)	–0.0052 (–1.42)	–0.0054 (–1.47)
Soe	0.3684*** (9.11)	0.3721*** (9.21)	0.0528*** (9.42)	0.0533*** (9.52)
_cons	–1.0849*** (–3.38)	–1.0394*** (–3.23)	0.9822*** (22.14)	0.9889*** (22.23)
Year	YES	YES	YES	YES
N	21,369	21,369	21,369	21,369
r2	0.1600	0.1608	0.1458	0.1467
r2_a	0.1591	0.1599	0.1450	0.1458

Note. *t*-Statistics in parentheses.
**$p < .05$. ***$p < .01$.

addition, all other control variables were controlled, and all regression coefficients were adjusted for heteroscedasticity robustness and clustered at the company and year levels; the specific fixed effects regression results are shown in Table 9. Consistently, the *DTS, lndts*, ESG, and lnESG coefficients were still significant, although they slightly decreased, which shows that the higher the degree of digital transformation in the manufacturing industry was, the better their ESG ratings were.

Replacing DT Measurements. In the above regression, the degree of digital transformation was based on the statistics of the frequency of digital transformation words. Considering that the length and proportion of digital word frequency in the total text may highlight the degree of enterprise digitalization, this study also used word frequency as a percentage of the total text length. The ratio (*Dfreq*) and the ratio multiplied by 100 (*Cpnum*) were used to measure the degree of DT. The results after

Table 8. Instrumental Variable Estimation.

	(1) Stage 1 DTS	(2) Stage 2 ESG	(3) Stage 1 lndts	(4) Stage 2 ESG
L.MDTS	0.9265*** (41.16)			
DTS		0.0223*** (8.36)		
L.Mlndts			0.8291*** (42.88)	
lndts				0.2102*** (9.09)
Controls	YES	YES	YES	YES
_cons	–8.4948*** (–5.53)	–0.6750*** (–3.97)	–1.7632*** (–10.39)	–0.4839*** (–2.79)
Year	YES	YES	YES	YES
N	19,055	19,055	19,055	19,055
r2	0.2040	0.1301	0.2978	0.1325
r2_a	0.2031	0.1291	0.2971	0.1315

Note. Figures reported in brackets are *t*-values adjusted for heteroscedasticity.
*** mean significance at 1%, 5%, and 10% levels, respectively.

Table 9. Fixed Effects Model Results.

	(1) ESG	(2) ESG	(3) lnESG	(4) lnESG
DTS	0.0030** (2.48)		0.0005*** (2.81)	
lndts		0.0458*** (4.39)		0.0076*** (4.81)
Controls	YES	YES	YES	YES
_cons	1.5176*** (2.68)	1.5717*** (2.78)	1.2541*** (14.51)	1.2625*** (14.64)
Year	YES	YES	YES	YES
N	20,147	20,147	20,147	20,147
r2	0.0443	0.0455	0.0456	0.0469
r2_a	0.0433	0.0445	0.0446	0.0459

Note. t-Statistics in parentheses.
**$p < .05$. ***$p < .01$.

replacing *DTS* and *lndts*, shown in Table 10 below, are consistent with those presented above.

Therefore, the contributions of DT to manufacturing ESG performance in Route 3 is demonstrated. These findings support hypothesis 1: The greater the digital transformation is, the better the ESG performance of manufacturing firms in developing economies is.

Mediated Effects Measurement

The coefficients (0.0003 and 0.0023) in Table 11 indicate a significant effect of DT on firm performance, and the coefficients values of 1.7759 and 1.7790 indicate a positive relationship between firm performance and ESG, which means that the better the firm performance was, the better the ESG performance was. This finding is supported by the coefficients in columns (5)−(6). *Therefore, the DESG theoretical framework for the manufacturing industry in Figure 1 is supported. Digital technologies facilitate business production and improve the business profits of manufacturing firms, so that manufacturers have sufficient profits to invest in ESG for sustainable development in a virtuous cycle.*

Heterogeneity Analysis

This study employed an existing method for measuring labor intensity through the logarithmic ratio of total cash payment to firm revenue, which has been used by others (Serfling, 2016). Table 12 shows the relationship between digitization and ESG in firms characterized by low and high labor intensity. The coefficients (0.0038 and 0.0006) in columns (2) and (4), respectively, were found to have a significant positive relationship in firms with high labor intensity compared to firms with low labor intensity. This result implies that digitization facilitated firm ESG performance for sustainable development in highly labor-intensive manufacturing firms. This finding supports hypothesis 2.

Furthermore, because of the imbalanced economic development between North and South China, the effect of digitization on ESG performance should be

differentiated among regions. Following Wang et al. (2022) , the sampled firms were divided into two groups from North and South China. The coefficients (.0023 and .0004) in Table 13 show the existence of a significant relationship between digitization and ESG performance in South China, but this is insignificant in North China; in other words, digitization may have contributed to ESG in South China. This spatial heterogeneity could be attributed to the economic heterogeneity among regions, with South China showing better economic performance

Table 10. Regression Results by Replacing DT Measurements.

	(1) ESG	(2) ESG	(3) lnESG	(4) lnESG
Dfreq	41.0223*** (2.65)		6.1432*** (2.86)	
Cpnum		0.2851** (2.34)		0.0427** (2.52)
Controls	YES	YES	YES	YES
_cons	–0.8066** (–2.48)	–0.8121** (–2.50)	1.0236*** (22.95)	1.0228*** (22.92)
Year	YES	YES	YES	YES
N	20,147	20,147	20,147	20,147
r2	0.1553	0.1551	0.1402	0.1399
r2_a	0.1544	0.1542	0.1393	0.1390

Note. *t*-Statistics in parentheses.
**$p < .05$. ***$p < .01$.

Table 11. Mediated Effects of DT on ESG Performance by Firm Performance.

	(1) ROA	(2) ROA	(3) ESG	(4) ESG	(5) lnESG	(6) lnESG
DTS	0.0003*** (4.69)				0.0006*** (3.60)	
lndts		0.0023*** (3.78)				0.0074*** (4.74)
ROA			1.7759*** (9.51)	1.7790*** (9.54)	0.2723*** (9.90)	0.2727*** (9.92)
Controls	YES	YES	YES	YES	YES	YES
_cons	–0.3739*** (–23.12)	–0.3750*** (–23.12)	–0.1612 (–0.49)	–0.1042 (–0.32)	1.1231*** (24.90)	1.1317*** (25.08)
Year	YES	YES	YES	YES	YES	YES
N	25,135	25,135	20,146	20,146	20,146	20,146
r2	0.3181	0.3176	0.1646	0.1657	0.1506	0.1518
r2_a	0.3174	0.3168	0.1637	0.1648	0.1497	0.1508

Note. *t*-Statistics in parentheses.
***$p < .01$.

Table 12. Associations of Digitization and ESG by Labor Intensity Heterogeneity.

	(1) ESG Low labor intensity	(2) ESG High labor intensity	(3) lnESG Low labor intensity	(4) lnESG High labor intensity
DTS	0.0034 (1.22)	0.0038** (2.39)	0.0005 (1.27)	0.0006** (2.46)
Controls	YES	YES	YES	YES
Year	YES	YES	YES	YES
_cons	–0.4590 (–0.83)	–1.0903** (–2.18)	1.0704*** (14.05)	0.9793*** (14.31)
N	5393	7629	5393	7629
r2	0.1357	0.1682	0.1222	0.1568
r2_a	0.1323	0.1659	0.1188	0.1545

Note. *t*-Statistics in parentheses.
**$p < .05$. ***$p < .01$.

than North China, because a positive relationship exists between ESG and economic development in the long run (Diaye et al., 2022). Therefore, southern companies were more likely to pursue sustainable ESG performance by means of digitization for economic sustainability than northern firms, and vice versa. This result supports hypothesis 3.

Lastly, there are remarkable differences between state-owned enterprises (SOEs) and non-SOEs in China; particularly, SOEs are closely politically connected and engage in social responsibility, while non-SOEs pursue profit-related activities. Due to the different strategic purposes, ESG performance also differs. Table 14 shows the heterogeneity between the two different types of firms. The coefficient values of .0042 and .0006 show that digitization made a significant contribution to ESG performance in non-SOEs but this was found to be insignificant in SOEs. Therefore, hypothesis 4 was accepted.

This novel finding is interesting, because the Chinese economy is dominated by SOEs with strong political connections that experience less financial stress on ESG than non-SOEs (Ge et al., 2022); therefore, SOEs should display more significant ESG performance than non-SOEs. This finding could be attributed to the SOE agency issues whereby SOE managers have incentives to invest in ESG for personal purposes, such as social reputation and political career (L. Xu et al., 2020).

Discussion

These findings enrich the relevant research on ESG influencing factors. At present, the literature has studied the economic consequences of ESG from various aspects, and believes that ESG can resist downside risks (Wen et al., 2022), restrain managers' misconduct (He et al., 2022), and improve corporate financial performance (Z. Chen & Xie, 2022; Friede et al., 2015), improve corporate value (B. Wang & Yang, 2022), etc. However, few literature discusses the influencing factors of corporate ESG ratings and proposes solutions to ESG performance. This article uses the data of Chinese manufacturing listed companies to directly analyze the impact of manufacturing digital transformation on its ESG performance and its internal mechanism and impact differences from the perspective of enterprise digital transformation.

Table 13. Spatial Heterogeneity of ESG Association With Digitization.

	(1) ESG South	(2) ESG North	(3) lnESG South	(4) lnESG North
DTS	0.0023* (1.74)	0.0040 (1.43)	0.0004* (1.89)	0.0006 (1.62)
Controls	YES	YES	YES	YES
Year	YES	YES	YES	YES
_cons	–0.3684 (–0.94)	–2.2877*** (–4.18)	1.0803*** (19.94)	0.8309*** (11.11)
N	13,855	6,292	13,855	6,292
r2	0.1176	0.1813	0.1059	0.1642
r2_a	0.1163	0.1787	0.1046	0.1616

Note. *t*-Statistics in parentheses.
*$p < .1$. ***$p < .01$.

Table 14. Different Relationships Between Digitization and ESG by Ownership Heterogeneity.

	(1) ESG SOE = 0	(2) ESG SOE = 1	(3) lnESG SOE = 0	(4) lnESG SOE = 1
DTS	0.0042*** (3.10)	0.0036 (1.30)	0.0006*** (3.27)	0.0005 (1.44)
Controls	YES	YES	YES	YES
_cons	0.0438 (0.10)	–1.4706*** (–2.72)	1.1142*** (18.59)	0.9629*** (13.35)
Year	YES	YES	YES	YES
N	14,144	6,003	14,144	6,003
r2	0.0939	0.1870	0.0910	0.1697
r2_a	0.0926	0.1843	0.0897	0.1669

Note. *t*-Statistics in parentheses.
***$p < .01$.

The findings are useful supplements to the study of ESG influencing factors and broaden the relevant literature.

The results expand the research on the economic spillover effects of digital transformation. Currently, there are abundant studies on the economic consequences and influencing factors of enterprise digital transformation. Strengths (Benner & Waldfogel, 2023; Bruce et al., 2017; Mikalef & Pateli, 2017), Organizational Performance (Johnson et al., 2017), Innovation Performance (Ferreira et al., 2019; Usai et al., 2021), customer welfare (Akram et al., 2021), and other aspects discuss the economic consequences of the digital transformation of enterprises in detail. There are also discussions on the influencing factors of the digital transformation of enterprises from the perspectives of corporate financialization (Huang et al., 2022), local economic growth goals (Yang et al., 2021), and the CEO's compound functional background (Mao et al., 2022). However, there is no literature that directly studies the interaction between corporate digital transformation and its ESG rating. Therefore, this paper studies the inherent economic consequences of digital transformation from another new perspective.

Finally, the research finds that the digital transformation in manufacturing enterprises can help promote their green technology innovation and improve the level of information disclosure, reduce environmental pollution levels, fulfill social responsibilities, improve governance capabilities, and ultimately improve ESG performance. This conclusion provides certain policy suggestions and inspirations for promoting enterprises, especially heavy polluting enterprises, improving ESG performance and fulfilling environmental social responsibilities under the low-carbon development strategy. At present, how to efficiently control carbon emissions to slow down global warming is a hot spot in the political, business and academic circles. As a manufacturing enterprise with high carbon emissions, it is the object of common concern from all countries in the world. The research proves that digital transformation can enable enterprises to carry out environmental governance, and improve their ESG performance. This conclusion is helpful for government policy makers and enterprise managers to use digital transformation to promote energy conservation and emission reduction in enterprises, and provides a certain theoretical reference and method reference for realizing green transformation and low-carbon goals.

Conclusions and Policy Implications

As a concept that focuses on corporate environmental protection, social responsibility, and corporate governance, ESG meets the requirements of sustainable development for green, ecological, low-carbon transformation. The digital transformation of enterprises has also become an important impetus to promote industrial upgrading and will likely continue to play a great role in empowering digital economic development in the future. With manufacturing being a national economic driver, its green, ecological, low-carbon transformation is the key to promoting high-quality economic development. Therefore, it is of great practical economic significance to explore how the digital transformation of manufacturing companies affects ESG performance.

Under these circumstances, this paper proposes a DESG theoretical framework to test the impact of digital transformation on the ESG performance of manufacturing companies by examining the heterogeneity of manufacturing ESG from different perspectives in the manufacturing industry. Based on samples of Chinese listed companies from 2009 to 2020, the research study shows that big companies and growing firms pay more attention to their ESG performance than others and that SOEs are keen on ESG performance but exhibit poorer performance than non-SOEs (see Table 6). Additionally, manufacturing DT may improve ESG performance in general, because DT improves firm operating performance, which in turns means that these firms have sufficient funds to invest in ESG, thus promoting their sustainable development. In particular, this study shows that manufacturers in economically developed regions show more significant ESG performance thanks to DT and that firms with higher labor intensity experience more significant effects of DT on ESG performance than their counterparts (see Tables 12 and 13). DT makes a significant contribution to ESG performance in non-SOEs, but this is insignificant in SOEs (see Table 14). Therefore, DESG contributes to the sustainable development of manufacturing in developing countries.

These findings support the proposed DESG theoretical framework for the manufacturing industry whereby digital technologies facilitate business production and improve the business profits of manufacturing firms, so that manufacturers have sufficient profits to invest in ESG for sustainable development in a virtuous cycle (see Figure 3 and Table 11).

This research has three practical implications. First, manufacturers should speed up the pace of DT, improve corporate green technology innovation, promote the green and low-carbon development of companies, and achieve a win–win situation of economic and social benefits. On the one hand, to provide a basis for business decision making, it is necessary to adapt to the development in the digital age; promote the digital transformation of various elements and links according to the actual situation and market demands; and focus on improving the intelligence level in many aspects, such as production, sales, investment, financing, and personnel management. On the other hand, it is also necessary to fully use the

social spillover effects of DT, improve green technology innovation, save resources and energy, reduce ecological pollution and damage, provide employees with a safe workplace, provide the public with energy-saving and environmentally friendly products, improve the environmental performance and social responsibility performance of enterprises, and ultimately improve social benefits. These efforts feedback economic benefits, improve the competitiveness of manufacturing companies, and promote high-quality economic development.

Second, the government should perfect the top-level structure of ESG and provide reference for other countries to build ESG rating systems. In addition, in order to prevent companies from using ESG concepts to mislead market participants, the government should guide and promote the construction of soft-market supervision and encourage rating agencies to continuously improve ESG assessment techniques, improve their ability to tap long-term corporate value, and maximize the soft market.

Third, the government should establish a digital service platform, build a complete digital infrastructure system, cultivate talents with digital skills, and promote the digital transformation and upgrading of the manufacturing industry. To do so, the government should build an efficient communication platform between enterprises and government departments, media, and industries and create a digital service platform to help manufacturing digitization. The government should also build a complete digital infrastructure system and help the digital economy to penetrate traditional industries, in order to provide external technical support for industrial green transformation. Furthermore, improving the digital literacy and skills of citizens and cultivating citizens with digital awareness and social responsibility may provide manufacturers with high-quality digital skills and interdisciplinary talents and effectively promote the digital transformation and upgrading of the manufacturing industry.

Research limitations: ESG was measured by ESG rating from AAA to C scoring from 9 to 1, so one of the research limitations in method is that ESG was not evaluated specifically in terms of environment, social responsibility, and governance, respectively, due to data limitation. The second one is lack of taking further insight into different industrial sections in manufacturing industry, which are expected to be investigated by the future research.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by 2020 Discipline Construction Scheme of the Thirteen Five Plans of Guangdong Philosophy and Social Science, (grant number: GD20XGL12). 2021 The First Round of Industry-University-Research Synergy Education Project Funded by the Bureau of Tertiary Education, Ministry of Education of the People's Republic of China, (grant number: 202101143023). 2022 Youth Scheme of the Fourteen Five Plans of Guangzhou Philosophy and Social Science, (grant number: 2022GZQN21). 2021 Philosophy and Social Science of Heyuan City, Guangdong, (grant number: HYSK21ZC12). 2017 PhD Research Initial Fund from Guangdong Polytechnic Normal University.

Research Involving Human Participants and/or Animals

N/A.

Informed Consent

N/A.

ORCID iD

Hai Long https://orcid.org/0000-0003-2323-7636

References

Aceto, G., Persico, V., & Pescape, A. (2020). Industry 4.0 and health: Internet of Things, big data, and cloud computing for Healthcare 4.0. *Journal of Industrial Information Integration*, *18*, 100129.

Agnese, P., & Giacomini, E. (2023). Bank's funding costs: Do ESG factors really matter? *Finance Research Letters*, *51*, 103437.

Aich, S., Thakur, A., Nanda, D., Tripathy, S., & Kim, H. C. (2021). Factors affecting ESG towards impact on investment: A structure approach. *Sustainability*, *13*, 10868.

Akram, U., Fülöp, M. T., Tiron-Tudor, A., Topor, D. I., & Căpuàneanu, S. (2021). Impact of digitalization on customers' well-being in the pandemic period: Challenges and opportunities for the retail industry. *International Journal of Environmental Research and Public Health*, *18*(14), 7533.

Albuquerque, R., Koskinen, Y., & Zhang, C. (2019). Corporate social responsibility and firm risk: Theory and empirical evidence. *Management Science*, *65*(10), 4451–4949.

Baker, E. D., Boulton, T. J., Braga-Alves, M. V., & Morey, M. R. (2021). ESG government risk and international IPO underpricing. *Journal of Corporate Finance*, *67*, 101913.

Baldini, M., Maso, L. D., Liberatore, G., Mazzi, F., & Terzani, S. (2018). Role of country- and firm- level determinants in environmental, social, and governance disclosure. *Journal of Business Ethics: JBE*, *150*, 79–98.

Banerji, R. (1975). *Exports of Manufactures from India: An Appraisal of the emerging pattern*. J.C.B. Mohr Siebeck.

Benner, M. J., & Waldfogel, J. (2023). Changing the channel: Digitization and the rise of "middle tail" strategies. *Strategic Management Journal*, *44*(1), 264–287.

Brammer, S., Brooks, C., & Pavelin, S. (2006). Corporate social performance and stock returns: UK evidence from disaggregate measures. *Financial Management*, *35*(3), 97–116.

Breinlich, H., Ottaviano, G. I., & Temple, J. R. (2014). Regional growth and regional decline. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth* (pp. 683–779). Elsevier.

Breuer, W., Müller, T., Rosenbach, D., & Salzmann, A. (2018). Corporate social responsibility, investor protection, and cost of equity: A cross-country comparison. *Journal of Banking & Finance*, *96*, 34–55.

Broadstock, D., Matousek, R., Meyer, M., & Tzeremes, N. G. (2020). Does corporate social responsibility impact firms' innovation capacity? The indirect link between environment & social governance implementation and innovation performance. *Journal of Business Research - Turk*, *119*, 99–110.

Bruce, N. I., Murthi, B. P. S., & Rao, R. C. (2017). A dynamic model for digital advertising: The effects of creative format, message content, and targeting on engagement. *Journal of Marketing Research*, *54*(2), 202–218.

Burritt, R., & Christ, K. (2016). Industry 4.0 and environmental accounting: A new revolution? *Asian Journal of Sustainability and Social Responsibility*, *1*, 23–38.

Chen, P., & Hao, Y. (2022). Digital transformation and corporate environmental performance: The moderating role of board characteristics. *Corporate Social Responsibility and Environmental Management*, *29*(5), 1757–1767.

Chen, Z., & Xie, G. (2022). ESG disclosure and financial performance: Moderating role of ESG investors. *International Review of Financial Analysis*, *83*, 102291.

Cheung, Y. L., Jiang, K., Mak, B. S. C., & Tan, W. (2013). Corporate Social Performance, firm valuation, and industrial difference: Evidence from Hong Kong. *Journal of Business Ethics: JBE*, *114*, 625–631.

Dai, Z., Niu, Y., Zhang, H., & Niu, X. (2022). Impact of the transforming and upgrading of China's labor-intensive manufacturing industry on the labor market. *Sustainability*, *14*, 13750.

Daugaard, D. (2020). Emerging new themes in environmental, social and governance investing: A systematic literature review. *Accounting and Finance*, *60*(2), 1501–1530.

Diaye, M. A., Ho, S. H., & Oueghlissi, R. (2022). ESG performance and economic growth: A panel co-integration analysis. *Empirica*, *49*, 99–122.

Du, X., & Jiang, K. (2022). Promoting enterprise productivity: The role of digital transformation. *Borsa Istanbul Review*, *22*(6), 1165–1181.

D'Amato, V., D'Ecclesia, R., & Levantesi, S. (2022). ESG score prediction through Random Forest algorithm. *Computational Management Science*, *19*, 347–373.

Ferreira, J. J. M., Fernandes, C. I., & Ferreira, F. A. F. (2019). To be or not to be digital, that is the question: Firm innovation and performance. *Journal of Business Research - Turk*, *101*, 583–590.

Fitzgerald, M., Kruschwitz, N., Bonnet, D., & Welch, M. (2014). Embracing digital technology: a new strategic imperative. *Sloan Management Review*, *55*(2), 1–12.

Fletcher, G., & Griffiths, M. (2020). Digital transformation during a lockdown. *International Journal of Information Management*, *55*, 102185.

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, *5*(4), 210–233.

Fülöp, M. T., Breaz, T. O., He, X., Ionescu, C. A., Cordos, G. S., & Stanescu, S. G. (2022). The role of universities' sustainability, teachers' wellbeing, and attitudes toward e-learning during COVID-19. *Frontiers in Public Health*, *10*, 981593.

Fülöp, M. T., Breaz, T. O., Topor, I. D., Ionescu, C. A., & Dragolea, L. L. (2023). Challenges and perceptions of e-learning for educational sustainability in the "new normality era". *Frontiers in Psychology*, *14*, 1104633.

Ge, G., Xiao, X., Li, Z., & Dai, Q. (2022). *Does ESG performance promote high-quality development of enterprises in China? The mediating role of innovation input*. *Sustainability*, *14*(7), 3843.

Gigante, G., & Manglaviti, D. (2022). The ESG effect on the cost of debt financing: A sharp RD analysis. *International Review of Financial Analysis*, *84*, 102382.

Gillan, S. L., Koch, A., & Starks, L. T. (2021). Firms and social responsibility: A review of ESG and CSR research in corporate finance. *Journal of Corporate Finance*, *66*, 101889.

Graetz, G., & Michaels, G. (2018). Robots at work. *The Review of Economics and Statistics*, *100*(5), 753–768.

Gupta, S., Meissonier, R., Drave, V. A., & Roubaud, D. (2020). Examining the impact of cloud ERP on sustainable performance: A dynamic capability view. *International Journal of Information Management*, *51*, 102028.

Hajli, M., Sims, J. M., & Ibragimov, V. (2015). Information technology (IT) productivity paradox in the 21st century. *International Journal of Productivity and Performance Management*, *64*(4), 457–478.

He, F., Du, H., & Yu, B. (2022). Corporate ESG performance and manager misconduct: Evidence from China. *International Review of Financial Analysis*, *82*, 102201.

Hsu, P.-H., Liang, H., & Matos, P. (2021). Leviathan Inc. and corporate environmental engagement. *Management Science*. https://doi.org/10.1287/mnsc.2021.4064

Huang, D., Xie, H., Meng, X., & Zhang, Q. (2021). Digital transformation and enterprise value: Empirical evidence based on text analysis methods. *Economist*, *33*(12), 41–51.

Huang, D., Xie, H., & Zou, M. (2022). Does financialization inhibit corporate digital transformation?——Evidence and mechanism explanation. *Modern Finance and Economics-Journal of Tianjin University of Finance and Economics*, *42*(7), 57–73.

Jabbour, A. B. L. S., Jabbour, C. J. C., Foropon, C., & Filho, M. G. (2018). When titans meet - Can industry 4.0 revolutionise the environmrntal-sustainable manufacturing wave? The role of critical success factors. *Technological Forecasting and Social Change*, *132*, 18–25.

Jiang, Y., Wang, C., Li, S., & Wan, J. (2022). Do institutional investors' corporate site visits improve ESG performance? Evidence from China. *Pacific-Basin Finance Journal*, *76*, 101884.

Johnson, G. A., Lewis, R. A., & Reiley, D. H. (2017). When less is more: Data and power in advertising experiments. *Marketing Science*,*36*(1), 43–53.

Jones, T. M. (1995). Instrumental stakeholder theory: A synthesis of ethics and economics. *The Academy of Management Review*, *20*(2), 404–437.

Khalid, F., Sun, J., Huang, G., & Su, C. Y. (2021). Environmental, social and governance performance of Chinese multinationals: A comparison of state- and non-state-owned enterprises. *Sustainability*, *13*, 4020.

Landaluce, H., Arjona, L., Perallos, A., Falcone, F., Angulo, I., & Muralter, F. (2020). A review of IoT sensing applications and challenges using RFID and wireless sensor networks. *Sensors*, *20*, 2495.

Lee, J.-G., & Kang, M. (2016). Geospatial big data: Challenges and opportunities. *Big Data Research*, *2*(2), 74–81.

Leonardi, P., & Contractor, N. (2018). Better people analytics measure who they know, not just who they are. *Harvard Business Review*, *96*(6), 70–81.

Li, D., & Shen, W. (2021). Can corporate digitalization promote green innovation? The moderating roles of internal control and institutional ownership. *Sustainability*, *13*, 13983.

Li, L. (2013). The path to made-in-China: How this was done and future prospects. *International Journal of Production Economics*, *146*(1), 4–13.

Lin, Y., Fu, X., & Fu, X. (2021). Varieties in state capitalism and corporate innovation: Evidence from an emerging economy. *Journal of Corporate Finance*, *67*, 101919.

Liu, X., Wu, H., Wu, W., Fu, Y., & Huang, G. Q. (2021). Blockchain-enabled ESG reporting framework for sustainable supply chain. In S. G. Scholz, R. J. Howlett, & R. Setchi, (Eds.), *Sustainable design and Manufacturing 2020* (pp. 403–413). Springer.

Luo, D., Mathur, I., & Neely, C. J. (2022). ESG, liquidity, and stock returns. *Journal of International Financial Markets Institutions and Money*, *78*, 101526.

Mackinnon, D. P., Warsi, G., & Dwyer, J. H. (1995). A simulation study of mediated effect measures. *Multivariate Behavioral Research*, *30*(1), 41–62.

Mao, J., Li, J., & Zhang, B. (2022). CEO's background of compound functions and digital transformation of enterprises. *Modern Finance and Economics*, *42*(9), 37–58.

Marler, J. H., & Dulebohn, J. H. (2005). A model of employee self-service technology acceptance. *Research in Personnel and Human Resources Management*, *24*(24), 137–180.

Mikalef, P., & Pateli, A. (2017). Information technology-enabled dynamic capabilities and their indirect effect on competitive performance: Findings from PLS-SEM and fsQCA. *Journal of Business Research*,*70*, 1–16.

Mu, W., Liu, K., Tao, Y., & Ye, Y. (2023). Digital finance and corporate ESG. *Finance Research Letters*, *51*, 103426.

Naffa, H., & Fain, M. (2020). Performance measurement of ESG-themed megatrend investments in global equity markets using pure factor portfolios methodology. *Plos One*, *15*(12), e0244225.

Pissarides, C. A. (2000). *Equilibrium unemployment theory: Pythagoras to present*. MIT Press.

Sætra, H. S. (2023). The AI ESG protocol: Evaluating and disclosing the environment, social, and governance implications of artificial intelligence capabilities, assets, and activities. *Sustainable Development*, *31*(2), 1027–1037.

Saxena, A., Singh, R., Gehlot, A., Akram, S. V., Twala, B., Singh, A., Montero, E. C., & Priyadarshi, N. (2023). Technologies empowered environmental, social, and governance (ESG): An Industry 4.0 landscape. *Sustainability*, *15*, 309.

Serfling, M. (2016). Firing costs and capital structure decisions. *The Journal of Finance*, *71*(5), 2239–2286.

Shahab, Y., Ntim, C. G., Chen, Y., Ullah, F., Li, H. X., & Ye, Z. (2020). CEO attributes, sustainable performance, environmental performance, and environmental reporting: New insights from upper echelons perspective. *Business Strategy and the Environment*, *29*(1), 1–16.

Shih, Y. C., Wang, Y., Zhong, R., & Ma, Y. M. (2021). Corporate environmental responsibility and default risk: Evidence from China. *Pacific-Basin Finance Journal*, *68*, 101596.

Shiu, A., & Lam, P. L. (2008). Causal relationship between telecommunications and economic growth in China and its regions. *Regional Studies*, *42*(5), 705–718.

Thorbecke, W., & Zhang, H. (2009). The effect of exchange rate changes on China's labour-intensive manufacturing exports. *Pacific Economic Review*, *14*(3), 398–409.

Tian, X., & Li, R. (2022). Digital technology empowers the transformation and development of real economy: An analysis framework based on Schumpeter's endogenous growth theory. *Management World*, *38*(05), 56–74.

Usai, A., Fiano, F., Petruzzelli, A. M., Paoloni, P., Briamonte, M. F., & Orlando, B. (2021). Unveiling the impact of the adoption of digital technologies on firms' innovation performance. *Journal of Business Research - Turk*, *133*(4), 327–336.

Varadarajan, R. (2020). Customer information resources advantage, marketing strategy and business performance: A market resources based view. *Industrial Marketing Management*, *89*, 89–97.

Wade, M., & Shan, J. (2020). Covid-19 has accelerate digital transformation, but may have made it harder not easier. *MIS Quarterly Executive*, *19*(3), 213–220.

Wang, H., Sun, P., & Guo, H. (2022). How does digital finance empower enterprise to archive digital transformation: Empirical evidence from Chinese listed companies. *Collected Essays on Finance and Economics*, *10*(290), 3–13.

Wang, B., & Yang, M. (2022). A study on the mechanism of ESG performance on corporate value—Empirical evidence from A-share listed companies in China. *Soft Science*, *36*(6), 78–84.

Wang, F., Xia, J., & Xu, J. (2020). To upgrade or to relocate? Explaining heterogeneous responses of Chinese light manufacturing firms to rising labor costs. *China Economic Review*, *60*, 101333.

Wen, H., Ho, K. C., Gao, J., & Yu, L. (2022). The fundamental effects of ESG disclosure quality in boosting the growth of ESG investing. *Journal of International Financial Markets Institutions and Money*, *81*, 101655.

Wu, F., Hu, H., Lin, H., & Ren, X. (2021). Enterprise digital transformation and capital performance: Empirical evidence from stock liquidity. *Management World*, *37*(7), 130–144.

Xu, L., Lin, C., Li, Q., & Karolyi, A. (2020). Political investment cycles of state-owned enterprises. *Review of Financial Studies*, *33*(7), 3088–3129.

Xu, X., Zeng, S., & Chen, H. (2018). Signaling good by doing good: How does environmental corporate social responsibility affect international expansion? *Business Strategy and the Environment*, *27*(7), 946–959.

Yang, X., Ning, Z., Xiang, H., & Chen, J. (2021). Local economic growth goals and corporate digital transformation: Based on empirical evidence of text recognition of listed companies' annual reports. *China Soft Science*, *11*, 172–184.

Yu, E. P., & Luu, B. V. (2021). International variations in ESG disclosure: Do cross-listed companies care more? *International Review of Financial Analysis*, *75*, 101731.

Yu, M., & Pan, H. (2010). Financial development, business credits and market competitiveness. *Management World*, *8*, 117–129.

Yuan, C., Xiao, S., Geng, X., & Sheng, Y. (2021). Digital transformation and division of labor between enterprises: Vertical specialization or vertical integration. *China Industrial Economics*, *9*, 137–155.

Zhou, G., Liu, L., & Luo, S. (2022). Sustainable development, ESG performance and company market value: Mediating effect of financial performance. *Business Strategy and the Environment*, *31*(7), 3371–3387.

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

Environmental social governance (ESG) in digitalization research: A bibliometric analysis / Tan, Q. L., Hashim, S., & Zheng, Z.

SAGE Open
Volume 15 Issue 1 (2025) Pages 1-15
https://doi.org/10.1177/21582440241310953
(Database: SAGE Publications Inc.)

Literature Review

SAGE Open
January-March 2025: 1–15

DOI: 10.1177/21582440241310953
journals.sagepub.com/home/sgo
Sage

Environmental Social Governance (ESG) in Digitalization research: A bibliometric analysis

Qin Lingda Tan[1], Sharizal Hashim[1], and Zhangwei Zheng[1]

Abstract

In the last decade, the intersection of Environmental, Social, and Governance (ESG) principles with digital innovation has become a crucial area of research, highlighted by the United Nations' Sustainable Development Goals and the emerging focus on Digital ESG (DESG). Despite rapid advancements, a unified theoretical framework for DESG remains undefined. This study conducts a bibliometric analysis on 455 Scopus-indexed documents to map the current landscape, themes, and future directions of ESG digitalization research. The review reveals a multidisciplinary interest, primarily within business management, with significant contributions from China, Malaysia, and the United States—indicating their leadership potential in ESG digitalization. This study spotlights key researchers and emphasizes foundational work's critical role in enhancing understanding of DESG and ESG's impact on consumer behavior, laying essential groundwork for deeper insights and future explorations into the effects of ESG values on consumer attitudes.

Keywords

environmental, social, and governance, ESG, digital, DESG, bibliometric analysis

Introduction

In the past decade, rapid technological advancements, market shifts, and the pressing challenges of climate change have prompted nations to prioritize sustainable development. Central to these efforts is the Environmental, Social, and Governance (ESG) framework, which has emerged as a crucial measure shaping the future of nations, businesses, and consumers (Galbreath, 2013; Pérez, 2022). Unlike traditional financial metrics, ESG evaluates a company's broader impact, incorporating environmental stewardship, social responsibility, and governance practices (Hou et al., 2023). As societies demand ethical consumption and social justice (Phan & Ninh, 2024), investors and consumers increasingly prefer companies with strong ESG performance, recognizing both financial and social benefits. Scholars, including Bruno and Henisz (2024), underscore ESG's role in areas like municipal debt and community development, emphasizing its potential to enhance social welfare and reduce inequalities. With regulations now mandating ESG disclosures, these principles are becoming integral to corporate strategy, boosting long-term competitiveness and value (Arun et al., 2022; Zumente & Bistrova, 2021).

Current ESG research largely focuses on investment (Broadstock et al., 2021; Van Duuren et al., 2016), financial performance (Friede et al., 2015; Ma et al., 2023). Despite its growing importance, the digital transformation of ESG, commonly referred to as Digital Environmental, Social, and Governance (DESG), remains an underexplored area. DESG involves leveraging technologies such as big data, cloud computing, and artificial intelligence to enhance ESG practices across the value chain, driving greater outcomes for stakeholders (Wang et al., 2023). As more industries undergo digital transformation, the integration of these

[1]Faculty of Economics and Management, Universiti Kebangsaan Malaysia, Bangi, Malaysia

Corresponding Author:
Sharizal Hashim, Faculty of Economics and Management, Universiti Kebangsaan Malaysia, Bangi, Selangor 43600, Malaysia.
Email: hsharizal@ukm.edu.my

technologies into ESG frameworks is critical. However, current research specifically addressing DESG is limited (Puriwat & Tripopsakul, 2022), highlighting a significant gap in the literature.

This study is motivated by the need to bridge this gap, exploring the intersection of ESG and digital innovation. While existing ESG reviews have focused on traditional corporate ESG topics—such as disclosure impacts (Khan, 2022), determinants of ESG performance (T. T. Li et al., 2021; Tsang et al., 2023), and country-specific studies (Shen et al., 2023)—few have examined the digital evolution of ESG practices (Xu et al., 2024). This study seeks to address this omission by conducting a bibliometric analysis of 455 Scopus-indexed documents, mapping the landscape of ESG digitalization research. It also emphasizes DESG's impact on consumer behavior, an area underexplored in prior studies. By investigating DESG, this research establishes a foundation for understanding how digitalization is reshaping ESG practices and perceptions, while also calling for a unified theoretical framework for DESG.

In summary, this study aims to clarify key contributors, themes, and trends in DESG and traditional ESG research, addressing three specific research questions: (a) What are the overall characteristics and publication trends in this field? (b) Who are the most influential authors, countries, journals, and articles? (c) What are the current key themes and future research directions? Following the review of bibliometric literature, the subsequent sections outline the methods employed, present the findings, and conclude with recommendations for future research.

Methodology

Research Design and Bibliometric Techniques

This study utilizes bibliometric analysis, a quantitative method increasingly acknowledged for its effectiveness in evaluating academic literature across diverse fields (Aksnes et al., 2019; Donthu et al., 2021). The research integrates multiple bibliometric techniques, notably performance analysis and scientific mapping, which encompass three distinct methodologies: co-authorship analysis, bibliographic coupling, and co-word analysis.

Performance analysis serves as a descriptive statistical method that aids in assessing the significance of various components within a research area (Cobo et al., 2015). Key indicators include the number of publications, reflecting productivity, and citation counts, indicating influence (Donthu et al., 2021). Conversely, scientific mapping techniques elucidate influential factors by revealing relationships among journals, authors, countries, and documents (Mubdir et al., 2024; Chen et al., 2015). For instance, co-authorship analysis uncovers collaborative relationships among authors and institutions (Donthu et al., 2021; Uddin et al., 2012), whereas bibliographic coupling highlights emerging trends in the field (Donthu et al., 2021; García-Lillo et al., 2019). In addition, co-word analysis focuses on the frequency of keywords in documents, facilitating the identification of trending topics and research themes (Donthu et al., 2021).

To enhance bibliometric mapping and visualize research networks, this study employs VOSviewer software (Van Eck & Waltman, 2010). This comprehensive approach aims to clarify the current state of research on ESG in the context of digitalization, thereby enriching the understanding of the evolving landscape in this field.

Search Strategy and Data Collection

The search strategy was designed to identify relevant articles on digital ESG (DESG) and traditional ESG. Data were sourced from Scopus, selected for its broad social sciences coverage and to minimize errors from manual intervention (Donthu et al., 2021). Although multiple databases could provide broader data, the use of a single database ensures consistency across formats. Journal articles were selected as the primary unit of analysis, representing peer-reviewed and validated knowledge, thereby ensuring credibility and reliability in the findings (Dadkhah et al., 2015; Donthu et al., 2021). To uphold a consistent standard of quality, other document types, such as conference proceedings, books, and trade journals, were excluded. To avoid capturing irrelevant studies from fields such as energy and bacteriology, abbreviations like ESG or DESG were not directly used in the search. Terms such as "diethylstilbestrol glucuronide" and "Electrospinogram" share similar abbreviations but are unrelated to the focus of this research. Although some scholars suggest that CSR is synonymous with ESG (Shen et al., 2023), the concept of ESG has evolved and gained consensus as an independent topic distinct from CSR. Therefore, CSR-related terms were excluded from the search to focus specifically on the digital transformation of ESG, rather than general or traditional ESG and CSR studies.

Given that this is a bibliometric analysis, the search was limited to article titles only, to ensure precision in identifying relevant publications. Abstracts and keywords were excluded to minimize noise in the dataset. The final search terms included "digital* environmental, social, and governance" and "environmental, social, and governance." Non-English articles were excluded to maintain linguistic consistency, and no disciplinary filters were applied, allowing for a comprehensive review of ESG-related literature. The search covered all articles published up to November 18, 2023.

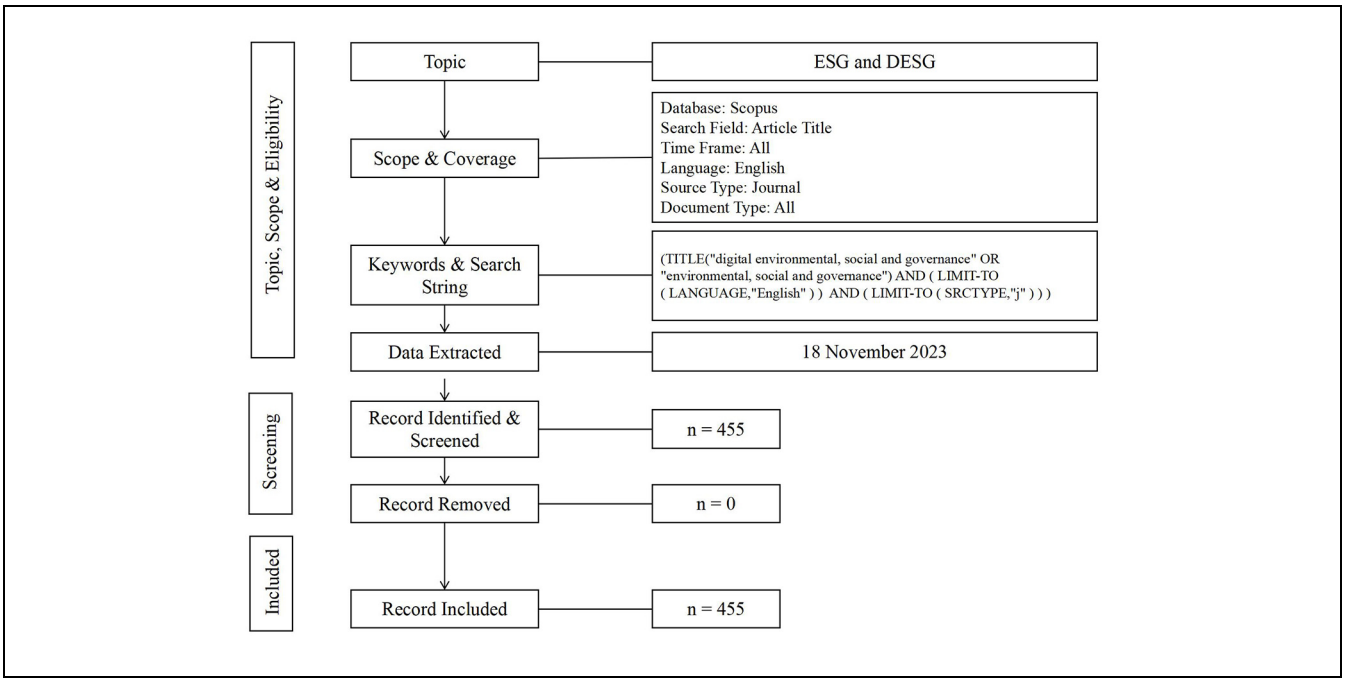


Figure 1. Searching strategy and data collection procedure.

The data collected were analyzed using descriptive and relational bibliometric indicators, including publication year, language, country, institution, and author co-occurrence. These indicators provided a detailed overview of the research landscape, helping to identify key contributors and emerging trends, as well as guiding future research directions. Figure 1 outlines the detailed steps, detailing the whole searching strategy and data collection procedure.

Results and Discussion

This research employed the aforementioned selection criteria to search the Scopus-indexed database. Subsequently, data extraction and analysis were performed on the retrieved 455 articles. The results and discussions are presented below.

Publications Per Year

As depicted in Figure 2, the distribution of articles across different time periods was observed. Despite the introduction of the ESG concept by the United Nations (UN) in 2004 (UN, 2004), this research, constrained by keyword limitations (explained in detail in the Limitations section), incorporates research from 2011. The results reveal that from 2011 to 2015, only 11 articles were disseminated, indicating an incipient stage in related research. This trend can be attributed to the establishment of the Climate Disclosure Standards Board (CDSB) in 2007 and the Sustainability Accounting Standards Board (SASB) in 2011, providing frameworks for ESG metric disclosure. During this period, articles published demonstrated innovativeness and pioneering contributions. The second phase, spanning from 2016 to 2020, witnessed an almost ninefold increase in the total number of papers, amounting to 93 articles. This surge is likely influenced by the introduction of the UN's Sustainable Development Goals (SDGs) in 2015 (UN, 2015), intensifying global attention on sustainable development. Additionally, the release of the Sustainable Development Accounting Standards by SASB in 2018 (SASB, 2018) contributed to the substantial growth in related research publications. The third phase, from 2021 to 2024, experienced a significant spike in the number of published articles, totaling 351. This surge indicates widespread attention to the relevant topics. It is likely driven by the heightened global focus on sustainable development and ESG following extreme events post-2019, including the COVID-19 pandemic and environmental disasters. Major countries such as the United States, China, and the European Union enacted regulations, leading to a substantial increase in ESG-related publications after 2021. The growth rate reached an impressive 114% in 2022, with 192 articles published in 2023, reflecting a 277% increase compared to the preceding period. These findings underscore the current prominence and developmental trends in DESG and ESG research. Looking ahead, the trajectory suggests potential diversification into new research directions, exploration of previously

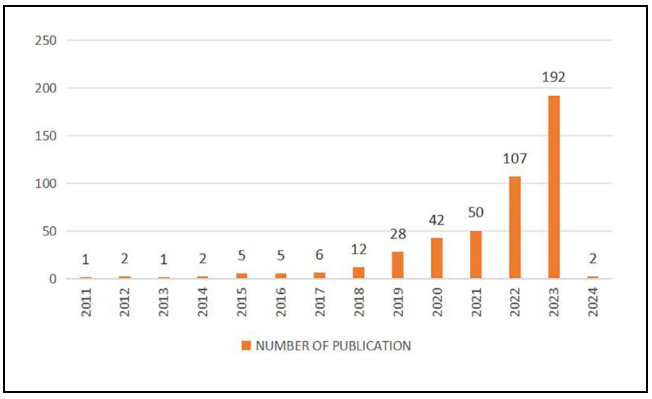


Figure 2. Articles on DESG&ESG per year.

limited domains, and addressing "conventional issues" through new frameworks. Additionally, delving into new international collaborations can contribute to expanding the scope of research.

Countries of Publications

This study reveals that articles were submitted from 71 countries or regions, with a significant concentration of authors affiliated with diverse institutions in China, Malaysia, the United States, Italy, Australia, the United Kingdom, India, and Spain. Figure 3 illustrates author nationalities and collaborative relationships, emphasizing geographical and cultural clusters, particularly around China, Malaysia, and the United States.

The ESG market in China is rapidly advancing, driven by government advocacy for green, low-carbon, and inclusive prosperity (China Academy of Translation, 2015). Government agencies prioritize policy research, issuing comprehensive ESG-related documents to facilitate the green transformation of the economy. The ESG philosophy closely aligns with China's modernization goals, addressing environmental issues like peak carbon emissions and biodiversity, social challenges such as rural revitalization and common prosperity, and governance concerns like anti-corruption and justice (The State Council of P.R. China, 2022). Furthermore, the Chinese government recognizes ESG as a critical indicator for assessing corporate sustainable development (China ESG30 Forum, 2022). China's international collaboration efforts, exemplified by the Belt and Road Initiative, have contributed to a notable increase in scholarly publications on ESG.

While Malaysia may not emphasize ESG as heavily as more mature markets in Europe and America, it leads Southeast Asia in the proportion of companies adhering to environmental supply chain policies (68.8% in Malaysia, 66% in Thailand, and 58.6% in Singapore) (PricewaterhouseCoopers [PwC], 2023). The Malaysian

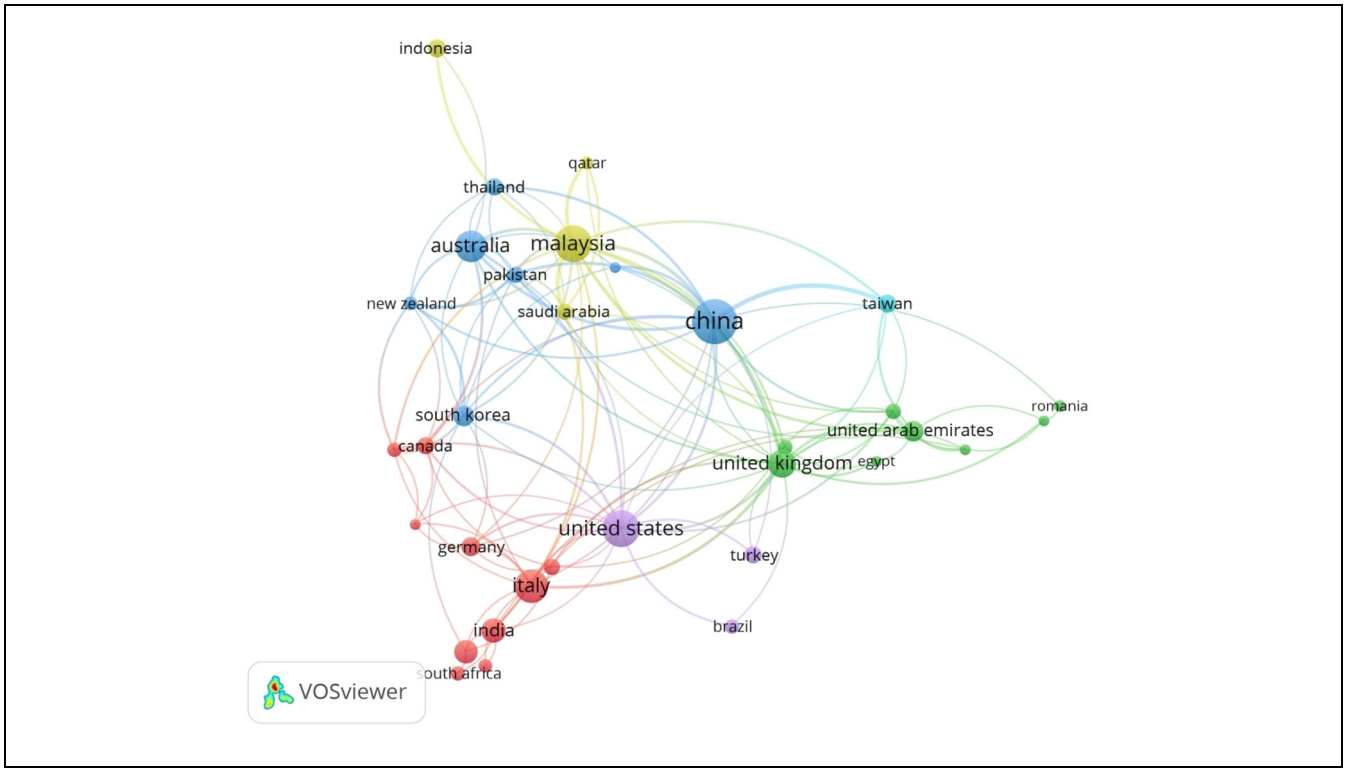


Figure 3. Authors' nationalities map.
Note. The size shows the relative proportion of articles and the closeness shows the collaboration between authors of those countries.

government has maintained a focus on sustainable development, actively responding to global ESG and responsible investment principles. Its comprehensive ESG policy and regulatory framework, guided by the Sustainable and Responsible Investment (SRI) ecosystem introduced in 2014, effectively directs market participants (Securities Commission Malaysia, 2019). Malaysia, significantly positioned in the global Islamic finance market, integrates Islamic finance principles with SRI through interconnected funds that emphasize sustainable development, as demonstrated by the SRI Sukuk Framework (Azman & Ali, 2016). The country aims to become a regional center for SRI investment by adapting international best practices to align with its unique economic and cultural characteristics, potentially making it a pivotal nation for ESG research.

In contrast, the United States (U.S.) adopts a different approach to ESG than Asia and Europe, with fewer proactive federal initiatives. Local initiatives, especially in California, lead the way, as seen in Senate Bill No. 185 (U.S. Congress, 2015) and Senate Bill No. 964 (U.S. Congress, 2018), which guide pension fund investments. ESG disclosure requirements on securities trading platforms primarily focus on environmental aspects. Following the UN's SDGs in 2015, the U.S. issued Interpretive Bulletin 2015-01 (U.S. Department of Labor, 2015), marking the first comprehensive ESG policy guidelines from the U.S. Subsequent Bulletins in 2016 and 2018 provided practical guidance on integrating ESG into investment practices (U.S. Securities and Exchange Commission, 2016; 2018), emphasizing fiduciary responsibility. Despite a lower level of federal initiatives and no exchange disclosure requirements, the U.S. remains a significant hub for ESG academic research due to its status as the world's largest economy and financial market.

As a developed ESG investment market, the United Kingdom (UK) actively engages with the UN's Sustainable Development Investment Initiative. Over the past decade, the UK has established a comprehensive ESG policy framework, reflecting its commitment to sustainable financial development (U.S. Department of State, 2015). Early initiatives in 2005 laid the groundwork, with subsequent revisions progressively expanding the applicability of ESG regulations within capital markets. By 2015, the UK's SRI market had surpassed 21 billion euros, indicating increasing acceptance of ESG principles (U.S. Department of State, 2015). The UK has demonstrated its commitment to sustainable finance through biennial revisions of ESG policies since 2014. Regulatory requirements have become more explicit, emphasizing ESG responsibilities within corporate governance and fostering communication between investors and companies. Although the UK formally departed from the EU in 2020, it remains dedicated to sustainable financial development, positioning itself as a core nation for independent ESG research.

This research posits that the concentration of articles by country yields two key outcomes (Acedo et al., 2006): it facilitates the exploration of more in-depth regional research topics and creates opportunities for international collaboration. Notably, the top two contributors to DESG and ESG research are developing countries, indicating that these nations are actively engaging in ESG studies to identify strategic directions for future sustainable development. The future development and practices of ESG in developing countries warrant scholarly attention, as does the potential for international collaboration on ESG initiatives.

Major Related Journals and Subject Area

These 455 articles were published across 161 journals, with over 67% concentrated in just 62 specific journals. Moreover, more than 70% of the citations are attributed to 32 key journals. Table 1 provides the details of these journals. This data helps identify the most influential journals in the field, such as Journal of Cleaner Production (12 articles), Business Strategy and the Environment (32 articles), Corporate Social Responsibility and Environmental Management (44 articles), and Sustainability Switzerland (43 articles). These diverse journals offer multiple perspectives within the field.

Identifying the core journals in this area also allows for integration with others approaching the topic from different angles. The map in Figure 4 visually represents the relationships between journals using bibliographic coupling analysis, showcasing their proximity and influence in constructing the knowledge structure of the field. Journals with higher publication and citation rates, particularly in management, occupy central positions. Other fields, like psychology and environmental science, are connected to this core, with specialized journals surrounding them.

As shown in Table 2, the majority of articles are concentrated in fields like "Business, Management and Accounting," "Social Sciences," "Environmental Science," and "Economics, Econometrics, and Finance." Articles published in other disciplines, while investigating corporate financial performance, investment strategies, and information disclosure, are classified based on the industry or journal category. For instance, Schneider et al. (2021) examined ESG investment among private German health insurers, publishing in the Journal of Medical Ethics, categorized under Nursing. Pirtea et al. (2021) studied ESG's relationship with agricultural

Table 1. Journals With Publications on DESG&ESG.

Source title	CiteScore	h_index	% Cited	Articles	All citations
Corporate social responsibility and environmental management	15.6	14	91	44	758
Sustainability Switzerland	5.8	16	75	43	813
Business strategy and the environment	17.8	19	94	32	1804
Journal of cleaner production	18.5	9	89	12	479
Accounting and Finance	4.5	6	73	8	278
Environmental science and pollution research	7.9	2	84	7	11
Sustainable development	15.2	4	91	5	133
Journal of business ethics	12	5	92	5	688
Research in international business and finance	9.1	3	80	5	266
Corporate governance (Bingley)	9	3	88	5	84
Sustainability accounting, management and policy journal	7	4	84	5	172
Economic Research-Ekonomska Istrazivanja	6.2	3	83	5	97
Meditari accountancy research	5	5	81	5	53
Frontiers in psychology	4.5	3	62	5	15
Frontiers in environmental science	3.1	3	50	5	19
British accounting review	7.2	4	75	4	899
Environment, development and sustainability	7.2	3	86	4	31
Borsa Istanbul review	5.8	3	72	4	42
Global business review	4.3	3	82	4	22
Australasian accounting, business and finance journal	3.4	4	97	4	42
Journal of environmental management	13.4	2	87	3	16
Finance research letters	10.8	2	75	3	8
Management of environmental quality	8.6	2	86	3	247
Journal of corporate finance	7.6	2	83	3	68
Business ethics, the environment and responsibility	6.2	0	77	3	0
Business strategy and development	5	2	83	3	33
Global finance journal	5	2	77	3	9
Journal of business economics and management	4.9	2	73	3	61
Journal of financial reporting and accounting	3.7	2	78	3	25
Asian review of accounting	2.9	0	68	3	0
Journal of risk and financial management	2.8	2	61	3	11
Management decision	10.3	2	95	5	9

company performance in Agricultural Economics (Czech Republic), categorized under Agricultural and Biological Sciences.

Some studies focus on foundational infrastructure, institutional aspects, and industry impacts related to ESG. For example, Zhai et al. (2023) explored urban digital infrastructure's link to ESG development, while Maybee et al. (2023) discussed ESG risks in the mining life cycle. However, most research on digital ESG and ESG in general emphasizes corporate financial performance, investment strategies, and information disclosure, focusing on ESG's application in specific countries and industries. The varying levels of ESG development across regions and the lack of a global standard framework have resulted in fragmented theoretical frameworks, tools, and scoring standards for ESG. Consequently, fewer studies explore the impact of ESG on energy and technology, with limited attention to the conceptual evolution of ESG, its foundational implementation structures, and the digitization of ESG practices.

Most Cited Articles

Literature from Scopus can be categorized in various ways, one of which is ranking articles by citation count to identify those that have garnered significant attention in the scientific community. Table 3 lists the top 20 most-cited articles among the 455 publications related to DESG and ESG, collectively accounting for over 40% of total citations in this area.

The most-cited paper is the 2018 study on ESG disclosure by Li, Gong, Zhang, and Koh, published in The British Accounting Review, with nearly 422 citations. This article outlines five arguments for how ESG disclosure promotes value creation, including offering additional information, improving stakeholder relationships, reducing information asymmetry, enhancing transparency, and lowering agency costs. The study concludes that firms with better ESG disclosure exhibit higher firm value.

The second most-cited article is Brooks and Oikonomou's (2018) editorial, which provides a

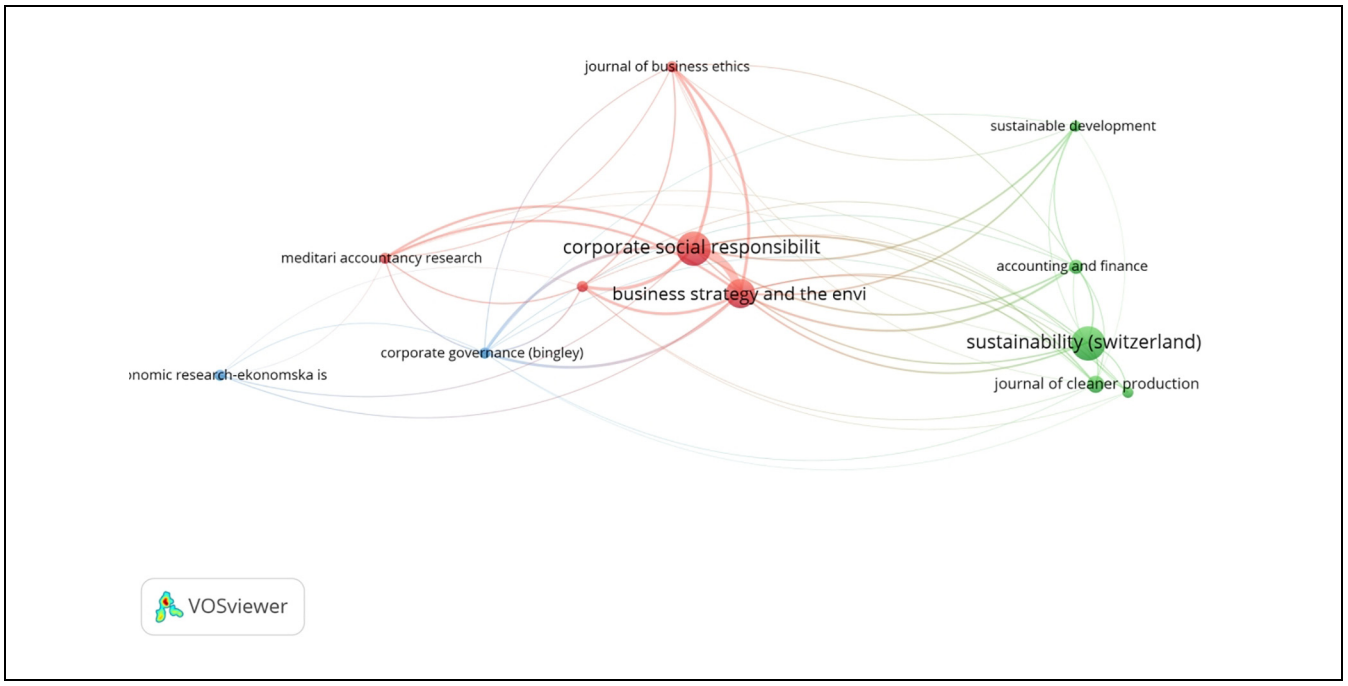


Figure 4. Journals bibliographic coupling map.
Note. The size of the nodes (journals) indicates the relative number of citations. The distance between the nodes (journals) represents the relative strength in the relationship between them. This research limited the visualization to 12 journals that accounted for 50 citations at least.

Table 2. Subject Areas of the Publications of DESG&ESG.

Subject area	Number of publication
Business, management and accounting	269
Social sciences	198
Environmental science	180
Economics, econometrics and finance	152
Energy	80
Computer science	40
Engineering	35
Decision sciences	25
Arts and humanities	19
Medicine	10
Psychology	8
Earth and planetary sciences	6
Mathematics	6
Chemical engineering	5
Multidisciplinary	5
Agricultural and biological sciences	4
Nursing	3
Materials science	2
Biochemistry, genetics and molecular biology	1
Chemistry	1
Physics and astronomy	1

comprehensive overview of ESG disclosure literature and its effects on firm value. It emphasizes the need for a detailed review of the research landscape, identifying knowledge gaps and future research opportunities.

Another highly cited work by Xie et al. (2019), with over 300 citations, examines the link between corporate efficiency and sustainability. The study identifies a positive correlation between ESG transparency and corporate efficiency, particularly at moderate disclosure levels. Additionally, five other influential papers, each with over 200 citations, focus primarily on ESG disclosure and its relationship with financial performance.

Most Productive and Influential Authors

Since the rise of "Digitalization and ESG" as a research topic, numerous scholars have made significant contributions to its development. This section introduces some of these researchers based on the volume of their publications, as retrieved from Scopus. The analysis highlights key contributors in the DESG and ESG fields, though it is important to acknowledge that alternative ranking criteria could bring other authors to the forefront.

Authors can be ranked by the number of publications or by citation frequency—both common methods in previous studies, such as Danvila-del-Valle et al. (2019), who ranked researchers using both the h-index and citation counts.

This paper adopts a dual approach. First, it presents the top 20 authors with the most publications among the 455 selected articles. Then, a separate list ranks 20 authors based on the number of citations their contributions have garnered, with each listed work cited at least 100 times.

Table 3. Top 20 Articles With the Highest Number of Citations Among the Selected 455 Articles.

Documents	Cites Per Year	Cites Per Author	Total Cites
Y. Li et al. (2018)	68.4	86	342
Brooks and Oikonomou (2018)	64	160	320
Xie et al. (2019)	75.25	60	301
Baldini et al. (2018)	47	47	235
Duque-Grisales and Aguilera-Caracuel (2021)	113.5	114	227
Bernardi and Stark (2018)	42	105	210
Husted and de Sousa-Filho (2019)	52.5	105	210
Lokuwaduge and Heenetigala (2017)	34.67	104	208
K. H. Lee et al. (2016)	28.43	66	199
Yu et al. (2020)	56.67	57	170
Yu et al. (2018)	30.2	50	151
Atan et al. (2018)	30	38	150
Husted and de Sousa-Filho (2017)	21.83	66	131
Weber (2014)	14.22	128	128
Brogi and Lagasio (2019)	30.25	61	121
Adams and Abhayawansa (2022)	119	60	119
Huang (2021)	59.5	119	119
Qureshi et al. (2020)	39.33	30	118
Taliento et al. (2019)	28.5	38	114
Camilleri (2015)	14.25	114	114

Table 4. Top 20 Authors With the Highest Number of Published Articles Among the Selected 455 Articles.

Author	h-index	Citations	Articles
F A Khatib, Saleh	15	681	5
Hussainey, Khaled	40	5,072	4
Wasiuzzaman, Shaista	16	746	4
Shakil, Mohammad Hassan	8	635	4
Lagasio, Valentina	8	429	4
Ellili, Nejla Ould Daoud	10	307	4
Suttipun, Muttanachai	9	187	4
Al Amosh, Hamzeh	8	180	4
Lu, Wen Min	33	3,886	3
Brogi, Matteo	31	3,371	3
Umar, Zaghum	34	2,635	3
Kweh, Qian Long	17	1,087	3
Abhayawansa, Subhash Asanga	20	1,014	3
Ting, Irene Wei Kiong	14	881	3
Zioło, Magdalena	13	869	3
Chang, Baoguang	10	269	3
Habib, Ahmed Mohamed	8	180	3
Huang, Danny Zhao Xiang	3	144	3
Ngo, Thanhquang	6	135	3
Wu, Kuosheng	4	41	3

These lists highlight prolific researchers, frequently cited works, and influential figures in the DESG and ESG domains. The results are presented in Tables 4 and 5.

Topics on Digital ESG or ESG

Although ESG and DESG differ conceptually, DESG research remains in its early stages, with its scope and definition still lacking broad consensus. As a result, DESG has not yet emerged as a distinct, mature subfield independent of ESG studies. Currently, DESG is viewed more as an emerging research trend rather than a separate domain. Therefore, this paper does not distinguish between the two but instead focuses on mapping the landscape and trends in digitalization-related ESG research.

Within the analyzed literature, 1,749 unique keywords were used to classify the studies. Table 6 and Figure 5

Table 5. Top 20 Authors With the Highest Number of Citations Among the Selected 455 Articles.

Author	h-index	All citations	Citations
Li, Yiwei	3	443	342
Husted, Bryan W.	39	5,579	341
Yu, Ellen Pei Yi	4	480	321
Brooks C	59	24,088	320
Xie, Jun	3	351	301
Baldini, Maria Assunta	3	265	235
Duque, E. A.	10	485	227
Bernardi, Cristiana	7	889	210
Lokuwaduge, Chitra De Silva	6	298	208
Lee, Ki Hoon	29	3,836	199
Atan, Ruhaya	6	266	150
Weber, Olaf	29	2,492	128
Brogi M.	15	1,447	121
Adams C.A.	55	21,102	119
Huang, Danny Zhao Xiang	3	144	119
Qureshi M.A	24	1,577	118
Camilleri, Mark A.	26	1,818	114
Taliento, Marco	2	120	114
Rajesh, R.	22	1,869	110
Ortas, Eduardo	21	1,381	110

display 41 keywords that appeared at least 10 times. The size of the nodes in Figure 5 represents the frequency of each term, while the lines and distances between nodes indicate the strength of the relationships between these terms. As expected, keywords such as ESG, environmental, social, and governance rank highly due to their function as selection criteria. The prominence of terms like ESG performance, investments, finance, financial performance, and performance assessment highlights that many scholars are investigating DESG and ESG from the perspectives of corporate management, financial practices, and asset evaluation. These findings align with the identified knowledge framework, key authors, and the most cited references within DESG and ESG studies.

China is notably the only regional keyword, which, when combined with the authors' nationalities map in Figure 3, suggests that China plays a significant role in DESG and ESG research. Foundational contributions by scholars such as Mănescu, Weber, Camilleri, Ortas, Lee, Lokuwaduge, and Husted have shaped the early knowledge base, focusing on the relationships between ESG and stock returns, ESG's application in various countries, and its ties to sustainable development. From its inception, ESG has been closely linked to topics such as investment, corporate asset evaluation, financial performance, strategic management, environmental governance, and sustainability.

As ESG evolves alongside technological advancements and market shifts, its subfields continue to expand and deepen, shaping the current research landscape for DESG and ESG. In terms of future trends, beyond the dominant themes of corporate management and financial performance, other subdomains—such as enhancing brand value and fostering consumer engagement—are likely to intersect with DESG and ESG, paving the way for new research directions and opportunities.

Future Directions

The future of research in Environmental, Social, and Governance (ESG) and Digital ESG (DESG) can be structured into three primary directions, each offering significant opportunities for advancement.

First, research should focus on refining the foundational elements of ESG, including principles, frameworks, disclosure requirements, and rating systems (Camilleri, 2015; Lokuwaduge & Heenetigala, 2017; Singhania & Saini, 2023; Whitelock, 2019). This involves adapting ESG evaluation standards to diverse economic and cultural contexts, expanding rating categories, and leveraging digital technologies to enhance the accuracy and transparency of ESG reporting. Key questions include: How can ESG rating systems be tailored to reflect regional differences? What role can technologies like AI and blockchain play in improving ESG reporting? How can ESG frameworks evolve to include emerging issues such as cybersecurity and digital infrastructure?

Second, the practical application of ESG in corporate strategy, performance, and operations should be explored. Future studies need to assess how companies can integrate ESG principles to boost both ratings and financial performance (Z. Chen & Xie, 2022; S. Chen

Table 6. Top 41 Keywords With the Highest Frequency Among the Selected 455 Articles.

Keyword	Frequency
ESG	120
Environmental	80
Governance approach	77
Sustainability	71
Sustainable development	62
Corporate social responsibility	52
ESG performance	48
Social	41
Corporate governance	33
Governance	31
China	29
ESG disclosure	27
Stakeholder	25
Financial performance	23
Investment	23
Environmental Economics	21
Stakeholder theory	21
Investments	20
Finance	18
Financial system	17
Performance assessment	17
Environmental, social, and governance	16
Firm performance	16
Industrial performance	16
Decision making	14
Environment	14
Performance	14
Social and governance (ESG)	14
Stakeholder engagement	14
Corporate strategy	11
Economic and social effects	11
Environmental management	11
Panel data	11
Social and governance	11
Climate change	10
Corporate social responsibility (CSR)	10
Environmental impact	10
Firm size	10
Gender diversity	10
Human	10
Sustainable development goal	10

et al., 2023; Friede et al., 2015). Research should examine the relationship between ESG performance and overall corporate success, including brand development, innovation, and governance (Piao et al., 2022; Velte, 2017). Important inquiries include: What strategies are most effective for integrating ESG into governance models? How do different industries approach ESG implementation? What risks arise from prioritizing ESG in corporate strategies, and how can firms mitigate these risks?

Third, the role of individuals—consumers, employees, and investors—must be addressed, as their engagement is vital for the success of ESG initiatives (Koh et al., 2022; H. J. Lee & Rhee, 2023). Future research should explore consumer attitudes toward ESG, the engagement of employees with ESG practices, and the factors influencing individual investors' ESG investment decisions (Afeef & Kakakhel, 2022; Rabaya & Saleh, 2022). Key questions include: How do consumer perceptions of ESG affect purchasing behavior? What drives employee engagement with corporate ESG initiatives? How do ESG-aligned investments compare to traditional options in terms of performance?

Additionally, research on DESG should investigate how ESG practices are adapted in emerging markets, the scalability of ESG practices through digital transformation, and the inclusion of non-financial outcomes like social welfare and environmental justice within ESG frameworks (Puriwat & Tripopsakul, 2022; Wang et al., 2023).

These research directions underscore the expanding scope of ESG studies and highlight their potential to shape corporate governance, sustainable development, and the broader implementation of ESG principles. As the field evolves, these pathways will be crucial for advancing both academic knowledge and practical applications.

Conclusion

The analysis reveals a significant increase in ESG research publication trends, starting with 11 articles from 2011 to 2015, surging to 93 articles from 2016 to 2020, and reaching 351 articles from 2021 to 2024. This trajectory indicates a growing global interest in ESG-related topics.

Research on DESG and ESG demonstrates a geographically diverse and multicentric distribution, with China, Malaysia, the United States, and the United Kingdom emerging as key research hubs. This concentration enriches regional discussions and fosters international collaboration, showcasing contributions from both developed and developing countries.

The most impactful journals in this field are primarily based in the United States and the United Kingdom, including the "Journal of Environmental Management," "Business Strategy and the Environment," and "Journal of Cleaner Production." Notable authors include F. A. Khatib, S. Hussainey, and K. Wasiuzzaman, while the most cited authors are Li, Y., Husted, B. W., and Yu, E. P. Y. Key literature identified for its productivity and influence includes works by Brooks and Oikonomou (2018), Y. Li et al. (2018), and Xie et al. (2019).

The findings underscore the expanding scope and relevance of ESG research, marked by increasing interest and publication rates. The identification of key geographic hubs and influential journals reflects the

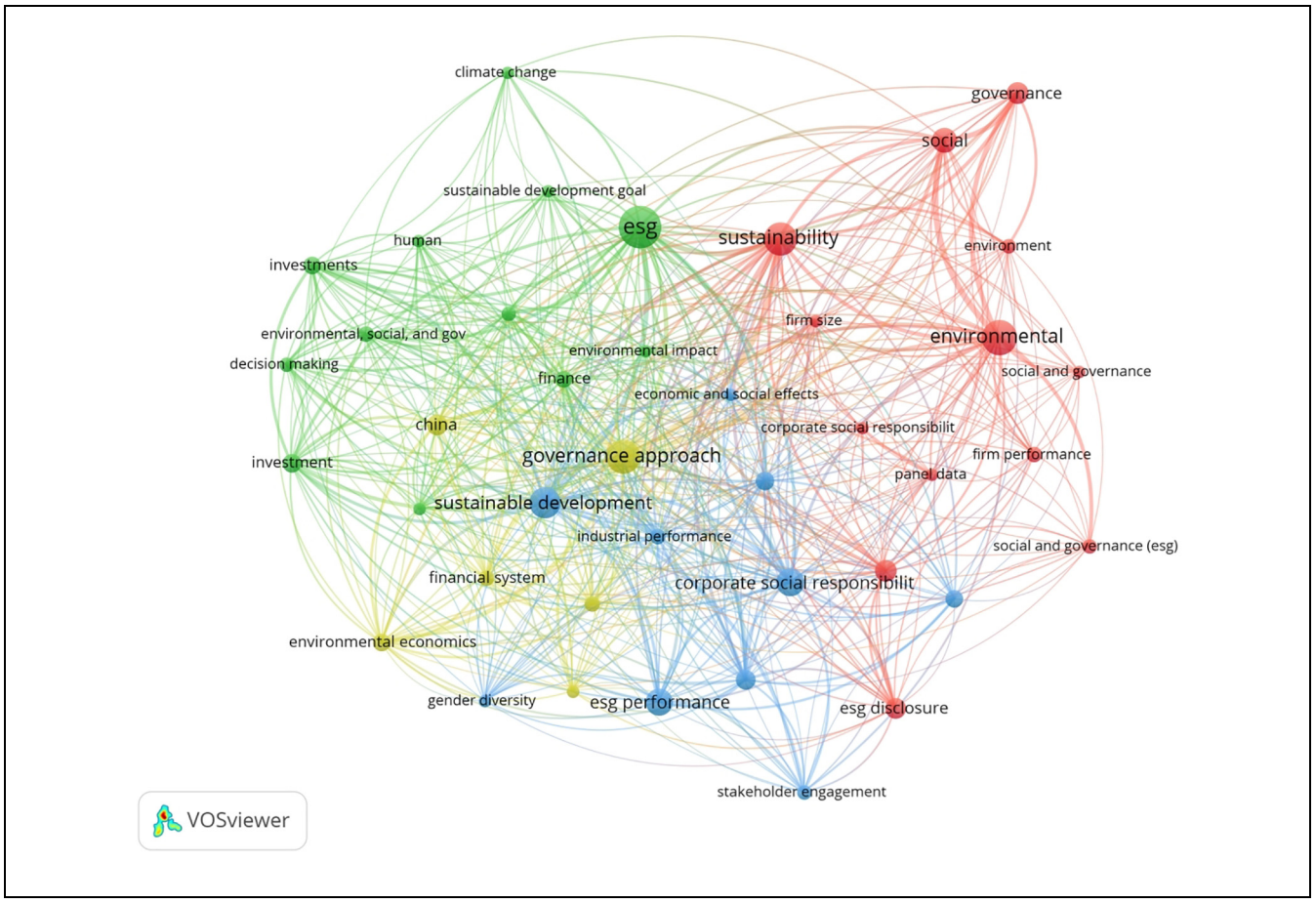


Figure 5. Co-occurrence of keywords map.

multifaceted nature of ESG studies, bridging both theoretical and practical contributions.

Theoretically, this research highlights the need for further exploration of underrepresented areas, such as consumer perspectives on ESG, technological acceptance, and the evolution of the ESG concept. These gaps present valuable opportunities for future scholarship aimed at deepening understanding and enhancing frameworks in the field.

Practically, the insights can guide policymakers, practitioners, and researchers in leveraging ESG principles for sustainable outcomes. As the ESG landscape evolves, sustaining momentum in popular domains while also investigating specialized areas, such as DESG and consumer values, will be crucial for advancing academic inquiry and practical applications in corporate governance and sustainable development.

Limitations and Future Research

This research has certain limitations. The search strategy encountered challenges in fields like energy studies and bacteriology, where ESG and DESG may refer to terms unrelated to "environmental, social, and governance," such as diethylstilbestrol glucuronide (DESG) and electrically suspended gyro (ESG). Excluding literature from these domains that incidentally used the abbreviations posed difficulties, and outright exclusion was not feasible, as relevant research might still exist within these fields. Consequently, the decision was made not to incorporate DESG and ESG into the search strategy, which may have resulted in the omission of significant studies.

Future research should broaden its scope by utilizing multiple databases to enhance the representativeness and credibility of findings. Comprehensive scoping or systematic reviews of DESG and ESG literature, especially in business management and economics, can provide valuable insights into the evolution of indicators from diverse perspectives. These methodologies allow for manual selection of articles, addressing limitations of bibliometric analyses. Additionally, categorizing literature by specific sub-fields will deepen the understanding of both well-explored and under-researched areas within management studies. By addressing these limitations, future

inquiries can effectively fill identified gaps, establishing a solid foundation for potential meta-analyses and further contributions to the field.

Acknowledgment

We sincerely thank our colleagues, mentors, and industry experts for their invaluable insights and guidance, which have been pivotal in advancing this research. Their commitment and constructive feedback have been essential to our study's development.

Author Contributions

Each author has made substantial contributions to the research: this includes conceptualization and methodology design, development of the search strategy, data curation, results presentation (visualization), and discussion. The drafting of the original manuscript was primarily undertaken by Qin Lingda Tan, while Sharizal Hashim and Zhangwei Zheng provided critical review and editing. All authors have reviewed and approved the final version of this article.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Financial support for publication from Universiti Kebangsaan Malaysia (GP-K024839).

Ethics Approval

This research did not collect empirical data so ethical approval was not required.

ORCID iDs

Qin Lingda Tan https://orcid.org/0009-0008-2435-4184
Sharizal Hashim https://orcid.org/0000-0003-1287-2490
Zhangwei Zheng https://orcid.org/0009-0004-9813-4214

Data Availability Statement

Data sharing is not applicable to this review article since there was no generation or analysis of new data in the study.

References

Acedo, F. J., Barroso, C., Casanueva, C., & Galán, J. L. (2006). Co-authorship in management and organizational studies: An empirical and network analysis. *Journal of Management Studies*, *43*(5), 957–983. https://doi.org/10.1111/j.1467-6486.2006.00625.x

Adams, C. A., & Abhayawansa, S. (2022). Connecting the COVID-19 pandemic, environmental, social and governance (ESG) investing and calls for 'harmonisation' of sustainability reporting. *Critical Perspectives on Accounting*, *82*, 102309. https://doi.org/10.1016/j.cpa.2021.102309

Afeef, M., & Kakakhel, S. J. (2022). ESG Factors and their influence on the investment behavior of individual investor: A case from Pakistan. *International Journal of Business and Management Sciences*, 3(3), 21–45.

Aksnes, D. W., Langfeldt, L., & Wouters, P. (2019). Citations, citation indicators, and research quality: An overview of basic concepts and theories. *Sage Open*, *9*(1), 2158244019829575. https://doi.org/10.1177/2158244019829575

Arun, T., Girardone, C., & Piserà, S. (2022). 17. ESG issues in emerging markets and the role of banks. *Handbook of Banking and Finance in Emerging Markets*, *321*, 900. https://doi.org/10.4337/9781800880900

Atan, R., Alam, M. M., Said, J., & Zamri, M. (2018). The impacts of environmental, social, and governance factors on firm performance: Panel study of Malaysian companies. *Management of Environmental Quality: An International Journal*, *29*(2), 182–194. https://doi.org/10.1108/MEQ-03-2017-0033

Azman, S. M. S., & Ali, E. R. A. E. (2016). The potential of innovative financial tools: Social Impact Bond (SIB) and Sustainable and Responsible Investment (SRI) sukuk, towards the sustainable growth of the Islamic finance industry. *European Journal of Islamic Finance*, *(4)*, 1–8. https://doi.org/10.13135/2421-2172/1644

Baldini, M., Maso, L. D., Liberatore, G., Mazzi, F., & Terzani, S. (2018). Role of country-and firm-level determinants in environmental, social, and governance disclosure. *Journal of Business Ethics*, *150*, 79–98. https://doi.org/10.1007/s10551-016-3139-1

Bernardi, C., & Stark, A. W. (2018). Environmental, social and governance disclosure, integrated reporting, and the accuracy of analyst forecasts. *The British Accounting Review*, *50*(1), 16–31. https://doi.org/10.1016/j.bar.2016.10.001

Broadstock, D. C., Chan, K., Cheng, L. T., & Wang, X. (2021). The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China. *Finance Research Letters*, *38*, 101716. https://doi.org/10.1016/j.frl.2020.101716

Brogi, M., & Lagasio, V. (2019). Environmental, social, and governance and company profitability: Are financial intermediaries different?. *Corporate Social Responsibility and Environmental Management*, *26*(3), 576–587. https://doi.org/10.1002/csr.1704

Brooks, C., & Oikonomou, I. (2018). The effects of environmental, social and governance disclosures and performance on firm value: A review of the literature in accounting and finance. *The British Accounting Review*, *50*(1), 1–15. https://doi.org/10.1016/j.bar.2017.11.005

Bruno, C. C., & Henisz, W. J. (2024). Environmental, social, and governance (ESG) outcomes and municipal credit risk. *Business & Society*, *63*(8), 1709–1756. https://doi.org/10.1177/00076503231220541

Camilleri, M. A. (2015). Environmental, social and governance disclosures in Europe. *Sustainability Accounting, Management and Policy Journal*, *6*(2), 224–242. https://doi.org/10.1108/SAMPJ-10-2014-0065

Chen, C., Dubin, R., & Schultz, T. (2015). Science mapping. In *Encyclopedia of information science and technology* (3rd ed.) (pp. 4171–4184). IGI Global. https://doi.org/10.4018/978-1-4666-5888-2.ch410

Chen, S., Song, Y., & Gao, P. (2023). Environmental, social, and governance (ESG) performance and financial outcomes: Analyzing the impact of ESG on financial performance. *Journal of Environmental Management*, *345*, 118829. https://doi.org/10.1016/j.jenvman.2023.118829

Chen, Z., & Xie, G. (2022). ESG disclosure and financial performance: Moderating role of ESG investors. *International Review of Financial Analysis*, *83*, 102291. https://doi.org/10.1016/j.irfa.2022.102291

China Academy of Translation. (2015). *Communiqué of the fifth plenary session of the 18th CPC central committee (Excerpts)*. China Academy of Translation. http://www.china.org.cn/chinese/catl/2015-11/30/content_37196189.htm

China ESG30 Forum. (2022). *China ESG development white paper 2022*. China ESG30 Forum.

Cobo, M. J., Martínez, M. A., Gutiérrez-Salcedo, M., Fujita, H., & Herrera-Viedma, E. (2015). 25years at knowledge-based systems: A bibliometric analysis. *Knowledge-based Systems*, *80*, 3–13. https://doi.org/10.1016/j.knosys.2014.12.035

Dadkhah, M., Obeidat, M. M., Jazi, M. D., Sutikno, T., & Riyadi, M. A. (2015). How can we identify hijacked journals?. *Bulletin of Electrical Engineering and Informatics*, *4*(2), 83–87. https://doi.org/10.11591/eei.v4i2.449

Danvila-del-Valle, I., Estévez-Mendoza, C., & Lara, F. J. (2019). Human resources training: A bibliometric analysis. *Journal of Business Research*, *101*, 627–636. https://doi.org/10.1016/j.jbusres.2019.02.026

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Duque-Grisales, E., & Aguilera-Caracuel, J. (2021). Environmental, social and governance (ESG) scores and financial performance of multilatinas: Moderating effects of geographic international diversification and financial slack. *Journal of Business Ethics*, *168*(2), 315–334. https://doi.org/10.1007/s10551-019-04177-w

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, *5*(4), 210–233. https://doi.org/10.1080/20430795.2015.1118917

Galbreath, J. (2013). ESG in focus: The Australian evidence. *Journal of Business Ethics*, *118*, 529–541. https://doi.org/10.1007/s10551-012-1607-9

García-Lillo, F., Claver-Cortés, E., Marco-Lajara, B., & Úbeda-García, M. (2019). Identifying the 'knowledge base' or 'intellectual structure' of research on international business, 2000–2015: A citation/co-citation analysis of JIBS. *International Business Review*, *28*(4), 713–726. https://doi.org/10.1016/j.ibusrev.2019.02.001

Hou, J., Du, M., & Zhou, Q. (2023). What people talk about multi-channel purchasing behavior and what they intend to do: Related perspective from ESG evaluation system. *SAGE Open*, *13*(4), 21582440231206970. https://doi.org/10.1177/21582440231206970

Huang, D. Z. (2021). Environmental, social and governance (ESG) activity and firm performance: A review and consolidation. *Accounting & Finance*, *61*(1), 335–360. https://doi.org/10.1111/acfi.12569

Husted, B. W., & de Sousa-Filho, J. M. (2017). The impact of sustainability governance, country stakeholder orientation, and country risk on environmental, social, and governance performance. *Journal of Cleaner Production*, *155*, 93–102. https://doi.org/10.1016/j.jclepro.2016.10.025

Husted, B. W., & de Sousa-Filho, J. M. (2019). Board structure and environmental, social, and governance disclosure in Latin America. *Journal of Business Research*, *102*, 220–227. https://doi.org/10.1016/j.jbusres.2018.01.017

Khan, M. A. (2022). ESG disclosure and firm performance: A bibliometric and meta analysis. *Research in International Business and Finance*, *61*, 101668. https://doi.org/10.1016/j.ribaf.2022.101668

Koh, H. K., Burnasheva, R., & Suh, Y. G. (2022). Perceived ESG (environmental, social, governance) and consumers' responses: The mediating role of brand credibility, Brand Image, and perceived quality. *Sustainability*, *14*(8), 4515. https://doi.org/10.3390/su14084515

Lee, H. J., & Rhee, T. H. (2023). How does corporate ESG Management affect consumers' brand choice?. *Sustainability*, *15*(8), 6795. https://doi.org/10.3390/su15086795

Lee, K. H., Cin, B. C., & Lee, E. Y. (2016). Environmental responsibility and firm performance: The application of an environmental, social and governance model. *Business Strategy and the Environment*, *25*(1), 40–53. https://doi.org/10.1002/bse.1855

Li, T. T., Wang, K., Sueyoshi, T., & Wang, D. D. (2021). ESG: Research progress and future prospects. *Sustainability*, *13*(21), 11663. https://doi.org/10.3390/su132111663

Li, Y., Gong, M., Zhang, X. Y., & Koh, L. (2018). The impact of environmental, social, and governance disclosure on firm value: The role of CEO power. *The British Accounting Review*, *50*(1), 60–75. https://doi.org/10.1016/j.bar.2017.09.007

Lokuwaduge, C. S. D. S., & Heenetigala, K. (2017). Integrating environmental, social and governance (ESG) disclosure for a sustainable development: An Australian study. *Business Strategy and the Environment*, *26*(4), 438–450. https://doi.org/10.1002/bse.1927

Ma, Y. M., Deng, Z., Teng, Y., Yang, Z., & Zheng, X. V. (2023). Firms' multi-sided platform construction efforts and ESG performance: An information processing theory perspective. *Industrial Marketing Management*, *115*, 455–469. https://doi.org/10.1016/j.indmarman.2023.10.018

Maybee, B., Lilford, E., & Hitch, M. (2023). Environmental, social and governance (ESG) risk, uncertainty, and the mining life cycle. *The Extractive Industries and Society*, *14*, 101244. https://doi.org/10.1016/j.exis.2023.101244

Mubdir, G. A., Hashim, S., Ayob, A. H., & Rosli, N. (2024). Online Purchase Intention using Social Media: A Systematic Literature Review. *Engineering, Technology & Applied Science Research*, *14*(5), 17261–17268. https://doi.org/10.48084/etasr.8395

Pérez, L., Hunt, V., Samandari, H., Nuttall, R., & Biniek, K. (2022). *Does ESG really matter—and why*. McKinsey Quarterly.

Phan, T. A., & Ninh, T. T. D. (2024) The impact of company field trips and representative image on students' CSR knowledge sharing intentions. *Business and Professional Communication Quarterly*, Advance online publication. https://doi.org/10.1177/23294906241237721

Piao, X., Xie, J., & Managi, S. (2022). Environmental, social, and corporate governance activities with employee psychological well-being improvement. *BMC Public Health*, *22*(1), 1–12. https://doi.org/10.1186/s12889-021-12350-y

Pirtea, M. G., Noja, G. G., Cristea, M., & Panait, M. (2021). Interplay between environmental, social and governance coordinates and the financial performance of agricultural companies. *Agricultural Economics*, *67*(12), 479–490. https://doi.org10.17221/286/2021-AGRICECON

PricewaterhouseCoopers (PwC). (2023). *Corporate Malaysia's journey towards a sustainable supply chain, 2023*. PricewaterhouseCoopers International Limited.

Puriwat, W., & Tripopsakul, S. (2022). From ESG to DESG: The impact of DESG (digital environmental, social, and governance) on customer attitudes and brand equity. *Sustainability*, *14*(17), 10480. https://doi.org/10.3390/su141710480

Qureshi, M. A., Kirkerud, S., Theresa, K., & Ahsan, T. (2020). The impact of sustainability (environmental, social, and governance) disclosure and board diversity on firm value: The moderating role of industry sensitivity. *Business Strategy and the Environment*, *29*(3), 1199–1214. https://doi.org/10.1002/bse.2427

Rabaya, A. J., & Saleh, N. M. (2022). The moderating effect of IR framework adoption on the relationship between environmental, social, and governance (ESG) disclosure and a firm's competitive advantage. *Environment, Development and Sustainability*, 24(2), 2037–2055. https://doi.org/10.1007/s10668-021-01519-5

Schneider, F., Gogolewska, J., Ahrend, K. M., Hohendorf, G., Schneider, G., Busse, R., & Schulz, C. M. (2021). Do private German health insurers invest their capital reserves of€ 353 billion according to environmental, social and governance criteria?. *Journal of medical ethics*, *47*(12), e48–e48. https://doi.org/10.1136/medethics-2020-106381

Securities Commission Malaysia (2019). *Sustainable and responsible investment road map for the Malaysian capital market*. Securities Commission Malaysia.

Shen, H., Lin, H., Han, W., & Wu, H. (2023). ESG in China: A review of practice and research, and future research avenues. China *Journal of Accounting Research*, *16*(4), 100325. https://doi.org/10.1016/j.cjar.2023.100325

Singhania, M., & Saini, N. (2023). Institutional framework of ESG disclosures: Comparative analysis of developed and developing countries. *Journal of Sustainable Finance & Investment*, *13*(1), 516–559. https://doi.org/10.1080/20430795.2021.1964810

Sustainability Accounting Standards Board (SASB). (2018). *Sustainable development accounting standards*. Sustainability Accounting Standards Board.

Taliento, M., Favino, C., & Netti, A. (2019). Impact of environmental, social, and governance information on economic performance: Evidence of a corporate 'sustainability advantage' from Europe. *Sustainability*, *11*(6), 1738. https://doi.org/10.3390/su11061738

The State Council of P.R. China. (2022). *Report to the 20th national congress of the communist party of China*. The State Council of P.R. China.

Tsang, A., Frost, T., & Cao, H. (2023). Environmental, social, and governance (ESG) disclosure: A literature review. *The British Accounting Review*, *55*(1), 101149. https://doi.org/10.1016/j.bar.2022.101149

U.S. Congress. (2015). *Senate bill No. 185*. U.S. Congress.

U.S. Congress. (2018). *Senate bill No. 964*. U.S. Congress.

U.S. Department of Labor. (2015). *Economically targeted investments (ETIs) and investment strategies that consider environmental, social and governance (ESG) factors*. U.S. Department of Labor.

U.S. Department of State. (2015). *United Kingdom investment climate statement 2015*. U.S. Department of State.

U.S. Securities and Exchange Commission. (2016). *Investor alerts and bulletins*. U.S. Securities and Exchange Commission.

U.S. Securities and Exchange Commission. (2018). *Investor alerts and bulletins*. U.S. Securities and Exchange Commission.

Uddin, S., Hossain, L., Abbasi, A., & Rasmussen, K. (2012). Trend and efficiency analysis of co-authorship network. *Scientometrics*, *90*(2), 687–699. https://doi.org/10.1007/s11192-011-0511-x

United Nations (UN). (2004). *Who cares wins: Connecting financial markets to a changing world*. United Nations Global Contact.

United Nations (UN). (2015). *Sustainable development: The 17 goals*. UN Department of Economic and Social Affairs.

Van Duuren, E., Plantinga, A., & Scholtens, B. (2016). ESG integration and the investment management process: Fundamental investing reinvented. *Journal of Business Ethics*, *138*, 525–533. https://doi.org/10.1007/s10551-015-2610-8

Van Eck, N., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Velte, P. (2017). Does ESG performance have an impact on financial performance? Evidence from Germany. *Journal of Global Responsibility*, *8*(2), 169–178. https://doi.org/10.1108/JGR-11-2016-0029

Wang, J., Hong, Z., & Long, H. (2023). Digital transformation empowers ESG performance in the manufacturing industry: From ESG to DESG. *SAGE Open*, *13*(4), 21582440231204158. https://doi.org/10.1177/21582440231204158

Weber, O. (2014). Environmental, social and governance reporting in China. *Business Strategy and the Environment*, *23*(5), 303–317. https://doi.org/10.1002/bse.1785

Whitelock, V. G. (2019). Multidimensional environmental social governance sustainability framework: Integration, using a purchasing, operations, and supply chain management context. *Sustainable Development*, *27*(5), 923–931. https://doi.org/10.1002/sd.1951

Xie, J., Nozawa, W., Yagi, M., Fujii, H., & Managi, S. (2019). Do environmental, social, and governance activities improve corporate financial performance?. *Business Strategy and the Environment*, *28*(2), 286–300. https://doi.org/10.1002/bse.2224

Xu, S., Zhang, S., Ren, Y., Jiang, Q., & Wu, D. (2024). Can Digital Transformation Restrain Corporate ESG GreenwashingA Test Based on Internal and External Joint Perspectives. *Systems*, *12*(9), 334. https://doi.org/10.3390/systems12090334

Yu, E. P. Y., Guo, C. Q., & Luu, B. V. (2018). Environmental, social and governance transparency and firm value. *Business Strategy and the Environment*, *27*(7), 987–1004. https://doi.org/10.1002/bse.2047

Yu, E. P. Y., Van Luu, B., & Chen, C. H. (2020). Greenwashing in environmental, social and governance disclosures. *Research in International Business and Finance*, *52*, 101192. https://doi.org/10.1016/j.ribaf.2020.101192

Zhai, C., Ding, X., Zhang, X., Jiang, S., Zhang, Y., & Li, C. (2023). Assessing the effects of urban digital infrastructure on corporate environmental, social and governance (ESG) performance: Evidence from the broadband China policy. *Systems*, *11*(10), 515. https://doi.org/10.3390/systems1110051

Zumente, I., & Bistrova, J. (2021). ESG importance for long-term shareholder value creation: Literature vs. practice. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(2), 127. https://doi.org/10.3390/joitmc7020127

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

How digital leadership guides ESG sustainability / Qiao, P., Zhao, Y., Fung, A., & Fung, H. G.

Research in International Business and Finance
Volume 73 Part B (2025) 102644 Pages 1-17
https://doi.org/10.1016/j.ribaf.2024.102644
(Database: ScienceDirect)

Research in International Business and Finance 73 (2025) 102644

Contents lists available at ScienceDirect

Research in International Business and Finance

journal homepage: www.elsevier.com/locate/ribaf

How digital leadership guides ESG sustainability☆

Penghua Qiao [a], Yuying Zhao [a], Anna Fung [b], Hung-Gay Fung [c,*]

[a] School of Business and Economics, Kunming University of Science and Technology, Kunming 650093, China
[b] Kogod School of Business, American University, 4400 Massachusetts Ave., Washington, DC 20016, USA
[c] College of Business Administration, University of Missouri, St. Louis, MO 63121, USA

ARTICLE INFO

Keywords:
Digital leadership
ESG
Digital transformation
Stock trading activity

ABSTRACT

This study examines how digital leadership increases corporate ESG performance in the Chinese manufacturing sector from 2009 to 2022. Our analysis reveals how digital leadership not only cultivates ESG excellence but also drives advancements in digital transformation and stock trading activities, which further improve ESG performance. Additionally, we note a significantly stronger positive relationship between digital leadership and ESG performance for companies led by female executives, those with executives possessing environmental expertise, firms offering liability insurance to board members and executives, and those operating in regions with robust governmental environmental policies.

1. Introduction

Digital technologies have attracted increasing attention by firms, policymakers, and scholars as they affect almost every facet of organizational performance and practice in modern society (Flyverbom et al., 2019; Memon and Ooi, 2023). While many factors influence the development of digital technologies, one key aspect is digital leadership – that is, having the leadership of individuals who can effectively manage their companies' various digital technologies. Digital leadership is the strategic use of digital technologies by leaders to enhance their decision-making processes and it involves blending leadership skills with digital tools to drive efficiency and effectiveness in decision-making and overall organizational performance (Tigre et al., 2024). Digital leadership allows firms to achieve greater success in crucial organizational areas such as digital transformation (AlNuaimi et al., 2022; Weber et al., 2019) and innovation capability (Benitez et al., 2022; Chen et al., 2023; Wang et al., 2022a).

An additional aspect of firm performance includes sustainable development, often measured as environmental, social, and governance (ESG) (Borah et al., 2022; Drempetic et al., 2020; Li et al., 2024a; Liu et al., 2023b). For example, firms use corporate ESG to create value and social legitimacy for sustainable development (Broadstock et al., 2020; He et al., 2023). These ESG activities enable firms to obtain financing resources to improve sustainable performance (Shu and Tan, 2023), external trade financing and lower risk (Boubaker et al., 2020; Lins et al., 2017; Luo et al., 2023). In addition, ESG echoes social responsibility commitment, causing lower agency cost and better transparency (Cheng et al., 2014; Cheung et al., 2020). Thus, it is surprising that prior studies on digital leadership have largely overlooked its effect on ESG, instead focusing on issues such as organizational sustainability (Borah et al.,

☆ This work was supported by the National Natural Science Foundation of China [Grants No. 71702084] and the Natural Science Foundation of Yunan Province [Grant No. 202201AT070175].

* Corresponding author.
E-mail addresses: oldbridge1221@126.com (P. Qiao), wxzhaoyuying@163.com (Y. Zhao), afung@american.edu (A. Fung), fungh@umsl.edu (H.-G. Fung).

https://doi.org/10.1016/j.ribaf.2024.102644
Received 31 March 2024; Received in revised form 4 September 2024; Accepted 27 October 2024
Available online 30 October 2024

2022) and responsible innovation (Memon and Ooi, 2023). In response to this research gap, this study seeks to demonstrate that digital leadership drives corporate ESG development. To do so, we use a sample of 25,706 listed companies from China's manufacturing industry from 2009 to 2022 for two main reasons. First, the Chinese economy is shifting from a high-speed growth to a high-quality ecological model. In its shift, China has been incentivizing ESG development through regulatory actions, developing a green financial system with green leading and green insurance, implementing a carbon neutrality framework. Second, more Chinese companies have started to conduct ESG practices and investments for sustainable green transformation and innovation (Tan et al., 2024). Although China is an emerging economy, still in its infancy of ESG development and growth, its experience provides lessons for other developing countries.

Our empirical tests provide convincing evidence that digital leadership promotes ESG. Furthermore, we find that digital leadership promotes the development of digital technology within the firms and trigger active participation of stock traders that are helpful for improving ESG score by outside agency. Four factors – the gender difference of executives, the environmental protection experience of the top management team (TMT), the liability insurance provided to directors and officers, and the government's environmental attention – amplify the positive effect of digital leadership on ESG performance.

Our contributions are fourfold. First, we enrich ESG literature by exploring the relationship between digital leadership and corporate ESG practices. Existing studies on ESG mostly focus on the career concerns of leaders (Kim and Kim, 2023), gender difference of leaders (Alkhawaja et al., 2023), and their foreign experience (Liu et al., 2023c). Less attention has been paid to digital leadership as a driver of corporate ESG performance. By doing so, we extend the literature to provide insights into the role of technical skills of leaders on corporate ESG performance.

Second, our study reveals two channels through which the digital leadership affects firms' ESG performance. Existing literature argues that digital leadership uses digital technologies to make business changes (AlNuaimi et al., 2022), and there are few accounts of digital technologies ultimately acting on business sustainability. Our results explain that some firms create more digital innovations than others because of their leaders who stimulate digital transformation to promote ESG. Given that previous research has linked financial market trading to ESG ratings (Feng and Yuan, 2024; Liu et al., 2023a), and the lack of financial market transactions in topics related to digital leaders influencing firms' ESG is rarely mentioned, we provide insights into how information spreads from the financial market to the rating agency. Institutional investors and professional analysts spend resources in performing their fiduciary duties to find the most profitable firms with an ESG orientation. Thus, stock trading provides a valuable signal to the ESG rating agency for evaluating the underlying firm's ESG performance.

Third, our study shows the importance of firm characteristics and government policy on the firm's ESG performance, corroborating with the literature (Rao and Tilt, 2016; Zhang, 2022). Gender diversity, executive's environmental protection experience, liability insurance provided to executives, and government environmental attention amplify the positive effect of digital leadership on ESG. The results confirm that incentives and policies enacted by firms and the government can effectively promote ESG performance. This study expands the understanding of the relationship between digital leadership and corporate ESG performance by exploring four key moderating factors.

Finally, our research assesses the impact of digital leadership on ESG performance, building on analyses of other aspects of sustainable development, such as social responsibility and responsible innovation (Borah et al., 2022; Memon and Ooi, 2023). Additionally, we advance upper echelons theory by connecting leadership skills to ESG outcomes, demonstrating how top leaders with digital expertise influence overall firm performance.

2. Literature review and hypothesis development

2.1. Literature review

The digital age underscores the growing importance of digital leadership for enhancing business performance. Research has explored how digital leadership impacts various aspects of innovation, including open innovation (Fatima and Masood, 2023), exploratory innovation (Wang et al., 2022a), and deviant innovation (Sun et al., 2024). Unlike traditional leaders, digital leaders leverage digital technology to drive digital transformation (AlNuaimi et al., 2022), enhance technology absorptive capacity and innovation (Xia et al., 2023), facilitate organizational co-creation, and maintain a competitive edge in a rapidly evolving environment (Cai et al., 2024), ultimately aiming for improved financial performance (Senadjki et al., 2024). However, while digital leaders focus on operational performance, they must also address sustainability performance across environmental, social, and governance (ESG) factors. Existing research has often fragmented the exploration of digital leadership's impact on ESG performance. This study addresses this gap by providing a comprehensive examination of how digital leadership influences ESG outcomes.

Tian et al. (2023) demonstrate that digital leaders leverage digital detection capabilities to navigate dynamic environments, interpreting policies and regulations related to low-carbon initiatives and environmental protection, while also monitoring sustainable trends in external markets. This enables them to make informed decisions about green innovation in complex settings. Similarly, Memon and Ooi (2023) argue that digital leadership must involve adopting cutting-edge digital strategies, such as big data technologies, to capture market information, identify social needs, and fulfill social responsibilities. Additionally, Sun et al. (2024) highlight that digital leaders foster a culture where internal personnel are encouraged to take risks with digital technologies, leading to significant improvements in quality.

Research on the relationship between digital leadership and ESG performance is still in its early stages, and there is a lack of consensus on how digital leadership impacts ESG outcomes, highlighting the need for further investigation. To address this gap, we employ upper echelons theory as our theoretical framework to explore the direct effects of digital leadership on corporate ESG

performance and to uncover the underlying mechanisms that connect the two.

2.2. Digital leadership and ESG

The upper echelon theory suggests that leaders' characteristics affect their business decisions (Hambrick et al., 1984). Leaders at firms play an important role in corporate environmental strategies, social responsibility fulfillment, and internal corporate governance (Christensen et al., 2014; Dubey et al., 2015; Evans, 2014; Gupta, Fung, and Murphy, 2021). We argue that, given today's technology, digital leadership should have a significant effect on corporate ESG performance for several reasons.

First, digital leadership is emblematic of technology change. Responsible leaders make ethical decisions consistent with the interest of stakeholders while analyzing the environmental conditions outside the firm to avoid social harm (Du et al., 2013; Memon and Ooi, 2023). Digital leadership can use emerging technologies in their production models to maximize the use of renewable energy to reduce emissions and promote green innovations (Li et al., 2023; Tian et al., 2023; Weber et al., 2019; Zhu et al., 2023). Thus, digital leadership improves environmental attention.

Second, digital leadership supports social causes that benefit both firms and their society at large (Volschenk, 2019). They have a transformative vision and forward looking perspective to anticipate market trends and equip employees to succeed, such as by encouraging employees to learn from coworkers, and by giving them opportunities to better themselves (Chatterjee et al., 2023; Kane et al., 2019). Moreover, digital leaders can use social media to enhance firm performance through increased information sharing (Borah et al., 2022), and to enhance leadership interconnections with constituents and stakeholders (Park and Wallace, 2020). We thus argue that digital leadership promotes social status and social responsibility.

Finally, digital leaders use technology to improve corporate governance. Digital technologies significantly improve information transparency, mitigating self-interested behaviors to bolster risk taking and collaboration, thus improving strategy and corporate governance (Kane et al., 2016; Zhu, 2019). Digital leadership can protect stakeholders to accommodate multiple initiatives and practices at the same time (Hacioglu and Aksoy, 2021; Obwegeser et al., 2020). In addition, digital leadership use microblogs and other social media platforms to connect to consumers and media who can externally monitor any improper firm behaviors. As a result, firms need to make public information disclosures to strengthen the supervision of firms and improve corporate governance (Gu and Kurov, 2020; Jia et al., 2020). Therefore, we argue that digital leadership significantly improves corporate governance:

Hypothesis 1. Digital leadership promotes ESG performance at firms.

3. Mediating analysis

3.1. Promotion of digital technology

Digital leadership focuses on the use of digital technology to drive corporate digital transformation (Benitez et al., 2022; Weber et al., 2022a, 2019). Digital technologies improve operations, create new value networks, and empower new digital organizational visions to solve work-related problems (Guo et al., 2023; Karim et al., 2022; Magesa and Jonathan, 2022). In addition, digital leaders can build digital platforms to integrate existing business resources and data and coordinate employees to achieve cross-functional work (Engelbrecht et al., 2017; Porfírio et al., 2021). In summary, an effective digital strategy requires leaders to develop different capabilities within operations and innovation (Westerman, 2012).

Firms with a high level of digital transformation tend to have a higher level of ESG for two reasons. First, for manufacturing firms, digital technology promotes energy conservation and emission reduction to improve sustainability (Fang et al., 2023). The deep integration of emerging technologies and low-carbon solutions increases the need for digital technologies that control pollution and waste, further promoting green transformation and innovation (Xu et al., 2021; Zhu et al., 2023). Second, digital technology improves the ease of information disclosure and corporate transparency to convey the firm's efforts in promoting charity and social responsibility (Gillan et al., 2021; Ma and Zhu, 2022). As discussed earlier, technology also improves corporate governance regarding transparency, social status, and ESG (Huang and Wei, 2023). Thus, we propose the following hypothesis:

Hypothesis 2a. . Digital leadership promotes digital transformation, which in turn stimulates ESG performance at firms.

3.2. Promotion of stock trading activity

Digital leadership can optimize business operations by integrating IT infrastructure and business data to establish a digital network platform (Benitez et al., 2022; Leong et al., 2019). Such a platform reduces the cost of searching for information and allows for easier collaboration and transaction between traders and firms (Benitez et al., 2022; Fink et al., 2005). In addition, digital leadership is likely to use big data, cloud computing, blockchain, and other technologies to manage the daily operations of the organization, with two important results. First, the firm is better able to collect data about itself; second, the market can access more authentic and reliable information about the firm (Wang et al., 2022b; Weber et al., 2022b). This decreased information asymmetry between the firm and market leads to increased information validity that improves the readability and quality of financial reports (Wang and He, 2024). Consequently, traders and investors are more willing to trade shares of the firm in a more transparent environment, increasing the trading liquidity of the firm.

Traders who participate in the trading activity of the firm include professional analysts and institutional investors who bring expertise to analyze the firm's business and operations to ensure their investment is valuable. They are interested in firms that engage

in ESG and have good profit potential (Yin et al., 2023). As investors bet on the shares, they must ensure a good return for their investments. In particular, professional analysts may have fiduciary duties to invest in ESG stocks. External rating agencies may value the judgment of such professional investors, such that increased trader participation sends clear positive investment signals and credibility about the firm's ESG engagement to the market. In fact, Feng and Yuan (2024) and Liu et al. (2023a) confirm that investors have a positive effect on ESG performance in Chinese firms. Because of these arguments, we propose the following hypothesis:

Hypothesis 2b. . Stock trading activity mediates the relationship between digital leadership and corporate ESG.

4. Moderating effects on digital leadership

4.1. Gender effect

While all stakeholders of a firm are integral to a firm, top management team members as internal stakeholders are especially influential in the decision-making process. Moreover, TMT members' strategic choices are influenced by their underlying demographics such as age and gender (Johnson et al., 2013). The gender role theory suggests that women and men may have different views on ethical and social norms, potentially affecting firm performance (Mason and Mudrack, 1996). One way this disparity may be evident is in the process of resource allocation, especially for costly investments such as ESG-related projects.

When digital leaders want to invest in ESG to reduce environmental hazards and avoid public scrutiny, other members of management may have different views about the economic benefits of such a decision (McWilliams and Siegel, 2000). While some may side with these leaders, others may pose challenges to implementing an ESG strategy.

Research has found that male executives tend to focus on the primary needs of shareholders, while female executives are typically more focused on the needs of broader stakeholders (Adams et al., 2011). Female members are keen on improving corporate human resources, occupational health and safety, corporate donations and ethical issues (Rao and Tilt, 2016). Thus, women are more likely to provide diverse social and environmentally friendly solutions to the firms on environmental and social issues (Ding et al., 2022; Javed et al., 2023; Shakil, 2021). When digital leaders decide to implement ESG strategies, we propose that female executives are more likely to support ESG initiatives and assist digital leaders in effectively addressing ESG-related issues:

Hypothesis 3a. . Female executives strengthen the positive relationship between digital leadership and ESG.

4.2. Environmental protection experience of TMT

Digital leadership is often hindered by capital and other constraints in maintaining ESG goals, diluting their commitment to the environment. However, executives with an environmental protection experience will be more motivated to protect the environment and take social responsibility seriously (Wang et al., 2023a). Managers with a high awareness of ecological and environmental issues pay closer attention to industry development policies and environmental regulations (Gadenne et al., 2009). They are more likely to promote ESG information disclosure about topics related to energy conservation, emission reduction and environmental protection measures (Deng et al., 2024; Huang and Wei, 2023).

When digital leaders work with executives with environmental protection experience, they are likely to exchange views on issues of corporate sustainability, converging towards increased ESG practices. They can identify market opportunities arising from ecological issues to assess the benefits underlying ESG actions (Deng et al., 2024) and save the company costs on green transformation and other measures (Li et al., 2024b; Zhang and Zhang, 2023). The presence of executives with environmental protection experience enables digital leaders to better allocate resources to deal with the conflict between ESG activities and financial performance. As a result, the combined efforts of the executives with environment experience and digital leadership will enable firms to have better ESG performance, improving the firm' s ESG rating.

Hypothesis 3b. . Environmental protection experience of TMT strengthens the positive relationship between digital leadership and ESG.

4.3. Liability insurance to directors and executives

Many firms offer liability insurance to director members and managers against personal liability arising from legal actions related to their organizational roles (Zhang et al., 2023b). This policy of directors-and-officers liability insurance (D&O) motivates managers to act in the best interests of stakeholders to reduce agency costs, mitigate litigation risks, and improve corporate governance (Holderness, 1990; Yuan et al., 2016). D&O insurance coverage typically requires directors and officers to comply with certain corporate governance standards and risk management practices. Qualifying companies must also show robust governance structures and transparency.

Firms with this insurance policy are subject to the underwriting monitoring services of insurance firms which watch closely the firm' s financial situation to prevent opportunistic behaviors of the executives and board members (Boyer and Tennyson, 2015). D&O insurance companies investigate in advance to ensure good behavior and to evaluate potential environmental litigation losses and risks caused by the firm's actions (Core, 2000). Thus, the board has incentives to strengthen the oversight of ESG-related risks and install adequate controls, improving ESG performance. As a result, a D&O insurance policy signals lower firm risk from stronger public supervision (Yuan et al., 2016). At the same time, the D&O policy prompts digital leaders to increase their support for green innovation

and environmental protection investment activities (Zhang et al., 2023b). Therefore, we expect the insured firms to have a better ESG rating as follows:

Hypothesis 3c. Liability insurance provided to directors and executives strengthens the positive relationship between digital leadership and ESG.

4.4. Role of the government

Local governments promote environmental policies by advocating for strong guidelines in announcements and publications, using language such as environmental protection, environmental pollution, energy consumption, coordinated development, and environmental co-governance in annual government reports (Bao and Liu, 2022; Liu et al., 2024). These government guidelines and policies shape firms' behaviors (Dai and Si, 2018; Liu et al., 2024).

The government is a powerful external stakeholder for firms (Harrison and St. John, 1996; Ocasio, 1997). Increased government environmental attention also leads to increased support for firms to commit to sustainable projects (Wang and Lei, 2021). Governments can provide financial incentives (such as grants, subsidies, or tax credits) to adopt ESG practices. Governments may facilitate public-private partnerships to mobilize resources, share knowledge, and leverage expertise to address ESG challenges. It can even initiate joint initiatives for sustainable infrastructure development or community engagement projects. For example, the Chinese government implemented a green loan program that enables firms to have better access to funds from banks for curbing pollution (Zhang, 2022). Digital leaders are likely to be sensitive to changes in government regulations and policies that reward environmental governance and increased social responsibility (Kane et al., 2019). Therefore, we propose the following hypothesis:

Hypothesis 3d. Government environmental attention strengthens the positive relationship between the digital leadership and ESG at firm.

The logical framework underlying the relationship between digital leadership and ESG is shown in Fig. 1. This relationship is mediated by digital transformation and stock trading, while the moderating mechanism includes the gender of the executives, the environmental protection experience of TMT, the insurance policy regarding board directors and management, and the role of government environmental attention.

5. Data and methods

5.1. Sample and data collection

We selected Chinese domestic firms in the manufacturing industry listed on the Shenzhen and Shanghai Stock Exchanges from 2009 to 2022. To gather information on digital experience, we collected the resume of each firm's executives from the China Stock Market Accounting Research (CSMAR) Database. We supplemented missing data from CSMAR by searching the RESSET database from Sina Finance (https://finance.sina.com.cn/). We selected keywords related to digital experience based on the statistical classification of Digital Economy and Its Core Industries (2021).

Huazheng ESG data, updated quarterly, integrates the Chinese context and capital market characteristics over an extended period. In contrast, most ESG rating indicators are updated semi-annually or annually, often providing a shorter-term perspective. Compared to quarterly or average ratings, year-end ratings offer more accurate and comprehensive insights. Companies are more likely to assess and report their ESG contributions at the end of the year, making year-end ratings a more precise reflection of their ESG performance over the past year. We used the Huazheng year-end ESG rating index to measure ESG performance of the firms because it is more extensive, covering all listed companies in China with multiple levels of indicators.[1] We also use the WIND database to conduct integrated semantic analysis and natural language process algorithms (Zhang et al., 2023a).

Finally, we eliminated firms that had risk warnings status and lacked financial and corporate governance data. We also winsorized all continuous variables at the 1 % and 99 % levels to reduce the effect of outliers. The final sample includes 3246 listed firms and 25,706 observations with 190,021 executives. The firm's financial data, equity information, media reports and other data are from the CSMAR database and the Chinese Research Data Services Platform (CNRDS) database.

5.2. Variable measures

5.2.1. ESG performance

ESG ratings consist of nine grades from "C" (lowest) to "AAA" (highest). In our empirical analysis, the ESG ratings are assigned values from 1 to 9. The larger the value, the better ESG performance (Lian et al., 2023). We measure environmental (*Enviro*), social (*Social*) and governance (*Govern*) in our study as calculated in previous studies (Kong et al., 2023).

[1] It includes three first-level indicators of environment, society, and governance, 16 s-level indicators, 44 third-level indicators, and nearly 80 fourth-level indicators (Lin et al., 2021; Tian and Tian, 2022).

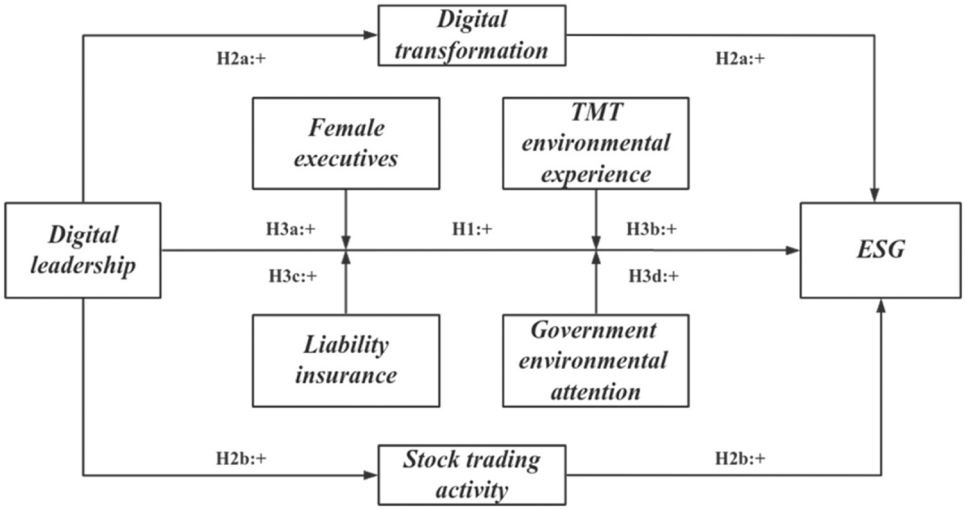


Fig. 1. Conceptual framework.

5.2.2. Digital leadership

The literature typically measures digital leadership using survey data with questionnaire interviews (Benitez et al., 2022; Fatima and Masood, 2023). This approach provides a limited perspective to explain the strengths and weaknesses of digital leadership, the problem of subjective cognitive bias cannot be avoided (Cycyota and Harrison, 2006). Text analysis can reflect the characteristics of a person by analyzing the words used in the target text (Miller and Ross, 1975; Pennebaker et al., 1999). Therefore, our study uses a textual analysis to create a novel digital leadership measure (*DLeader*) by examining leaders' resumes.

We define digital leaders to have digital technology experience in education and work. Education experience covers experience in wireless, radio and communication, software, computer, digital technology, automation, network, circuit, integrated circuits, big data, and industrial robots. Work experience related to website, technology, information, IT planning department, IT Center, System and Software Engineer, Core Technical Personnel, Technology Officer, Information Officer, Information Integration, Cloud Platform, Information Technology, Digital Center, R&D related work (such as R&D director and R&D center) and information technology center (such as industry and university research center), information management center, and network work (such as network R&D, network security, and planning).

We follow the approach by Wang et al. (2023b) to label DLeader as one if any of the top management team members (TMT) has a professional experience or education experience in the digital technology, two if the TMT member with digital experience also serves on the board, and three if the digital leader was the CEO or the chairman of the board, and zero if a firm did not have any digital leader. This variable reflects a structural power approach that measures the different levels of power implicit in TMT positions (Wang et al., 2023b). The greater the TMT structural rights, the stronger its control over the firm's decision-making process.

5.2.3. Mediator variables

We selected two mediators in our study. First, we measured digital transformation (*DigitT*) using the selected digital-related keywords scaled by the total words in the annual report (Guo et al., 2023). The keywords, obtained from CSMAR, include artificial intelligence technology, big data technology, cloud computing technology, blockchain technology and digital technology application. We normalized the digital transformation variable for the firm by the industry group.

Our second mediator is stock trade turnover (*Turnover*), which indicates the extent to which trading activities take place. Stock trading is a good proxy for liquidity because it reflects the trading intensity by the traders for the firm (Barber and Odean, 2008). Thus, we use the average turnover rate (i.e., the number of shares traded over the total outstanding shares in a day) over the 30 days before the release date of the annual report to measure the activity of traders (Loh, 2008). We also use 60-day measure of turnover for robustness. The results are similar.

5.2.4. Moderating variables

We select four moderators in the analysis. First, executive characteristics will affect the relationship between digital leadership and ESG. We use female executives serving on the TMT (*TMT_Female*) as a moderating variable (Badrul Muttakin et al., 2022). It is a dummy that equals 1 if there are women in the top management team, otherwise 0. Our second moderator is the executives' environmental protection experience (*TMT_Enviro*) (Huang and Wei, 2023). If the TMT members have experience with environmental protection, it is equal to 1; otherwise, it is 0.

Second, there are external factors that may affect the relationship between digital leadership and ESG. The directors' and officers' liability insurance (*Insured*) is our third moderator. If the firm provides the directors and TMT with a liability insurance in that year, it is equal to 1; otherwise, it is 0 (Zhang et al., 2023b). Finally, we use the government environmental attention (*Gov_Attention*) as the

fourth moderator, which is the frequency of environmental words to the number of words in the full text of the provincial government report where the firm is registered (Zhang et al., 2024).

5.2.5. Control variables

We also include the following control variables in our analysis. We first include the firm specific variables. *FirmSize* is the natural logarithm of the number of employees at a firm (Ma et al., 2023). *FirmAge* is the number of years that the firm has been listed on the exchange (Alkhawaja et al., 2023). *Lev* is the total liability divided by total assets. *ROA* measures profitability. Itis the net income divided by total assets. *Loss* equals 1 if a firm has a negative profit in the year, otherwise 0 (Liu and Zhang, 2023). Finally, *Liquid* is the ratio of current assets to current liabilities.

Second, we control for the managerial and governance attributes. *Mshare* is the percentage of shares held by the management team (Huang and Wei, 2023). *Dual* equals 1 if the CEO also serves as the chairperson, otherwise it is 0. To reflect the importance of corporate governance, we use *Top1* as the ratio of the largest shareholder' s shareholding to the rest of the stockholder's shares. *Indep* is the ratio of independent directors to the total board size. *SOE* equals 1 if the firm is a state-owned enterprise, otherwise it is 0 (Fu et al., 2024; He et al., 2023). *Tenure* is the average tenure of TMT members at that firm ((Liu and Zhang, 2023).

5.3. Methods

The panel data is composed of listed firms in different years. The dependent variable is ESG score, which ranges from 1 to 9. A Hausman test shows that the fixed effect model is better than the random effect model (p=0.00) (Hausman, 1978). In addition, we include fixed effects for the firm, industry, and year levels (Alkhawaja et al., 2023). We measure the effect of digital leadership on the ESG scores of the current year as follows:

$$ESG_{i,t} = \alpha_0 + \alpha_1 DLeader_{i,t} + \sum controls_{i,t} + \sum Firm + \sum Year + \sum Industry + \varepsilon_{i,t} \quad (1)$$

where *ESG* is the dependent variable and *DLeader* is the independent variable. In the above equation, *i* represents the firm and *t* represents the year. We also add firm fixed effects (*Firm*), year fixed effects (*Year*) and industry fixed effects (*Industry*), where $\varepsilon_{i,t}$ represents the error term and α_1 captures the influence of digital leadership on corporate ESG. We expect the coefficient α_1 to be positive and significant, implying that digital leadership improves corporate ESG performance. A positive result of α_1 supports H1.

We follow the approach by Baron and Kenny (1986) to examine the mediating mechanism of digital leadership on corporate ESG in Eqs. (1)-(3) to test Hypotheses 2a-2b.

$$Med_{i,t} = \beta_0 + \beta_1 DLeader_{i,t} + \sum controls_{i,t} + \sum Firm + \sum Year + \sum Industry + \varepsilon_{i,t} \quad (2)$$

$$ESG_{i,t} = r_0 + r_1 DLeader_{i,t} + r_2 Med_{i,t} + \sum controls_{i,t} + \sum Firm + \sum Year + \sum Industry + \varepsilon_{i,t} \quad (3)$$

We use two mediator variables–digital transformation and stock trading activity–in Eqs. (2) and (3). The partial mediation effect holds when the coefficients α_1 and β_1 are positive and significant and while the coefficient of digital leadership, r_1 in Eq. (3) is smaller than α_1 in Eq. (1).

6. Empirical results

6.1. Descriptive statistics

Columns (1) and (2) in Table 1 present the number and proportion of ESG ratings within the original dataset. The ESG performance of Chinese manufacturing firms shows significant variability. Of the 25,706 firms included in our analysis, only 0.37 % have an ESG score of 7, 0.01 % have an ESG score of 8, and none have an ESG score of 9, with all these scores representing less than 1 % of the total sample. To refine the dataset and address these disparities, we have focused on a narrower range of ESG scores, as detailed in columns

Table 1
Summary of ESG ratings.

Variable	(1)	(2)	(3)	(4)
ESG ratings	Original data		Sample data	
	Number of ratings	% ratings	Number of ratings	% ratings
1	541	2.10	541	2.10
2	1251	4.87	1251	4.87
3	4626	18.00	4626	18.00
4	10,216	39.74	10,216	39.74
5	7343	28.57	7343	28.57
6	1632	6.35	1729	6.73
7	94	0.37	0	0.00
8	3	0.01	0	0.00
9	0	0.00	0	0.00

(3) and (4) of Table 1. Consequently, the maximum ESG score in the final sample is 6.

Table 2 shows the description of all the variables including the total number of samples, mean, standard deviation, minimum and maximum values. The mean value of ESG performance is 4.0794, with a minimum value of 1 and a maximum value of 6, indicating that ESG performance varies considerably across firms. The mean value of digital leadership is 0.9110, with a minimum value of 0 and a maximum value of 3, reflecting that there is room for progress in the cultivation of digital leadership in firms.

6.2. Correlation analysis

Table 3 shows the correlation coefficient matrix of the main variables. The Pearson correlation coefficient between digital leadership and corporate ESG performance is positive and significant, indicating that a strong relationship between digital leadership and ESG performance, supporting Hypothesis 1. We calculated the variance inflation factor (VIF) scores to evaluate multicollinearity between variables. As the maximum value of the VIF is 2.31 and the average value is 1.41, both are below 10, indicating that the data do not have serious collinearity issues (Solakov et al., 1987)

6.3. Effect of the digital leadership on ESG

Table 4 reports the regression results on the relationship between digital leadership and ESG. Column (1) indicates that the digital leadership has a positive effect (β = 0.0304, $p<0.01$) on environment, social, and governance (ESG). The results support our main hypothesis. We also show the positive effect of digital leadership on *Environmental* (0.0242) in column (2), on Social (0.0221) in column (3) and on Govern (0.0318) in column (4). They are all statistically significantly at the 1 % level.

We compute the economic significance of digital leadership on ESG and others (Environmental, Social and Govern) using the marginal effect concept, which is computed by multiplying one standard deviation of the digital leadership variable with its regression coefficient. For example, the regression coefficient of DLeader on ESG is 0.0304; its standard error is 1.0793 % (shown in Table 2). Thus, the marginal effect of the digital leadership on ESG is 0.0328 % (=0.0304×1.0793). Similarly, the digital leadership regression coefficient on environment is 0.0242. Its standard error is 1.0793 %. The marginal effect of digital leadership on environmental is 0.0261 % (=0.0242×1.0793) in column (2). The marginal effect of digital leadership on Social is 0.0239 % (=0.0221×1.0793 %) in column (3) and on *Governance* is 0.0343 % (=0.0318×1.0793 %) in column (4). The results show that the influence of digital leaders on ESG mainly comes from the performance of corporate governance with the largest marginal effect as compared with Environmental and Social. Corporate governance relates to internal governance factors such as board structure and gender.

In addition, we estimated the effect of digital leadership hierarchy on ESG. Column (5) reports that the positive effect of digital top leaders (i.e., CEO or board chair) on ESG is 0.0600, ($p<0.01$). Column (6) shows that the effect of executives with digital experience serving on the board is 0.0502 ($p<0.01$). Column (7) reports that the positive effect of digital TMT on ESG is 0.0491 ($p<0.01$). It should be noted that the effect of top leader on ESG is the strongest on ESG, followed by the executive board. The results make sense because the top leaders have the strongest influence on decision-making, in line with our structural power argument.

6.4. Endogeneity test

We have taken several steps to ensure robustness of the results. First, we use a battery of tests to mitigate sample selection bias. We first use the Heckman model to mitigate sample selection bias from non-randomly selected samples (Heckman, 1981). We introduce an exogenous variable, Digital_Birthplace, which indicates whether the CEO or board chair was born in a region with a relatively advanced digital economy. This binary variable (1,0) serves as a dependent variable in a probit regression within the Heckman two-stage analysis. The results are shown in column (1) of Table 5. When a CEO or board chair originates from a region with a well-developed digital economy, their digital leadership is influenced by this exposure to digital technology. However, this background does not impact the firm's ESG performance. Therefore, Digital_Birthplace is an effective instrumental variable for digital leadership, providing a valid exogenous source for our analysis. In the first stage of the Heckman's analysis, we obtain the inverse Mill's ratio (IMR) variable, which is entered into the second-stage regression. The results of the second stage are shown in column (2) and underscore that across several methods, digital leadership has a positive and significant effect on ESG.

Moreover, we use a two-stage least squares (2SLS) method to mitigate further endogenous problems (Semadeni et al., 2014). In the first stage, we use an instrumental variable that assesses the number of industrial robot applications (*Robot*) in the United States in that same year. Even though this variable represents a technological trend that may encourage Chinese firms to undertake digital technology, it is not related to the ESG performance of the Chinese firms. Column (3) shows that *Robot* increases the culture of digital leadership (β=0.0312, $p<0.1$) in the first stage. In the second stage, we compute the predicted value of digital leadership and examine its effect on ESG. Column (4) shows that digital leadership has a positive effect (β=1.5782, $p<0.01$) on ESG.

6.5. Robustness test

To mitigate sample selection bias, we adopted the propensity score matching (PSM) method (Shipman et al., 2016). The method assembles a sample in which confounding factors are balanced between treatment groups. We used the nearest neighbor matching, kernel matching and radius matching to identify the matched sample. In Table 6, columns (1)-(3) report the results.

Second, we examine the effect of digital leadership beyond the current time span. Considering the complexity of the ESG rating process, the effect of digital leadership on ESG may be persistent over time. Therefore, following the previous study of Xing et al.

Table 2
Descriptive statistics.

Variable	N	Mean	SD	Min	Max
ESG	25,706	4.0797	1.0547	1.0000	6.0000
DLeader	25,706	0.9110	1.0793	0.0000	3.0000
DigitT	25,706	−0.0119	0.8900	−0.8080	4.5288
Turnover	25,706	0.0280	0.0263	0.0021	0.1478
TMT_Female	25,706	0.9551	0.2071	0.0000	1.0000
TMT_Enviro	25,706	0.3554	0.4786	0.0000	1.0000
Insured	25,706	0.1260	0.3319	0.0000	1.0000
Gov_Attention	25,706	0.4194	0.0097	0.3972	0.4400
FirmSize	25,706	7.6387	1.1507	5.0106	10.8070
FirmAge	25,706	9.8976	7.1922	1.0000	28.0000
Lev	25,706	0.3959	0.2017	0.0503	0.9510
ROA	25,706	0.0411	0.0650	−0.2473	0.2157
Liquid	25,706	0.1114	0.3146	0.0000	1.0000
Loss	25,706	2.7558	2.8447	0.3778	18.0124
Dual	25,706	0.3183	0.4658	0.0000	1.0000
Top1	25,706	0.3356	0.1408	0.0891	0.7163
Indep	25,706	0.3759	0.0532	0.3333	0.5714
Mshare	25,706	0.1568	0.2075	0.0000	69.6337
Tenure	25,706	49.9079	21.8138	11.5556	119.7692
SOE	25,706	0.2835	0.4507	0.0000	1.0000

Table 3
Correlation coefficients.

Variable	1	2	3	4	5	6	7
1.ESG	1						
2.DLeader	0.075***	1					
3.DigitT	0.032***	0.059***	1				
4.Turnover	−0.008	0.063***	−0.011*	1			
5.TMT_Female	−0.002	0.011*	0.021***	−0.008	1		
6.TMT_Enviro	0.038***	0.062***	−0.007	0.005	0.026***	1	
7.Insured	0.039***	0.042***	0.019***	−0.066***	0.025***	0.070***	1
8.Gov_Attention	0.062***	0.088***	0.030***	−0.015**	0.078***	0.138***	0.259***
9.FirmSize	0.158***	−0.079***	0.052***	−0.209***	−0.047***	0.034***	0.115***
10.FirmAge	−0.160***	−0.142***	0.000	−0.183***	−0.028***	0.003	0.153***
11.Lev	−0.174***	−0.090***	−0.004	−0.091***	−0.044***	0.052***	0.075***
12.ROA	0.252***	0.050***	0.002	−0.026***	0.009	−0.025***	−0.035***
13.Liquid	−0.192***	−0.035***	0.010	0.010	0.006	0.013**	0.053***
14.Loss	0.102***	0.107***	−0.011*	0.078***	0.039***	−0.066***	−0.045***
15.Dual	0.013**	0.063***	0.021***	0.084***	0.041***	0.011*	−0.034***
16.Top1	0.100***	−0.023***	−0.010	−0.050***	−0.024***	−0.045***	−0.036***
17.Indep	0.064***	−0.001	0.018***	0.023***	0.018***	−0.012**	0.028***
18.Mshare	0.135***	0.090***	0.007	0.189***	0.051***	−0.020***	−0.078***
19.Tenure	0.067***	−0.063***	0.023***	−0.136***	0.011*	−0.021**	0.038***
20.SOE	−0.001	−0.068***	−0.020***	−0.120***	−0.081***	−0.028***	0.071***
	8	9	10	11	12	13	14
8.Gov_Attention	1						
9.FirmSize	0.002	1					
10.FirmAge	0.028***	0.351***	1				
11.Lev	−0.079***	0.408***	0.367***	1			
12.ROA	0.020***	0.034***	−0.179***	−0.398***	1		
13.Liquid	0.032***	−0.055***	0.135***	0.251***	−0.671***	1	
14.Loss	0.006	−0.389***	−0.293***	−0.666***	0.244***	−0.127***	1
15.Dual	0.109***	−0.151***	−0.243***	−0.135***	0.045***	−0.022***	0.120***
16.Top1	−0.097***	0.143***	−0.105***	−0.029***	0.139***	−0.099***	0.024***
17.Indep	0.074***	−0.035***	−0.026***	−0.013**	−0.017***	0.018***	0.006
18.Mshare	0.110***	−0.283***	−0.533***	−0.319***	0.165***	−0.114***	0.259***
19.Tenure	0.149***	0.176***	0.245***	0.022***	0.026***	−0.023***	−0.104***
20.SOE	−0.190***	0.286***	0.485***	0.289***	−0.114***	0.060***	−0.188***
	15	16	17	18	19	20	
15.Dual	1						
16.Top1	−0.015**	1					
17.Indep	0.102***	0.046***	1				
18.Mshare	0.231***	−0.025***	0.070***	1			
19.Tenure	−0.008	−0.107***	−0.002	−0.079***	1		
20.SOE	−0.294***	0.135***	−0.065***	−0.448***	−0.033***	1	

Table 4
Effect of digital leadership on ESG in a firm-fixed effects model.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ESG	Enviro	Social	Govern	ESG	ESG	ESG
DLeader	0.0304***	0.0242***	0.0221***	0.0318***			
	(0.0072)	(0.0072)	(0.0074)	(0.0095)			
DLeader_top leader					0.0600***		
					(0.0214)		
DLeader_board						0.0502***	
						(0.0171)	
DLeader_TMT							0.0491***
							(0.0147)
FirmSize	0.2574***	0.1406***	0.2441***	0.1501***	0.2576***	0.2577***	0.2565***
	(0.0131)	(0.0131)	(0.0135)	(0.0174)	(0.0131)	(0.0131)	(0.0131)
FirmAge	−0.1266***	−0.0309	−0.0415	−0.0429	−0.1273***	−0.1268***	−0.1271***
	(0.0427)	(0.0426)	(0.0440)	(0.0566)	(0.0427)	(0.0427)	(0.0427)
Lev	−0.8808***	−0.1420**	−0.6868***	−1.7980***	−0.8808***	−0.8826***	−0.8799***
	(0.0592)	(0.0590)	(0.0609)	(0.0784)	(0.0592)	(0.0592)	(0.0592)
ROA	0.5569***	−0.1754	0.8154***	0.7237***	0.5675***	0.5556***	0.5597***
	(0.1384)	(0.1379)	(0.1425)	(0.1833)	(0.1384)	(0.1384)	(0.1384)
Loss	−0.0234	0.0112	−0.0035	−0.0381	−0.0228	−0.0239	−0.0234
	(0.0239)	(0.0238)	(0.0246)	(0.0316)	(0.0239)	(0.0239)	(0.0239)
Liquid	0.0172***	0.0177***	0.0211***	0.0217***	0.0173***	0.0174***	0.0174***
	(0.0034)	(0.0034)	(0.0035)	(0.0045)	(0.0034)	(0.0034)	(0.0034)
Dual	−0.0224	−0.0140	−0.0111	0.0127	−0.0216	−0.0240	−0.0231
	(0.0176)	(0.0175)	(0.0181)	(0.0233)	(0.0176)	(0.0176)	(0.0176)
Top1	0.3246***	−0.0610	0.2165**	0.8371***	0.3286***	0.3237***	0.3200***
	(0.0911)	(0.0907)	(0.0938)	(0.1207)	(0.0911)	(0.0911)	(0.0911)
Indep	1.0047***	−0.1464	0.9161***	1.9766***	0.9875***	1.0145***	0.9995***
	(0.1557)	(0.1551)	(0.1603)	(0.2063)	(0.1557)	(0.1559)	(0.1557)
Mshare	0.8044***	0.1212*	0.7361***	1.2152***	0.8097***	0.8085***	0.8046***
	(0.0683)	(0.0680)	(0.0703)	(0.0905)	(0.0683)	(0.0683)	(0.0683)
Tenure	0.0016***	0.0002	0.0006	0.0029***	0.0015***	0.0015***	0.0016***
	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0004)	(0.0004)	(0.0004)
SOE	0.0571	0.0750**	0.0638*	0.1360***	0.0551	0.0550	0.0550
	(0.0363)	(0.0362)	(0.0374)	(0.0481)	(0.0363)	(0.0363)	(0.0363)
Intercept	2.5040***	0.7135***	1.7032***	4.6300***	2.5305***	2.5204***	2.5219***
	(0.2309)	(0.2301)	(0.2378)	(0.3059)	(0.2308)	(0.2309)	(0.2309)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.0581	0.0676	0.1521	0.2058	0.0576	0.0577	0.0578
#Observations	25,706	25,706	25,706	25,706	25,706	25,706	25,706

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

(2024), we use the following year's ESG (i.e., ESG in year t+1) for additional analysis. Table 6 shows that the effect of digital leadership on ESG_{t+1} is 0.0163 (p<0.05) in column (4).

Finally, this paper tests the consistency of the findings by measuring ESG performance in other ways (Xing et al., 2024). We supplement the robustness test using an alternative ESG score from Chinese Research Data Services Platform (CNRDS) database as the dependent variable (*ESG_R*). This score ranges from 0 to 100. Column (5) of Table 6 reports the regression result, which shows that digital leadership has a positive effect (β= 0.2138, p<0.01) on *ESG_R*. Our additional analysis confirms that digital leadership promotes corporate ESG.

6.6. *Mediating analysis*

In the mediating analysis, we need to show that digital leadership first affects digital transformation (*DigitT*), which in turn affects ESG. Column (1) shows that digital leadership has a positive effect on digital transformation (0.0128, p<0.05). Column (2) includes the effect of both digital leadership and digital transformation on ESG. Digital leadership has a positive effect on ESG (0.0302, p<0.01), while digital transformation also has a positive effect on ESG (0.0225, p<0.01). These results indicate that digital leadership improves ESG performance by promoting digital transformation, supporting Hypothesis 2a.

Hypothesis 2b. suggests that digital leadership will attract increased trading, which improves the performance of ESG. The results of column (3) show that digital leadership (DLeader) has a positive effect on turnover (0.0011, p<0.01). Column (4) shows that digital leadership (Dleader) can promote ESG (β= 0.0293, p <0.01), and that turnover will also improve ESG performance (β= 1.0637,

Table 5
Endogeneity test.

	(1)	(2)	(3)	(4)
	Heckman−2-stage		2SLS	
	1-stage	2-stage	1-stage	2-stage
DLeader		0.0303***		
		(0.0072)		
DLeader_Birthplace	0.0494**			
	(0.0252)			
IMR		0.5994		
		(0.5518)		
Robot			0.0312*	
			(0.0173)	
Predict_DLeader				1.5782***
				(0.5985)
FirmSize	−0.0211**	0.2470***	−0.0124	0.2766***
	(0.0096)	(0.0163)	(0.0122)	(0.0151)
FirmAge	−0.0171***	−0.1342***	−0.0474	−0.0531***
	(0.0018)	(0.0433)	(0.0397)	(0.0145)
Lev	0.0833	−0.8462***	−0.0235	−0.8443***
	(0.0671)	(0.0672)	(0.0550)	(0.0612)
ROA	0.7245***	0.8909***	0.2738**	0.1332
	(0.1989)	(0.3372)	(0.1287)	(0.2140)
Loss	0.0034	−0.0217	0.0023	−0.0270
	(0.0387)	(0.0239)	(0.0222)	(0.0240)
Liquid	0.0205***	0.0263***	0.0133***	−0.0034
	(0.0040)	(0.0090)	(0.0032)	(0.0087)
Dual	0.1149***	0.0299	−0.0262	0.0182
	(0.0195)	(0.0512)	(0.0163)	(0.0236)
Top1	−0.1817***	0.2437**	−0.0261	0.3650***
	(0.0674)	(0.1176)	(0.0847)	(0.0920)
Indep	−1.1207***	0.4879	−0.4738***	1.7379***
	(0.1732)	(0.5006)	(0.1448)	(0.3238)
Mshare	0.0008	0.0084***	0.2896***	0.3561*
	(0.0005)	(0.0008)	(0.0635)	(0.1889)
Tenure	−0.0012***	0.0011*	−0.0045***	0.0086***
	(0.0004)	(0.0006)	(0.0003)	(0.0027)
SOE	0.0030	0.0568	−0.1274***	0.2543***
	(0.0258)	(0.0363)	(0.0338)	(0.0843)
Intercept	−0.7265***	1.7135**	1.2656***	0.1759
	(0.1355)	(0.7635)	(0.2055)	(0.8411)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
χ^2 /R^2	1961.51	0.0581	0.0206	0.0573
#Observation	25,706	25,706	25,706	25,706

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

p<0.01). These results support Hypothesis 2b. Column (5) suggests that trade turnover mediates the relationship between digital leadership and corporate ESG. To ensure the robustness of the results, we further expand the turnover variable with a trade turnover period of 60 days.[2] We also use it to conduct the mediating variable. The results are reported in columns (6) and (7) of Table 7. Similar to the previous regression results, the trade turnover using 30 days and 60 days plays an important mediating role in the relationship between digital leadership and ESG.

To test the effect of the mediating variable between the independent variable and the dependent variable, we use the Sobel test (Sobel, 1982). As shown in Table 7, digital transformation and trade turnover have a significant mediating effect on ESG performance. The results of the Sobel test further support the mediating effect of digital transformation and trade turnover between digital leadership and ESG, which further supports our mediator hypothesis.

6.7. *Moderating analysis*

Table 8 reports the results of the moderation analysis. Column (1) shows the interaction of digital leadership and female executives (β= 0.0559, p<0.05). The result supports Hypothesis 3a, indicating that female executives magnify the positive effect of digital leadership on ESG.

Column (2) shows the interaction between digital leadership and *TMT_Enviro* (β= 0.0290, p<0.01). The result implies that digital

[2] We thank the executive editor for suggesting this analysis.

Table 6
Robustness test.

	(1)	(2)	(3)	(4)	(5)
	PSM			1-year ahead	Alternative ESG score
	Neighbor matching	Kernel Matching	Radius Matching		
	ESG	ESG	ESG	ESG_{t+1}	ESG_R
DLeader	0.0302***	0.0305***	0.0303***	0.0163**	0.2138***
	(0.000)	(0.000)	(0.000)	(0.0077)	(0.0817)
FirmSize	0.2572***	0.2575***	0.2576***	0.2377***	0.2462*
	(0.000)	(0.000)	(0.000)	(0.0141)	(0.1495)
FirmAge	−0.1264***	−0.1265***	−0.1244***	−0.1600**	−1.3315***
	(0.003)	(0.003)	(0.004)	(0.0803)	(0.4861)
Lev	−0.8767***	−0.8831***	−0.8773***	−0.7620***	1.2174*
	(0.000)	(0.000)	(0.000)	(0.0638)	(0.6734)
ROA	0.5634***	0.5614***	0.5576***	1.4111***	−1.2558
	(0.000)	(0.000)	(0.000)	(0.1490)	(1.5746)
Loss	−0.0230	−0.0232	−0.0243	−0.3347***	−0.2854
	(0.337)	(0.332)	(0.309)	(0.0259)	(0.2718)
Liquid	0.0178***	0.0171***	0.0180***	0.0068*	−0.0150
	(0.000)	(0.000)	(0.000)	(0.0036)	(0.0390)
Dual	−0.0227	−0.0227	−0.0234	−0.0126	−0.5936***
	(0.198)	(0.197)	(0.183)	(0.0188)	(0.2000)
Top1	0.3233***	0.3256***	0.3281***	0.2123**	−2.1980**
	(0.000)	(0.000)	(0.000)	(0.0982)	(1.0364)
Indep	0.9957***	1.0055***	1.0010***	0.6296***	−4.7303***
	(0.000)	(0.000)	(0.000)	(0.1657)	(1.7720)
Mshare	0.8044***	0.0080***	0.0080***	0.4912***	−0.0167**
	(0.000)	(0.000)	(0.000)	(0.0741)	(0.0078)
Tenure	0.0016***	0.0016***	0.0016***	0.0009**	0.0063
	(0.000)	(0.000)	(0.000)	(0.0004)	(0.0042)
SOE	0.0566	0.0570	0.0568	0.0817**	0.4742
	(0.119)	(0.116)	(0.118)	(0.0393)	(0.4132)
Intercept	2.5081***	2.5044***	2.4946***	2.5781***	26.0721***
	(0.000)	(0.000)	(0.000)	(0.3042)	(2.6285)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
R^2	0.0581	0.0581	0.0582	0.0876	0.0258
#Observation	25,650	25,705	25,691	22,424	25,698

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

leaders work with TMT who have environmental protection experience to promote ESG. Column (3) provides the interaction of the degree of digital leadership (*DLeader*) and directors' and officers' liability insurance (*Insured*), at 0.0328 ($p<0.05$). Liability insurance indeed influences the role of digital leadership. The results support Hypothesis 3c. Column (4) reports the moderating effect of government environmental attention (*Gov_Attention*) on ESG. The results indicate that the effect of the interaction between digital leadership and government environmental attention is 1.8642 ($p<0.01$), implying that government indeed amplifies the effect of digital leadership on ESG.

7. Conclusion

Our research reveals that digital leadership plays a pivotal role in driving the adoption of corporate sustainability strategies. By analyzing data from Chinese A-share manufacturing listed firms spanning from 2009 to 2022, we empirically examine the impact of digital leadership on corporate ESG performance. Our findings indicate a positive relationship between digital leadership and corporate ESG performance. This correlation remains robust even after conducting various tests, highlighting the significant influence of digital leadership. Specifically, we find that digital leadership exerts the greatest influence on corporate governance, trailed respectively by environmental performance and social responsibility.

Second, our study explores the mechanism of how digital leadership affects corporate ESG. The mediation analysis suggests that digital leadership enhances firms' ESG performance by driving firms' digital transformation and by improving liquidity of the stock trading. In addition, we argue that certain stakeholders (professional analysts) moderate the link between digital leadership and ESG. We find that, internally, the presence of female executives strengthens the relationship between digital leadership and corporate ESG activities; executives' past experience related to environmental protection also increases the relationship between digital leadership and ESG. We also find that external stakeholders can moderate the relationship between digital leadership and ESG: D&O insurance enrollment behavior increases the propensity of digital leaders to engage in ESG activities, and the government's focus on the environment also strengthens the link between the two.

Our study has some theoretical contributions. First, leaders with digital leadership adhere to high levels of ethical standards and social responsibility, and the characteristics of digital leadership influence the tendency of corporate managers to increase green

Table 7
Mediating role of digital transformation and traders between digital leadership and ESG.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	DigitT	ESG	Turnover (30 days)	ESG (30-day TV)	ESG (30-day TV)	Turnover (60 days)	ESG (60-day TV)
DLeader	0.0128**	0.0302***	0.0011***	0.0293***	0.0290***	0.0011***	0.0293***
	(0.0056)	(0.0072)	(0.0002)	(0.0072)	(0.0072)	(0.0002)	(0.0072)
DigitT		0.0225***			0.0229***		
		(0.0085)			(0.0085)		
Turnover (TV)				1.0637***	1.0701***		1.0398***
				(0.2361)	(0.2361)		(0.2634)
FirmSize	0.0699***	0.2559***	−0.0019***	0.2595***	0.2579***	−0.0018***	0.2593***
	(0.0103)	(0.0131)	(0.0004)	(0.0131)	(0.0131)	(0.0003)	(0.0131)
FirmAge	0.0011	−0.1266***	−0.0057***	−0.1205***	−0.1205***	−0.0029***	−0.1235***
	(0.0335)	(0.0427)	(0.0012)	(0.0427)	(0.0427)	(0.0011)	(0.0427)
Lev	−0.1269***	−0.8779***	−0.0018	−0.8789***	−0.8760***	−0.0028*	−0.8779***
	(0.0464)	(0.0592)	(0.0017)	(0.0592)	(0.0592)	(0.0015)	(0.0592)
ROA	−0.0552	0.5581***	0.0055	0.5510***	0.5523***	0.0085**	0.5480***
	(0.1084)	(0.1384)	(0.0039)	(0.1383)	(0.1383)	(0.0035)	(0.1383)
Loss	0.0008	−0.0234	0.0020***	−0.0256	−0.0256	0.0029***	−0.0264
	(0.0187)	(0.0239)	(0.0007)	(0.0239)	(0.0239)	(0.0006)	(0.0239)
Liquid	−0.0091***	0.0174***	0.0005***	0.0167***	0.0169***	0.0007***	0.0165***
	(0.0027)	(0.0034)	(0.0001)	(0.0034)	(0.0034)	(0.0001)	(0.0034)
Dual	−0.0042	−0.0223	0.0010**	−0.0235	−0.0234	0.0006	−0.0230
	(0.0138)	(0.0176)	(0.0005)	(0.0176)	(0.0176)	(0.0004)	(0.0176)
Top1	−0.1925***	0.3289***	0.0034	0.3209***	0.3253***	0.0052**	0.3192***
	(0.0714)	(0.0911)	(0.0026)	(0.0910)	(0.0910)	(0.0023)	(0.0911)
Indep	−0.5617***	1.0173***	0.0096**	0.9945***	1.0073***	0.0028	1.0018***
	(0.1220)	(0.1558)	(0.0044)	(0.1557)	(0.1557)	(0.0039)	(0.1557)
Mshare	−0.0978*	0.8066***	0.0199***	0.7832***	0.7853***	0.0002***	0.0078***
	(0.0535)	(0.0683)	(0.0019)	(0.0684)	(0.0684)	(0.0000)	(0.0007)
Tenure	0.0009***	0.0016***	−0.0001***	0.0018***	0.0018***	−0.0001***	0.0018***
	(0.0003)	(0.0004)	(0.0000)	(0.0004)	(0.0004)	(0.0000)	(0.0004)
SOE	−0.0519*	0.0582	−0.0001	0.0572	0.0584	−0.0011	0.0582
	(0.0284)	(0.0363)	(0.0010)	(0.0363)	(0.0363)	(0.0009)	(0.0363)
Intercept	−0.0524	2.5052***	0.0512***	2.4496***	2.4504***	0.0494***	2.4526***
	(0.1809)	(0.2309)	(0.0065)	(0.2311)	(0.2311)	(0.0059)	(0.2312)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sobel test	0.0003*		0.0011***			0.0011***	
	(0.0002)		(0.0003)			(0.0003)	
R^2	0.0221	0.0584	0.1051	0.0589	0.0592	0.1267	0.0587
#Observations	25,706	25,706	25,706	25,706	25,706	25,706	25,706

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

transformation and management disclosure. Digital leaders focus on corporate digital transformation and stock trading turnover performance to drive corporate ESG strategies. Second, our study also advances the field's understanding of stakeholders. Leaders need to manage relationships with stakeholders (Harrison and St. John, 1996), and stakeholders may hold different perspectives on ESG activities with their firms. When deciding whether to invest in ESG activities, digital leaders may vary in their willingness, depending on the perspectives of their stakeholders. This finding helps us to better understand the role of stakeholders in digital leaders' decision-making.

As a result, we offer three practical recommendations based on the findings of this paper. Firms may be able to utilize leaders' digital leadership to assess the potential to steer the firm towards a sustainable path; it may be more effective for firms' digital leaders to start improving ESG performance in terms of improving the level of governance within the firm than in terms of both environmental protection and social responsibility taking; digital leadership is not the only factor that affects corporate ESG performance, and the potential influence of stakeholders' personalities on corporate operations cannot be ignored.

However, our study is limited by using only Chinese firms. While this allows us to control for a more specific sample in this initial study, researchers for future research may want to explore whether this conclusion is equally applicable in developed countries, or regions with different institutions, economies, and cultures. Second, the measurement of digital leadership may be refined with new methods in the field. With the development of online media, the personal remarks by corporate leaders on online media might be used to conduct an exploration of the digital leadership style of leaders. Furthermore, future research should investigate how the combination of leadership gender and digital technology impacts a firm's ESG performance. This will offer a more comprehensive understanding of digital leadership's effect on ESG outcomes.

Table 8
Moderating effects of female executives, TMT environmental protection experience, liability insurance for executives, and government environmental attention on ESG.

	(1)	(2)	(3)	(4)
	ESG	ESG	ESG	ESG
DLeader	0.0304***	0.0289***	0.0298***	0.0311***
	(0.0072)	(0.0072)	(0.0072)	(0.0072)
TMT_Female	−0.0283			
	(0.0310)			
DLeader*TMT_Female	0.0559**			
	(0.0263)			
TMT_Enviro		0.0384***		
		(0.0147)		
DLeader*TMT_Enviro		0.0290**		
		(0.0120)		
Insured			0.0563**	
			(0.0238)	
DLeader*Insured			0.0328**	
			(0.0161)	
Gov_Attention				2.3655*
				(1.2531)
DLeader*Gov_Attention				1.8642***
				(0.5934)
FirmSize	0.2566***	0.2565***	0.2554***	0.2548***
	(0.0131)	(0.0131)	(0.0131)	(0.0132)
FirmAge	−0.1267***	−0.1266***	−0.1273***	−0.1267***
	(0.0427)	(0.0427)	(0.0427)	(0.0427)
Lev	−0.8789***	−0.8787***	−0.8804***	−0.8841***
	(0.0592)	(0.0592)	(0.0592)	(0.0592)
ROA	0.5611***	0.5591***	0.5606***	0.5597***
	(0.1384)	(0.1383)	(0.1384)	(0.1384)
Loss	−0.0230	−0.0229	−0.0224	−0.0227
	(0.0239)	(0.0239)	(0.0239)	(0.0239)
Liquid	0.0173***	0.0174***	0.0172***	0.0174***
	(0.0034)	(0.0034)	(0.0034)	(0.0034)
Dual	−0.0220	−0.0227	−0.0212	−0.0227
	(0.0176)	(0.0176)	(0.0176)	(0.0176)
Top1	0.3243***	0.3285***	0.3235***	0.3296***
	(0.0911)	(0.0911)	(0.0911)	(0.0911)
Indep	1.0002***	1.0076***	0.9938***	1.0006***
	(0.1557)	(0.1557)	(0.1557)	(0.1557)
Mshare	0.8053***	0.8027***	0.8076***	0.8103***
	(0.0683)	(0.0683)	(0.0683)	(0.0683)
Tenure	0.0016***	0.0017***	0.0017***	0.0016***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
SOE	0.0583	0.0547	0.0558	0.0578
	(0.0363)	(0.0363)	(0.0363)	(0.0363)
Intercept	2.5293***	2.5052***	2.5229***	1.5623***
	(0.2326)	(0.2309)	(0.2310)	(0.5597)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
R^2	0.0583	0.0586	0.0585	0.0586
#Observations	25,706	25,706	25,706	25,706

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Author statement

Penghua Qiao is responsible for funding, planning, and overall ideas of the paper;
Kaizhong Qiu is responsible for collecting data, conducting the empirical analysis and partial writing;
Anna Fung develops the hypothesis and responsible for writing and editing;
Hung-Gay Fung oversees the overall structure and execution of the project.

CRediT authorship contribution statement

Yuying Zhao: Formal analysis. **Penghua Qiao:** Conceptualization. **Hung-Gay Fung:** Conceptualization. **Anna Fung:** Writing – review & editing.

Data availability

Data will be made available on request.

References

Adams, R.B., Licht, A.N., Sagiv, L., 2011. Shareholders and stakeholders: How do directors decide? Strateg. Manag. J. 32 (12), 1331–1355.
Alkhawaja, A., Hu, F., Johl, S., Nadarajah, S., 2023. Board gender diversity, quotas, and ESG disclosure: global evidence. Int. Rev. Financ. Anal. 90, 102823.
AlNuaimi, B.K., Singh, S.K., Ren, S., Budhwar, P., Vorobyev, D., 2022. Mastering digital transformation: the nexus between leadership, agility, and digital strategy. J. Bus. Res. 145 (3), 636–648.
Badrul Muttakin, M., Chatterjee, B., Khan, A., Getie Mihret, D., Roy, R., Yaftian, A., 2022. Corporate political donations, board gender diversity, and corporate social responsibility: evidence from Australia. J. Bus. Res. 152 (3), 290–299.
Bao, R., Liu, T., 2022. How does government attention matter in air pollution control? Evidence from government annual reports. Resour. Conserv. Recycl. 185, 106435.
Barber, B.M., Odean, T., 2008. All that glitters: the effect of attention and news on the buying behavior of individual and institutional investors. Rev. Financ. Stud. 21 (2), 785–818.
Baron, R.M., Kenny, D.A., 1986. The moderator–mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J. Personal. Soc. Psychol. 51 (6), 1173–1182.
Benitez, J., Arenas, A., Castillo, A., Esteves, J., 2022. Impact of digital leadership capability on innovation performance: the role of platform digitization capability. Inf. Manag. 59 (2), 103590.
Borah, P.S., Iqbal, S., Akhtar, S., 2022. Linking social media usage and SME's sustainable performance: the role of digital leadership and innovation capabilities. Technol. Soc. 68, 101900.
Boubaker, S., Cellier, A., Manita, R., Saeed, A., 2020. Does corporate social responsibility reduce financial distress risk? Econ. Model. 91, 835–851.
Boyer, M.M., Tennyson, S., 2015. Directors' and officers' liability insurance, corporate risk and risk taking: new panel data evidence on the role of directors' and officers' liability insurance. J. Risk Insur. 82 (4), 753–791.
Broadstock, D.C., Matousek, R., Meyer, M., Tzeremes, N.G., 2020. Does corporate social responsibility impact firms' innovation capacity? The indirect link between environmental & social governance implementation and innovation performance. J. Bus. Res. 119, 99–110.
Cai, Q., Wu, J., Wu, T., Chang, P.-C., Mardani, A., 2024. The impact of digital leadership on hidden champions' competitive advantage: a moderated mediation model of ambidextrous innovation and value co-creation. J. Bus. Res. 182, 114819.
Chatterjee, S., Chaudhuri, R., Vrontis, D., Giovando, G., 2023. Digital workplace and organization performance: moderating role of digital leadership capability. J. Innov. Knowl. 8 (1), 100334.
Chen, L., Khurram, M.U., Gao, Y., Abedin, M.Z., Lucey, B., 2023. ESG disclosure and technological innovation capabilities of the Chinese listed companies. Res. Int. Bus. Financ. 65, 101974.
Cheng, B., Ioannou, I., Serafeim, G., 2014. Corporate social responsibility and access to finance. Strateg. Manag. J. 35 (1), 1–23.
Cheung, Y.-L., Tan, W., Wang, W., 2020. Where do banks value corporate social responsibility more? Evidence on the role of national culture. J. Bank. Financ. 118, 105810.
Christensen, L.J., Mackey, A., Whetten, D., 2014. Taking responsibility for corporate social responsibility: the role of leaders in creating, implementing, sustaining, or avoiding socially responsible firm behaviors. Acad. Manag. Perspect. 28 (2), 164–178.
Core, J.E., 2000. The directors' and officers' insurance premium: an outside assessment of the quality of corporate governance. J. Law Econ. Organ. 16 (2), 449–477.
Cycyota, C.S., Harrison, D.A., 2006. What (not) to expect when surveying executives: a meta-analysis of top manager response rates and techniques over time. Organ. Res. Methods 9 (2), 133–160.
Dai, W., Si, S., 2018. Government policies and firms' entrepreneurial orientation: strategic choice and institutional perspectives. J. Bus. Res. 93, 23–36.
Ding, R., Duan, T., Hou, W., Liu, X., Xu, Z., 2022. Do women drive corporate social responsibility? Evidence from gender diversity reforms around the world. Int. Rev. Law Econ. 72, 106097.
Drempetic, S., Klein, C., Zwergel, B., 2020. The influence of firm size on the ESG score: corporate sustainability ratings under review. J. Bus. Ethics 167 (2), 333–360.
Du, S., Swaen, V., Lindgreen, A., Sen, S., 2013. The roles of leadership styles in corporate social responsibility. J. Bus. Ethics 114, 155–169.
Dubey, R., Gunasekaran, A., Samar Ali, S., 2015. Exploring the relationship between leadership, operational practices, institutional pressures and environmental performance: a framework for green supply chain. Int. J. Prod. Econ. 160, 120–132.
Engelbrecht, J., Johnston, K.A., Hooper, V., 2017. The influence of business managers' IT competence on IT project success. Int. J. Proj. Manag. 35 (6), 994–1005.
Evans, G.L., 2014. A mega review of cultural studies: linking leadership to corporate governance. Econ. Bus. Rev. 14 (1), 76–126.
Fang, M., Nie, H., Shen, X., 2023. Can enterprise digitization improve ESG performance? Econ. Model. 118, 106101.
Fatima, T., Masood, A., 2023. Impact of digital leadership on open innovation: a moderating serial mediation model. J. Knowl. Manag. 28 (1), 161–180.
Feng, J., Yuan, Y., 2024. Green investors and corporate ESG performance: evidence from China. Financ. Res. Lett. 60, 104892.
Fink, C., Mattoo, A., Neagu, I.C., 2005. Assessing the impact of communication costs on international trade. J. Int. Econ. 67 (2), 428–445.
Flyverbom, M., Deibert, R., Matten, D., 2019. The governance of digital technology, big data, and the internet: new roles and responsibilities for business. Bus. Soc. 58 (1), 3–19.
Fu, C., Yu, C., Guo, M., Zhang, L., 2024. ESG rating and financial risk of mining industry companies. Resour. Policy 88, 104308.
Gadenne, D.L., Kennedy, J., McKeiver, C., 2009. An empirical study of environmental awareness and practices in SMEs. J. Bus. Ethics 84 (1), 45–63.
Gillan, S.L., Koch, A., Starks, L.T., 2021. Firms and social responsibility: a review of ESG and CSR research in corporate finance. J. Corp. Financ. 66 (3), 101889.
Gu, C., Kurov, A., 2020. Informational role of social media: evidence from Twitter sentiment. J. Bank. Financ. 121, 105969.
Guo, X., Li, M., Wang, Y., Mardani, A., 2023. Does digital transformation improve the firm's performance? From the perspective of digitalization paradox and managerial myopia. J. Bus. Res. 163, 113868.
Gupta, A., Fung, A., Murphy, C., 2021. Out of character: CEO political ideology, peer influence, and adoption of CSR executive position by Fortune 500 firms. Strateg. Manag. J. 42 (3), 529–557.
Hacioglu, U., Aksoy, T., 2021. Financial Ecosystem and Strategy in the Digital Era. Global Approaches and New Opportunities. Springer.
Hambrick, D., Mason, C., P, A., 1984. Upper Echelons: the organization as a reflection of its top managers. Acad. Manag. Rev. 9 (2), 193–206.
Harrison, J.S., St. John, C.H., 1996. Managing and partnering with external stakeholders. Acad. Manag. Perspect. 10 (2), 46–60.
Hausman, J.A., 1978. Specification tests in econometrics. Econometrica 46 (6), 1251–1271.
He, F., Guo, X., Yue, P., 2023. Media coverage and corporate ESG performance: evidence from China. Int. Rev. Financ. Anal. 91, 103003.
Heckman, 1981. Sample selection bias as a specification error: a comment. Econometrica 49 (3), 795–798.
Holderness, C.G., 1990. Liability insurers as corporate monitors. Int. Rev. Law Econ. 10 (2), 115–129.
Huang, R., Wei, J., 2023. Does CEOs' green experience affect environmental corporate social responsibility? Evidence from China. Econ. Anal. Policy 79, 205–231.
Javed, M., Wang, F., Usman, M., Ali Gull, A., Uz Zaman, Q., 2023. Female CEOs and green innovation. J. Bus. Res. 157, 113515.
Jia, W., Redigolo, G., Shu, S., Zhao, J., 2020. Can social media distort price discovery? Evidence from merger rumors. J. Account. Econ. 70 (1), 101334.
Johnson, S.G., Schnatterly, K., Hill, A.D., 2013. Board composition beyond independence: social capital, human capital, and demographics. J. Manag. 39 (1), 232–262.
Kane, G.C., Palmer, D., Phillips, A.N., Kiron, D., Buckley, N., 2016. Aligning the organization for its digital future. MIT Sloan Management Review and Deloitte University Press.

Kane, G.C., Phillips, A.N., Copulsky, J., Andrus, G., 2019. How digital leadership is(n't) different. MIT Sloan Manag. Rev. 60 (3), 34–39.
Karim, M.S., Nahar, S., Demirbag, M., 2022. Resource-Based Perspective on ICT Use and Firm Performance: a meta-analysis investigating the moderating role of cross-country ICT development status. Technol. Forecast. Soc. Change 179, 121626.
Kim, K., Kim, T.-N., 2023. CEO career concerns and ESG investments. Financ. Res. Lett. 55, 103819.
Kong, G., Kong, T.D., Qin, N., Yu, L., 2023. Ethnic diversity, trust and corporate social responsibility: the moderating effects of marketization and language. J. Bus. Ethics 187 (3), 449–471.
Leong, C., Pan, S.L., Leidner, D.E., Huang, J.-S., 2019. Platform leadership: managing boundaries for the network growth of digital platforms. J. Assoc. Inf. Syst. 20 (10), 1531–1565.
Li, G., Jin, Y., Gao, X., 2023. Digital transformation and pollution emission of enterprises: evidence from China's micro-enterprises. Energy Rep. 9, 552–567.
Li, L., Saat, M., Jiayi, W., 2024a. The effect of ESG disclosure on firm value: an empirical evidence from chinese listed companies. Int. J. Acad. Res. Bus. Soc. Sci. 14 (1).
Li, X., Guo, F., Wang, J., 2024b. A path towards enterprise environmental performance improvement: how does CEO green experience matter? Bus. Strategy Environ. 33 (2), 820–838.
Lian, Y., Ye, T., Zhang, Y., Zhang, L., 2023. How does corporate ESG performance affect bond credit spreads: empirical evidence from China. Int. Rev. Econ. Financ. 85 (3), 352–371.
Lin, Y., Fu, X., Fu, X., 2021. Varieties in state capitalism and corporate innovation: evidence from an emerging economy. J. Corp. Financ. 67, 101919.
Lins, K.V., Servaes, H., Tamayo, A., 2017. Social capital, trust, and firm performance: the value of corporate social responsibility during the financial crisis. J. Financ. 72 (4), 1785–1823.
Liu, B., Johl, S., Lasantha, R., 2023a. ESG scores and cash holdings: the role of disciplinary trading. Financ. Res. Lett. 55, 103854.
Liu, H., Zhang, Z., 2023. The impact of managerial myopia on environmental, social and governance (ESG) engagement: Evidence from Chinese firms. Energy Econ. 122, 106705.
Liu, K., Wang, J., Liu, L., Huang, Y., 2023b. Mixed-ownership reform of SOEs and ESG performance: evidence from China. Econ. Anal. Policy 80, 1618–1641.
Liu, X., Cifuentes-Faura, J., Zhao, S., Wang, L., 2024. The impact of government environmental attention on firms' ESG performance: evidence from China. Res. Int. Bus. Financ. 67, 102124.
Liu, Y., Zhang, F., Zhang, H., 2023c. CEO foreign experience and corporate environmental, social, and governance (ESG) performance. Bus. Strategy Environ. 1–25.
Loh, R., 2008. Investor inattention and the under-reaction to stock recommendations. Financ. Manag. 39 (3), 1223–1252.
Luo, C., Wei, D., He, F., 2023. Corporate ESG performance and trade credit financing – Evidence from China. Int. Rev. Econ. Financ. 85, 337–351.
Ma, D., Zhu, Q., 2022. Innovation in emerging economies: research on the digital economy driving high-quality green development. J. Bus. Res. 145 (3)), 801–813.
Ma, Y.M., Deng, Z., Teng, Y., Yang, Z., Zheng, X., 2023. Firms' multi-sided platform construction efforts and ESG performance: an information processing theory perspective. Ind. Mark. Manag. 115, 455–469.
Magesa, M.M., Jonathan, J., 2022. Conceptualizing digital leadership characteristics for successful digital transformation: the case of Tanzania. Inf. Technol. Dev. 28.
Mason, E.S., Mudrack, P.E., 1996. Gender and ethical orientation: a test of gender and occupational socialization theories. J. Bus. Ethics 15 (6), 599–604.
McWilliams, A., Siegel, D., 2000. Corporate social responsibility and financial performance: correlation or misspecification? Strateg. Manag. J. 21 (5), 603–609.
Memon, K.R., Ooi, S.K., 2023. Identifying digital leadership's role in fostering competitive advantage through responsible innovation: a SEM-Neural Network approach. Technol. Soc. 75, 102399.
Miller, D.T., Ross, M., 1975. Self-serving biases in the attribution of causality: Fact or fiction? Psychol. Bull. 82 (2), 213–225.
Obwegeser, N., Yokoi, T., Wade, M., Voskes, T., 2020. 7 key principles to govern digital initiatives. MIT Sloan Manag. Rev. 61 (3), 1–9.
Ocasio, W., 1997. Towards an attention-based view of the firm. Strateg. Manag. J. 18 (S1), 187–206.
Park, K.M., Wallace, F., 2020. Leadership and power in the digital economic revolution: celebrity status, social media, and big blunders? J. Glob. Bus. Technol. 16 (2), 1–17.
Pennebaker, J.W., Francis, M.E., Booth, R.J., 1999. Linguistic inquiry and word count (LIWC). Lawrence Erlbaum Associates Mahwah Nj.
Porfírio, J.A., Carrilho, T., Felício, J.A., Jardim, J., 2021. Leadership characteristics and digital transformation. J. Bus. Res. 124, 610–619.
Rao, K., Tilt, C., 2016. Board composition and corporate social responsibility: the role of diversity, gender, strategy and decision making. J. Bus. Ethics 138 (2), 327–347.
Semadeni, M., Withers, M., Certo, T., 2014. The perils of endogeneity and instrumental variables in strategy research: understanding through simulations. Strateg. Manag. J. 35 (7), 1070–1079.
Senadjki, A., Au Yong, H.N., Ganapathy, T., Ogbeibu, S., 2024. Unlocking the potential: the impact of digital leadership on firms' performance through digital transformation. J. Bus. Socio-Econ. Dev. 4 (2), 161–177.
Shakil, M.H., 2021. Environmental, social and governance performance and financial risk: moderating role of ESG controversies and board gender diversity. Resour. Policy 72, 102144.
Shipman, J.E., Swanquist, Q.T., Whited, R.L., 2016. Propensity score matching in accounting research. Account. Rev. 92 (1), 213–244.
Shu, H., Tan, W., 2023. Does carbon control policy risk affect corporate ESG performance? Econ. Model. 120, 106148.
Sobel, M.E., 1982. Asymptotic confidence intervals for indirect effects in structural equation models. Sociol. Methodol. 13, 290–312.
Solakov, E., Vuchkov, I., Boyadjieva, L., 1987. Applied Linear Regression Analysis. John Wiley & Sons, Russian.
Sun, Z.-Y., Li, J.-M., Li, B., He, X.-Y., 2024. Digital leadership and deviant innovation: the roles of innovation self-efficacy and employee ambitions. Curr. Psychol. 43 (26), 22226–22237.
Tan, X., Liu, G., Cheng, S., 2024. How does ESG performance affect green transformation of resource-based enterprises: evidence from Chinese listed enterprises. Resour. Policy 89, 104559.
Tian, H., Tian, G., 2022. Corporate sustainability and trade credit financing: evidence from environmental, social, and governance ratings. Corp. Soc. Responsib. Environ. Manag. 29 (5), 1896–1908.
Tian, H., Han, J., Sun, M., Lv, X., 2023. Keeping pace with the times: research on the impact of digital leadership on radical green innovation of manufacturing enterprises. Eur. J. Innov. Manag. https://doi.org/10.1108/EJIM-1111-2022-0647.
Tigre, F.B., Henriques, P.L., Curado, C., 2024. The digital leadership emerging construct: a multi-method approach. Manag. Rev. Q. https://doi.org/10.1007/s11301-023-00395-9.
Volschenk, F., 2019. Socially responsible digital leadership: a framework for digital organizations. Monarch Manag. Rev. ISSN: 1925-2668.
Wang, J., Lei, P., 2021. The tournament of Chinese environmental protection: strong or weak competition? Ecol. Econ. 181, 106888.
Wang, L., Li, Y., Lu, S., Boasson, V., 2023a. The impact of the CEO's green ecological experience on corporate green innovation—The moderating effect of corporate tax credit rating and tax burden. Front. Environ. Sci. 11, 1126692.
Wang, T.D., Lin, X.Y., Sheng, F., 2022a. Digital leadership and exploratory innovation: from the dual perspectives of strategic orientation and organizational culture. Front. Psychol. 13, 902693.
Wang, X., Li, Y., Tian, L., Hou, Y., 2023b. Government digital initiatives and firm digital innovation: evidence from China. Technovation 119, 102545.
Wang, Y., He, P., 2024. Enterprise digital transformation, financial information disclosure and innovation efficiency. Financ. Res. Lett. 59, 104707.
Wang, Y.-Y., Tao, F., Wang, J., 2022b. Information disclosure and blockchain technology adoption strategy for competing platforms. Inf. Manag. 59 (7), 103506.
Weber, E., Krehl, E.-H., Büttgen, M., Schweikert, K., 2019. The digital leadership framework: insights into new leadership roles facing digital transformation. Acad. Manag. Proc. 2019, 13650.
Weber, E., Büttgen, M., Bartsch, S., 2022a. How to take employees on the digital transformation journey: an experimental study on complementary leadership behaviors in managing organizational change. J. Bus. Res. 143, 225–238.
Weber, E., Krehl, E.H., Büttgen, M., 2022b. The digital transformation leadership framework: conceptual and empirical insights into leadership roles in technology-driven business environments. J. Leadersh. Stud. 16 (1), 6–22.

Westerman, G., 2012. The digital advantage: how digital leaders outperform their peers in every industry. MIT Sloan Manag. Capgemini Consult., MA 2, 2–23.
Xia, Y., Liu, X., Wang, X., Deng, H., Han, C., Liu, Z., Tsai, S.-B., 2023. The power of role models in a team: the impact of lead entrepreneur's digital leadership on digital entrepreneurial success. Inf. Process. Manag. 60 (6), 103498.
Xing, T., Li, X., Feng, N., 2024. Is bank competition conducive to corporate ESG performance? Int. Rev. Financ. Anal. 95, 103509.
Xu, L., Fan, M., Yang, L., Shao, S., 2021. Heterogeneous green innovations and carbon emission performance: evidence at China's city level. Energy Econ. 99, 105269.
Yin, Z., Li, X., Si, D., Li, X., 2023. China stock market liberalization and company ESG performance: the mediating effect of investor attention. Econ. Anal. Policy 80, 1396–1414.
Yuan, R., Sun, J., Cao, F., 2016. Directors' and officers' liability insurance and stock price crash risk. J. Corp. Financ. 37, 173–192.
Zhang, D., 2022. Does the green loan policy boost greener production?–Evidence from Chinese firms. Emerg. Mark. Rev. 51 (B). https://doi.org/10.1016/j.ememar.2021.100882.
Zhang, J., Zhang, K., 2023. How does CEO green experience affect green innovation of energy firms? Evidence from China. Energy Environ. https://doi.org/10.1177/0958305X231207057.
Zhang, J., Li, Y., Xu, H., Ding, Y., 2023a. Can ESG ratings mitigate managerial myopia? Evidence from Chinese listed companies. Int. Rev. Financ. Anal. 90, 102878.
Zhang, M., Yang, Y., Du, P., Wang, J., Wei, Y., Qin, J., Yu, L., 2024. The effect of public environmental participation on pollution governance in China: the mediating role of local governments' environmental attention. Environ. Impact Assess. Rev. 104, 107345.
Zhang, X., Huang, S., Li, W., Wang, Y., 2023b. Directors' and officers' liability insurance, environmental regulation and firms' envi ronmental responsibility. Ecol. Econ. 208, 107796.
Zhu, C., 2019. Big data as a governance mechanism. Rev. Financ. Stud. 32 (5), 2021–2061.
Zhu, Q., Ma, D., He, X., 2023. Digital transformation and firms' pollution emissions. Technol. Forecast. Soc. Change 197, 122910.

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

Technology empowerment: Digital transformation and enterprise ESG performance-Evidence from China's manufacturing sector / Wu, X., Li, L., Liu, D., & Li, Q.

PLoS ONE
Volume 19 Issue 4 (2024) 0302029 Pages 1-24
https://doi.org/10.1371/JOURNAL.PONE.0302029
(Database:PLoS ONE)

PLOS ONE

RESEARCH ARTICLE

Technology empowerment: Digital transformation and enterprise ESG performance—Evidence from China's manufacturing sector

Xianyun Wu, Longji Li*, Dekuan Liu, Qian Li

School of Management, Dalian Polytechnic University, Dalian, China

* m1446050591@163.com

OPEN ACCESS

Citation: Wu X, Li L, Liu D, Li Q (2024) Technology empowerment: Digital transformation and enterprise ESG performance—Evidence from China's manufacturing sector. PLoS ONE 19(4): e0302029. https://doi.org/10.1371/journal.pone.0302029

Editor: Jianhua Zhu, Harbin Institute of Technology, CHINA

Received: November 29, 2023

Accepted: March 26, 2024

Published: April 17, 2024

Peer Review History: PLOS recognizes the benefits of transparency in the peer review process; therefore, we enable the publication of all of the content of peer review and author responses alongside final, published articles. The editorial history of this article is available here: https://doi.org/10.1371/journal.pone.0302029

Data Availability Statement: All relevant data are within the manuscript and its Supporting information files.

Abstract

In light of the long-term constraints posed by the "dual carbon" objective, can digital technology emerge as a transformative solution for enterprises to embark on a sustainable development trajectory? The existing body of research has yet to reach a consensus. In order to shed further light on the intricate relationship between digital transformation and ESG performance of enterprises, this study empirically examines the mechanisms and boundaries through which digital transformation influences ESG performance, based on observational data from A-share manufacturing listed companies in Shanghai Stock Exchange and Shenzhen Stock Exchange spanning from 2011 to 2021. The findings demonstrate that digital transformation exerts a significant positive impact on the ESG performance of manufacturing enterprises. Mechanism analysis reveals that the enabling effect of digital transformation primarily enhances company transparency, thereby fostering continuous improvements in ESG performance among manufacturing enterprises. The performance expectation gap will give rise to the phenomenon of "stop-loss in time" and impede the promotional impact of digital transformation. Further investigation into industrial characteristics and industry competition intensity indicates that state-owned enterprises and those operating within highly competitive environments experience more pronounced effects of digital transformation on their ESG performance. This study expands the mechanism and boundary of digital transformation on ESG performance of manufacturing enterprises, and provides a new perspective for manufacturing enterprises to realize the collaborative transformation of digital and green.

Introduction

In 2004, the United Nations introduced the concept of ESG (Environmental, Social, and Governance) in its initiative report titled "Who Cares Wins" [1]. This report provided a new direction for businesses on how to implement sustainable development principles. The concept of ESG originates from ethical investment and responsible investment, rejecting the profit-

Funding: This study is a stage research result of the Liaoning Economic and Social Development Research Project 2024 (Project No. 2024lslybwzzkt-034), the Liaoning Social Science Planning Fund Educational Science Project (Project No. L21AED005), and the Dalian Municipal Science and Technology Bureau's Soft Science Project (Project No. 2023JJ13FG087).

Competing interests: The authors have declared that no competing interests exist.

centric business philosophy, and advocating for enterprises to incorporate environmental, social, and governance factors into their investment decisions while considering economic benefits [2–4]. Currently, there is a global wave of low-carbon transformation underway, leading all countries worldwide to introduce ESG-related policies and regulations. Examples include "the Corporate Sustainability Reporting Directive" and "IFRS S1—General Requirements for Disclosure of Information Sustainability-related Financial Information". In recent years, China's "dual carbon" goal has accelerated the development process of ESG in China [5]. Regulators have issued a series of policies and regulations that gradually require listed companies to disclose ESG-related information; thus making ESG practices an essential aspect for enterprise development. However, challenges such as insufficient willingness and limited participation in specific corporate practices undermine the positive impact of the ESG system on China's economic transformation. Therefore, it is crucial to explore both internal and external factors influencing enterprises' performance in implementing ESG.

At present, China is in a critical period of transformation from a manufacturing power to a manufacturing power [6]. Manufacturing is the backbone of the country's economic development, Facing the medium and long term constraints of "dual carbon" target, whether manufacturing enterprises can explore a sustainable transformation path is related to the long-term healthy development of China's economy [7]. The wave of digital transformation offers a novel perspective for the sustainable development of manufacturing enterprises. Digital transformation is regarded as the extensive application of digital technology across various aspects of enterprise survival, operation, and sales [8]. Previous studies have demonstrated that the adoption of digital technology can enhance the economic efficiency of manufacturing enterprises by improving resource allocation efficiency, innovation capability and Profit level [9–11]. However, can the technological advancements and resource utilization resulting from digital transformation effectively stimulate the inherent capabilities of manufacturing enterprises to enhance their environmental, social, and governance (ESG) performance? Although previous studies have made preliminary explorations into the relationship between digital transformation and ESG performance [12, 13], the mechanism underlying digital transformation remains incompletely elucidated, necessitating further exploration of working conditions. Therefore, this study aims to further expand the existing research on this topic in order to address the limitations identified in previous studies.

Building upon China's "dual carbon" goal policy context, this study delves into the potential of digital transformation in the manufacturing industry to stimulate endogenous drivers for enhancing ESG performance within enterprises. This investigation aims to unveil the underlying mechanisms of digital transformation, augment existing research findings, and hold significant theoretical and practical implications. Consequently, this study adopts corporate transparency as a foundational aspect and integrates the performance expectation gap into its research framework. Empirical analysis is conducted using observation data from A-share manufacturing listed companies on Shanghai and Shenzhen Stock Exchanges spanning from 2011 to 2021 to examine the boundaries and mechanisms through which digital transformation influences corporate ESG performance.

Compared to previous studies, this study innovatively addresses the following aspects: (1) Previous studies did not investigate whether the relationship between digital transformation and ESG performance of enterprises would be influenced during periods of declining enterprise performance. By introducing the situational condition of performance period gap, this study further defines the impact of digital transformation on ESG performance and enriches research on between digital transformation and performance feedback. (2) From a corporate transparency perspective, this paper elucidates the mechanism through which digital

transformation affects ESG performance in manufacturing enterprises, offering new theoretical references and practical insights for sustainable development enabled by digital technology.

Literature review

Since the inception of the ESG concept in 2004, it has garnered significant attention from investors and business managers owing to its unique ability to balance economic benefits with social values. Consequently, academic research in ESG-related fields has witnessed substantial growth [14], with scholars predominantly favoring investigations into the impact of ESG [15]. Mainstream scholars contend that ESG practices can enhance enterprise brand valuation and foster green innovation capabilities, thereby mitigating business risks and ultimately improving enterprise value [16–19]. Scholars have also started examining the influencing factors of enterprise ESG performance. Previous research indicates that factors such as regional digital finance development and environmental protection tax legislation can significantly contribute to enhancing enterprise ESG performance [20, 21]. However, existing studies pay more attention to the external factors that affect the ESG performance of enterprises. In order to fully play the positive role of ESG system in the low-carbon transformation of Chinese enterprises, it is necessary to stimulate the endogenous motivation of enterprises to improve ESG performance.

With the advent of a new wave of scientific and technological revolution, digital technologies such as big data and blockchain offer a novel avenue for facilitating the high-quality development of manufacturing enterprises. Esteemed scholars contend that leveraging digital technology can enhance resource allocation efficiency, innovation capabilities, and customer information advantage, thereby fostering the high-quality development of manufacturing enterprises [9, 11, 22]. In addition to researching the economic benefits of digital transformation, scholars have also begun to focus on its non-economic value. Specifically, they argue that the application of digital technology can facilitate green innovation in enterprises and lead to a reduction in carbon emissions [23, 24]. With the advancement of research, scholars have started to establish a connection between digital transformation and enterprise ESG performance, leading to two main categories in existing research findings: the "empowerment" effect and the “too much is not good” effect. The "empowerment" effect is specifically reflected in the fact that digital transformation can improve the ESG performance of enterprises by reducing agency costs and improving corporate reputation and dynamic capabilities [25, 26]. The “too much is not good” effect is specifically reflected in the fact that a high level of digitalization may weaken the ability and motivation of enterprises to carry out ESG practices. Asymmetric digital transformation and organizational transformation process make it difficult to play the enabling effect of digital technology, which may lead to "information overload" and reduce the information processing ability of enterprises. In addition, a large amount of capital investment in the materialization of digital technology may induce "crowding-out effect" and delay the process of enterprise green transformation [27–29].

The concept of transparency emerged from research in the field of information disclosure [30]. As research on information disclosure expanded, scholars introduced the notion of "company transparency," which refers to providing specific company information to external stakeholders [31]. With the deepening of research, Chinese scholars have refined the concept of company transparency, that is, the higher the transparency of a company, the wider and deeper the scope and level of external investors’ access to internal information of a company, and the stronger the liquidity of information [32]. The application of digital technology offers a novel perspective for researching company transparency. However, upon reviewing existing literature, it is evident that scholars tend to associate digital transformation with analysts’

forecasts and corporate governance [33, 34]. These studies suggest that while there may be a close relationship between digital transformation and company transparency, further exploration is necessary.

The aforementioned analysis reveals that despite the existence of relevant studies demonstrating the correlation between digital transformation and ESG performance, certain limitations persist, primarily in the following aspects: (1) the existing research mainly discusses the influence between the two from the perspective of internal control, green innovation and information disclosure quality, and its internal influence mechanism needs to be further expanded. (2) The measurement approach for assessing the extent of digital transformation within enterprises remains singular, making it challenging to mitigate potential deviations resulting from false corporate disclosures. (3) What are the requisite conditions for effectively harnessing the impact of digital transformation empowerment?

Building upon this premise, the present study adopts corporate transparency as a focal point, integrates the performance expectation gap into the research framework, and explores whether digital transformation can incentivize enterprises to engage in ESG practices. The present study contributes to the existing literature on the mechanisms of digital transformation, elucidates the impact of digital transformation in situations characterized by performance expectation gaps, and addresses a research gap in this domain.

Theoretical analysis and research hypotheses

Digital transformation and enterprise ESG performance

The process of digital transformation involves a comprehensive reshaping of the traditional business model, governance mechanism, and organizational structure of an enterprise by integrating artificial intelligence, big data, blockchain, and other digital technologies into various aspects such as production, sales, and transportation [35]. Existing literature primarily focuses on the economic performance of digital transformation and its individual non-economic aspects [36, 37], while only recently has there been exploration of the relationship between digital transformation and integrated environmental, social, and corporate governance (ESG) performance [38]. The present study posits that the digital transformation is poised to enhance the ESG performance of manufacturing enterprises through bolstering their capabilities and fostering intrinsic motivation.

From the perspective of behavioral outcomes, digital transformation improves the comprehensive strength of enterprises to carry out ESG practices. First of all, the rapid development of digital finance has broadened the financing channels of manufacturing enterprises [39]. It has also improved the matching efficiency of both parties of credit, effectively reduced the probability of resource mismatch and credit default, solved the financial discrimination problem of "Large enterprises are allocated a substantial loan quota, whereas small enterprises receive a limited loan quota" [40]. To a certain extent, and reduced the dependence of manufacturing enterprises on "resource-based" shareholders and large customers due to financing constraints [9, 41]. This has greatly improved the discourse power of environment-sensitive executives and improved the intellectual support for enterprises' ESG practices. In addition, the application of digital technology can refine the production and research and development process of products, reduce the probability of research and development manipulation [42], and provide conditions for enterprises to give full play to green innovation resources. This undoubtedly helps improve the green innovation ability of manufacturing enterprises, and then promote the quality and efficiency of green patents of enterprises, and provide technical support for ESG practices of manufacturing enterprises [43, 44]. The application of digital platforms and big data technology has broken the barriers to information acquisition of manufacturing

enterprises, narrowed the distance between enterprises and customers, and enabled enterprises to accurately grasp the differentiated needs of customers and improve the competitiveness of enterprises' products [45]. At the same time, the application of digital technology improves the ability of enterprises to integrate internal resources and acquire external resources, blurs the business boundary of enterprises, transforms the single chain management structure of enterprises into a diversified network management structure, improves the sustainable competitiveness of enterprises, and provides economic possibilities for enterprises' ESG practices [46, 47]. Digital transformation consolidates the overall strength of manufacturing enterprises through the three aspects of "talent-technology-economy", and provides realistic conditions for manufacturing enterprises to improve their ESG performance.

From the perspective of behavioral motivation, digital transformation improves the willingness of manufacturing enterprises to carry out ESG practices. On the one hand, the application of digital technology breaks the constraints of time and space of traditional information exchange, connects stakeholders together through digital platforms, and improves the frequency of internal and external information interaction of enterprises [48]. Active disclosure of enterprises is no longer the only channel for stakeholders to obtain enterprise information, narrowing the "information fault line" between enterprises and stakeholders. It provides an opportunity for external investors to realize the identity transformation from "free rider" to "administrator" in corporate governance [49]. In addition, the application of big data technology makes any behavior of enterprises to follow, and R&D manipulation, false information disclosure and other violations are contained, which promotes the improvement of the quality of information disclosed externally and strengthens the internal motivation of enterprises to improve ESG performance [50, 51]. On the other hand, digital transformation, as a positive signal of change, will attract the attention of external market players such as the government, analysts and media [52]. When enterprises are placed under the "spotlight", their business behaviors will be amplified infinitely, resulting in a sharp increase in the pressure of external attention, which is both an opportunity and a challenge for enterprises. Positive ESG practices will be spread rapidly by the media and analysts, improve the corporate image, and gradually increase its recognition among the government and consumers, It improves the advantages of enterprises in obtaining political resources and consumer trust [4, 53]. However, when market observers dramatize poor market performance, the negative impact of enterprises rises geometrically and may be "labeled" as a shackles that restrict the development of enterprises. Therefore, in this case, the willingness of enterprises to ESG practices will increase significantly. Based on the above analysis, this paper proposes the following hypothesis:

H1: Digital transformation will promote the improvement of ESG performance of manufacturing enterprises.

Digital transformation, company transparency and corporate ESG performance

This study posits that digital transformation primarily enhances company transparency, thereby continuously improving the ESG performance of manufacturing enterprises. On the one hand, it mitigates the issue of information asymmetry and facilitates external shareholders' participation in corporate governance through its traceability, immutability, and timeliness [54, 55]. Furthermore, it curbs managers from exploiting information asymmetry to manipulate environmental and social responsibility for profit-driven stock price escalation while enhancing internal governance transparency to improve non-financial information disclosure quality [50].

On the other hand, the application of digital technology will improve the circulation frequency of internal and external information of enterprises. The existence of asymmetric information between enterprises and stakeholders also gives rise to stakeholders' distrust and even aversion to enterprises with high information acquisition costs and low information disclosure quality, which reduces the market attention of such enterprises [56, 57]. In order to obtain more external resources to make up for the loss of sustainable strategy, enterprises are more willing to take advantage of the convenience of digital technology and the characteristics of low information disclosure cost to actively promote the positive achievements of corporate environment and social responsibility, and shift from passively improving the quality of information disclosure to actively improving it [58]. At the same time, the diversified information sharing channels derived from digital transformation make it easier for enterprises to identify false or low-quality information disclosure behaviors, which improves the quantity, quality and depth of enterprise information obtained by stakeholders [34]. External analysts, media and other market intermediaries can make more objective and fair market evaluations [59, 60]. It helps enterprises to improve their green and environmental reputation among consumers and governments, and encourages enterprises to carry out ESG practices with confidence. To sum up, company transparency is the channel through which digital transformation can improve the ESG performance of manufacturing enterprises. Based on this, this paper puts forward the following hypothesis:

H2: The digital transformation facilitates the enhancement of ESG performance through augmenting company transparency.

Digital transformation, performance expectation gap and enterprise ESG performance

The performance expectation gap refers to the difference between an enterprise's actual performance and its expected performance [61]. According to the theory of corporate behavior, the performance expectation gap is an important reference for managers to formulate corporate future strategies [62]. Among them, the expected performance represents the minimum level of output anticipated by management, and whether the actual performance aligns with management's expectations will significantly influence subsequent strategic planning decisions.

Currently, there is no consensus among academia regarding the potential impact of the performance expectation gap. On one hand, when managers observe that actual performance falls short of expectations, it may lead to a "make or break" situation. According to the Resource Based View, an enterprise's competitive advantage relies on its unique resources [63]. When an enterprise fails to meet expectations in terms of performance, its competitive advantage begins to decline. As a crucial component of enterprises' sustainable development strategy, ESG practices may temporarily compromise their operational performance due to high investment costs and extended return periods. However, forward-thinking managers recognize that ESG practices hold significant appeal in terms of corporate reputation, political resources, and consumer recognition [64, 65]. In order to establish sustainable competitive advantages for enterprises, managers are more inclined to forego short-term interests and pursue long-term developmental benefits. At the same time, the talent reserve and organizational structure of enterprises need to be timely matched with the process of digital transformation to play an enabling role [66]. However, because the enterprise performance is not up to expectations, the capital market will cause doubts about the operating conditions of enterprises, making it more difficult for enterprises to obtain resources from the outside. In the face of "internal and external challenges", managers will use limited organizational resources to make up for the gap

between the application of digital technology and the organizational governance system, give full play to the enabling role of digital technology, and improve the level of digital governance of enterprises [30].

However, the performance expectation gap can also result in the occurrence of a phenomenon known as "stop-loss in time"effect. The decline in business performance leads to internal anxiety among management and doubts from external investors, which subsequently affects managers' judgment and execution capabilities [67, 68]. Since both digital transformation and ESG practices require significant resource investments, companies that are struggling financially may find it challenging to sustain these high-cost reform solely with their own resources. As a result, the enterprise's transformation process slows down and ESG practices are reduced or even suspended. Additionally, according to threat-rigidity theory [69], when faced with continuous expectation gaps, enterprises tend to prioritize survival over thriving. Consequently, decision-making becomes more conservative as organizations immersed in pessimism experience sluggish information processing and acceptance capacities [70, 71]. In such circumstances, limited market information becomes the basis for strategic decisions made by management. Choosing riskier reforms or investments during this period would expose enterprises to devastating strategic risks that not only fail to alleviate their predicament but also deplete their resources further. Furthermore, lack of resources exacerbates the difficulty of implementing ESG practices at this time. Even if enterprise management is willing to exhaust all options in pursuing original strategic goals, they remain powerless due to resource constraints [72]. Based on the aforementioned analysis, this paper proposes the following hypothesis:

H3a: Performance expectation gap has a positive moderating effect on the relationship between digital transformation and ESG performance of manufacturing enterprises.

H3b: Performance expectation gap has a negative moderating effect on the relationship between digital transformation and ESG performance of manufacturing enterprises.

Research design

Research sample and data sources

This study utilizes a sample of manufacturing enterprises listed on the A-shares of the Shanghai Stock Exchange and Shenzhen Stock Exchange, covering the period from 2011 to 2021. To ensure consistency with previous studies, the initial sample is refined through the following steps: ① Exclusion of samples classified as ST and *ST in the current year; ② Elimination of samples with missing data on core variables; ③ Exclusion of samples with less than three consecutive years of data; ④ To mitigate the impact of extreme values, all continuous variables are winsorized at the 1% and 99% levels. Consequently, a total of 6044 observation samples are obtained.

The original financial data utilized in this study, as well as the robustness test concerning the extent of digital transformation, were sourced exclusively from the China Stock Market & Accounting Research Database(CSMAR). Furthermore, the word frequency analysis pertaining to digital transformation primarily relied upon annual reports disclosed by listed companies through Juchao Consulting Network, Shenzhen Stock Exchange, and Shanghai Stock Exchange. The data analysis was conducted using Python and Stata version 16.0.

Measurement of variables

Dependent variable. ESG performance (ESG). Currently, there exist notable disparities in the measurement of ESG ratings domestically and internationally, with influential rating

systems including MSCI, Bloomberg, Shangdao Ronglv, Huazheng, among others. The ESG rating score provided by Bloomberg was chosen as the proxy index for the core explanatory variable, based on the sample characteristics outlined in this paper.

Independent variables. Digital transformation (Digital). The measurement method employed in this study for assessing the extent of digital transformation primarily draws upon existing research [73], utilizing the construction of digital dictionaries and text analysis to determine the degree of digital transformation within enterprises. In contrast to previous approaches that relied on intangible assets related to digital technology, questionnaire surveys, and ERP system applications [74–76], this measurement method establishes a relatively objective and comprehensive digital term dictionary based on semantic expressions found in national policies pertaining to the digital economy. Subsequently, it employs text analysis techniques to construct a more holistic indicator reflecting the level of digitization among Chinese enterprises. Meanwhile, considering the "right-skewed" feature word frequency data and avoiding the impact of enterprises not carrying out digital transformation, the total word frequency is added by 1 and then logarithmized.

Mediating variables. Company transparency (Tra). Drawing upon the methodologies proposed by LANG et al. (2012) and Xiang et al. (2020) [77, 78], this study adopts four comprehensive indicators to assess company transparency: earnings quality, audit company quality, information disclosure rating, and analyst attention.

The first indicator is earnings quality, and this paper chooses DD model to measure corporate earnings quality:

$$TCA_{i,t} = a_1 + a_2 CFO_{i,t-1} + a_3 CFO_{i,t} + a_4 CFO_{i,t+1} + a_5 \Delta REV_{i,t} + a_6 PPE_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where TCA represents total current accruals, defined as operating profit minus operating cash flow plus depreciation and amortization expense; CFO denotes operating cash flow; ΔREV signifies change in operating income; PPE refers to the value of fixed assets at year-end. All variables are normalized by dividing them with annual average total assets to mitigate the impact of firm size. The residual value was derived by conducting sub-annual regression analysis. Subsequently, the standard deviation is computed based on the five-year residuals from year t and its preceding four years, thereby obtaining the enterprise's earnings quality index for year t. Additionally, considering comparability with other indicators, the earnings quality index is multiplied by -1.

The second indicator is the quality of the audit company, which is measured by whether the listed company employs the auditors of the Big Four domestic accounting firms to conduct audit.

The third indicator is the information disclosure rating, which primarily pertains to the disclosure ratings of the Shanghai and Shenzhen Stock Exchanges. In this context, A denotes excellent, B represents good, C signifies pass, and D indicates fail. This study assigns a numerical value to each rating in descending order: A = 4 and D = 1. Consequently, a higher score corresponds to a superior quality of information disclosure.

The fourth indicator is analyst attention, referring to the existing research, how many analysts (teams) have followed the company within a year. in order to avoid the impact of 0 value, it is added by 1 to take the logarithm.

Based on the aforementioned four indicators, this study constructs a comprehensive indicator to assess company transparency (Tra) by adopting the approach proposed by Xin Qingquan et al. (2014) [79]. This is accomplished as follows: computing the average of sample percentiles for each variable. Considering the delayed initiation of SSE's information disclosure rating and missing data in certain years, the company transparency index is determined

as the average of three remaining index sample percentiles. A higher Tra index indicates greater company transparency.

Moderating variables. Performance expectation gap, referring to Qiu et al. (2022) [80], is measured by the difference between actual business performance and expected business performance. The specific calculation formula is as follows:

$$HA_{i,t} = \alpha HA_{i,t-1} + (1-\alpha)P_{i,t-1} \tag{2}$$

$$\mathrm{A_{i,t}} = \beta HA_{i,t} + (1-\beta)\,\mathrm{SA_{i,t}} \tag{3}$$

The enterprise's historical expected performance ($HA_{i,t}$) is determined by a weighted combination of its historical expected performance in period t − 1 and the actual operating performance in period t − 1, where α represents the weight assigned to this combination and takes a value between (0,1). Following the practices of Cao Yanan (2023) and Chen(2008) [81, 82], we set α as 0.4 for calculating historical expected performance. The comprehensive expected performance is calculated by weighting the historical expected performance of the enterprise and the industry's expected performance. SA represents the enterprise's expected performance in relation to the industry, which is determined as the mean value of ROA for all enterprises in the industry except Company i. The β weight setting follows Guo Rong et al. (2019) and Rudy (2016) [83, 84]. Initially set at 0.5, β increases by 0.1 incrementally each time. The weight is determined based on model fitting, with results indicating that the best fit occurs when β = 0.5; therefore, this paper selects β = 0.5 to weigh the comprehensive expected performance.

When the actual performance falls below the expected performance (P-A<0), a negative gap is observed between the actual and expected performances. Conversely, when the actual performance exceeds the expected performance, a positive gap in expected performance is evident. To further analyze the impact of digital transformation on ESG performance of manufacturing enterprises considering this expectation-performance gap, we introduce a dummy variable L1 in this study. The value of L1 is set to 1 when the expectation-performance gap is < 0 and 0 when it is ≥ 0. The constructed variable $L1^{*}gap_{i,t}$ represents instances where actual performance lags behind expectations, with smaller values indicating larger gaps. Additionally, for ease of comprehension, we multiply $L1^{*}gap_{i,t}$ by -1 to obtain an indicator for the expected performance gap ($Ngap_{i,t}$). Higher values indicate greater disparities between actual and anticipated performances.

Control variables. Drawing on the existing literature, This paper adds enterprise Size (Size), asset-liability ratio (Lev), growth rate of operating income (Grow), Cashflow ratio (Cashflow), proportion of independent directors (Indira), years of company establishment (Listage) and shareholding ratio of the largest shareholder (Top1) as control variables in the regression model. The detailed variable definition and calculation method are shown in Table 1.

Model setting

In terms of setting the benchmark model, we adopt a methodology commonly employed in previous studies [19, 85] and construct the following model to empirically test H1 as proposed in this study:

$$ESG_{\mathrm{i,t}} = \beta_0 + \beta_1 Digital_{i,t} + \sum control_{i,t} + Year + Industry + \varepsilon_{i,t} \tag{4}$$

Where i represents the enterprise and t represents the year. ESGi, t represents the ESG rating index of enterprise i in year t, Digitali, t represents the degree of digital transformation at the

Table 1. Variable definitions.

Variable names	Symbols	Variable explanation
ESG performance	ESG	Bloomberg ESG Ratings Index
Digital transformation	Digital	The logarithm of digital transformation word frequency +1 in the annual report
Company transparency	Tra	The percentages of earnings quality, analyst attention, audit firm quality, and disclosure rating were averaged
Performance expectation gap	Ngap	The difference between actual and expected performance of a firm $\geq$0 is assigned a value of 0, and $<$ 0 is multiplied by -1
Enterprise size	Size	Take the logarithm of the total assets of the business
Asset-liability ratio	Lev	Total year-end responsible/total year-end assets
Growth rate of operating income	Grow	Current operating income/previous operating income
Cash flow ratio	Cashflow	Net cash flow from operating activities/total assets
Percentage of independent directors	Indira	Number of independent directors/total number of board members
Number of years since the establishment of the company	Listage	The logarithm of the number of years since the establishment of the enterprise at the end of the current year +1.
Shareholding ratio of the largest shareholder	Top1	Number of shares held by the largest shareholder/total share capital at the end of the year

https://doi.org/10.1371/journal.pone.0302029.t001

enterprise-year level, and Σcontroli,t represents all the control variables in this paper. In addition to the above control variables, this paper controls the industry and time dummy variables in the model.

Empirical results analysis

Descriptive statistics and correlation analysis

The descriptive statistical results of the main variables in this paper are presented in Table 2. Among these, the mean value of ESG performance for manufacturing enterprises is 28.199, indicating a moderate level of environmental, social, and governance performance among the sample manufacturing enterprises that are implementing the "dual carbon" target. there is still significant room for improvement. Furthermore, the minimum value observed among the sample enterprises is 11.488, while the maximum value is 56.121, suggesting a substantial disparity in ESG practice input between leaders and followers. The digital variable exhibits a maximum value of 6.544 and a minimum value of 1.386, highlighting considerable variation in digital transformation degrees across sample enterprises. The results of other control variables are basically similar to those of existing studies [28, 29].

Table 2. Descriptive statistics.

Variables	N	Mean	Min	Max	Sd	P50
ESG	6044	28.199	11.488	56.121	8.988	25.923
Digital	6044	3.646	1.386	6.544	1.108	3.583
Size	6044	23.02	20.42	26.16	1.212	22.923
Lev	6044	0.449	0.0569	0.866	0.192	0.458
Grow	6044	0.170	0.414	2.042	0.331	0.1197
Cashflow	6044	0.0644	0.108	0.255	0.0676	0.0585
Indire	6044	0.375	0.333	0.571	0.0561	0.333
Listage	6044	2.912	1.792	3.497	0.323	2.944
Top1	6044	0.361	0.0890	0.789	0.154	0.343

https://doi.org/10.1371/journal.pone.0302029.t002

Additionally, this study conducts a Pearson correlation test on the main variables, and the results demonstrate a significantly positive correlation coefficient between digital transformation and enterprise ESG performance, thereby providing preliminary support for hypothesis 1 proposed in this paper. Furthermore, the selected control variables exhibit a statistically significant correlation with enterprise ESG performance, indicating the reasonable selection of control variables in this study. The average VIF of each variable in the model regression is 1.18, indicating that there is no serious multicollinearity problem in the model.

Benchmark regression results

The regression results in Table 3 demonstrate the impact of digital transformation on enterprise ESG performance. In Column (1), only industry and year dummy variables are controlled, while other control variables selected in this study are not included. The regression analysis reveals a significantly positive coefficient of 0.304 for Digital at the 1% level, providing preliminary evidence for a positive correlation between digital transformation and ESG

Table 3. Regression results.

VARIABLES	ESG	ESG	Mechanism test		Moderating effect
			Tra	ESG	ESG
Digital	0.304***	0.278***	0.009***	0.203**	0.327***
	(0.112)	(0.097)	(0.002)	(0.094)	(0.101)
Tra				7.982***	
				(0.558)	
Ngap					4.997
					(5.326)
Digital*Ngap					-3.000**
					(1.281)
Size		2.422***	0.079***	1.790***	2.376***
		(0.092)	(0.002)	(0.096)	(0.094)
Lev		-2.887***	-0.239***	-0.979*	-2.421***
		(0.487)	(0.012)	(0.505)	(0.515)
Grow		-0.430*	0.007	-0.489**	-0.576**
		(0.248)	(0.007)	(0.242)	(0.253)
Cashflow		3.137***	0.428***	-0.280	2.628**
		(1.183)	(0.030)	(1.183)	(1.215)
Indire		-1.423	0.004	-1.452	-1.256
		(1.432)	(0.037)	(1.405)	(1.432)
Listage		1.195***	-0.052***	1.607***	1.183***
		(0.289)	(0.008)	(0.285)	(0.288)
Top1		2.389***	0.056***	1.944***	2.252***
		(0.587)	(0.014)	(0.565)	(0.596)
Constant	21.202***	-34.529***	-1.411***	-23.265***	-33.847***
	(1.874)	(3.653)	(0.074)	(4.039)	(3.714)
Observations	6,044	6,044	6,044	6,044	6,044
R-squared	0.498	0.575	0.311	0.591	0.576
Industry	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES

Note: Heteroscedasticity robust standard errors in parentheses;
***, ** and * indicate significance at the level of 1%, 5% and 10%.

https://doi.org/10.1371/journal.pone.0302029.t003

performance. Building upon these findings, Column (2) incorporates additional control variables identified in this research, resulting in a slight decrease in the coefficient of Digital; however, it remains statistically significant at the 1% level. These results indicate that even after accounting for industry-specific factors, temporal effects, and firm characteristics, digital transformation continues to play a significant role in enhancing enterprise ESG performance, thereby confirming Hypothesis 1 posited in this paper. The aforementioned findings demonstrate that the benefits derived from digital transformation, including technological advancements, resource optimization, and enhanced management capabilities, can serve as an endogenous driving force for enterprises to engage in ESG practices. These advantages not only provide the necessary material foundation but also offer technical support for businesses to effectively implement ESG initiatives.

Moreover, considering the coefficients of control variables, it can be observed that well-established large enterprises with ample cash flow and high ownership concentration exhibit a greater inclination and capability to leverage the benefits derived from digital transformation in order to enhance their ESG performance. Conversely, enterprises with limited revenue capacity and a high debt ratio display a higher degree of reluctance towards allocating scarce resources for ESG practices due to prevailing survival pressures. The findings of this study are in line with the existing body of research [86, 87].

Robustness and endogeneity test

Change the measurement method of variables. Firstly, in order to enhance stock prices and attract the attention of uninformed investors, some enterprises tend to embellish facts in their annual reports, extensively publicize their digital transformation blueprint through verbose narratives, and captivate investors with enticing stories and aspirations. Consequently, relying solely on keyword frequency analysis within the annual report becomes inadequate for accurately assessing the extent of digital transformation within these enterprises [88]. Therefore, this study adopts the Digital Transformation Index from CSMAR as a substitute variable that encompasses various dimensions including word frequency related to enterprise transformation, investment in digital resources, formulation of digital strategies, alignment of organizational structure with digital transformation goals, accomplishments in digital transformation endeavors, and application of digital technologies. This comprehensive measurement system aims to rectify the limitations associated with single-indicator assessments. Following a baseline regression approach, we incorporate the Digital Transformation Index (Digital_index) into our model for re-regression analysis. The results are presented as M1 in Table 4 where it is evident that the regression coefficient for Digital_index exhibits significant positive association at a 1% level of significance–consistent with previous findings.

Moreover, this study employs the ESG rating provided by huazheng as an alternative index (ESG_H). Specifically, a value of 9 is assigned to AAA and subsequently decreases in descending order. A higher score indicates better ESG performance of the company. To minimize result deviation caused by different rating systems, the mean value of quarterly ratings is selected as a substitute variable in this paper. The aforementioned empirical method is employed to test the robustness of the baseline regression results, which are presented in M2 within Table 4. Notably, the Digital regression coefficient exhibits significant positive association at a 1% level, thereby further confirming H1 posited in this study.

Extend the observation period. Considering that it takes a certain amount of time for the technological, management and resource advantages brought by digital transformation to affect the ESG practice activities of enterprises, we draw on the practice of existing research to extend the observation period and delay ESG by one, two and three periods. The results are

Table 4. Robustness test.

VARIABLES	M1 ESG	M2 ESG_H	M3 ESG(-1)	M4 ESG(-2)	M5 ESG(-3)	M6 ESG	M7 ESG
Digital		0.080***	0.289***	0.254**	0.209*	0.542***	0.388***
		(0.016)	(0.105)	(0.110)	(0.116)	(0.148)	(0.131)
Digital_index	0.079***						
	(0.011)						
Size	2.316***	0.249***	2.242***	2.063***	1.912***	1.895***	2.331***
	(0.092)	(0.013)	(0.100)	(0.105)	(0.109)	(0.189)	(0.129)
Lev	-2.882***	-1.117***	-2.516***	-2.023***	-1.765***	-3.331***	-2.625***
	(0.486)	(0.088)	(0.514)	(0.536)	(0.559)	(0.718)	(0.690)
Grow	-0.389	-0.178***	-0.458*	-0.406	-0.197	-0.336*	-0.540*
	(0.245)	(0.040)	(0.274)	(0.291)	(0.316)	(0.192)	(0.326)
Cashflow	3.134***	0.659***	3.446***	3.472***	2.105	1.508	4.256***
	(1.180)	(0.205)	(1.233)	(1.308)	(1.368)	(1.132)	(1.605)
Indire	-1.732	1.403***	-2.190	-2.368	-3.342**	0.953	-1.099
	(1.423)	(0.232)	(1.501)	(1.570)	(1.676)	(1.765)	(1.992)
Listage	1.260***	0.065	1.385***	1.602***	1.833***	2.114	1.079***
	(0.282)	(0.048)	(0.308)	(0.334)	(0.371)	(1.404)	(0.409)
Top1	2.638***	0.121	2.579***	2.596***	2.790***	1.862	2.069**
	(0.586)	(0.092)	(0.625)	(0.668)	(0.722)	(1.144)	(0.843)
Constant	-33.625***	-2.710*	-31.622***	-18.708***	-27.416***	-23.092***	-30.249***
	(3.498)	(1.435)	(2.120)	(2.419)	(3.016)	(5.589)	(2.969)
Observations	6,044	6,044	5,314	4,654	3,993	5,962	3,182
R-squared	0.578	0.135	0.528	0.509	0.484	0.848	0.551
Industry	YES	YES	YES	YES	YES	NO	YES
year	YES	YES	YES	YES	YES	NO	YES
High latitude fixed effects	NO	NO	NO	NO	NO	YES	NO

Note:

***, ** and * indicate significance at the 1%, 5% and 10% levels.

https://doi.org/10.1371/journal.pone.0302029.t004

shown in M3, M4 and M5 in Table 4. The regression results are significantly positive at the levels of 1%, 5% and 10% respectively, indicating that H1 in this paper is still robust after the observation period is extended.

Fixed effect model. Considering the possible estimation errors caused by unobservable factors that do not change with individuals, this study incorporates individual fixed effects and industry-year joint fixed effects into the model to enhance its robustness. Moreover, given that the fixed effect of high latitude already encompasses the impact of industry and year, dummy variables for industry and year are not included in the regression analysis. The results, presented in M6 of Table 4, exhibit a significantly positive association at a 1% significance level.

PSM. In order to address the endogeneity problem arising from potential sample self-selection, this study employs propensity score matching (PSM) for testing purposes. Firstly, enterprises are categorized based on the median degree of digital transformation. Subsequently, all control variables selected in this study are utilized as covariates to pair the samples using a 1:1 nearest neighbor matching method. To ensure the validity of the matching results, a balance test is conducted on the matched outcomes, with all normalized bias absolute values being less than 10%. This indicates that the matching results largely meet the requirements.

Finally, after matching, regression analysis is performed on 3182 samples and presented in M7 of Table 4. The regression coefficient of Digital remains significantly positive at a level of significance of 1%, indicating that the conclusion remains robust after addressing sample self-selection issues.

Tool variable method. Given the potential reverse causality between digital transformation and ESG performance of enterprises, wherein digital transformation can foster improvements in ESG performance while enterprises exhibiting good ESG performance may also demonstrate a greater inclination towards undertaking digital transformation, this study employs the instrumental variable method to mitigate endogeneity issues arising from reverse causality. Referring to the existing research [89, 90], we select regional communication level as the instrumental variable in this study. This choice is motivated by the influence of digital infrastructure development and communication level in the city where enterprises are located on their digital transformation process. A higher communication level enhances support for information, technology, consumer demand, and other aspects crucial for enterprises, thereby accelerating their digital transformation process. Hence, this variable satisfies the correlation condition of instrumental variables. Additionally, regional communication level primarily reflects micro-level application of information technology and does not directly impact enterprise ESG performance, meeting the exogeneity condition. Specifically, we employ mobile phone penetration rate (per 100 people) in the province where an enterprise operates as a proxy for regional communication level. As shown in Table 5, two-stage regression results using instrumental variables exhibit significantly positive effects consistent with previous findings. The Kleibergen-Paap rk LM statistic is significant at the level of 1%, which passes the underidentification test. The Kleibergen-Paap rk Wald F statistic is 53.288, which is larger than the 16.38 critical value of F test at 10% level in weak instrumental variable identification, and passes the weak instrumental variable test, indicating that the selection of instrumental variables in this paper is reasonable to some extent. To sum up, after considering the endogeneity problem, digital transformation can still promote the improvement of ESG performance.

Further analysis

Mechanism test. In order to investigate the mechanism underlying company transparency in digital transformation and its impact on corporate ESG performance, we construct models (5) and (6) based on Model (4), following the approach of Wen and Ye (2014) [91], to empirically test the mediating effect as outlined below:

$$Tra_{i,t} = \gamma_0 + \gamma_1 Digital_{i,t} + \sum control_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (5)$$

$$ESG_{i,t} = \xi_0 + \xi_1 Digital_{i,t} + \xi_2 Tra_{i,t} + \sum control_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (6)$$

Columns (4) and (5) of Table 3 show the test results of the action mechanism of digital transformation affecting enterprise ESG performance. Among them, the coefficient before digital transformation in Column (4) is significantly positive, indicating that technological advantages and organizational structure changes brought by digital transformation will significantly improve company transparency. Column (5) is the estimated result of Model 3. The results show that the coefficient of company transparency (Tra) is significantly positive, indicating that company transparency plays an intermediary role in the process of digital transformation affecting the ESG performance of enterprises. The research findings demonstrate that the utilization of digital technology enhances corporate transparency, thereby augmenting the

Table 5. Tool variable method.

VARIABLES	Digital	ESG
IV	0.003***	
	(0.000)	
Digital		4.848***
		(1.218)
Size	0.049***	2.177***
	(0.013)	(0.129)
Lev	-0.354***	-1.091
	(0.072)	(0.754)
Grow	0.153***	-1.122***
	(0.035)	(0.347)
Cashflow	-0.586***	5.938***
	(0.160)	(1.547)
Indire	0.471**	-3.466*
	(0.192)	(1.774)
Listage	-0.349***	2.924***
	(0.039)	(0.576)
Top1	-0.128*	2.790***
	(0.075)	(0.691)
Constant	2.780***	-48.852***
	(0.656)	(7.390)
Observations	6,044	6,044
R-squared	0.483	0.409
Industry	YES	YES
Year	YES	YES

Note:
***, ** and * indicate significance at the 1%, 5% and 10% levels.

https://doi.org/10.1371/journal.pone.0302029.t005

frequency of interaction between enterprises and external investors as well as improving internal supervision efficiency. Consequently, this engenders both internal and external governance effects, ultimately enhancing corporate ESG performance.

At the same time, Sobel method is used to test the mediating effect, in which the z-value of Sobel test is 3.96, $p<0.01$, which further verfies H2 hypothesis in this paper.

Moderating effect test. In order to deeply reveal what changes will occur in the effect of Digital transformation on ESG performance when there is performance expectation gap in manufacturing enterprises, this paper constructs the interaction between performance expectation gap and digital transformation (Digital*Ngap), referring to the existing literature [, On the basis of Model (4), construct (7) to test the moderating effect of performance expectation gap:

$$ESG_{i,t} = \mu_0 + \mu_1 Digital_{i,t} + \mu_2 Ngap_{i,t} + \mu_3 Digital_{i,t} \times Ngap_{i,t} + \mu_4 \sum control_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (7)$$

The empirical results of the moderating effect are presented in (6) of Table 3, revealing a significantly negative regression coefficient (-2.787) for the interaction term (Digital*Ngap) at a 5% significance level. This indicates that the performance expectation gap does not trigger a "make or break" effect on enterprises. On the contrary, due to the presence of this gap, internal

survival pressures and external investor doubts lead to reduced environmental protection investments and fulfillment of social responsibility by enterprise management.

Furthermore, when actual performance falls short of expectations, disputes may arise within internal management regarding whether to continue with strategic reforms. If there is an entrenched resistance within management circles, managers from different positions face significant threats. In such circumstances, persisting with implementing reform strategies escalates strategic risks and potentially triggers a "stop-loss in time" effect. Additionally, based on limited attention hypothesis, conflicts over internal control rights further divert managerial focus away from utilizing digital transformation's technical advantages to enhance internal governance efficiency–resulting in declining corporate environmental, social, and governance performance levels. The hypothesis H3b in this paper is thus confirmed, indicating that the performance expectation gap plays a negative moderating role in the relationship between digital transformation and corporate ESG realization.

Heterogeneity analysis

Nature of property rights. State-owned enterprises possess inherent advantages in resource acquisition, market competition, innovation strength, strategic reform risk, and other aspects due to their unique institutional advantages [92]. The process of digital transformation requires significant capital investment, the recruitment of digital technology talents, and the implementation of digital technologies. State-owned enterprises enjoy strong credit endorsement which makes financial institutions and external investors prefer supporting them financially [93]. This effectively mitigates the crowding-out effect on innovation behavior, environment, and society caused by dedicated capital investment during enterprise reform.

Moreover, state-owned enterprises' excellent corporate image attracts more talent compared to non-state-owned enterprises, thereby addressing the personnel allocation-technical resources mismatch during digital transformation that hinders leveraging the enabling effect of digital technology. Therefore, as key players in China's ESG system and national strategic policy implementation initiatives, state-owned enterprises are more proactive in improving their ESG performance. By contrast, non-state-owned enterprises prioritize seeking economic benefits through leveraging competitive advantages offered by digital technology amidst fierce market competition and environmental uncertainty. Non-economic benefits are often not their core objective. Therefore, based on this analysis,the promotion effect of digital transformation on ESG performance is significantly greater for state-owned enterprises than for non-state-owned ones.

This study categorizes enterprises into state-owned and non-state-owned based on their ownership nature. Columns (1) and (2) of Table 6 present the regression results for different ownership types. The findings indicate that, in comparison to non-state-owned enterprises, state-owned enterprises exhibit a higher regression coefficient, suggesting a more significant role of digital transformation in enabling state-owned enterprises.

Intensity of industry competition. The level of market competition within an industry significantly influences the strategic formulation of enterprises [94]. In highly competitive industries, products exhibit high homogeneity and strong substitutability. When transformative breakthroughs in product innovation are unattainable, enterprises are inclined to leverage digital technology's information resources, organizational changes, business models, and other competitive advantages to enhance non-financial performance in environmental sustainability, social responsibility, and corporate governance. This approach aims to bolster enterprise reputation, cultivate distinctive soft power capabilities, and facilitate differentiation amidst intense market competition [16, 64].

Table 6. Heterogeneity test.

VARIABLES	State-owned enterprises	Non-state-owned enterprises	High competition	Low competition
	ESG	ESG	ESG	ESG
Digital	0.305**	0.246*	0.419***	0.078
	(0.139)	(0.137)	(0.133)	(0.145)
Size	2.478***	2.419***	2.118***	2.675***
	(0.132)	(0.142)	(0.141)	(0.125)
Lev	-5.580***	0.069	-3.768***	-1.975***
	(0.714)	(0.673)	(0.682)	(0.694)
Grow	-0.349	-0.509*	-0.062	-0.826**
	(0.451)	(0.293)	(0.332)	(0.381)
Cashflow	3.888**	3.962**	1.086	4.249***
	(1.822)	(1.591)	(1.764)	(1.612)
Indire	-6.249***	2.383	-4.898**	1.865
	(2.161)	(2.022)	(1.992)	(2.038)
Listage	0.940*	0.892**	1.872***	0.597
	(0.570)	(0.354)	(0.363)	(0.467)
Top1	6.093***	-0.056	3.502***	0.884
	(0.887)	(0.828)	(0.828)	(0.831)
Constant	-33.667***	-40.501***	-25.086***	-38.910***
	(4.133)	(3.083)	(3.162)	(4.145)
Observations	2,747	3,297	3,016	3,028
R-squared	0.603	0.574	0.575	0.578
Industry	YES	YES	YES	YES
Year	YES	YES	YES	YES

Note:
***, ** and * indicate significance at the 1%, 5% and 10% levels.

https://doi.org/10.1371/journal.pone.0302029.t006

Therefore, this paper argues that the impact of digital transformation on enterprise ESG performance is more pronounced in highly competitive industries. To test this hypothesis, we adopt the established research methodology [95] and employ the Herfindahl index (the sum of squared ratios of each company's main business income to the total main business income of the industry) as a measure of industry competition intensity. The regression results are presented in columns (3) and (4) of Table 6. The findings indicate that low competition does not yield statistically significant results, whereas high competition exhibits a significantly positive effect at a 1% level of significance. This suggests that in highly competitive environments, enterprises can achieve more substantial improvements in their ESG performance through leveraging digital technology.

Discussion

Firstly, the empirical analysis results confirm the hypothesis (H1) proposed in this study. This finding aligns with existing research and further substantiates that digital transformation not only positively impacts financial performance but also serves as an internal driver for enhancing ESG performance within enterprises [13, 25, 26].

Furthermore, this study confirms the proposition H2. Existing literature predominantly examines the relationship between digital transformation and ESG performance through the lenses of total factor productivity and dynamic capability, neglecting the role of corporate

transparency in this context. On one hand, the application of digital technology brings about technological advantages that generate a "governance effect," enhancing internal governance capabilities by increasing shareholder participation in decision-making and curbing managerial discretion [48]. On the other hand, digital transformation yields a "spotlight effect" that amplifies market attention towards enterprises and facilitates greater interaction frequency of internal and external information [59], thereby promoting environmental and social investments among manufacturing firms to enhance their ESG performance. This research finding expands upon existing knowledge regarding the mechanisms linking digital transformation with enterprise ESG performance while contributing to non-economic value research within the domain of digital transformation.

This study also investigates whether the relationship between digital transformation and ESG performance is influenced by the performance expectation gap, and the empirical findings confirm the hypothesis H3b proposed in this study. The underlying reason is that during a performance expectation gap, enterprises face increased strategic risks and heightened internal and external pressures on management [61, 62]. Pursuing strategic reforms at such times may not yield immediate turnaround results but can potentially lead to organizational difficulties. Consequently, the performance expectation gap tends to foster more conservative strategic decision-making by management, thereby limiting the extent to which digital transformation can promote ESG performance. This conclusion underscores the significance of performance feedback in understanding the intrinsic connection between digital transformation and ESG performance within enterprises while addressing existing research limitations.

Conclusion

In the face of medium and long-term constraints posed by the 'dual carbon' goal, leveraging competitive advantages brought about by digital transformation to stimulate ESG practice motivation and help enterprises explore a sustainable development path with economic and social benefits has become a major concern for academia and industry. While scholars have begun exploring the impact mechanism and effect of digital transformation on enterprise ESG performance, the 'black box' remains unopened, with impact boundaries yet to be fully revealed. Therefore, this paper empirically investigates the impact of digital transformation on ESG performance in manufacturing industries, elucidating its internal mechanisms from a company transparency perspective while revealing differences in relationships between digital transformation and ESG performance under conditions of performance expectation gaps. This study provides new theoretical references and policy implications for deep integration between digital transformation and green transformations. The findings demonstrate that: (1) Digital transformation has a significant positive impact on enterprise ESG performance.(2) Analysis of the influence mechanism reveals that company transparency partially mediates the relationship between digital transformation and enterprise ESG performance. (3) The performance expectation gap will give rise to the phenomenon of "timely stop loss" and impede the transformative impact of digitalization on the ESG performance of manufacturing enterprises. (4) Through heterogeneity analysis of the internal and external environment, it is observed that in highly competitive industries within the external environment, digital transformation exhibits a more pronounced positive influence on enterprise ESG performance. State-owned enterprises can fully leverage the enabling role of digital transformation.

Theoretical and practical contributions

The exploration of ESG practice in emerging markets holds significant theoretical significance for the advancement of the ESG field [96]. Despite China's rapid development as an

emerging economy, its research in the realm of ESG is still nascent [97]. By focusing on China as a research subject, this study not only expands the investigation into influencing factors on ESG within China but also offers insights applicable to sustainable development in other developing nations. Moreover, from a corporate transparency perspective, this study elucidates the logical framework linking digital transformation and enterprise ESG performance while broadening our understanding of how digital transformation impacts such performance. It also explores the significance of the performance expectation gap in the internal relationship between digital transformation and ESG performance, thereby addressing the limitations of existing research.

From a practical perspective, this study unveils the mechanism and impact of digital transformation on the ESG performance of enterprises, offering a novel empirical reference for effectively aligning digitization with environmental sustainability efforts in underperforming companies. Moreover, it provides fresh insights for governments to formulate incentivizing policies. Specifically, organizations need to shift their development mindset and fully recognize the long-term advantages of investing in environmental, social, and governance initiatives. Simultaneously, careful attention should be paid to potential adverse effects arising from digital transformation; thus necessitating timely adjustments in personnel allocation, organizational structure, and business processes to ensure optimal utilization of digital technologies' enabling capabilities. Furthermore, The government should prioritize the impact of altruistic preferences [98] and develop a robust policy incentive framework encompassing capital infusion, talent cultivation, and equipment provisioning. This will help alleviate resource scarcity-induced reluctance or apprehension towards ESG investments during the process of enterprise digitization while partially sharing change-related risks.

Limitation and future research

There are certain limitations in this study. Despite employing text analysis and utilizing data from the CSMAR database to measure the extent of enterprise digital transformation, it is still unable to completely mitigate the influence of management behavior such as false disclosure and exaggeration, which may introduce some deviation between the measurement indicators and the actual scenario. Future research could explore alternative measurement methods to minimize potential errors. Furthermore, due to data constraints, this study does not investigate the effects of the COVID-19 outbreak on enterprises' ESG practices; Therefore, future studies can explore disparities in impact before and after the outbreak. Lastly, it is important to note that our sample only encompasses Chinese market enterprises with ESG rating agency coverage and does not encompass emerging markets comprehensively. Subsequent research could concentrate on discerning differences between digital transformation and ESG performance in developed versus developing countries.

Supporting information

S1 Data.
(XLSX)

Acknowledgments

We would like to express our heartfelt gratitude to the anonymous reviewers, editor, and everyone who contributed to the writing of this paper.

Author Contributions

Conceptualization: Xianyun Wu, Longji Li.

Data curation: Xianyun Wu, Longji Li.

Formal analysis: Longji Li.

Funding acquisition: Xianyun Wu.

Investigation: Longji Li.

Methodology: Longji Li.

Project administration: Longji Li.

Software: Longji Li.

Supervision: Xianyun Wu.

Visualization: Longji Li.

Writing – original draft: Xianyun Wu, Longji Li.

Writing – review & editing: Xianyun Wu, Dekuan Liu, Qian Li.

References

1. Pollman E. The making and meaning of ESG[J]. U of Penn, Inst for Law & Econ Research Paper, 2022 (22–23).
2. Tarmuji I, Maelah R, Tarmuji N H. The impact of environmental, social and governance practices (ESG) on economic performance: Evidence from ESG score[J]. International Journal of Trade, Economics and Finance, 2016, 7(3): 67.
3. Fangyuan Liu, Yunlong Wu. Digital transformation and corporate ESG responsibility Performance under the "dual-carbon" goal: Impact, effect and mechanism [J/OL]. Science and Technology Progress and Countermeasures, 1–10[2024-02-13].
4. Zhang X, Zhang J, Feng Y. Can companies get more government subsidies through improving their ESG performance? Empirical evidence from China[J]. Plos one, 2023, 18(10): e0292355. https://doi.org/10.1371/journal.pone.0292355 PMID: 37788255
5. XU Fengmin, JING Kui, LI Xuepeng. Portfolio research based on ESG integration under the background of "double carbon" goal [J]. Financial Research, 2023, (08): 149–169.
6. Li L. China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0"[J]. Technological forecasting and social change, 2018, 135: 66–74.
7. Zhu J, Dou Z, Yan X, et al. Exploring the influencing factors of carbon neutralization in Chinese manufacturing enterprises[J]. Environmental Science and Pollution Research, 2023, 30(2): 2918–2944. https://doi.org/10.1007/s11356-022-21386-5 PMID: 35939192
8. Wen H, Zhong Q, Lee C C. Digitalization, competition strategy and corporate innovation: Evidence from Chinese manufacturing listed companies[J]. International Review of Financial Analysis, 2022, 82: 102166.
9. Peng Y, Tao C. Can digital transformation promote enterprise performance?—From the perspective of public policy and innovation[J]. Journal of Innovation & Knowledge, 2022, 7(3): 100198.
10. Niu Y, Wen W, Wang S, et al. Breaking barriers to innovation: The power of digital transformation[J]. Finance Research Letters, 2023, 51: 103457.
11. Zhu J, Feng T, Lu Y, et al. Using blockchain or not? A focal firm's blockchain strategy in the context of carbon emission reduction technology innovation[J]. Business Strategy and the Environment, 2024.
12. Yunchen Wang, Ruoyi Yang, Kang He et al. Can Digital transformation improve ESG performance?—Research based on legitimacy theory and Information asymmetry theory [J]. Securities Market Review,2023(07):14–25.
13. Zhao X, Cai L. Digital transformation and corporate ESG: Evidence from China[J]. Finance Research Letters, 2023, 58: 104310.
14. Gillan S L, Koch A, Starks L T. Firms and social responsibility: A review of ESG and CSR research in corporate finance[J]. Journal of Corporate Finance, 2021, 66: 101889.

15. Wong W C, Batten J A, Mohamed-Arshad S B, et al. Does ESG certification add firm value?[J]. Finance Research Letters, 2021, 39: 101593.

16. Lee M T, Raschke R L, Krishen A S. Signaling green! firm ESG signals in an interconnected environment that promote brand valuation[J]. Journal of Business Research, 2022, 138: 1–11.

17. Fu Q, Zhao X, Chang C P. Does ESG performance bring to enterprises' green innovation? Yes, evidence from 118 countries[J]. Oeconomia Copernicana, 2023, 14(3): 795–832.

18. Sassen R, Hinze A K, Hardeck I. Impact of ESG factors on firm risk in Europe[J]. Journal of business economics, 2016, 86: 867–904.

19. Fatemi A, Glaum M, Kaiser S. ESG performance and firm value: The moderating role of disclosure[J]. Global finance journal, 2018, 38: 45–64.

20. Mu W, Liu K, Tao Y, et al. Digital finance and corporate ESG[J]. Finance Research Letters, 2023, 51: 103426.

21. He Y, Zhao X, Zheng H. How does the environmental protection tax law affect firm ESG? Evidence from the Chinese stock markets[J]. Energy Economics, 2023, 127: 107067.

22. Zhu J, Baker J S, Song Z, et al. Government regulatory policies for digital transformation in small and medium-sized manufacturing enterprises: an evolutionary game analysis[J]. Humanities and Social Sciences Communications, 2023, 10(1): 1–18.

23. Hao X, Li Y, Ren S, et al. The role of digitalization on green economic growth: Does industrial structure optimization and green innovation matter?[J]. Journal of environmental management, 2023, 325: 116504. https://doi.org/10.1016/j.jenvman.2022.116504 PMID: 36272290

24. Zhu J, Lu Y, Song Z, et al. The choice of green manufacturing modes under carbon tax and carbon quota[J]. Journal of Cleaner Production, 2023, 384: 135336.

25. Su X, Wang S, Li F. The Impact of Digital Transformation on ESG Performance Based on the Mediating Effect of Dynamic Capabilities[J]. Sustainability, 2023, 15(18): 13506.

26. Wu S, Li Y. A Study on the Impact of Digital Transformation on Corporate ESG Performance: The Mediating Role of Green Innovation[J]. Sustainability, 2023, 15(8): 6568.

27. Yinghuan Wang, Yongzhen Guo. Enterprise digital transformation and ESG performance: Based on empirical evidence of listed enterprises in China [J]. Journal of Finance and Economics, 2019, 49 (09):94–108.

28. Xu Wang, Xiaoning Zhang, Yuewei Niu. "Data-driven" and "Capability Curse": The strategic paradox of enterprise digital transformation under the guidance of green innovation strategy upgrading [J]. Research and Development Management, 2002, 34(04):51–65.

29. Lateef A, Omotayo F O. Information audit as an important tool in organizational management: A review of literature[J]. Business Information Review, 2019, 36(1): 15–22.

30. Baraibar-Diez E, Sotorrío L L. The mediating effect of transparency in the relationship between corporate social responsibility and corporate reputation[J]. Revista brasileira de gestão de negócios, 2018, 20: 05–21.

31. Bushman R M, Piotroski J D, Smith A J. What determines corporate transparency?[J]. Journal of accounting research, 2004, 42(2): 207–252.

32. Wei Liu, Jianying Li. Can media buzz effectively reduce the risk of stock price crashes? Study on the moderating effect of corporate transparency [J]. China Management Science,2019, 27(11):39–49.

33. Manita R, Elommal N, Baudier P, et al. The digital transformation of external audit and its impact on corporate governance[J]. Technological Forecasting and Social Change, 2020, 150: 119751.

34. Chen W, Zhang L, Jiang P, et al. Can digital transformation improve the information environment of the capital market? Evidence from the analysts' prediction behaviour[J]. Accounting & Finance, 2022, 62 (2): 2543–2578.

35. Gong C, Ribiere V. Developing a unified definition of digital transformation[J]. Technovation, 2021, 102: 102217.

36. Mubarak M F, Shaikh F A, Mubarik M, et al. The impact of digital transformation on business performance: A study of Pakistani SMEs[J]. Engineering technology & applied science research, 2019, 9(6): 5056–5061.

37. Shang Y, Raza S A, Huo Z, et al. Does enterprise digital transformation contribute to the carbon emission reduction? Micro-level evidence from China[J]. International Review of Economics & Finance, 2023, 86: 1–13.

38. Kwilinski A, Lyulyov O, Pimonenko T. Unlocking sustainable value through digital transformation: An examination of ESG performance[J]. Information, 2023, 14(8): 444.

39. Li C, Wang Y, Zhou Z, et al. Digital finance and enterprise financing constraints: Structural characteristics and mechanism identification[J]. Journal of Business Research, 2023, 165: 114074.

40. Ren X, Zeng G, Gozgor G. How does digital finance affect industrial structure upgrading? Evidence from Chinese prefecture-level cities[J]. Journal of Environmental Management, 2023, 330: 117125. https://doi.org/10.1016/j.jenvman.2022.117125 PMID: 36603250

41. Yao Youfu. The impact of enterprise digital transformation on the tunneling behavior of major shareholders [J]. Contemporary Finance and Economics,2022(11):137–148.

42. Lin B, Ma R. How does digital finance influence green technology innovation in China? Evidence from the financing constraints perspective[J]. Journal of environmental management, 2022, 320: 115833. https://doi.org/10.1016/j.jenvman.2022.115833 PMID: 35940011

43. Tang M, Liu Y, Hu F, et al. Effect of digital transformation on enterprises' green innovation: Empirical evidence from listed companies in China[J]. Energy Economics, 2023, 128: 107135.

44. Sun S, Guo L. Digital transformation, green innovation and the Solow productivity paradox[J]. Plos one, 2022, 17(7): e0270928. https://doi.org/10.1371/journal.pone.0270928 PMID: 35802578

45. Matarazzo M, Penco L, Profumo G, et al. Digital transformation and customer value creation in Made in Italy SMEs: A dynamic capabilities perspective[J]. Journal of Business Research, 2021, 123: 642–656.

46. Enrique D V, Lerman L V, de Sousa P R, et al. Being digital and flexible to navigate the storm: How digital transformation enhances supply chain flexibility in turbulent environments[J]. International Journal of Production Economics, 2022, 250: 108668.

47. Zaki M. Digital transformation: harnessing digital technologies for the next generation of services[J]. Journal of Services Marketing, 2019, 33(4): 429–435.

48. Jianbing Shao, Luye Wang. Can digital transformation curb executive corruption?—Based on the perspective of minority shareholders' participation in governance [J]. Journal of Shanghai University of Finance and Economics,2023, 25(02):64–77.

49. Zhao T, Yan N, Ji L. Digital transformation, life cycle and internal control effectiveness: Evidence from China[J]. Finance Research Letters, 2023, 58: 104223.

50. Zhang K, Pan Z, Zhang K, et al. The effect of digitalization transformation on greenwashing of Chinese listed companies: an analysis from the dual perspectives of resource-based view and legitimacy[J]. Frontiers in Environmental Science, 2023, 11: 1179419.

51. Rui-kun Duan, Yong-jia Duan, Yi Liu. Can enterprise digitalization promote "Less words and more actions" of environmental responsibility [J]. Contemporary Finance and Economics,2023(10):85–96.

52. Hu Z, Ma H, Xiong J, et al. Convergence or divergence: A computational text analysis of stakeholder concerns on manufacturing upgrading in China[J]. IEEE Transactions on Engineering Management, 2022.

53. Jeffrey S, Rosenberg S, McCabe B. Corporate social responsibility behaviors and corporate reputation [J]. Social Responsibility Journal, 2019, 15(3): 395–408.

54. Wu K, Fu Y, Kong D. Does the digital transformation of enterprises affect stock price crash risk?[J]. Finance Research Letters, 2022, 48: 102888.

55. Chen Deqiu, Hu Qing. Research on Corporate Governance in the era of Digital Economy: Frontiers of paradigm innovation and Practice [J]. Management World,2022, 38(06):213–240.

56. Billett M T, Garfinkel J A, Yu M. The effect of asymmetric information on product market outcomes[J]. Journal of Financial Economics, 2017, 123(2): 357–376.

57. Cheng Xiang, Lu Jing. Corporate transparency and earnings Announcement inertia: An empirical study based on investor concern [J]. Management Science, 2019, 33(03):138–154.

58. de la Fuente G, Ortiz M, Velasco P. The value of a firm's engagement in ESG practices: Are we looking at the right side?[J]. Long Range Planning, 2022, 55(4): 102143.

59. Yu Yan, Wang Xue-ying, Hao Jinxing et al. Wine is still afraid of deep alleys? Digital transformation signal and Capital market pricing of Manufacturing enterprises [J/OL]. Nankai Management Review, 1–27 [2024-02-20].

60. Wang Yao, Feng Xiaoqing, Hou Desai. Can Enterprise Digital Transformation Improve the accuracy of analyst prediction—Based on dual perspectives of information Disclosure and information Mining [J]. Journal of Zhongnan University of Economics and Law, 2023, (04): 16–27+135.

61. Huang Jianbin, Song Tiebo, Chen Yujiao. Research on the impact of performance expectation Gap on digital transformation response of dominant manufacturing firms [J]. Journal of Management,2023, 20 (07):974–983.

62. Cyert R M, March J G. A behavioral theory of the firm[J]. Englewood Cliffs, NJ, 1963, 2(4): 169–187.

63. Barney J B, Arikan A M. The resource-based view: origins and implications[J]. The Blackwell handbook of strategic management, 2005: 123–182.

64. Sethi S P, Martell T F, Demir M. Building corporate reputation through corporate social responsibility (CSR) reports: The case of extractive industries[J]. Corporate Reputation Review, 2016, 19: 219–243.

65. Giese G, Lee L E, Melas D, et al. Foundations of ESG investing: How ESG affects equity valuation, risk, and performance[J]. The Journal of Portfolio Management, 2019, 45(5): 69–83.

66. Lian Yanling, He Xiaogang, Gao Hao. Performance expectation gap and corporate strategy adjustment: An Empirical study of Chinese listed companies [J]. Management World,2014(11):119–132+188.

67. Li Xi, ZHENG Xin, ZHANG Jianqi. Will the performance dilemma of manufacturing Enterprises promote innovation? An analysis based on the expansion of expectation gap dimension [J].China Industrial Economy,2018(08):174–192.

68. Desai V M. The behavioral theory of the (governed) firm: Corporate board influences on organizations' responses to performance shortfalls[J]. Academy of Management Journal, 2016, 59(3): 860–879.

69. Wu Jianzu, Yuan Haichun. The inverse U-shaped relationship between performance expectation gap and corporate environmental strategy [J]. Journal of Management,20, 17(10):1453–1460.

70. Chng D H M, Shih E, Rodgers M S, et al. Managers' marketing strategy decision making during performance decline and the moderating influence of incentive pay[J]. Journal of the Academy of Marketing Science, 2015, 43: 629–647.

71. Trahms C A, Ndofor H A, Sirmon D G. Organizational decline and turnaround: A review and agenda for future research[J]. Journal of management, 2013, 39(5): 1277–1307.

72. Wang Tao, WANG Xingyue, FENG Qiaogen. Expected performance feedback and Enterprise digital transformation: Thinking about Danger or thinking about change [J]. Journal of Guangdong University of Finance and Economics,2023, 38(02):46–59.

73. XIAO Tusheng, Ruiqi Sun, Yuan Chun et al. Corporate digital transformation, human capital structure adjustment and labor income share [J]. Management World, 2022, 38 (12): 220–237.

74. Aral S, Weill P. IT assets, organizational capabilities, and firm performance: How resource allocations and organizational differences explain performance variation[J]. Organization science, 2007, 18(5): 763–780.

75. Tambe P, Hitt L M. The productivity of information technology investments: New evidence from IT labor data[J]. Information systems research, 2012, 23(3-part-1): 599–617.

76. Wang Liyan, Zhang Jidong. The Relationship between ERP system implementation and company performance growth: An empirical analysis based on the data of Chinese listed companies [J]. Management World, 2007, (03): 116–121+137.

77. Lang M, Lins K V, Maffett M. Transparency, liquidity, and valuation: International evidence on when transparency matters most[J]. Journal of Accounting Research, 2012, 50(3): 729–774.

78. Xiang Cheng,Lu Jing. Corporate Transparency and Surplus Announcement Inertia-An Empirical Study Based on Investors' Attention[J]. Management Science,2020, 33(03):138–154.

79. Qingquan Xin, Dongmin Kong, Ying Hao. Corporate transparency and stock price volatility [J]. Financial Research,2014(10):193–206.

80. Chen Qiu, Huixin Yang. How does performance expectation Gap promote technological innovation?—Empirical evidence of firms' imitation learning object selection [J]. Industrial Economics Research,2022 (01):57–70.

81. Cao Yanan, ZHAO Ziye, Sun Wenlong. Is there information manipulation in digital transformation disclosure? Evidence from companies with operating expectation Gap [J]. Economic Management, 2019, 45 (06):177–192.

82. Chen W R. Determinants of firms' backward-and forward-looking R&D search behavior[J]. Organization Science, 2008, 19(4): 609–622.

83. Guo Rong, Wen Qiaotian. Dual performance feedback, internal and external governance mechanisms and strategic risk taking [J]. Economic Management,2019, 41(08):91–112.

84. Rudy B C, Johnson A F. Performance, aspirations, and market versus nonmarket investment[J]. Journal of management, 2016, 42(4): 936–959.

85. Nekhili M, Boukadhaba A, Nagati H. The ESG–financial performance relationship: Does the type of employee board representation matter?[J]. Corporate Governance: An International Review, 2021, 29 (2): 134–161.

86. Javeed S A, Latief R, Cai X, et al. What is the role of the board sustainable committee for corporate social responsibility? The moderating effect of gender diversity and ownership concentration[J]. Journal of Cleaner Production, 2022, 379: 134710.

87. Chen S, Song Y, Gao P. Environmental, social, and governance (ESG) performance and financial outcomes: Analyzing the impact of ESG on financial performance[J]. Journal of Environmental Management, 2023, 345: 118829. https://doi.org/10.1016/j.jenvman.2023.118829 PMID: 37688968

88. Ma Lianfu, SONG Jingnan, WANG Bo. Research on the value effect of information disclosure in digital transformation: Evidence from conceptual speculation [J]. Economics and Management Research, 2019, 44(08):17–37.

89. Chen Junhua, Hao Shuya, Yi Cheng.Digital transformation, bankruptcy risk and corporate resilience [J]. Economic Management,2023, 45(08):26–44.47.

90. Zhao Chenyu. Digital development and service-oriented transformation: Empirical evidence from listed manufacturing companies [J]. Nankai Management Review, 2019, 24(02):149–163.

91. Wen Zhonglin, Ye Baojuan. Mediation Effect Analysis: Development of methods and models [J]. Advances in Psychological Science, 2014, 22 (05): 731–745.

92. Sheng H, Zhao N. China's state-owned enterprises: Nature, performance and reform[M]. World Scientific, 2013.

93. Fan G, Hope N C. The role of state-owned enterprises in the Chinese economy[J]. China-US 2022, 2013, 7.93

94. Grant R M. The resource-based theory of competitive advantage: implications for strategy formulation [J]. California management review, 1991, 33(3): 114–135.

95. Zhang Q, Yang H, Wang Q, et al. Impact of high-speed rail on market concentration and Lerner index in China's airline market[J]. Journal of Air Transport Management, 2020, 83: 101755.

96. Martins H C. Competition and ESG practices in emerging markets: Evidence from a difference-in-differences model[J]. Finance Research Letters, 2022, 46: 102371.

97. Weber O. Environmental, social and governance reporting in China[J]. Business Strategy and the Environment, 2014, 23(5): 303–317.

98. Zhu J, Lu Y, Feng T. The influence of the altruistic preferences of e-commerce platforms on the carbon emission reduction of manufacturers[J]. Electronic Commerce Research, 2023: 1–25.

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

The AI ESG protocol: Evaluating and disclosing the environment, social, and governance implications of artificial intelligence capabilities, assets, and activities / Sætra, H. S.

Sustainable Development
Volume 31 Issue 2 (2023) 10991719 Pages 1027–1037
https://doi.org/10.1002/sd.2438
(Database:Wiley Online Library)

Received: 15 August 2022 | Revised: 4 October 2022 | Accepted: 17 October 2022

DOI: 10.1002/sd.2438

RESEARCH ARTICLE

Sustainable Development

WILEY

The AI ESG protocol: Evaluating and disclosing the environment, social, and governance implications of artificial intelligence capabilities, assets, and activities

Henrik Skaug Sætra

Faculty of Computer Science, Engineering and Economics, Østfold University College, Halden, Norway

Correspondence
Henrik Skaug Sætra, Faculty of Computer Science, Engineering and Economics, Østfold University College, Remmen, N-1757 Halden, Norway.
Email: henrik.satra@hiof.no

Abstract

AI and data are key strategic resources and enablers of the digital transition. Artificial Intelligence (AI) and data are also intimately related to a company's environment, social, and governance (ESG) performance and the generation of sustainability related impacts. These impacts are increasingly scrutinized by markets and other stakeholders, as ESG performance impacts both valuation and risk assessments. It impacts an entity's potential to contribute to good, but it also relates to risks concerning, for example, alignment with current and coming regulations and frameworks. There is currently limited information on and a lack of a unified approach to AI and ESG and a need for tools for systematically assessing and disclosing the ESG related impacts of AI and data capabilities. I here propose the AI ESG protocol, which is a flexible high-level tool for evaluating and disclosing such impacts, engendering increased awareness of impacts, better AI governance, and stakeholder communication.

KEYWORDS
big data, AI data, ESG, reporting, sustainability

1 | INTRODUCTION

Understanding how artificial intelligence (AI) and data impact businesses and organizations is crucial both for their valuation and governance, and in this article, I propose a flexible high-level framework for systematically evaluating and reporting on how an organization's AI and data capabilities, assets, and activities impact sustainability related issues. Capabilities describe competencies, tools, methods, and processes related to developing AI systems and gathering data. This might include, for example, a company's competencies related to developing specific types of algorithms or capabilities for generating data from sensors. Assets are the algorithms, systems, and data the entity controls and includes, for example, specific data sets or a social network platform. Activities describe how capabilities and assets are used in ways relevant for understanding an entity's business value, development, and position. These relate to how a company, for example, develops products where its development capabilities are used to provide customers with new ways to utilize their data in order to optimize various processes.

AI and data have become key enablers of the digital transformation (Holmström, 2022; Sivarajah et al., 2017; Verhoef et al., 2021) as they impact a company's growth and capacity for innovation and value generation (Leitner-Hanetseder & Lehner, 2022; Wamba-Taguimdje et al., 2020). Being able to communicate technology related soft assets to investors and other stakeholders is imperative for allowing markets to correctly value an entity and for enabling good governance (Leitner-Hanetseder & Lehner, 2022). Since AI and data are intimately related to a company's environment, social, and governance

(ESG) performance due to the impacts of data-based AI systems on both people and the natural world—through, for example, biased and discriminatory systems or the carbon footprint of training algorithms (Crawford, 2021)—understanding the ESG related risks and impacts of these technologies is consequently crucial for internal decision-makers, markets, and other stakeholders. In addition, actors such as the European Union (EU) is pursuing relatively aggressive regulation on data, AI, and digital services/markets (European Commission, 2022b). Such developments entail new demands for transparency and risk management and are of obvious importance to companies operating in the EU, but also others, as regulators elsewhere might pursue similar paths (Mäntymäki et al., 2022b).

Sustainability related impacts are increasingly emphasized by markets and other stakeholders (Dimson et al., 2020), as ESG performance impacts both valuation and risk assessments (Fafaliou et al., 2022; Friede et al., 2015), and potentially also engenders innovation capacity (Ambec et al., 2013; Fafaliou et al., 2022; Porter & Van der Linde, 1995). It relates to and describes an entity's potential to contribute to good, for example to the achievement of the UN's sustainable development goals (SDGs), but it also relates to risks concerning, for example, alignment with current and coming sustainability related regulations.

ESG is not a new concept (Crona & Sunsdström, 2023), but the ESG and sustainability reporting and disclosure landscape is rapidly evolving, and there is no shortage of frameworks, standards, or rating providers (Dimson et al., 2020; Esty & Cort, 2020; Sætra, 2021b). This generates challenges for those in charge of making decisions both within and about entities, but also society more broadly, as reflected through the framework of stakeholder capitalism (Freeman et al., 2007; World Economic Forum, 2020). It also causes problems for companies struggling to analyze and report on their ESG performance, and for investors who face a lack of good and comparable data to assess potential investments (Berg et al., 2022; Dimson et al., 2020; Eng et al., 2021).

A large number of standards and frameworks have led to numerous calls for harmonization (Eng et al., 2021), and efforts to do so are underway on several fronts, such as the European Unions' Sustainable Finance Disclosure Regulation (SFDR), Corporate Sustainability Reporting Directive (CSRD) and EU taxonomy (EU Technical expert group on sustainable finance, 2020; European Commission, 2022a, 2022c), and the IFRS's International Sustainability Standards Board (ISSB) (IFRS, 2022).

Adding to this are the challenges associated with understanding how AI relates to sustainability and ESG (Sætra, 2021a, 2021b, 2022; van Wynsberghe, 2021). The purpose of this article is to present the *AI ESG Protocol*, which is a tool for systematically evaluating and disclosing a company's AI and data-driven risks and opportunities related to ESG and sustainability. While all companies can use the protocol, it will be particularly relevant for AI and data-intensive companies where such technologies and assets are considered material for their stakeholders. This article mainly refers to the entities who adopt the protocol, and it is primarily addressed at directors and managers, while the data and statements production will require the participation of many other actors in the organization using the protocol. The end result of using the protocol, however, is both intended to be action-oriented and useful for the reporting entity, but also of use for investors, public officials, and other stakeholders.

AI ESG protocol is flexible and high-level and is intended as a supplement that interacts with other frameworks and internal business processes. Like the Greenhouse Gas Protocol (World Resources Institute, 2021), the AI ESG protocol distinguishes between scopes 1, 2, 3, and provides a set of questions that allows all types of entities to better understand and disclose their impacts, addressing identified needs for increased awareness and better governance of AI in relation to ESG (Minkkinen et al., 2022). The protocol allows entities to identify opportunities and to bridge identified gaps, which can also be disclosed to markets, investors, and other stakeholders. By using the AI ESG Protocol, the entity will also have to consider questions such as AI readiness and maturity (Holmström, 2022), and it consequently provides value beyond simply mapping ESG impacts.

I begin by establishing the basics related to navigating the world of ESG and sustainability reporting, as this is required for understanding both why the AI ESG Protocol is useful, and how it might be used in combination with other standards and frameworks. The next section establishes the main linkages between AI, ESG, and sustainability to identify the key issues to be mapped and considered. Finally, the basic structure of the AI ESG protocol is presented.

2 | THE CHAOTIC WORLD OF ESG AND SUSTAINABILITY REPORTING

Talk of sustainability and ESG abounds in markets, boardrooms, and C-suites nowadays, and in the context of this article, the main focus is on sustainability and ESG reporting related to AI and data capabilities, assets, and activities. However, existing standards and frameworks are insufficient (Sætra, 2021b), and in order to develop the protocol for assessing the impacts of AI and data, a brief examination of what is meant by sustainability and ESG is in order.

Sustainability here refers to the concept sustainable development, described in the 1987 report *Our Common Future* produced by the United Nations' (UN) Brundtland commission (Brundtland et al., 1987). Sustainable development was here described as meeting current needs without preventing future generations from doing the same, and it consists of three interdependent dimensions, namely the environmental, social, and economic. To achieve sustainable development, issues belonging to all three dimensions must be dealt with simultaneously, as we cannot, for example, deal effectively with climate change unless we also handle issues related to inequality and environmental justice. This concept of sustainable development forms the foundation of the UN's SDGs and Agenda 2030 (United Nations, 2015). The 17 SDGs describe challenges related to all three sustainability dimensions, and the aim is to reach the goals by 2030. While they are not intended as a framework for ESG or sustainability reporting, they are increasingly often used and referred to in this context (Arena et al., 2022; Bose, 2020; García-Sánchez et al., 2022; Sætra, 2021b; SDG Compass, 2015).

FIGURE 1 The SDGs through the lens of ESG. From Sætra (2021b). *Source*: Inspired by Berenberg (2018) [Colour figure can be viewed at wileyonlinelibrary.com]

Sustainable development is now increasingly recognized as something that not only governments, but also private entities must play a significant role in promoting (Esty & Cort, 2020). Initiatives such as EU's Green Deal is consequently premised on the notion that private capital and activity is essential for reaching sustainability related goals (European Commission, 2019). Having businesses factor in ESG entails a move from traditional shareholder capitalism to what is at times referred to as stakeholder capitalism (Freeman et al., 2007; Schwab & Vanham, 2021), and corporations are getting on board for three main reasons. First, regulation and formal requirements, such as the EU Taxonomy, the SFDR and the CSRD (ERM, 2022; EU Technical expert group on sustainable finance, 2020; European Commission, 2022a, 2022c). Second, investor pressure and financial market incentives (ERM, 2022; Friede et al., 2015; Marczewska & Kostrzewski, 2020; Moon, 2014; Nosratabadi et al., 2019; Verbin, 2020). Third, processes related to increased public demand for responsible business practices and what is often term the social license to operate (Demuijnck & Fasterling, 2016; ERM, 2022; He & Harris, 2020; Verbin, 2020).

The concept of sustainable development also forms the basis of sustainability and ESG reporting, but it is not necessarily ideal to rely on the three sustainability dimensions in the finance and reporting context. With the ESG concept, the economic dimension is replaced by the governance dimension. While this entails a change in terminology, it is nevertheless unproblematic to connect ESG reporting to sustainable development and the SDGs. Figure 1, for example, shows how the SDGs can be classified under the E, S, and G dimensions of ESG. The goals most often considered economic (SDG 8 and 9, for example) are here classified as social goals, as it is the social implications of economic activity that most clearly relates to the nonfinancial considerations and risks not covered by a company's financial reporting. An additional benefit is that governance is given ample attention, and this is particularly important for businesses working to improve the ESG impact of their AI and data related activities.

The obligations to gather and disclose sustainability related data varies between countries, regions, and sectors, and an examination of all these varieties is beyond this scope of this article. However, the AI ESG protocol described below is designed to complement common frameworks, standards, and ratings in order to fill the gap related to the ESG related impact of a company's AI and data based capabilities, assets, and activities, and it can be used regardless of which reporting regime the entity is under and framework they have chosen to use.

Due to the changes in the pressures and nature of expectations of corporations activities, the term corporate social responsibility (CSR) has largely given way to ESG reporting, strategies, and plans (Esty & Cort, 2020; Moon, 2014), which is broader and better reflects how companies are increasingly taking environmental, social, and governance issues seriously (Verbin, 2020). The European Union is emerging as a proactive and strong actor pushing for increasing transparency and disclosure, and Eckhart (2020) describes the mandatory obligations in the EU as opposed the approach of the US Securities and Exchange Commission (SEC). However, things move fast in this domain, and, for example, the SEC recently approved NASDAQ's change in reporting requirements on board diversity (Securities and Exchange Commission, 2021), which had caused wide debates about the role of issuers in the United States.

Two of the major actors in the world of sustainability and ESG reporting have been the Global Reporting Initiative (GRI) and the more investor focused Sustainability Accounting Standards Board (SASB). The latter become the Value Reporting Foundation, which in turn becomes part of the ISSB mentioned above (ERM, 2022). The latter is also a major new development aimed at providing a global standard for meeting the demand for "high quality, transparent, reliable, and

comparable reporting" on ESG (IFRS, 2022). There are a wide range of other standards and frameworks as well, some focusing on specific issues (such as the Carbon Disclosure Project [CDP] and Task Force on Climate-Related Financial Disclosures [TCFD]), while others are general frameworks intended to unify and simplify other frameworks (such as the World Economic Forum's [WEF] Stakeholder Capitalism Metrics [SCM]).

The need for better and more easily comparable data is key for investors who increasingly rely on information about firms' ESG performance. The lack of good and comparable data has led to the growth of ESG ratings agencies, such as Kinder, Lydenberg, Domini, Sustainalytics, Moody's ESG, S&P Global, Refinitiv, and MSCI (Berg et al., 2022). However, due to differences in methodology, and the aforementioned lack of data quality, these rating agencies display high variability when ranking the same company (Berg et al., 2022; Dimson et al., 2020), creating a host of problems related to market uncertainty, but also, for example, attempts to link executive remuneration to ESG performance (Berg et al., 2022).

3 | ESG AND AI

While AI ethics and digital ethics have arguably reached the pinnacle of the hype cycle (Goasduff, 2020), there is still little research linking AI and the concept of ESG, sustainable finance, and sustainability reporting (Minkkinen et al., 2022; Musleh Al-Sartawi et al., 2022). Much work has been and is being done on AI and general issues related to general or aspects of sustainability (Sætra, 2021a, 2022; van Wynsberghe, 2021; Vinuesa et al., 2020), but this is rarely connected to ESG.

In a recent article Minkkinen et al. (2022) identified a research gap in this area, finding only three extant relevant articles on the subject, namely Sætra (2021b), Du and Xie (2021), and Brusseau (2021). While dealing with the linkage between AI and ESG, none of the articles focus on providing a tool for evaluating and disclosing AI related ESG impacts, and the need for such a tool is emphasized by Minkkinen et al. (2022).

It is also worth noting that there is a lot of research on how AI can be used in ways relevant to the world of ESG, for example in accounting (Bose & Bhattacharjee, 2022), in generating ESG ratings (Crona & Sunsdström, 2023), and for addressing the need to find a way to properly value data and AI capabilities in financial reporting (Leitner-Hanetseder & Lehner, 2022). However, the AI ESG protocol here developed focuses on providing a method for evaluating and disclosing the ESG related impacts of using AI, and these other areas of AI use are consequently not directly relevant. Such use of AI can, however, be reported as ESG relevant through the protocol.

The remainder of this section explains key foundational elements of the AI ESG protocol in some detail. First, I explain how impacts are split into three scopes, before briefly presenting the major dimensions to be considered when evaluating AI and data based impacts related to *environment*, *social*, and *governance*. The scope of this article precludes a comprehensive mapping of all sustainability related effects of AI, however, but issues identified in the broader research literature are reflected in the protocol (Sætra, 2022; Vinuesa et al., 2020).

3.1 | Three scopes of impacts

The complexities of ESG related impacts can at times stand in the way of undertaking ESG analyses, and when they do not, the resulting analyses are often not particularly actionable. In order to remedy this challenge, I build on Sætra (2022) and the proposed analytical approach to the sustainability related impacts of AI. This approach is partly inspired by the Greenhouse Gas Protocol (World Resources Institute, 2021) which distinguishes emissions from Scopes 1, 2, and 3, and by doing so, the AI ESG Protocol also ties directly into the most popular and widely used methods used in the climate change section of all other frameworks and standards. Figure 2 shows some of the main sources of risks and impacts in each scope, and these are discussed in more detail below.

While similar, and partly overlapping, measuring impact is slightly different from measuring only emissions due to the broader range of issues to be considered. For the AI ESG Protocol, the scopes are defined as described below, and examples follow in the next sections.

Scope 1 deals with impacts related directly to a company's core activities and governance, limited to internal social and governance impacts and the environmental impacts related to the computing infrastructure the company directly controls (owns or leases). Data gathered by the entity is part of Scope 1. Figure 2 shows, for example, issues related to cybersecurity, the impact of own machines and data, and own staff.

Scope 2 encompasses the upstream consequences related directly to the entity's supply chain. Procurement of electricity and cloud services is part of Scope 2, and the same goes for the procurement of development services, support, and algorithms. An important part of Scope 2 is all the second-hand data the company avails itself of, complementing the data gathered by the entity itself as detailed under Scope 1. Figure 2 shows this through, for example, the purchasing of cloud services, the humans involved in the upstream supply chain, upstream cybersecurity, and energy sourcing.

Scope 3 is the broader upstream *and* downstream impacts of the company's AI and data-based capabilities, assets, and activities. This includes, for example, an algorithm used for AI in hiring, and how this might entail risks of discrimination, or potentially the reduced occurrence of bias in hiring. It also includes how the entity's activities encourages or discourages consumption, if the entity sells or disseminates tools that, for example, drive emissions up- or downstream. Figure 2 shows this through, for example, the datafication of human relations, increasing use of internet of things (IoT) in the business and private sector, increased targeting and surveillance of individuals and groups, value creation and innovation, transportation, impact on water use, nature and biodiversity, and so forth.

In sum, detailing the impacts in these three scopes encompasses all ESG related impacts stemming from AI and data, which helps both the entity and its stakeholders understand where in the value chain

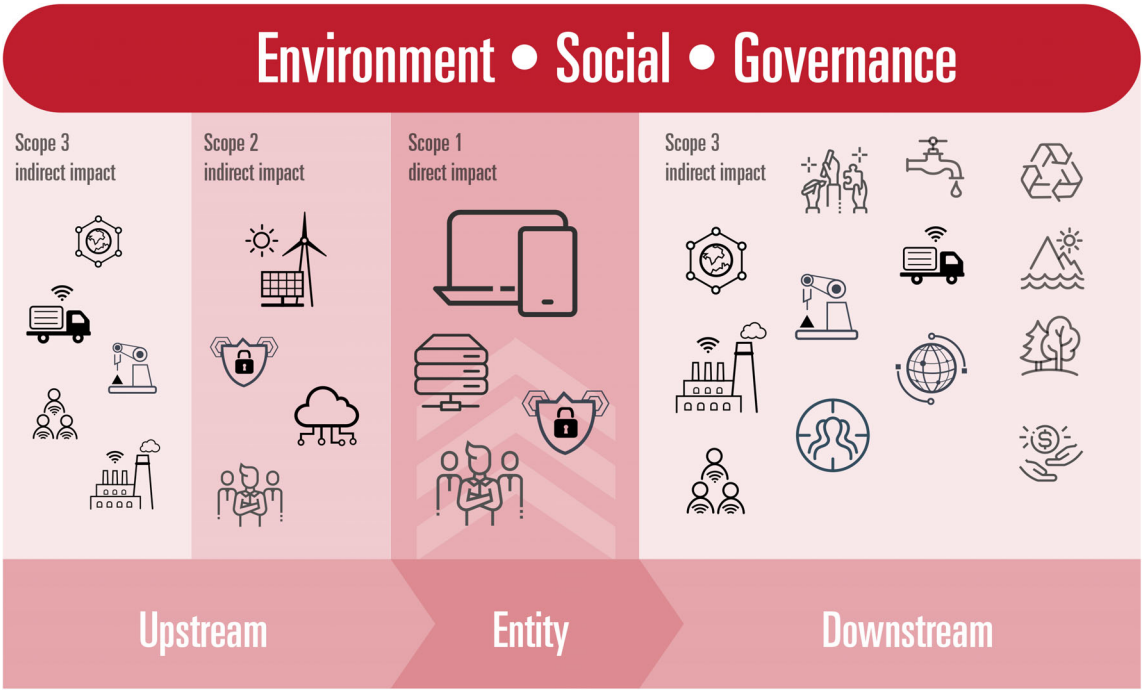


FIGURE 2 Examples of sources of impact and risks in Scopes 1, 2, and 3. *Source*: Author's own arrangement [Colour figure can be viewed at wileyonlinelibrary.com]

the impacts and risks occur and consequently what can and must be done to either minimize the negative impacts and risks or maximize and exploit upside risk and positive impact.

The three scopes help sort impacts from various sources up- and downstream, but another key distinction needs to be made between different types of impacts and risks. As the protocol is based on the ESG approach, the main types to which I now turn relate to environmental, social, and governance issues.

3.2 | Environmental impacts and risks

The environmental dimension is currently getting most attention in the ESG world (ERM, 2022), and climate has been the obvious headline grabber. The Paris agreement is still key for understanding climate targets (UNFCCC, 2022). Companies are now increasing setting NetZero targets and strategies (ERM, 2022), and AI and data related emissions must be part of such strategies. The integrity of natural systems is, however, increasingly attracting attention both on its own and because it is integral to solving climate related challenges (ERM, 2022).

The main issue related to AI in this dimension is how AI both consumes energy and generates emissions (Bender et al., 2021), and potentially allows for solutions that help mitigate climate change and promote adaption efforts (Rolnick et al., 2022). AI will potentially simultaneously have both positive and negative emission related impacts, and determining whether or not an entity's use of AI is sustainable requires us to understand both sides of the equation (Sætra, 2022). The direct emissions generated from AI will often be confined to Scopes 1 and 2, while Scope 3 is where an entity can demonstrate positive impact.

Computing infrastructure also has a material basis (Barley, 2020; Brevini, 2021). This necessitates a consideration of the use of materials in and environmental impacts of the machinery used, either by the entity itself, or through data on or from, for example, cloud providers in the supply chain. While emissions from the production of equipment matters, so do aspects related to hazardous waste, rare minerals, and so forth.

As has become clear, AI is not only relevant with regard to climate change adaptation and mitigation, but also has potential impacts related to, for example, biodiversity, innovation, and making sense of data in order to face environmental challenges, land use change, use of water (Crawford, 2021; Sætra, 2022; Vinuesa et al., 2020).

3.3 | Social impacts and risks

Investors are increasingly focusing on the social aspects of an entity's activities. A range of developments encourage this, and examples of drivers include COVID-19 and the great resignation, the black lives matter movement, and new regulation related to modern slavery (ERM, 2022; He & Harris, 2020). This all means that issues related to (a) employee satisfaction, engagement, and retention, (b) supply chain issues and human rights, and (c) the broader impact related to social justice and discrimination are important for investors.

These are all issues known to be relevant for the use of AI and data. The broader impacts of AI is a staple of mainstream digital or AI

ethics, and issues of discrimination and bias in such systems are increasingly well understood. Such issues mainly fall into Scope 3 in the AI ESG protocol. Regarding supply chain issues, Crawford (2021), for example, has explored these issues in great detail. In the context of the AI ESG protocol, issues related to the rights of *data* subjects are included in the analysis of supply chain human rights issues in Scope 2 and own data gathering in Scope 1.

In addition to discrimination and bias, there is also a need to deal with the *economic* consequences related to inequality, poverty, access to infrastructure, and so forth under the social dimension of the AI ESG protocol. As discussed by Sætra (2021a, 2022), AI is part of a broader and potentially unsustainable socio-technical system, which is arguably not conducive to promoting all aspects of SDGs 8, 9, and 10, for example. Who owns the data, who has access to services, who benefits from the solutions made, and so forth, are important questions in this context. Issues related to using AI and data to promote growth and innovation are also relevant in this category, but they must be coupled with an analysis of the social consequences to be complete.

Finally, issues related to consumer activity and political institutions must also be analyzed under the social banner. This reflects broader market trends related to expectations for companies to take responsibility for and make efforts to engender positive and sustainable behavior from their customers and partners (ERM, 2022), and also how their products, solutions, and systems relate to and interact with democracy and political institutions, which has become relevant due to, for example, how social media have been used to impact elections (Greenfield, 2018).

3.4 | Governance

One of the main benefits of using the AI ESG protocol is that it focuses attention on governance related issues, and that it does so based on approaches from the finance and investor world where such issues have a long history and where mature and well-established frameworks and tools exist. This is arguably particularly important for governing AI and data intensive entities, as they are part of a relatively immature industry with rapid growth—struggling to find good governance approaches. There is, for example, an extreme proliferation of frameworks for responsible, trustworthy, and otherwise "ethical" AI (Floridi & Cowls, 2019; Jobin et al., 2019; Mittelstadt, 2019), and ongoing debates about the relationships between ethics and politics and regulation, both in and of corporations using AI and data based solutions (Floridi, 2018; Sætra & Fosch-Villaronga, 2021). Nevertheless, there are emerging governance approaches to AI worth noting, and these both can and should be considered when using the AI ESG protocol. The protocol itself favors no specific approach, and simply requires an entity to describe and disclose their approach to the governance of AI and data related risks and opportunities, and this could be based on some of the approaches to AI governance being developed (Mäntymäki et al., 2022a; Mäntymäki et al., 2022b; Papagiannidis et al., 2022; Schneider et al., 2022). It is, however, imperative that AI governance is seen as an integrated part of an entity's existing governance structure, and the proposals by Mäntymäki et al. (2022a) and Mäntymäki et al. (2022b) account for this need and focus on AI unique aspects and how AI governance relates to, for example, IT and data governance. Governance also related to stakeholders, and Cihon et al. (2021) highlights the need for multistakeholder approaches and cooperation for good AI governance. This is in line with existing approaches to sustainability and ESG, for example with the network, forum, and guidance approach found in UN Global Compact (UN Global Compact, 2022).

In addition to broader governance related issues, the protocol can also be combined with various approaches to auditing and assurance of AI systems (Raji et al., 2020). On a lower level, impact assessments for specific algorithms have also been proposed and presented as the natural evaluation of auditing and assurance (Metcalf et al., 2021). While impact assessments are required, it remains unclear if replacing topical assessments (e.g., "environmental impact assessments") with technology defined ones (algorithmic impact assessment) negates the need for auditing and assurance. In the world of sustainability reporting and disclosure, internal and external auditing processes, and limited or reasonable assurance work will most likely retain their functions.

In the AI ESG protocol, governance issues relate to risk control, governance systems, auditing systems, and to what degree a corporation has strategies and plans related to AI and data capabilities, assets, and activities. Scope 1 encompasses most of these issues, but governance is also included in the other scopes through, for example, indicators related to performing due diligence and assessments of their suppliers and partners.

As the AI ESG protocol is not a complete and full ESG reporting framework, issues related to *general* issues of governance, such as board composition, and so forth, will be handled through the more general framework used. The TCFD framework, for example, provides recommendations for disclosure on governance and risk management that could with good effect be incorporated into the reporting on the governance issues in the AI ESG protocol (TCFD, 2022). If the company does not report on ESG through broader frameworks, certain general indicators could be included in the protocol, but this will mainly be relevant for companies that are highly AI and data intensive, for which the AI ESG protocol will reflect most material issues.

4 | THE AI ESG PROTOCOL

With the preliminaries in place, we can now see how this all comes together in constituting the AI ESG protocol. The protocol is a high-level tool and method that allows all companies to systematically evaluate and disclose the impacts of their AI and data based *capabilities*, *assets*, and *activities*. These three categories were selected as they cover the key factors related to ESG related potential for impact (capabilities and assets), whereas activities highlight current and actual use of AI and data. Combined with the distinction between three scopes, the structure of the protocol can be shown as the cube in Figure 3.

The protocol ties directly into the GHG protocol, as discussed, and if the environmental impacts covered by the AI ESG protocol are calculated according to the GHG protocol, this can feed directly into

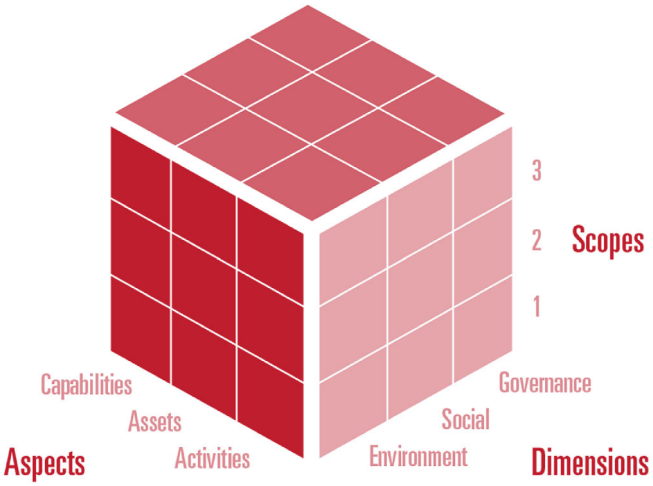


FIGURE 3 The elements of the AI ESG protocol. *Source*: Author's own arrangement [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 4 The AI ESG protocol structure. *Source*: Author's own arrangement [Colour figure can be viewed at wileyonlinelibrary.com]

the entity's general climate accounting, while also allowing for separating the AI and data driven emissions. This resembles the approach of the TCFD, which is a framework for reporting on climate related financial risks and opportunities. This framework also requires the use of the GHG protocol for climate related metrics and targets, and provides a set of recommendations for governance, strategy, and risk management disclosures, with 11 key disclosures in total (TCFD, 2022).

The AI ESG protocol is flexible as it is built to connect with other standards and frameworks and internal processes and governance structures. This flexibility enables the protocol to be used by many different actors in highly varied contexts. However, the high-level nature and flexible approach also entail that the protocol is not primarily targeted at stakeholders interested in purely quantitative and directly comparable data for companies within or between sectors.

The protocol was gradually developed through the author's own work on the AI ethics and the relation to governance and sustainability reporting (Sætra, 2021a, 2021b, 2022), and through his work as a sustainability consultant in KPMG Norway. This combined experience demonstrated both the lack of actionable potential in much AI ethics related work, as it tends to be developed far away from corporate C-suites, and how existing sustainability and ESG related standards and frameworks lack sufficient sector specific guidance for AI and data intensive companies. The process consisted of an examination of relevant existing standards and frameworks and the subsequent development of the new AI ESG protocol which incorporates key insights from, for example, AI ethics.

4.1 | Protocol structure

The AI ESG protocol can be completed through manual reconstruction of the information contained in this article, or through ready-made tools online or offline, being produced and scheduled to be made available spring 2023.[1] The structure of the entire protocol is presented in Figure 4, and while a completed protocol provides the most value to the reporting entity and stakeholders, it is also possible to only do parts of the protocol. Decisions regarding how to use the protocol must be made on the basis of how the protocol fits into the entity's existing ESG and sustainability related strategy and reporting structures. The AI ESG protocol's four main parts are the initial descriptive statement, the main impact statement, the risks and opportunities statement, and an action plan, each of which is described below.

The *Initial descriptive statement* contains a qualitative description of how and where AI and data capabilities and assets reside in the organization, and what sort of activities are related to these capabilities and assets. Users of the protocol are encouraged to include an organizational chart which helps situate AI and data in the organization. This statement should also help clarify who is operationally in charge of developing and handling AI and data in the organization, but also who is formally responsible. Furthermore, any relevant strategy, action plan, and governance related documents should be linked to and briefly explained, including, for example, processes related to AI and data internal audits (Minkkinen et al., 2022; Raji et al., 2020). Finally, if relevant, the entity should describe its ethics policy and whether this is based on existing frameworks or guidelines related to, for example, trustworthy or responsible AI (Dignum, 2019; High-Level Expert Group on Artificial Intelligence, 2019).

Key elements in the initial descriptive statement:

1. Where in the entity is AI used?
2. What sort of data does the entity control?
3. What sort of AI and data related capabilities does the entity have?
4. How is AI and data used in the contexts described above?
5. Who is operatively in charge, and who holds responsibility?
6. What are the relevant strategies, plans, and governance documents?
7. Is there an ethics policy, and/or does the entity subscribe to any ethics/sustainability standard?

The *Main impact statement* is the core of the AI ESG protocol and is described in more detail in the next section detailing the impact questionnaire. This is the part of the protocol where impacts related

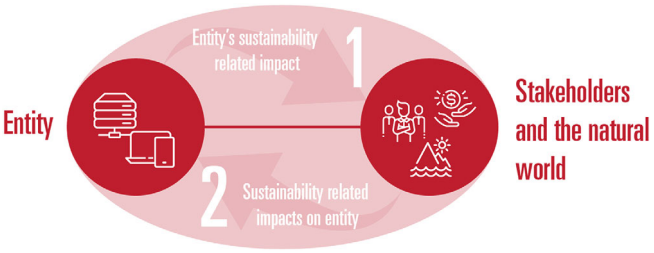


FIGURE 5 Double materiality, with outbound impact considered first, then inbound risks and opportunities. *Source*: Author's own arrangement [Colour figure can be viewed at wileyonlinelibrary.com]

to ESG for all scopes are mapped based on a set structure and guiding questions. This statement is both qualitative and quantitative and presents both known impacts *and* data and knowledge gaps. Key elements in the main impact statement are described in the next section.

In the *Risks and opportunities* part, an entity will evaluate the content of Parts 1 and 2 in order to arrive at a comprehensive picture of the risks and opportunities (upside risk) related to the entity's AI and data based capabilities, assets, and activities. This is facilitated by the structure of the main impact statement, which conveys both known impacts and identified data and knowledge gaps. Depending on the entity's approach to risk management, this analysis can be integrated into a broader approach. If the entity does not have other supporting processes the AI and data risk assessment can be integrated into, the AI ESG Protocol suggests constructing a risk matrix and performing a materiality analysis of AI and data related topics (Jebe, 2019; Ni et al., 2010), and finally coupling this with an AI and data readiness assessment. The protocol is open for a variety of approaches to these latter aspects, and a business can, for example, use the AI readiness framework proposed by Holmström (2022).

Key elements in the risks and opportunities statement:

1. What are the main identified risks and opportunities?
2. Risk analysis and matrix
3. Materiality analysis and matrix
4. Readiness assessment

It is highly encouraged to adopt a *double materiality* approach to the identification of material issues do be disclosed, which is also the approach adopted in the GRI framework and European regulation on sustainability disclosure for financial (SFDR) companies and others (as seen in the EU taxonomy and in the coming CSRD) (Adams et al., 2021; Deloitte, 2022). The double materiality approach proposed is shown in Figure 5 and highlights how material issues are not restricted to those that pose financial risks and opportunities for a company (left/inbound arrow), but also the sustainability related impacts of the company's activities (right/outbound arrow). It is recommended to start with an analysis of outbound impact before assessing the risks and opportunities for the company's development, performance, and position (often referred to as financial materiality and the approach adopted in the TCFD), as this encourages casting the net broadly enough to avoid unduly prioritizing traditional financial risks (Adams et al., 2021).

Finally, it is encouraged to follow Step 3 with the development of an action plan for improving ESG performance, unless AI and data are naturally integrated in existing strategies and action plans. Based on the risk assessment and materiality analysis, the entity can identify which AI and data related aspects require attention, either in terms of negative impact mitigation, positive impact development, or attending to gaps in AI and data readiness. The action plan should describe which topics are addressed, what should be done, when it should be done, and describe in detail who oversees implementation and who controls progress on the initiatives described. It is also highly recommended to include a roadmap and a discussion of where the entity is currently at in its "AI ESG journey." When first reporting according to the protocol, not all data and statements will be complete, and it will be useful both for the entity and stakeholders to know what plans are in place for improving ESG performance and reporting in subsequent years.

Key elements in the action plan:

1. What must be done to limit risks and exploit opportunities?
2. What is the timeline for each action?
3. Who is responsible for implementation and overseen implementation?
4. How will the action be implemented?

4.2 | Impact questionnaire outline

The impact statement will partly be a statement of qualitative answers related to policy and approaches, and partly indicators measuring the quantity of capabilities, assets, and activities. As indicated by the presentation of potentially relevant topics above, all potential aspects cannot be covered in this article, but the main categories of the initial impact questionnaire are presented in Figure 6. The protocol builds on the division of AI impacts into the micro, meso, and macro levels (Sætra, 2022), and also uses the guide questions presented in *AI for the SDGs* (Sætra, 2022) as a starting point for many of the topics. This provides an approach which ensures that all major impacts are considered, but users of the protocol can decide to use other approaches if this is considered beneficial for their context.

For each topic, the AI ESG protocol suggests providing a qualitative statement and one or more of the following, depending on suitability:

1. Quantitative data on relevant indicators
2. Links and references to relevant indicators from other standards and framework (i.e., GRI)
3. Links to data sources (internal/external)
4. Links to policies, assessments, processes
5. Person/department responsible
6. External sources of information (suppliers, partners, etc.)

AI ESG protocol questionnaire, v0.1b AIESGprotocol

Scope	Up/down-stream	ESG	Topic
1	-	E	Number of owned computers - Type and categories
1	-	E	Cooling/power etc owned and operated on premises
1	-	G	Datasets produced and owned - governance and cybersecurity
1	-	S/G	Datasets produced and owned - Privacy and user interests
1	-	S	Workers exposure to environmental harms
1	-	S	Workers exposure to harmful data etc
1	-	E	Algorithms/models (internally developed) - energy cost in training (potentially also equipment costs/degradation)
1	-	S	Algorithms/models (internally developed) - negative impacts related to source data, privacy, etc
1	-	S	Algorithms/models (internally developed) - positive impacts related to source data, privacy, etc
1	-	G	Algorithms/models (internally developed) - documentation of origin and legality of data used
1	-	G	AI readiness evaluation results
2	Up	E	Electricity bought (for own computers - AI related)
2	Up	E	Type of electricity used (category)
2	Up	E	Algorithms/models (externally developed) - energy cost training and approx. number of users (potentially also equipment costs/degradation)
2	Up	S	Algorithms/models (externally developed) - negative impacts related to source data, privacy, etc
2	Up	S	Algorithms/models (externally developed) - positive impacts related to source data, privacy, etc
2	Up	G	Algorithms/models (externally developed) - risk assessment origin and legality of data used, due dilligence
3	Up	E	Own and sourced computer equipment - Production (life cycle assessment)
3	Up	S	Own and sourced computer equipment - Workers' rights
3	Up	G	Own and sourced computer equipment - Materials and circularity
3	Down	E	Use of company's AI based services - Positive environmental impact
3	Down	E	Use of company's AI based services - Negative environmental impact
3	Down	S	Use of company's AI based services - Positive social impact
3	Down	S	Use of company's AI based services - Negative social impact
3	Down	S	Use of company's AI based services - Positive sustainability related economic impact
3	Down	S	Use of company's AI based services - Negative sustainability related economic impact
3	Down	G	Use of company's AI based services - ESG risk assessment

FIGURE 6 Main categories in the impact questionnaire. *Source*: Author's own arrangement [Colour figure can be viewed at wileyonlinelibrary.com]

The AI ESG protocol is a high-level framework intended to be used with other frameworks, and this is also in line with the Esty and Cort's (2020) proposal to see reporting as *tiered*. Tier one contains the core mandatory disclosure elements, whereas tier two contains industry-specific indicators tailored specifically to, in this case, AI and data intensive entities.

As described above, general corporate governance related issues are reported through, for example GRI indicators on board composition, qualifications, and so forth, while the AI ESG protocol supplements the Tier 1 framework with more specialized information on governance related specifically to AI and data based capabilities, assets, and activities. Furthermore, the goal of the AI ESG protocol is not to subsume all existing or future more specialized frameworks and approaches to AI and data, and it can accommodate various approaches to, for example, ethical AI, AI auditing, AI impact assessments and AI governance approaches.

Another example of an additional framework already mentioned is the AI readiness framework of Holmström (2022). This framework consists of questions related to past and present issues related to AI in the categories of *technologies*, *activities*, *boundaries*, and *goals*, and constitutes one potentially valuable tool for use within the protocol—both in the initial descriptive statement, but particularly in the risks and opportunities part of the protocol.

5 | CONCLUSION

As AI and data capabilities, assets, and activities are increasingly important parts of modern organizations, understanding how these generate impacts, risks, and opportunities is imperative for proper governance and oversight. There is a lack of tools for systematically evaluating and disclosing such impacts and risks (Minkkinen et al., 2022), and the AI ESG protocol has here been proposed to meet this need.

The AI ESG protocol is a high-level and flexible tool intended to supplement existing standards and frameworks (e.g., the GHG protocol and the TCFD) and serves the Tier 2 function in the proposed future ESG hierarchy proposed by Esty (2020), as it provides specialized tools and indicators particularly relevant for AI and data intensive entities.

Another aspect of flexibility is that the protocol opens for various optional activities related to risk and maturity assessments and the development of action plans. This is done to meet the need for making ESG data more actionable and valuable not just for investors, but also for those making strategic decisions in the entity (Minkkinen et al., 2022).

AUTHOR CONTRIBUTIONS

Henrik Skaug Sætra is responsible for the conception and writing of all parts of the article.

ACKNOWLEDGMENT

Open access publication provided by Østfold University College. The author also wants to thank the anonymous reviewers and Matthew Smith at FCG Norway for their valuable comments and inputs on early versions of the manuscript.

CONFLICT OF INTEREST

The author is developing a solution to make the use of the AI ESG protocol easier and is consequently in a position to potentially gain from the adoption of the AI ESG protocol.

ORCID

Henrik Skaug Sætra https://orcid.org/0000-0002-7558-6451

ENDNOTE

[1] www.aiesgprotocol.com.

REFERENCES

Adams, C. A., Alhamood, A., He, X., Tian, J., Wang, L., & Wang, Y. (2021). The double-materiality concept: Application and issues. Retrieved from https://www.globalreporting.org/media/jrbntbyv/griwhitepaper-publications.pdf

Ambec, S., Cohen, M. A., Elgie, S., & Lanoie, P. (2013). The Porter hypothesis at 20: Can environmental regulation enhance innovation and competitiveness? *Review of Environmental Economics and Policy*, *7*(1), 2–22.

Arena, M., Azzone, G., Ratti, S., Urbano, V. M., & Vecchio, G. (2022). Sustainable development goals and corporate reporting: An empirical investigation of the oil and gas industry. *Sustainable Development*, *31*(1), 12–25.

Barley, S. R. (2020). *Work and technological change*. Oxford University Press.

Bender, E. M., Gebru, T., McMillan-Major, A., & Shmitchell, S. (2021). On the dangers of stochastic parrots: Can language models be too big. *Proceedings of FAccT*. https://doi.org/10.1145/3442188.3445922

Berenberg, J. (2018). *Understanding the SDGs in sustainable investing*. Joh. Berenberg, Gossler & Co. KG. Retrieved from https://www.berenberg.de/files/ESG%20News/SDG_understanding_SDGs_in_sustainable_investing.pdf

Berg, F., Koelbel, J. F., & Rigobon, R. (2022). Aggregate confusion: The divergence of ESG ratings. *Review of Finance*. https://doi.org/10.1093/rof/rfac033

Bose, D., & Bhattacharjee, S. (2022). Big data, data analytics and artificial intelligence in accounting: An overview. In S. Akter & S. F. Wamba (Eds.), *Handbook of big data methods*. Edward Elgar Publishing.

Bose, S. (2020). Evolution of ESG reporting frameworks. In D. C. Esty & T. Cort (Eds.), *Values at work* (pp. 13–33). Palgrave McMillan.

Brevini, B. (2021). *Is AI good for the planet?* Polity.

Brundtland, G. H., Khalid, M., Agnelli, S., Al-Athel, S., & Chidzero, B. (1987). *Our common future: The report of the world commission on environment and development*. Oxford University Press.

Brusseau, J. (2021). AI human impact: Toward a model for ethical investing in AI-intensive companies. *Journal of Sustainable Finance & Investment*, *1-28*, 1–28. https://doi.org/10.1080/20430795.2021.1874212

Cihon, P., Schuett, J., & Baum, S. D. (2021). Corporate governance of artificial intelligence in the public interest. *Information*, *12*(7), 275. https://doi.org/10.3390/info12070275

Crawford, K. (2021). *The atlas of AI: Power, politics, and the planetary costs of artificial intelligence*. Yale University Press.

Crona, B., & Sunsdström, E. (2023). Sweet spots or dark corners? An environmental sustainability examination of big data and AI in ESG. In T. Rana, A. Lowe, & J. Svanberg (Eds.), *Handbook of big data and analytics in accounting and auditing*. Springer Singapore.

Deloitte. (2022). The Challenge of Double Materiality: Sustainability Reporting at a Crossroad. Retrieved from https://www2.deloitte.com/cn/en/pages/hot-topics/topics/climate-and-sustainability/dcca/thought-leadership/the-challenge-of-double-materiality.html

Demuijnck, G., & Fasterling, B. (2016). The social license to operate. *Journal of Business Ethics*, *136*(4), 675–685. https://doi.org/10.1007/s10551-015-2976-7

Dignum, V. (2019). *Responsible artificial intelligence: How to develop and use AI in a responsible way*. Springer.

Dimson, E., Marsh, P., & Staunton, M. (2020). Divergent ESG ratings. *The Journal of Portfolio Management*, *47*(1), 75–87. https://doi.org/10.3905/jpm.2020.1.175

Du, S., & Xie, C. (2021). Paradoxes of artificial intelligence in consumer markets: Ethical challenges and opportunities. *Journal of Business Research*, *129*, 961–974. https://doi.org/10.1016/j.jbusres.2020.08.024

Eckhart, M. (2020). Financial regulations and ESG investing: Looking back and forward. In D. C. Esty & T. Cort (Eds.), *Values at work* (pp. 211–228). Palgrave McMillan.

Eng, L. L., Fikru, M., & Vichitsarawong, T. (2021). Comparing the informativeness of sustainability disclosures versus ESG disclosure ratings. *Sustainability Accounting, Management and Policy Journal*., *13*, 494–518. https://doi.org/10.1108/SAMPJ-03-2021-0095

ERM. (2022). *What's Next for Sustainable Business? 2022 Trends Report*. Retrieved from https://www.sustainability.com/thinking/2022-sustainability-trends-report/

Esty, D. C. (2020). Creating investment-grade corporate Sustainbility metrics. In D. C. Esty & T. Cort (Eds.), *Values at work* (pp. 51–80). Palgrave McMillan.

Esty, D. C., & Cort, T. (Eds.). (2020). *Values at work: Sustainable investing and ESG reporting*. Palgrave McMillan.

EU Technical expert group on sustainable finance. (2020). *Taxonomy: Final report of the Technical Expert Group on Sustainable Finance*. Retrieved from https://knowledge4policy.ec.europa.eu/publication/sustainable-finance-teg-final-report-eu-taxonomy_en

European Commission. (2019). *The European Green Deal*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640&from=EN

European Commission. (2022a). Corporate sustainability reporting. Retrieved from https://ec.europa.eu/info/business-economy-euro/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

European Commission. (2022b, June 22). A European approach to artificial intelligence. Retrieved from https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence

European Commission. (2022c). Sustainability-related disclosure in the financial services sector. Retrieved from https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/sustainability-related-disclosure-financial-services-sector_en

Fafaliou, I., Giaka, M., Konstantios, D., & Polemis, M. (2022). Firms' ESG reputational risk and market longevity: A firm-level analysis for the United States. *Journal of Business Research*, *149*, 161–177. https://doi.org/10.1016/j.jbusres.2022.05.010

Floridi, L. (2018). Soft ethics, the governance of the digital and the general data protection regulation. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *376*(2133), 20180081.

Floridi, L., & Cowls, J. (2019). A unified framework of five principles for AI in society. *Harvard Data Science Review*, *1.1*, 8cd550d1. https://doi.org/10.1162/99608f92.8cd550d1

Freeman, R. E., Martin, K., & Parmar, B. (2007). Stakeholder capitalism. *Journal of Business Ethics*, *74*(4), 303–314. https://doi.org/10.1007/s10551-007-9517-y

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, *5*(4), 210–233. https://doi.org/10.1080/20430795.2015.1118917

García-Sánchez, I. M., Aibar-Guzmán, B., Aibar-Guzmán, C., & Somohano-Rodríguez, F. M. (2022). The drivers of the integration of the sustainable development goals into the non-financial information system: Individual and joint analysis of their influence. *Sustainable Development*, *30*(4), 513–524. https://doi.org/10.1002/sd.2246

Goasduff, L. (2020, September 28). 2 Megatrends Dominate the Gartner Hype Cycle for Artificial Intelligence, 2020. Retrieved from https://www.gartner.com/smarterwithgartner/2-megatrends-dominate-the-gartner-hype-cycle-for-artificial-intelligence-2020/?utm_medium=social&utm_source=linkedin&utm_campaign=SM_GB_YOY_GTR_SOC_SF1_SM-SWG&utm_content=&sf238248256=1

Greenfield, P. (2018, March 26). The Cambridge Analytica files: The story so far. *The Guardian*. Retrieved from https://www.theguardian.com/news/2018/mar/26/the-cambridge-analytica-files-the-story-so-far

He, H., & Harris, L. (2020). The impact of Covid-19 pandemic on corporate social responsibility and marketing philosophy. *Journal of Business Research*, *116*, 176–182. https://doi.org/10.1016/j.jbusres.2020.05.030

High-Level Expert Group on Artificial Intelligence. (2019). *Ethics Guidelines for Trustworthy AI*. Retrieved from https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

Holmström, J. (2022). From AI to digital transformation: The AI readiness framework. *Business Horizons*, *65*(3), 329–339. https://doi.org/10.1016/j.bushor.2021.03.006

IFRS. (2022). International Sustainability Standards Board. Retrieved from https://www.ifrs.org/groups/international-sustainability-standards-board/

Jebe, R. (2019). The convergence of financial and ESG materiality: Taking sustainability mainstream. *American Business Law Journal*, *56*(3), 645–702. https://doi.org/10.1111/ablj.12148

Jobin, A., Ienca, M., & Vayena, E. (2019). The global landscape of AI ethics guidelines. *Nature Machine Intelligence*, *1*(9), 389–399.

Leitner-Hanetseder, S., & Lehner, O. M. (2022). AI-powered information and big data: Current regulations and ways forward in IFRS reporting. *Journal of Applied Accounting Research*. https://doi.org/10.1108/JAAR-01-2022-0022

Marczewska, M., & Kostrzewski, M. (2020). Sustainable business models: A bibliometric performance analysis. *Energies*, *13*(22), 6062. https://doi.org/10.3390/en13226062

Metcalf, J., Moss, E., Watkins, E. A., Singh, R., & Elish, M. C. (2021). Algorithmic impact assessments and accountability: The co-construction of impacts. *Proceedings of the 2021 ACM conference on fairness, accountability, and transparency*.

Minkkinen, M., Niukkanen, A., & Mäntymäki, M. (2022). *What about investors? ESG analyses as tools for ethics-based AI auditing*. AI & Society. https://doi.org/10.1007/s00146-022-01415-0

Mittelstadt, B. (2019). Principles alone cannot guarantee ethical AI. *Nature Machine Intelligence*, *1*(11), 501–507.

Moon, J. (2014). *Corporate social responsibility: A very short introduction*. OUP Oxford.

Musleh Al-Sartawi, A. M., Hussainey, K., & Razzaque, A. (2022). *The role of artificial intelligence in sustainable finance* (pp. 1–6). Taylor & Francis.

Mäntymäki, M., Minkkinen, M., Birkstedt, T., & Viljanen, M. (2022a). *Defining organizational AI governance* (pp. 1–7). AI and Ethics. https://doi.org/10.1007/s43681-022-00143-x

Mäntymäki, M., Minkkinen, M., Birkstedt, T., & Viljanen, M. (2022b). Putting AI ethics into practice: The hourglass model of organizational AI governance. *arXiv preprint arXiv:2206.00335*.

Ni, H., Chen, A., & Chen, N. (2010). Some extensions on risk matrix approach. *Safety Science*, *48*(10), 1269–1278. https://doi.org/10.1016/j.ssci.2010.04.005

Nosratabadi, S., Mosavi, A., Shamshirband, S., Kazimieras Zavadskas, E., Rakotonirainy, A., & Chau, K. W. (2019). Sustainable business models: A review. *Sustainability*, *11*(6), 1663. https://doi.org/10.3390/su11061663

Papagiannidis, E., Enholm, I. M., Dremel, C., Mikalef, P., & Krogstie, J. (2022). Toward AI governance: Identifying best practices and potential barriers and outcomes. *Information Systems Frontiers*, *1-19*, 1–19. https://doi.org/10.1007/s10796-022-10251-y

Porter, M. E., & Van der Linde, C. (1995). Green and competitive: Ending the stalemate. *Harvard Business Review*, *73*, 5, Retrieved from. https://hbr.org/1995/09/green-and-competitive-ending-the-stalemate

Raji, I. D., Smart, A., White, R. N., Mitchell, M., Gebru, T., Hutchinson, B., Smith-Loud, J., Theron, D., Barnes, P. (2020). Closing the AI accountability gap: defining an end-to-end framework for internal algorithmic auditing. *Proceedings of the 2020 Conference on Fairness, Accountability, and Transparency*.

Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., Ross, A. S., Milojevic-Dupont, N., Jaques, N., Waldman-Brown, A., Luccioni, A. S., Maharaj, T., Sherwin, E. D., Mukkavilli, S. K., Kording, K. P., Gomes, C. P., Ng, A. Y., Hassabis, D., Platt, J. C., … Waldman-Brown, A. (2022). Tackling climate change with machine learning. *ACM Computing Surveys (CSUR)*, *55*(2), 1–96.

Schneider, J., Abraham, R., Meske, C., & Vom Brocke, J. (2022). Artificial intelligence governance for businesses. *Information Systems Management*, *1-21*, 1–21. https://doi.org/10.1080/10580530.2022.2085825

Schwab, K., & Vanham, P. (2021). *Stakeholder capitalism: A global economy that works for Progress, people and planet*. Wiley.

SDG Compass. (2015). *SDG Compass: The guide for business action on the SDGs*. Retrieved from https://sdgcompass.org

Securities and Exchange Commission. (2021). Self-Regulatory Organizations; The Nasdaq Stock Market LLC; Order Approving Proposed Rule Changes, as Modified by Amendments No. 1, to Adopt Listing Rules Related to Board Diversity and to Offer Certain Listed Companies Access to a Complimentary Board Recruiting Service [Press release]. Retrieved from https://www.sec.gov/rules/sro/nasdaq/2021/34-92590.pdf

Sivarajah, U., Kamal, M. M., Irani, Z., & Weerakkody, V. (2017). Critical analysis of big data challenges and analytical methods. *Journal of Business Research*, *70*, 263–286. https://doi.org/10.1016/j.jbusres.2016.08.001

Sætra, H. S. (2021a). AI in context and the sustainable development goals: Factoring in the unsustainability of the sociotechnical system. *Sustainability*, *13*(4), 13041738. https://doi.org/10.3390/su13041738

Sætra, H. S. (2021b). A framework for evaluating and disclosing the ESG related impacts of AI with the SDGs. *Sustainability*, *13*(15), 8503.

Sætra, H. S. (2022). *AI for the sustainable development goals*. CRC Press.

Sætra, H. S., & Fosch-Villaronga, E. (2021). Research in AI has implications for society: How do we respond? *Morals & Machines*, *1*(1), 60–73.

TCFD. (2022). Task Force on Climate-related Financial Disclosures. Retrieved from https://www.fsb-tcfd.org

UN Global Compact. (2022). United Nations Global Compact. Retrieved from https://www.unglobalcompact.org

UNFCCC. (2022). Paris agreement. Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. Division for Sustainable Development Goals.

van Wynsberghe, A. (2021). Sustainable AI: AI for sustainability and the sustainability of AI. *AI and Ethics*, *1-6*, 213–218. https://doi.org/10.1007/s43681-021-00043-6

Verbin, I. (2020). *Corporate responsibility in the digital age: A Practitioner's roadmap for corporate responsibility in the digital age*. Routledge.

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, *122*, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., Tegmark, M., & Nerini, F. F. (2020). The role of artificial intelligence in achieving the sustainable development goals. *Nature Communications*, *11*(1), 1–10. https://doi.org/10.1038/s41467-019-14108-y

Wamba-Taguimdje, S.-L., Wamba, S. F., Kamdjoug, J. R. K., & Wanko, C. E. T. (2020). Influence of artificial intelligence (AI) on firm performance: The business value of AI-based transformation projects. *Business Process Management Journal*, *26*(7), 1893–1924. https://doi.org/10.1108/BPMJ-10-2019-0411

World Economic Forum. (2020). *Measuring Stakeholder Capitalism: Towards Common Metrics and Consistent Reporting of Sustainable Value Creation*. Retrieved from https://www.weforum.org/reports/measuring-stakeholder-capitalism-towards-common-metrics-and-consistent-reporting-of-sustainable-value-creation

World Resources Institute. (2021). We set the standards to measure and manage emissions. Retrieved from https://ghgprotocol.org

How to cite this article: Sætra, H. S. (2023). The AI ESG protocol: Evaluating and disclosing the environment, social, and governance implications of artificial intelligence capabilities, assets, and activities. *Sustainable Development*, *31*(2), 1027–1037. https://doi.org/10.1002/sd.2438

ARTICLES FOR FACULTY MEMBERS

A NEW DIGITAL TRANSFORMATION FRAMEWORK TO ENHANCE ESG PERFORMANCE FOR PUBLIC LISTED COMPANIES IN MALAYSIA

The impact of digital transformation on ESG performance / Li, Y., Zheng, Y., Li, X., & Mu, Z.

International Review of Economics & Finance
Volume 96 Part B (2024) 103686 Pages 1-16
https://doi.org/10.1016/j.iref.2024.103686
(Database:ScienceDirect)

International Review of Economics and Finance 96 (2024) 103686

Contents lists available at ScienceDirect

International Review of Economics and Finance

journal homepage: www.elsevier.com/locate/iref

The impact of digital transformation on ESG performance

Yuxuan Li [a], Yingxue Zheng [b], Xuesong Li [a,*], Zi Mu [c]

[a] Economics and Management School, Wuhan University, Wuhan, 430072, China
[b] School of Foreign Languages, Central China Normal University, Wuhan, 430079, China
[c] School of Environment, Education & Development, The University of Manchester, Manchester, M13 9PL, United Kingdom

ARTICLE INFO

Keywords:
Digital transformation
Enterprise growth capacity
ESG performance
Intermediary effect

ABSTRACT

This paper constructs an analytical framework of digital transformation affecting enterprise ESG performance based on the investment perspective. And empirical analyses are conducted using firm-level panel data of Chinese A-share listed companies from 2009 to 2020 in the China's Stock Markets. It is found that digital transformation significantly improves enterprise ESG performance. Digital transformation improves enterprise ESG performance by enhancing risk-taking capacity, mitigating agency conflicts, and suppressing management overconfidence. Heterogeneity analyses show that the effects of digital transformation on capital investment efficiency and firms' ESG performance are more pronounced among firms in mature and declining stages. Digital transformation has a significant impact on capital investment efficiency and corporate ESG performance in both technology-intensive and capital-intensive firms. These findings are crucial for understanding the key role of digital transformation in shaping long-term economic growth potential and sustainability from an investment perspective.

1. Introduction

Adam Smith pointed out in "The Wealth of Nations" that value creation is the fundamental driving force for a country's wealth accumulation and growth. In the era of the industrial economy, enterprises, as the main body of value creation, are the source of power to promote social progress. As the core element of enterprise management, capital scarcity, and liquidity play a vital role in enterprise growth capacity creation and become the concentration of enterprise control rights. Reflect. Since the reform and opening up, Chinese enterprises have undergone tremendous changes for more than 40 years, creating double miracles of scale expansion and value growth. However, in the face of the changes in the domestic "triple pressure" situation, Chinese enterprises still have insufficient industrial integration and low factor efficiency (Wang & Lee, 2022). As well as the lack of new development momentum and other issues, the extensive value growth model of "large-scale capital investment promotion" is unsustainable. The most direct economic consequence of the application of digital technology is a change in factor efficiency. Capital is one of the core production factors for economic growth and development. In the past, crude investments have reduced capital efficiency, and they will inevitably be affected by the all-round transformation of digital technology - application of digital technology (Li et al., 2023). The application of digital technology will make the mode of capital factor application gradually shift from crude capital accumulation to precise and efficient capital efficiency enhancement, pointing out the direction for improving enterprise ESG performance and promoting the ability of economic

* Corresponding author.
E-mail addresses: tanshui2333@163.com (Y. Li), Kelly199909@163.com (Y. Zheng), Xsli@whu.edu.cn (X. Li), zi.mu@postgrad.manchester.ac.uk (Z. Mu).

https://doi.org/10.1016/j.iref.2024.103686
Received 11 June 2024; Received in revised form 9 October 2024; Accepted 14 October 2024
Available online 16 October 2024

transformation and sustainable development.

When exploring the factors influencing enterprise Environmental, Social, and Governance (ESG) Performance, current research focuses on the dual dimensions of overall corporate behavior and individual behavior of top executives. The overall behavior of a company is manifested in its comprehensive commitment and strategic deployment regarding environmental protection, social responsibility, and corporate governance, directly impacting the company's ESG performance (Clementino & Perkins, 2021). The investment capability, educational background, and emotional and psychological characteristics of top executives also play a crucial role in shaping enterprise ESG performance. Additionally, corporate governance capability, organizational flexibility, clarity of strategic actions, and the construction of social relationship networks are all considered significant factors influencing enterprise ESG performance (Singh & Pillai, 2022). Therefore, enterprises need to comprehensively consider all aspects in order to accurately formulate and implement strategies that meet enterprise ESG standards, thereby promoting both sustainable economic development and social value.

In analyzing the transmission mechanisms of how digital transformation affects enterprise ESG performance, existing literature presents diverse viewpoints and insufficient exploration of transmission mechanisms. On the one hand, Alkaraan et al. (2022) argue that digital transformation can effectively enhance a company's ESG performance through measures such as improving information transparency and optimizing decision-making processes. Luo et al. (2023) believe that digital transformation can drive companies to more actively fulfill ESG responsibilities, leading to a significant improvement in ESG performance. On the other hand, Fang et al. (2023) suggest that during the process of digital transformation, companies may experience significant changes in talent and resource structures, which could have a short-term adverse impact on ESG performance. Especially in the context of the digital economy era, enterprises ESG performance may faces challenges that will inevitably lead to profound changes in traditional production methods and models.

As a comprehensive indicator for assessing the non-financial performance of enterprises, enterprise ESG performance not only reflects the performance of enterprises in various aspects such as environmental sustainability, social responsibility and corporate governance, but also profoundly reflects the ability of long-term economic growth and sustainable development. As a key indicator of capital allocation and utilization, investment efficiency is directly related to the rationality and effectiveness of economic resource allocation. Efficient investment efficiency means that an enterprise is able to accurately identify market opportunities and optimize capital allocation in order to maximize the use of economic resources. Key factors such as the governance mechanism, decision-making efficiency and risk management capability of enterprises are fully reflected in investment efficiency. Further, economies with efficient investment tend to be better able to balance short-term economic interests with long-term sustainable development. While pursuing economic returns, enterprises continue to improve their enterprise ESG performance through continuous innovation and improvement to realise long-term values such as environmental protection and social responsibility, which ultimately benefit the whole economy. Therefore, investment efficiency significantly reflects the core values of enterprise ESG performance and economic sustainability.

Given that current research lacks in-depth analysis from the investment perspective when exploring the relationship between digital transformation and ESG performance, this paper focuses on the three dimensions of investment willingness, investment confidence, and investment sentiment to systematically explore the mechanism of digital transformation's impact on enterprise ESG performance. By adopting rigorous empirical research methods such as fixed effects, this paper aims to examine the specific effects of digital transformation on ESG performance and reveal the underlying mechanisms. This research not only helps to enrich the theoretical discussions in related academic fields, provides an important basis for the optimal allocation of economic resources and sustainable economic development strategies in the context of the digital economy.

2. Theoretical analysis and hypothesis formulation

With the in-depth application of digital technology, the operational logic of enterprises is undergoing unprecedented changes, which in turn has a profound impact on ESG performance. First, the advancement of digital transformation has optimized ESG-related investment decisions by significantly reducing information asymmetry inside and outside the enterprise, with enterprises more accurately assessing the risks of investment projects. Second, the organizational model changes driven by digital technology have enhanced the level of information governance in enterprises, and also motivated management to more actively seize market opportunities and assume social responsibility, and to continuously improve corporate governance (Zhang & Zhao, 2023). The dual-wheel drive of operation logic and organizational model change comprehensively improves the ESG performance and lays a solid foundation for sustainable and long-term development economically. Based on the above analysis, this article puts forward the following hypotheses.

H1. *Digital transformation improves enterprise ESG performance.*

The depth of empowerment that digital technologies provide to businesses elicits various responses from internal elements and behaviors within the enterprise. ESG performance, as an essential pursuit for sustainable development, undergoes changes in its performance during the process of digital transformation. Firstly, there is the impact of excessive ESG performance. Excessive ESG performance in companies often stems from limitations in the company's capacity to manage environmental, social, and governance risks, preferences of leaders towards certain ESG performance aspects, and external macroeconomic factors. In a digital environment, companies can utilize the efficient information dissemination capabilities of digital technologies to reduce information asymmetry regarding ESG performance both internally and externally. This helps leaders gain a deeper understanding of the actual circumstances of projects, standardize ESG performance preferences, and enhance the scientific assessment of ESG risks and expected returns of projects. Secondly, there is the impact of insufficient ESG performance. The organizational restructuring process brought about by

digital transformation in companies can effectively reform the governance structure of ESG performance both internally and externally. The improvement in governance levels helps urge management to seize ESG profit opportunities, reduce tendencies of management to seek stability, and shrink investments in ESG, thereby addressing issues of insufficient ESG performance. Therefore, this article proposes the following hypotheses.

H2. *Digital transformation improves risk-taking and boosts enterprise ESG performance.*

In reality, due to incomplete and asymmetric information, it is often difficult to optimize corporate decision-making within the environmental, social and governance (ESG) domain, which in turn triggers a series of problems such as environmental damages, lack of social responsibility and poor governance. However, with the advent of the digital era, digital transformation of corporate governance structures and organizational models provides new perspectives and tools for improving ESG performance. Specifically, digital transformation significantly improves the transparency and efficiency of corporate decision-making management, internal control and other processes in the ESG area by building an accurate and reliable data information system. First, digital transformation reconfigures the traditional organizational power structure and promotes the formation of a decentralized and disintermediated grid organizational model. The open and ecological organizational model helps the rise of grassroots autonomous organizations, which in turn reduces the marginal cost of information acquisition and processing, realizes ESG-related multi-agent autonomous decision-making, and improves the efficiency and quality of ESG decision-making. Second, digital technology, with its intuitive and quantitative features, can accurately depict the production, sales and innovation activities of enterprises, especially in terms of environmental and social responsibility. With the help of data analysis and visualization technologies, companies are able to examine their own performance in ESG more clearly, weakening the information advantage of controlling shareholders and management and reducing agency costs. Based on the above analysis, this article puts forward the following hypotheses.

H3. *Digital transformation can effectively improve enterprise ESG performance by reducing corporate agency conflicts.*

Traditional financial theory emphasizes that firms should aim to maximize profits, but in practice, managers are often constrained by irrational factors. In particular, when managers are overconfident, they may overestimate the company's ESG performance, misleading investors and leading to misallocation of resources, which only harms the long-term value of the enterprise and may also have a negative impact on economic sustainable and long-term development. In the context of the digital era, digital transformation helps company management gain a more comprehensive understanding of the company's ESG performance and clarify the boundaries of the company's dynamic ESG capabilities, thus avoiding unrealistic ESG commitments or investment decisions made due to overconfidence. Through accurate data analysis and real-time monitoring, management can more accurately assess the company's enterprise ESG performance and formulate an ESG strategy that is in line with the company's actual situation. Second, digital transformation can widely mobilize the participation of employees and external stakeholders to strengthen the company's enterprise ESG governance through its powerful external expansion and internal penetration capabilities. Internal and external partners form a good interaction and jointly promote the improvement of enterprise ESG performance. In addition, in the process of manager turnover, the historical data formed by the detailed preservation and analysis of past ESG performance data by digital technology can help the new manager understand the company's enterprise ESG status and form a lasting accumulation of ESG experience. It ensures the consistency and continuity of enterprise ESG strategy and promotes the long-term stable development. Based on the above analysis, this article puts forward the following hypotheses.

H4. *Digital transformation reduces management overconfidence and effectively improves enterprise ESG performance.*

Digital technology is an innovative and increasingly important tool that has shown great potential to drive enterprise ESG performance improvement. Digital technology not only possesses a high threshold of application and a deep knowledge base, but is also conceptually complementary to other management tools and techniques. First, from the perspective of factor endowment theory, technology-intensive enterprises have effectively promoted the optimization of environmentally friendly practices, social responsibility commitment and corporate governance structure by building an internal enterprise ESG knowledge system. When digital technology is applied, the various production sectors in the economy can quickly adapt to the new digital technology, reducing the difficulty of resource integration in the economy, thus accelerating the achievement of the goal of sustainable economic development. Meanwhile, capital, as a core element of enterprise operations, has a direct relationship with enterprise ESG performance in terms of its liquidity and utilization efficiency. Introducing digital technology into enterprise operations builds a financial information system that realizes accurate management and monitoring of enterprise capital flow. With the further application of digital technology, enterprises are able to allocate resources more efficiently and promote the overall improvement of enterprise ESG performance. In addition, based on the perspectives of enterprise organization theory and learning theory, the functional characteristics of digital technology provide opportunities for enterprise management to quickly collect and learn cross-industry knowledge. In the early stages of corporate organizational growth, with the increase of industry knowledge barriers and the complexity of corporate organizational structure, the challenges faced by management in decision-making become increasingly severe. However, with the aid of digital technology, management can quickly grasp industry dynamics and best practices, forming a late-mover advantage and thus driving a breakthrough in enterprise ESG performance and economic growth. Based on this, the following hypotheses are proposed.

H5. *The effect of digital transformation on enterprise ESG performance is heterogeneous for firms with different life cycles and factor endowments.*

3. Research design

3.1. Model setting and variable selection

3.1.1. Model setting

An efficient investment decision-making process often implies that a firm is able to fully consider the potential impact of its projects on the environment, pay attention to employee welfare and social responsibility, and maintain a good corporate governance structure (Landi et al., 2022). Therefore, a firm's investment decision and capital allocation process directly reflects its consideration of ESG performance. Further, by focusing on a firm's investment efficiency, it not only provides insight into the strengths and weaknesses of its financial performance, but also indirectly evaluates the firm's performance in terms of ESG (Ellili, 2022). Therefore, corporate investment efficiency can be used as a proxy indicator for ESG performance to comprehensively assess the comprehensive performance of enterprises from the perspective of investment, providing a more comprehensive and objective evaluation basis for the sustainable development of enterprises. The investment non-efficiency index proposed by Richardson and Chen is selected as the proxy index of corporate capital investment efficiency, and the following model is constructed with reference to the intermediary effect model:

$$Invest_{\text{Richit}} = \beta_0 + \beta_1 DCG_{1it} + \beta_{it} X + \varepsilon_i + \varepsilon_t + \mu_{it} \tag{1}$$

$$Invest_{\text{Chenit}} = \beta_0 + \beta_1 DCG_{1it} + \beta_{it} X + \varepsilon_i + \varepsilon_t + \mu_{it} \tag{2}$$

$$TobinQ_{it} = \beta_0 + \beta_1 DCG_{1it} + \beta_2 Invest_{\text{Richit}} + \beta_{it} X + \varepsilon_i + \varepsilon_t + \mu_{it} \tag{3}$$

$$TobinQ_{it} = \beta_0 + \beta_1 DCG_{1it} + \beta_2 Invest_{\text{Chenit}} + \beta_{it} X + \varepsilon_i + \varepsilon_t + \mu_{it} \tag{4}$$

3.1.2. Core variables

3.1.2.1. Digital transformation indicators. In order to ensure the robustness and accuracy of the conclusion, this article uses a variety of indicators to measure the degree of digital transformation of enterprises based on the analysis and reference of relevant academic research.

(1) Digital text word frequency index. This study uses Python tools to compile annual reports of A-share listed companies on the Shanghai Stock Exchange and Shenzhen Stock Exchange. Then, it uses the JavaPDFbox library to extract all text content from these reports. These text data are used as data sources for subsequent filtering of feature words (Chen et al., 2019). We built an indicator system for enterprise digital transformation. Taking into account the "right-skew" characteristics of the data, we logarithmically processed it to obtain an overall indicator that is more consistent with the distribution characteristics to describe the degree of digital transformation of the enterprise.

(2) Pilot indicators for implementing enterprise "integration of informatization and informatization" projects. This article refers to the method of constructing binary dummy variables: (1) Set Dum as a dummy variable for whether the enterprise has become a pilot enterprise for the integration of "informatization and informatization." Dum = 1 represents the enterprise during the sample period. Becomes a pilot enterprise for the integration of "two informatization," Dum = 0 means that the listed company has not become a pilot enterprise for the integration of "two informatization"; (2) Set Time as a dummy variable after the enterprise becomes a pilot enterprise for the integration of "two informatization," that is, the year (including the current year) after the enterprise becomes a "two-informatization" integration pilot enterprise, the value is assigned to 1. Otherwise, it is 0. The cross-multiplication term of the above binary dummy variable is set to the double difference statistic Dum × Time to form a digital transformation index. This reflects the impact of being a pilot enterprise of "two-technology" integration on ESG performance.

3.1.2.2. Investment efficiency index.

(1) Richardson model capital investment efficiency ($Invest_{Rich}$)

First, we estimate the expected investment of enterprises based on the model of Richardson (2006). The specific equation is as follows:

$$Invest_t = \alpha_0 + \alpha_1 Growth_{t-1} + \alpha_2 Lev_{t-1} + \alpha_3 Cash_{t-1} + \alpha_4 LnAge_{t-1} + \alpha_5 LnAsset_{t-1} + \alpha_6 Return_{t-1} + \alpha_7 Invest_{t-1} + \varepsilon_t \tag{1}$$

(2) Chen model capital investment efficiency ($Invest_{Chen}$)

First, we estimate the expected investment of enterprises based on the model of Chen and Chen (2011). The specific equation is as follows:

$$Invest_{it} = \alpha_0 + \alpha_1 Growth_{it-1} + \alpha_2 NEG_{it-1} + \alpha_3 Growth_{it-1} \times NEG_{t-1} + \varepsilon_{it} \tag{2}$$

in, *NEG* is a dummy variable, which takes 1 when the operating income growth rate is less than zero and 0 otherwise. Growth is defined in the same way as model (1). Through annual and industry regression, the absolute value of the residual is the enterprise's inefficient investment level (a reverse indicator of capital investment efficiency).

3.1.2.3. Mechanism variables.

(1) Enterprise agency conflict

Generalized agency costs consist of three components: the principal's supervision costs, the agent's guarantee costs, and residual losses, but no method can directly measure agency costs. The existing literature on quantitative research on agency costs is provided by Ang et al. (2000), who chose two indicators, management expense rate, and asset turnover rate, to measure two aspects of agency costs, respectively. Since then, relevant research at home and abroad has followed this idea (Anderson & Reeb, 2003; Li, 2007). The sales expense ratio (Expense, Operating Expense Ratio) is the ratio of operating expenses to annual sales. This indicator can effectively measure the degree of effective control of operating costs by company management, including excess allowance consumption and other direct agency costs (Cheng & Meng, 2023). It can be said that under a specific ownership and management structure, the product of the difference in sales expense ratio between a company and a benchmark company without agency problems and the company's total assets reflects the amount of expenses related to the company's excess agency costs.

(2) Corporate risk-taking

This article measures corporate risk-taking from the following four dimensions: (1) Performance dimension, measured by the volatility of corporate profits and annual volatility of stock returns. (2) Policy behavior dimension, measured by R&D intensity and debt ratio. (3) Survival status dimension, the measurement index is the company's survival time. (4) Attitude dimension, the measurement index is the weighted average investment life of failed projects within the company within nine years. Considering that most literature measures risk-taking levels from the performance dimension and that China's stock market has problems such as high volatility.

(3) Corporate management is overconfident

Referring to the research of Libby and Rennekamp (2012), we can judge whether the managers of listed companies are overconfident based on whether their profit forecasts have changed. We selected companies that disclosed first-quarter reports, semi-annual reports, third-quarter reports, and annual report profit forecasts from 2009 to 2020 as the objects of sample selection. We collect these earnings forecast information and stipulate that if the company's actual earnings level is lower than the predicted earnings level at least once during the sample period, the company's managers will be defined as overconfident.

3.1.2.4. Control variables. Table 1 shows the names of measurement variables and their related definitions. It is not difficult to see that in Table 1, this article selected indicators such as Ratio of independent directors and The large shareholder holdings to measure the

Table 1
Names of measurement variables and their related definitions.

variable name	variable tag	Variable definitions
corporate governance variables		
board size	*Boardsize*	Board size
Ratio of independent directors	Indepen	Ratio of number of independent directors to board size
The largest shareholder holds shares	Dor1	Proportion of shares held by the largest shareholder to total share capital
Whether the two positions are combined into one	Dual	When the chairman and general manager are the same person, the value is 1; otherwise, the value is 0
firm characteristic variables		
Company Size	Size	The logarithm of the company's total assets at the end of the year
ownership attributes	Nature	The actual owner attribute of the company, when Nature
Company financial resource status		
company return on assets	ROA	Net profit before tax/average total assets
Interest coverage ratio	LXBZ	Corporate EBIT/Interest Expense
Inventory turnover	ITA	Enterprise sales revenue/ending inventory value
Leverage ratio	LEVE	Total equity capital/total assets
Main business growth rate	GMP	(Operating income for the current period - Operating income for the previous period)/Operating income for the previous period
Industry characteristic variables		
industry return on assets	*LnROA*	Average ROA calculated by year and industry according to the industry classification of the China Securities Regulatory Commission
Industry financial leverage	*Lnleve*	The average asset-liability ratio calculated by year and industry according to the industry classification of the China Securities Regulatory Commission

equity structure of the enterprise, and also selected indicators such as Company Size, Company return on assets, and Leverage ratio to measure the operational and debt paying capabilities of the enterprise. In addition, to further enhance the stability of the results, this article also added industry control variables such as Industry characteristic variables, Industry return on assets, and Industry financial leverage to eliminate the influence of industries on the empirical results.

3.1.3. Descriptive statistics

Table 2 is the descriptive statistics and correlation analysis table of the main variables involved in this study. Observing the standard deviation of the variables, it can be found that there is a significant difference between the maximum value and the minimum value of the capital investment efficiency of listed companies, indicating that there are still many listed companies in China that have more room for improvement in terms of enterprise ESG performance investment. In addition, the differences in agency conflicts among listed companies are also large, which shows that many listed companies in my country still have problems, such as information asymmetry in their governance structures and mechanisms. The relationship between risk-taking and corporate investment efficiency also shows a specific positive correlation. However, the correlation coefficient between management overconfidence and corporate investment efficiency is positive, which is different from some actual situations, so it is still worthy of scrutiny and further verification.

4. Empirical analysis

4.1. Baseline regression

Based on the in-depth theoretical analysis, this section aims to further empirically validate the potential impact of digital transformation on enterprise ESG performance from the perspective of corporate investment decisions. To this end, a research framework similar to the previous one is adopted, and regression analysis is conducted through the digital word frequency index of annual reports as the key explanatory variable. From the empirical results in Table 3, both Models 1 and 2 significantly indicate that there is a positive correlation between enterprise digital transformation and its enterprise ESG performance. Specifically, the empirical model verifies that digital transformation helps to reduce corporate misbehavior or underperformance in investment decisions, which in turn enhances enterprise ESG performance. This is attributed to the positive impact of digital transformation on enterprise ESG performance in several ways. Digital transformation enhances enterprise ESG effectiveness by improving the ability to collect, analyze and process data, optimizing an enterprise's governance structure, and improving the efficiency and transparency of decision-making, enabling an enterprise to identify and manage investment risks more effectively, and reduce the adverse impacts arising from investments. To further enhance the robustness of this conclusion, the Tobit model is introduced as an alternative empirical test. The Tobit model has a unique advantage in dealing with restricted dependent variables and can more accurately capture the marginal impact of digital transformation on enterprise ESG performance. The regression analysis of the Tobit model yields conclusions consistent with the fixed effects model, further confirming the positive effect of digital transformation on enterprise ESG performance. This confirms hypothesis 1.

4.2. Robustness check

To ensure the robustness of the empirical results, this paper uses other explanatory variables to conduct regression and verify whether conclusions similar to the above regression results can be obtained.

Table 2
Descriptive statistics of variables from 2009 to 2020.

	minimum value	maximum value	mean	median number	standard deviation	Correlation coefficient
Q	0.152	126.951	2.137	1.643	2.571	1
DCG_1	0	6.098	0.888	0	1.180	0.069
DCG_2	0	1	0.409	0	0.492	0.183
$Invest_{Rich}$	0.006	130.699	44.701	34.310	46.495	−0.025
$Invest_{Chen}$	0.012	128.562	44.235	33.488	46.175	−0.027
Conflict	0.021	87.452	0.324	0.140	17.023	−0.332
Risk	0.086	0.182	0.118	0.119	0.028	0.089
OC	0	1	0.367	0	0.482	0.046
Board	1.098	2.890	2.146	2.197	0.197	−0.120
Indepen	0.090	0.800	0.369	0.333	0.054	0.024
Dual	0	1	0.273	0	0.445	0.075
*Dor*1	3	89.091	34.403	32.165	14.479	−0.076
Size	17.388	27.386	21.642	21.533	1.224	−0.422
ROA	−1.751	1.560	0.041	0.040	0.082	0.372
LXBZ	−19621.8	97970.7	35.858	2.103	1056.742	0.005
ITA	0	411161	38.693	3.561	3402.075	−0.049
LEVE	0.007	16.329	0.416	0.403	0.288	−0.339
GMP	−0.999	665.541	0.332	0.124	6.757	0.088
InROA	−0.128	0.187	0.048	0.045	0.022	0.017
Inleve	−1.638	3.039	0.392	1.210	0.228	0.136

Table 3
Empirical results of digital transformation and capital investment efficiency.

	(1)	(2)	(3)	(4)
	$Invest_{Rich}$	$Invest_{Chen}$	$Invest_{Rich}$	$Invest_{Chen}$
	Fixed effect	*Fixed effect*	*Tobit*	*Tobit*
DCG_1	−0.871 ***	−0.905***	−0.019***	−0.018***
	(-2.67)	(-2.75)	(-4.38)	(-4.23)
Board	2.006	1.385	0.012	0.016
	(0.42)	(0.29)	(0.36)	(0.49)
Indepen	−1.624	−4.400	0.070	0.090
	(-0.11)	(-0.31)	(0.62)	(0.80)
Dual	2.544*	2.389	0.016	0.017
	(1.65)	(1.54)	(1.33)	(1.44)
*Dor*1	0.278***	0.283***	0.002***	0.001***
	(3.79)	(3.86)	(4.71)	(4.46)
Size	−12.072***	−12.472 ***	−0.070 ***	−0.067***
	(-13.33)	(-13.76)	(-12.16)	(-11.80)
ROA	110.929***	105.756***	0.107***	0.112***
	(8.73)	(8.32)	(9.96)	(10.45)
LXBZ	−0.015	−0.023	−0.000	−0.000
	(-0.42)	(-0.64)	(-0.87)	(-0.68)
GMP	1.040***	0.990***	0.009***	0.009***
	(10.04)	(9.56)	(9.65)	(10.02)
ITA	−0.007**	−0.007**	−0.000	−0.000
	(-2.31)	(-2.30)	(-1.62)	(-1.57)
LEVE	43.291***	41.645***	0.044***	0.045***
	(9.17)	(8.81)	(13.09)	(13.42)
Inleve	−5.080	−4.298	0.040	−0.003
	(-1.62)	(-1.37)	(0.15)	(-0.01)
InROA	0.716	0.618**	0.026	0.006
	(1.64)	(1.97)	(0.56)	(0.24)
Constants	272.670***	284.598***	0.164***	0.155***
	(11.33)	(11.82)	(11.21)	(10.78)
individual effect	control	control		
time effect	control	control		
N	11578	11578	10524	10524
R2 -	0.059	0.058		
F	47.111	46.551		

4.2.1. Endogeneity test—instrumental variable regression

According to the development laws of the telecommunications industry, when China builds communication infrastructure, it mainly promotes it from two aspects. The first is to erect aerial cables and optical fibers, and the second is to lay underground communication optical cables. Therefore, we believe there is a positive relationship between the density of underground pipe corridors and urban informatization, and it assists the digitalization of local enterprises. Therefore, we collected the underground pipe network density in 1984 by collecting provincial and municipal statistical yearbooks and city statistical yearbooks as the instrumental variables of this article. On the one hand, urban pipe corridors lay a first-mover advantage for the construction of information infrastructure and provide the possibility for the digitalization of enterprises in the jurisdiction; on the other hand, the density of underground pipe networks at the urban level has nothing to do with the investment efficiency of the enterprise itself. Therefore, the density of urban underground pipe networks also meets exogenous conditions in terms of economic explanation.

Through two-stage instrumental variable regression, it was found that the density of underground pipe networks in the city where the company was located in 1984 positively affected its level of digital transformation. Table 4 shows the regression results of instrumental variables. After two-stage instrumental variable regression, it is found that consistent with the previous article, digital transformation indicators and instrumental variable regression shows a positive and significant effect in the first stage of regression. After removing confounding factors in the second stage, digital transformation still has a significant impact on reducing inefficient investments and promoting enterprise ESG performance. At the same time, the Cragg-Donald Wald F tests of the two sets of regressions are 16.087 and 18.016, respectively, which are much greater than 10. This shows that the selected instrumental variables do not have the problem of weak instrumental variables, and the above conclusion is robust.

4.2.2. Propensity score matching and difference-in-differences estimation

1) Variable setting and propensity score matching

In order to further verify the robustness of the relevant conclusions, this study uses the 'two informatization' integration standard

Table 4
Instrumental variable regression of digital transformation and capital investment efficiency.

	(1)	(2)	(3)	(4)
	DCG_1 The first stage	$Invest_{Rich}$ second stage	DCG_1 The first stage	$Invest_{Chen}$ second stage
DCG_1		−3.446**		−4.056***
		(-2.02)		(-3.49)
Boardsize	−0.826**	−0.102***	−0.623*	−0.216**
	(-1.98)	(-3.21)	(-1.85)	(-2.20)
Indepen	−0.041	−0.053	−0.032**	−0.043***
	(-1.59)	(-1.34)	(-2.26)	(-2.42)
Dual	0.045*	−0.084***	−0.065***	0.084**
	(1.81)	(-3.45)	(-3.64)	(2.01)
*Dor*1	−0.271***	−0.146**	−0.099**	−0.062**
	(-3.01)	(-2.05)	(-1.73)	(-1.94)
Size	−0.079***	0.058	0.018**	0.054**
	(-3.64)	(2.05)	(1.70)	(2.06)
ROA	−0.128***	−0.087***	0.109	0.091
	(-3.49)	(-2.58)	(1.12)	(1.34)
LXBZ	−0.002*	−0.001	0.001*	0.002**
	(-1.77)	(-1.01)	(1.84)	(1.75)
GMP	0.489***	0.158**	−0.094***	−0.041**
	(3.49)	(2.05)	(-3.18)	(-2.16)
ITA	0.001	0.000	0.002 *	0.001 **
	(1.54)	(1.19)	(1.70)	(2.11)
LEVE	0.002	0.058	0.015	0.004
	(1.19)	(1.26)	(1.54)	(0.39)
Inleve	−0.071	−0.067 **	0.013	0.057 *
	(-0.36)	(-2.15)	(1.33)	(1.88)
InROA	0.094**	0.291	0.078	0.036***
	(2.10)	(1.04)	(1.49)	(2.65)
IV	1.380***		1.064***	
	(5.05)		(5.49)	
Constants	−9.482***	−4.056***	−16.194***	−13.241***
	(-2.84)	(-2.60)	(-6.31)	(-3.18)
individual effect	control	control	control	control
time effect	control	control	control	control
N	12483	12483	12483	12483
R2 -	0.159	0.242	0.341	0.105
Cragg-Donald Wald F statistic	16.087		18.016	

implementation pilot as the digital external impact of the benchmark enterprise to construct double differential variables. The term' two informatization' refers to integrating informatization and industrialization, a key concept in this study. Then, the propensity score matching (PSM) method is used to form a PSM sample as a robustness test for the above conclusion. During the experiment, the samples were divided into the participating group (also called the experimental group, where 'Treated = 1′ indicates companies that were designated as 'informatization and industrialization' integration standards) and the non-participating group (also called the control group, where 'Treated = 0′ indicates companies that were not designated as such). The preliminary difference analysis is shown in Table 5.

2) Measurement results of double differential

This section verifies the robustness of the mechanism of digital transformation's impact on enterprise ESG performance and its

Table 5
Mean and median difference test.

	Participate in the " integration of informatization and informatization " certification	Not participating in the " integration of informatization and informatization " certification	mean difference
	mean	mean	t -statistic
$Invest_{Rich}$*rowhead*	38.221	56.127	−12.025***
$Invest_{Chen}$*rowhead*	36.654	55.161	−11.921***
	median number	median number	Median difference
$Invest_{Rich}$*rowhead*	29.542	38.498	−9.182***
$Invest_{Chen}$*rowhead*	28.969	37.541	−10.426***

breakdown based on the external impact of the "two-technology" integration policy and the double-difference model. Table 6 shows the measurement results of digital transformation on capital investment efficiency under the double-difference estimation. The results show that the coefficient of the double-difference variable is significantly positive, reaching the 1% significance level. This indicates that the conclusion that digital transformation improves enterprise ESG performance is robust. Moreover, this effect is more evident in the PSM sample. The above conclusion is also consistent with the conclusion in Table 3 in the previous article, which verifies the robustness of the benchmark regression results in this article.

5. Further discussion

5.1. Analysis of impact mechanism

5.1.1. Digital transformation, risk tolerance and enterprise ESG performance

Digitalization not only bolsters the external financing capabilities of enterprises but also fortifies their financial stability, thereby enhancing enterprise ESG performance. Table 7 presents the crucial findings of our study, which explores the relationship between enterprise digital transformation and enterprise ESG performance in the full sample. Our research reveals that digital transformation significantly enhances the risk-taking ability of enterprises. This finding, verified in Model 1 underscores the role of digital technology in improving corporate organizational and financial resilience. Moreover, our study demonstrates that the positive impact of digital transformation on risk-taking capabilities is robust and universally applicable to both state-owned and private enterprises. This significant finding, in line with our hypothesis 2, contributes to the understanding of the transformative power of digitization in the corporate finance landscape. Model 3 and Model 4 provide crucial insights into the role of corporate risk-taking capabilities in enhancing enterprise ESG performance. The empirical results underscore that bolstering these capabilities can curtail inefficient investments, laying a robust groundwork for corporate investment and augmenting enterprise ESG performance. This affirms that corporate digital transformation can foster ESG performance by augmenting risk-taking capabilities.

Table 6
Digital transformation and capital investment efficiency (PSM-DID method).

	(1) $Invest_{Rich}$	(2) $Invest_{Chen}$	(3) $Invest_{Rich}$	(4) $Invest_{Chen}$
	Full sample	Full sample	PSM sample	PSM sample
DCG_2	−0.009 ***	−0.008 ***	−0.007 **	−0.016 **
	(-2.75)	(-2.67)	(-2.41)	(-2.02)
Board	−0.049	−0.061	−0.011	−0.006
	(-0.25)	(-0.31)	(-1.11)	(-0.64)
Indepen	−0.034	−0.036	−0.008	0.018
	(-0.63)	(-0.67)	(-0.03)	(0.63)
Dual	0.012	0.011	−0.006 *	−0.005
	(1.58)	(1.51)	(-1.77)	(-1.52)
*Dor*1	0.041	0.037	−0.015	−0.015
	(1.55)	(1.41)	(-1.05)	(-0.98)
Size	−0.057	−0.053	−0.006 ***	−0.006 ***
	(-1.40)	(-1.32)	(-3.00)	(-3.20)
ROA	−0.005	0.015	−0.035	−0.012
	(-0.09)	(0.27)	(-1.34)	(-0.45)
LXBZ	−0.001	−0.001	−0.001	−0.001
	(-0.31)	(-0.21)	(-0.87)	(-0.89)
GMP	0.022 ***	0.022 ***	−0.010 ***	−0.008 **
	(5.45)	(5.60)	(-2.71)	(-2.12)
ITA	0.002	0.004	0.012 *	0.008
	(0.15)	(0.32)	(1.81)	(1.17)
LEVE	−0.025	−0.020	0.020 *	0.011
	(-1.05)	(-0.85)	(1.77)	(0.97)
Inleve	−0.013	−0.015	−0.010 *	−0.009
	(-1.05)	(-1.16)	(-1.87)	(-1.63)
InROA	−0.004	0.052	−0.003 *	−0.025 *
	(-1.18)	(1.35)	(-1.84)	(-1.93)
Constants	0.190 *	0.181 *	0.196 ***	0.199 ***
	(1.93)	(1.87)	(3.90)	(3.82)
individual effect	control	control	control	control
time effect	control	control	control	control
N	9080	9080	4560	4530
R2 -	0.122	0.130	0.112	0.105
F	5.139	5.527	3.075	2.827

Table 7
Digital transformation risk tolerance and capital investment efficiency.

	(1)	(2)	(3)	(4)	(5)	(6)
	Risk	*Risk*	$Invest_{Rich}$	$Invest_{Chen}$	$Invest_{Rich}$	$Invest_{Chen}$
DCG	0.030 ***	0.022 ***			−0.057 ***	−0.051 ***
	(7.97)	(5.09)			(-3.02)	(-2.72)
DCG × *Nat*		0.025 ***				
		(3.42)				
Risk			−0.068 ***	−0.061 ***	−0.046 **	−0.042 *
			(-3.71)	(-3.37)	(-1.99)	(-1.84)
Risk × *Nat*			0.026	0.022		
			(0.89)	(0.75)		
Nature		0.039	−0.006	−0.006		
		(1.54)	(-1.27)	(-1.29)		
Board	−0.015 ***	−0.015 ***	−0.004	−0.001	−0.015 ***	−0.015 ***
	(-5.36)	(-5.27)	(-0.10)	(-0.02)	(-5.48)	(-5.39)
Indepen	0.010	0.010	0.053	0.058	0.010	0.010
	(1.15)	(1.16)	(0.39)	(0.43)	(1.15)	(1.19)
Dual	−0.016 *	−0.019 **	0.028 *	0.027 *	−0.017 *	−0.019 **
	(-1.77)	(-2.02)	(1.83)	(1.79)	(-1.83)	(-2.06)
*Dor*1	−0.020 ***	−0.019 ***	0.017 **	0.017 **	−0.022 ***	−0.020 ***
	(-4.31)	(-4.06)	(2.43)	(2.50)	(-4.76)	(-4.42)
Size	0.096 ***	0.097 ***	−0.012 ***	−0.012 ***	0.102 ***	0.103 ***
	(18.78)	(18.96)	(-16.34)	(-16.11)	(21.09)	(21.15)
ROA	−0.010	−0.009	0.109 ***	0.113 ***	−0.009	−0.008
	(-1.46)	(-1.33)	(8.66)	(9.02)	(-1.32)	(-1.17)
LXBZ	0.00	0.000	−0.000	−0.000	0.000	0.000
	(0.39)	(0.40)	(-0.62)	(-0.41)	(0.41)	(0.41)
GMP	−0.008 **	−0.008 **	0.009 ***	0.009 ***	−0.008 **	−0.008 **
	(-2.05)	(-2.10)	(8.87)	(9.34)	(-2.05)	(-2.09)
ITA	−0.000	−0.000	−0.000 **	−0.000 **	−0.000	−0.000
	(-0.95)	(-0.92)	(-2.11)	(-2.12)	(-0.96)	(-0.93)
LEVE	−0.015	−0.014	0.042 ***	0.043 ***	−0.017	−0.017
	(-0.59)	(-0.56)	(9.34)	(9.61)	(-0.68)	(-0.68)
Inleve	0.019 ***	0.019 ***	−0.046 **	−0.051 **	0.019 ***	0.019 ***
	(9.85)	(9.83)	(-1.98)	(-2.18)	(9.98)	(9.91)
InROA	0.008 *	0.021 ***	0.141 **	0.091 ***	0.098 **	0.072 ***
	(1.91)	(3.98)	(2.25)	(4.92)	(2.43)	(3.81)
Constants	−0.063 ***	−0.068 ***	0.292 ***	0.285 ***	−0.075 ***	−0.080 ***
	(-4.52)	(-4.85)	(13.82)	(13.52)	(-5.51)	(-5.78)
individual effect	control	control	control	control	control	control
time effect	control	control	control	control	control	control
N	12484	12305	11407	11407	12483	12304
R2 -	0.103	0.104	0.058	0.059	0.102	0.102
F	104.784	89.035	43.215	43.750	103.449	87.906

5.1.2. Digital transformation, agency conflict and enterprise ESG performance

This section first examines the perspective of investment initiative, selecting agency conflict as the characterization criterion. The primary reason is that agency conflict encapsulates the discord between management and shareholders, with the ultimate goal of corporate investment behavior being to maximize corporate profits. Therefore, the ability of management to invest to maximize shareholders' interests has emerged as a crucial factor influencing the efficiency of enterprise ESG performance. The potential benefits of digital transformation in this context are significant, offering a promising avenue for improving enterprise ESG performance.

As evidenced by the results in Table 8, in Model 1, without considering the moderating effect of the nature of the enterprise, enterprise digital transformation can significantly reduce agency conflicts, with the significance level of the regression coefficient reaching 1%. We have initially concluded that digital transformation can significantly reduce agency costs. In Model 2, the coefficient of the cross-product term of enterprise nature variables and digitalization indicators is significantly negative. It is significantly larger than the regression coefficient of digital transformation indicators. Although this indicates to some extent that digital transformation has reduced agency costs of state-owned enterprises more significantly, the effect does not appear to be that pronounced. This may be due to the inherent separation of management rights and ownership of state-owned enterprises and the existence of soft budget constraints in state-owned enterprises, which results in the limited role of digital transformation. Model 3 and Model 4 studies the relationship between corporate agency conflict and enterprise ESG performance. It can be seen that agency conflict increases inefficient investment reduces ESG performance. In other words, agency conflict is significantly negatively related to ESG performance. The regression coefficients in Models 5 and 6 reach a significance level of 5%, confirming that digital transformation of enterprises can improve ESG performance of private enterprises by reducing agency conflicts. However, according to the regression coefficient of the cross-product between the nature of the enterprise and the efficiency of capital investment, it can be found that agency conflict within

Table 8
Digital Transformation, Agency Conflict and capital investment efficiency.

	(1)	(2)	(3)	(4)	(5)	(6)
	Conflict	*Conflict*	$Invest_{Rich}$	$Invest_{Chen}$	$Invest_{Rich}$	$Invest_{Chen}$
DCG	−0.029 **	−0.006 **			−0.012 ***	−0.010 **
	(-2.30)	(-2.23)			(-2.37)	(-1.99)
DCG × *Nat*		−0.072 *				
		(-1.72)				
Conflict			0.063 **	0.043 *	0.002**	0.023***
			(2.25)	(1.87)	(2.09)	(2.77)
Conflict × *Nat*			−0.016	−0.016		
			(-1.26)	(-1.25)		
Nature		0.025 *	−0.008	−0.013		
		(1.71)	(-0.19)	(-0.32)		
Board	−0.039 **	−0.039 **	0.002	0.014	−0.039 **	−0.038 **
	(-2.39)	(-2.31)	(0.00)	(0.03)	(-2.38)	(-2.30)
Indepen	−0.015	−0.008	0.004	0.004	−0.016	−0.010
	(-0.31)	(-0.17)	(0.30)	(0.29)	(-0.33)	(-0.21)
Dual	0.059	0.069	0.027 *	0.027 *	0.060	0.070
	(1.10)	(1.26)	(1.82)	(1.77)	(1.12)	(1.28)
*Dor*1	−0.003	−0.003	0.018 ***	0.018 ***	−0.003	−0.003
	(-1.34)	(-1.30)	(2.60)	(2.67)	(-1.18)	(-1.20)
Size	0.013 ***	0.013 ***	−0.012 ***	−0.012 ***	0.012 ***	0.012 ***
	(4.70)	(4.64)	(-16.95)	(-16.68)	(4.34)	(4.33)
ROA	0.998 ***	1.019 ***	0.108 ***	0.112 ***	0.996 ***	1.017 ***
	(25.24)	(25.47)	(8.57)	(8.90)	(25.19)	(25.41)
LXBZ	−0.000	−0.000	−0.000	−0.000	−0.000	−0.000
	(-1.22)	(-1.23)	(-0.65)	(-0.44)	(-1.20)	(-1.20)
GMP	−0.007 ***	−0.008 ***	0.092 ***	0.096 ***	−0.007 ***	−0.008 ***
	(-3.74)	(-3.75)	(8.97)	(9.41)	(-3.74)	(-3.75)
ITA	0.000	0.000	−0.000 **	−0.000 **	0.000	0.000
	(0.10)	(0.09)	(-2.08)	(-2.09)	(0.09)	(0.08)
LEVE	0.064 ***	0.062 ***	0.042 ***	0.043 ***	0.064 ***	0.062 ***
	(4.39)	(4.19)	(9.34)	(9.59)	(4.39)	(4.20)
Inleve	0.028 **	0.029 ***	−0.060 ***	−0.066 ***	0.029 ***	0.030 ***
	(2.55)	(2.60)	(-2.59)	(-2.84)	(2.58)	(2.66)
InROA	0.004	−0.005	−0.021 ***	−0.005 ***	0.011 *	0.004 **
	(1.65)	(-1.54)	(-3.18)	(-4.15)	(1.82)	(1.98)
Constants	−0.113	−0.129	0.291 ***	0.285 ***	−0.081	−0.098
	(-1.41)	(-1.58)	(13.71)	(13.47)	(-1.03)	(-1.24)
individual effect	control	control	control	control	control	control
time effect	control	control	control	control	control	control
N	12367	12190	11321	11321	12366	12189
R2 -	0.057	0.059	0.057	0.057	0.057	0.059
F	55.089	48.195	41.913	42.612	54.943	48.087

the enterprise does not have a significant impact on the capital investment efficiency and ESG performance of state-owned enterprises, and even agency conflict improves the capital investment efficiency and ESG performance to a certain extent.

Based on the previous empirical results, it can be speculated that digital transformation cannot improve the capital investment efficiency and ESG performance of state-owned enterprises by reducing agency conflicts. The difference in this mechanism between state-owned and private enterprises may stem from the differences in their investment decision-making methods and governance mechanisms. It also shows that the optimization of information symmetry by digitization can only play a limited role in state-owned enterprises that naturally form agency conflicts. In general, the empirical evidence in this section further validates part of Hypothesis 3. It points out the differences in the mechanism effect of digitization on corporate capital investment efficiency and ESG performance by mitigating agency conflicts under the different natures of enterprises.

5.1.3. Digital transformation, management overconfidence and enterprise ESG performance

Overconfidence stems from corporate management's cognitive bias and the need to understand their element endowments, capability boundaries, and market conditions. This overconfidence can, to a certain extent, increase putschism in the business process and raise investment risks. The gambler mentality that arises from management under the guidance of blind self-confidence can lead to deformed investment behavior, waste corporate resources, and ultimately damage enterprise ESG performance. However, integrating digital technology can steepen the corporate management's learning curve for internal and external information and data, enhance the rational motivation for investment, and reduce the management's blind confidence.

Table 9 presents the comprehensive measurement results of digital transformation on management overconfidence. Model 1 reveals that digital transformation can significantly diminish the emotional interference of corporate management's overconfidence.

Table 9
Digital transformation, management overconfidence and capital investment efficiency.

	(1)	(2)	(3)	(4)	(5)	(6)
	OC	*OC*	$Invest_{Rich}$	$Invest_{Chen}$	$Invest_{Rich}$	$Invest_{Chen}$
DCG	−0.010***	−0.002			−0.044*	−0.042*
	(-2.55)	(-0.77)			(-1.74)	(-1.77)
DCG × *Nat*		−0.025***				
		(-2.48)				
OC			0.103**	0.008*	0.009*	0.002**
			(2.05)	(1.88)	(1.79)	(2.15)
OC × *Nat*			0.004***	0.006***		
			(3.14)	(4.19)		
Nature		−0.080	−0.056	−0.063		
		(-2.28)	(-1.10)	(-1.24)		
Board	−0.016	−0.024	−0.002	−0.001	−0.016	−0.025
	(-0.43)	(-0.62)	(-0.41)	(-0.23)	(-0.43)	(-0.65)
Indepen	−0.180	−0.156	−0.013	−0.010	−0.181	−0.164
	(-1.51)	(-1.29)	(-0.77)	(-0.59)	(-1.52)	(-1.35)
Dual	0.326 ***	0.323 ***	0.003 **	0.003 **	0.326 ***	0.323 ***
	(26.97)	(26.28)	(1.98)	(2.04)	(26.99)	(26.29)
*Dor*1	−0.026 ***	−0.027 ***	0.031 ***	0.032 ***	−0.026 ***	−0.027 ***
	(-4.30)	(-4.35)	(3.54)	(3.65)	(-4.27)	(-4.38)
Size	−0.029 ***	−0.027 ***	−0.012 ***	−0.011 ***	−0.030 ***	−0.028 ***
	(-4.15)	(-3.86)	(-11.88)	(-11.64)	(-4.54)	(-4.23)
ROA	−0.377 ***	−0.380 ***	0.102 ***	0.104 ***	−0.380 ***	−0.386 ***
	(-3.62)	(-3.62)	(6.71)	(6.88)	(-3.65)	(-3.68)
LXBZ	−0.000	−0.000	−0.000	−0.000	−0.000	−0.000
	(-0.35)	(-0.39)	(-0.65)	(-0.45)	(-0.35)	(-0.38)
GMP	0.022 **	0.021 **	0.006 ***	0.006 ***	0.022 **	0.022 **
	(2.32)	(2.31)	(4.91)	(5.32)	(2.32)	(2.33)
ITA	0.002 ***	0.002 ***	0.018 *	0.025 ***	0.002 ***	0.002 ***
	(3.26)	(3.23)	(1.90)	(2.65)	(3.25)	(3.24)
LEVE	−0.004	−0.010	0.037 ***	0.040 ***	−0.001	−0.084
	(-0.00)	(-0.28)	(6.62)	(7.13)	(-0.00)	(-0.22)
Inleve	0.028	0.030	−0.003	−0.004	0.028	0.030
	(1.11)	(1.19)	(-0.94)	(-1.31)	(1.10)	(1.20)
InROA	−0.082 *	−0.010	0.051	−0.009	0.015 ***	−0.005
	(-1.84)	(-1.48)	(1.08)	(-1.11)	(2.65)	(-1.46)
Constants	1.085 ***	1.070 ***	0.286 ***	0.275 ***	1.110 ***	1.103 ***
	(5.63)	(5.48)	(10.02)	(9.66)	(5.89)	(5.78)
individual effect	control	control	control	control	control	control
time effect	control	control	control	control	control	control
N	9862	9716	8416	8416	9862	9716
R2 -	0.085	0.084	0.047	0.049	0.085	0.083
F	65.355	54.303	24.568	25.543	65.323	54.068

However, Model 2 indicates that the digital transformation indicator's regression coefficient is insignificant. These results suggest that digital transformation can notably reduce the overconfidence of state-owned enterprise managers. It can be seen from Model 3 and Model 4 that management overconfidence significantly increases the company's inefficient investment and causes a certain degree reduction in enterprise ESG performance. The main reason lies in the irrational emotional interference of managers during the investment process. The underlying reason could be that state-owned enterprises, with their stronger credit endorsement and looser financing environment, tend to overestimate the market environment and form incorrect intuitions about the profit expectations of investment projects. However, in the digital transformation process, digital technology reshapes the market perception of corporate management.

Combining the previous empirical results on digital transformation and management overconfidence, it can be believed that state-owned enterprises can reduce the irrational emotions of corporate management's overconfidence through the implementation of digital transformation, further promote corporate investment efficiency-added, and improve enterprise ESG performance. Moreover, digital management and control of the operation, planning, and construction of investment projects can also allow corporate management to standardize budgets and effectively reduce blind investment motivation, reducing resource waste and increasing enterprise ESG performance. Based on the above analysis, hypothesis 4 is confirmed.

5.2. Heterogeneity analysis

Based on the above analysis, we found that state-owned enterprises and non-state-owned enterprises are affected by the differences in the nature and factor endowments of the enterprises themselves, and the impact mechanisms of digital transformation on enterprise

ESG performance are also significantly different. We conducted sub-sample regression for enterprises at different stages of development and different endowment resources to further explore the heterogeneous characteristics of the effect of digital transformation on enterprise ESG performance. The results are shown in Table 10 and Table 11.

5.2.1. Heterogeneous impact of life cycle

It is generally believed that at different stages of enterprise development, in the face of changes in governance mechanisms, business structure, and financial status, enterprises' investment and financing strategies also have different characteristics. What deserves more attention is that the cash flow distribution of enterprises at different development stages is also different, which may also have a heterogeneous impact on the capital investment efficiency and enterprise ESG performance of enterprises. Therefore, the life cycles of enterprises are distinguished according to the cash flow portfolio division method. The results are shown in Table 10. Generally speaking, enterprise digital transformation has a certain degree of impact on enterprise inefficiency investments at different stages. Specifically, it can be seen from Model 3 and Model 6 that digital transformation has the most significant impact on the capital investment efficiency and enterprise ESG performance of enterprises in a recession, which is relatively significant. This may be due to the fact that companies in recession have weak cash flow capabilities and internal control capabilities, and their business segments and product structures lag behind market demand, which may lead to large deviations in the investment process. Digital technology-enabled enterprises can improve the above problems to a large extent, thus reducing inefficient investments in enterprises to enhance ESG performance.

In comparison, digital transformation also has a significant reduction effect on mature enterprises' inefficient investments. This may be more due to the improvement of internal control of enterprises by digital technology and the smooth flow of internal and external information channels. On the contrary, growth-stage companies' businesses are relatively single, and their budgets are tight. This results in the management of growth-stage companies being willing to have a deeper understanding of the supply and demand side of the market and the company when making external investments and expansions and acting more cautiously. Therefore, in Model 1 and Model 4, the insignificant impact of digital transformation on corporate inefficiency investment is reflected more. Based on the above analysis, hypothesis 5 is partially verified.

Table 10
Regression results for different life cycles.

	(1)	(2)	(3)	(4)	(5)	(6)
	growth period	mature stage	Recession	growth period	mature stage	Recession
	$Invest_{Rich}$	$Invest_{Rich}$	$Invest_{Rich}$	$Invest_{Chen}$	$Invest_{Chen}$	$Invest_{Chen}$
DCG_1	0.001	−0.106 *	−0.263 **	−0.015	−0.083 **	−0.237 **
	(0.01)	(-1.91)	(-2.41)	(-0.12)	(-2.17)	(-2.14)
Board	−0.215	0.360	1.213	−0.276	0.386	1.933 **
	(-0.21)	(0.69)	(1.48)	(-0.27)	(0.73)	(2.20)
Indepen	−0.014	0.021	−0.001	−0.017	0.020	0.009
	(-0.48)	(1.45)	(-0.08)	(-0.56)	(1.36)	(0.38)
Dual	0.027	−0.006	−0.020	0.028	−0.003	−0.008
	(0.84)	(-0.40)	(-0.76)	(0.88)	(-0.19)	(-0.28)
*Dor*1	0.033 **	0.025 ***	0.012	0.031 **	0.024 ***	0.016
	(2.11)	(3.10)	(0.93)	(2.00)	(2.91)	(1.14)
Size	−0.015 ***	−0.003 ***	−0.003 ***	−0.014 ***	−0.003 ***	−0.009 ***
	(-8.82)	(-3.39)	(-5.33)	(-8.59)	(-3.32)	(-4.97)
ROA	0.210 ***	0.045 ***	0.017	0.213 ***	0.048 ***	0.020
	(6.90)	(3.58)	(0.92)	(7.03)	(3.84)	(1.02)
LXBZ	−0.000	−0.000 *	0.000	−0.000	−0.000	0.000
	(-1.24)	(-1.82)	(1.05)	(-0.95)	(-1.50)	(1.10)
GMP	0.082 ***	0.0416 ***	0.027	0.087 ***	0.041 ***	−0.030
	(6.08)	(7.33)	(0.14)	(6.48)	(7.13)	(-0.14)
ITA	−0.000 ***	−0.009	0.021 *	−0.000 ***	−0.005	0.027 **
	(-2.74)	(-1.19)	(1.90)	(-2.77)	(-0.62)	(2.29)
LEVE	0.037 ***	0.008	0.057 ***	0.038 ***	0.008	0.063 ***
	(3.81)	(1.49)	(6.77)	(4.02)	(1.48)	(7.03)
Inleve	−0.004	0.001	0.052	−0.062	0.008	0.013
	(-0.76)	(0.05)	(0.88)	(-0.97)	(0.03)	(0.22)
InROA	0.005	−0.001	−0.021	0.056	−0.003	−0.005
	(0.54)	(-1.04)	(-0.14)	(0.59)	(-0.34)	(-1.52)
Constants	0.365 ***	0.083 ***	0.200 ***	0.357 ***	0.082 ***	0.176 ***
	(7.58)	(2.95)	(4.37)	(7.43)	(2.88)	(3.59)
individual effect	control	control	control	control	control	control
time effect	control	control	control	control	control	control
N	4756	4017	1677	4756	4017	1677
R2 -	0.070	0.047	0.113	0.071	0.045	0.110
F	21.741	11.426	8.867	21.924	11.029	8.641

Table 11
Regression results of different factor endowments.

	(1)	(2)	(3)	(4)	(5)	(6)
	labor	technology	capital	labor	technology	capital
	$Invest_{Rich}$	$Invest_{Rich}$	$Invest_{Rich}$	$Invest_{Chen}$	$Invest_{Chen}$	$Invest_{Chen}$
DCG_1	0.062	−0.067 ***	−0.073 ***	0.053	−0.058 ***	−0.086 ***
	(0.41)	(-8.09)	(-5.76)	(0.35)	(-8.28)	(-5.86)
Board	0.016	−0.005	0.001	0.019 *	−0.004	0.006
	(1.43)	(-0.82)	(0.17)	(1.72)	(-0.78)	(0.07)
Indepen	0.035	−0.002	−0.036	0.035	0.002	−0.033
	(1.15)	(-0.13)	(-1.39)	(1.17)	(0.12)	(-1.27)
Dual	0.084	0.144	0.010	−0.092	0.191	0.040
	(0.22)	(0.72)	(0.03)	(-0.24)	(0.96)	(0.14)
*Dor*1	0.041 **	0.019 *	0.024 *	0.044 **	0.017 *	0.022 *
	(2.06)	(1.85)	(1.92)	(2.27)	(1.73)	(1.75)
Size	−0.004 *	−0.012 ***	−0.014 ***	−0.004	−0.011 ***	−0.014 ***
	(-1.85)	(-10.71)	(-8.81)	(-1.59)	(-10.50)	(-8.59)
ROA	0.180 ***	0.083 ***	0.066 ***	0.191 ***	0.088 ***	0.065 ***
	(5.13)	(4.83)	(3.10)	(5.50)	(5.09)	(3.04)
LXBZ	−0.000	−0.000	0.000	−0.000	−0.000	0.000
	(-0.64)	(-0.49)	(0.09)	(-0.46)	(-0.33)	(0.20)
GMP	0.024 ***	0.007 ***	0.072 ***	0.022 ***	0.008 ***	0.078 ***
	(7.62)	(6.81)	(4.26)	(7.30)	(7.37)	(4.62)
ITA	−0.000 **	0.022	0.004	−0.000 **	0.029	0.009
	(-2.27)	(1.02)	(0.20)	(-2.30)	(1.35)	(0.49)
LEVE	0.036 ***	0.041 ***	0.031 ***	0.034 ***	0.045 ***	0.031 ***
	(2.88)	(6.70)	(3.69)	(2.78)	(7.24)	(3.69)
Inleve	0.011	−0.015 ***	−0.001	0.009	−0.017 ***	−0.001
	(1.07)	(-2.58)	(-0.45)	(0.93)	(-2.81)	(-0.45)
InROA	−0.009 **	−0.077 *	−0.012	0.007 *	−0.058	−0.005
	(-2.08)	(-1.94)	(-0.59)	(1.93)	(-1.62)	(-0.48)
Constants	0.059	0.298 ***	0.358 ***	0.036	0.290 ***	0.351 ***
	(0.89)	(9.83)	(7.94)	(0.56)	(9.53)	(7.76)
individual effect	control	control	control	control	control	control
time effect	control	control	control	control	control	control
N	1806	5750	3825	1806	5750	3739
R2 -	0.080	0.065	0.086	0.080	0.067	0.652
F	11.158	28.443	26.435	11.186	29.349	511.633

5.2.2. Heterogeneous impact of factor endowments

Generally speaking, differences in factor endowments such as human, physical, and technological capital will affect the direction and preferences of corporate investment and financing decisions. This may also have heterogeneous effects on enterprise ESG performance. This section distinguishes enterprises based on differences in enterprise factor endowments. It divides them into three types: technology-intensive, labor-intensive, and capital-intensive, and uses a double fixed effect model for regression. The results are shown in Table 11. For capital-intensive and technology-intensive enterprises, inefficient investments formed under both calculation methods can be reduced under digital transformation conditions. This may be because technology-intensive companies can better understand and connect with digital technologies. At the same time, technological investment projects of technology-intensive enterprises are often characterized by high risks, high information barriers, and high sunk costs. Therefore, digital technology helps companies better understand technical issues in investment projects, reduce information barriers, and improve capital investment efficiency and enterprise ESG performance. In addition, for capital-intensive enterprises, abundant capital projects mean more significant capital investment, but more significant capital investment means an increased possibility of more incredible capital waste, and digital technology hurts capital-intensive enterprises. The application may be more reflected in controlling and supervising financial budgets. On the contrary, the impact of digital transformation on the capital investment efficiency and enterprise ESG performance of labor-intensive enterprises is insignificant, and inefficient investment is increased to a certain extent. Based on the above analysis, hypothesis 5 is partially verified.

6. Conclusion and enlightenment

Enterprise ESG performance not only reflects the long-term value and sustainability of an enterprise, but also profoundly embodies the trend of economic transformation towards sustainable development, the rise of green economy, and the restructuring of economic structure. Digital transformation is the core driving force of current economic development, not only transforming the operational models of enterprises but also profoundly influencing ESG performance, revealing the inevitable trend of economic transformation towards sustainable development. Based on the investment perspective, this paper explores the impact of digital transformation on

enterprise ESG performance from the perspectives of investment intention, investment confidence and investment sentiment. Taking Chinese A-share listed companies as the research object, the results show that (1) digital transformation significantly improves enterprise ESG performance. (2) Digital transformation improves enterprise ESG performance by enhancing risk-taking ability, mitigating agency conflicts, and curbing management overconfidence. (3) Enterprise digital transformation significantly inhibits management overconfidence, which is more significant for managing state-owned enterprises. In addition, suppressed managerial overconfidence can significantly improve the capital investment efficiency and enterprise ESG performance of state-owned enterprises, but it has no significant impact on private enterprises. (4) For companies in different life cycles, digital transformation has an impact on capital investment efficiency and enterprise ESG performance is more evident for companies in mature and declining stages. For enterprises with different factor endowments, digital transformation has a significant impact on the capital investment efficiency and enterprise ESG performance of technology-intensive and capital-intensive enterprises. Then, this study also uses a quasi-natural experiment method and combines two econometric techniques to verify the robustness of the conclusions in this study. The research findings are paramount in understanding the critical role of digital transformation in shaping the long-term economic growth potential and sustainable development capabilities from an investment perspective.

After an in-depth analysis, the following macro-level insights can be drawn. Firstly, enterprise ESG has become the focus of global attention against the backdrop of the increasing prominence of the topic of sustainable development of the global economy. Digital transformation, as an innovative development path, plays a significant role in enhancing enterprise ESG performance and promoting sustainable economic development. Through the use of advanced technology and data analysis methods, economic systems can accurately assess and manage their impact on enterprise ESG performance, and thus build a more sustainable and responsible development model. The digital transformation not only meets society's continued elevation and expectations of enterprise ESG standards, but also provides a key impetus for the economy's transition to a greener, more inclusive and transparent direction. Secondly, given that different industries and enterprises are at different stages of development with varying life cycle characteristics and needs, the implementation of digital transformation should take full account of their differences. Through the implementation of personalized and enterprise-specific digital transformation strategies and close attention to the life cycle characteristics and needs of different industries and enterprises, the comprehensive, coordinated and sustainable development of the economy can be more effectively promoted.

Statement

Based on the investment perspective, this paper provides an in-depth discussion on the impact mechanism of digital transformation on enterprise ESG (environmental, social and governance) performance and constructs a corresponding analytical framework. By using firm-level panel data of Chinese A-share listed companies from 2009 to 2020, we conduct an exhaustive empirical analysis. The findings show that digital transformation plays an important role in significantly enhancing firms' ESG performance. Specifically, digital transformation significantly improves enterprise ESG performance through mechanisms such as enhancing firms' risk-taking capacity, effectively mitigating agency conflicts, and curbing management overconfidence. These improvements are reflected not only in environmental protection and social responsibility performance, but also in the optimization of corporate governance structure. Further heterogeneity analyses reveal that the impact of digital transformation on capital investment efficiency as well as corporate ESG performance is particularly significant among firms in maturity and decline. This suggests that digital transformation can play a positive and facilitating role in helping firms achieve sustainable growth at different stages of the firm life cycle. In addition, we find that digital transformation has a significant impact on the efficiency of capital investment as well as the ESG performance of firms in both technology-intensive and capital-intensive firms. This finding further confirms the key role of digital transformation in driving enterprises to transform and upgrade and achieve high-quality development.

These findings not only help us to better understand the critical role of digital transformation in shaping long-term economic growth potential and sustainability from an investment perspective, but also provide a strong reference for governments, enterprises and investors in formulating relevant policies and strategies.

Data availability

The authors do not have permission to share data.

References

Alkaraan, F., Albitar, K., Hussainey, K., & Venkatesh, V. G. (2022). Corporate transformation toward Industry 4.0 and financial performance: The influence of environmental, social, and governance (ESG). *Technological Forecasting and Social Change, 175*, Article 121423.

Anderson, R. C., & Reeb, D. M. (2003). Founding-family ownership and firm performance: Evidence from the S&P 500. *The Journal of Finance, 58*(3), 1301–1328.

Ang, J. S., Cole, R. A., & Lin, J. W. (2000). Agency costs and ownership structure. *The Journal of Finance, 55*(1), 81–106.

Chen, L. J., & Chen, S. Y. (2011). The influence of profitability on firm value with capital structure as the mediator and firm size and industry as moderators. *Investment Management and Financial Innovations, 8*(Iss. 3), 121–129.

Chen, C. H., Zhu, L., & Zhong, H. (2019). Innovative research on the practical perspective of digital survival management of Chinese enterprises. *Journal of management science, 22*(10), 8, 2019.

Cheng, Z., & Meng, X. (2023). Can carbon emissions trading improve corporate total factor productivity? *Technological Forecasting and Social Change, 195*, Article 122791.

Clementino, E., & Perkins, R. (2021). How do companies respond to environmental, social and governance (ESG) ratings? Evidence from Italy. *Journal of Business Ethics, 171*(2), 379–397.

Ellili, N. O. D. (2022). Impact of ESG disclosure and financial reporting quality on investment efficiency. *Corporate Governance: The International Journal of Business in Society, 22*(5), 1094–1111.
Fang, M., Nie, H., & Shen, X. (2023). Can enterprise digitization improve ESG performance? *Economic Modelling, 118*, Article 106101.
Landi, G. C., Iandolo, F., Renzi, A., & Rey, A. (2022). Embedding sustainability in risk management: The impact of environmental, social, and governance ratings on corporate financial risk. *Corporate Social Responsibility and Environmental Management, 29*(4), 1096–1107.
Li, S. X. (2007). Property rights, agency costs and agency efficiency. *Economic Research, 1*, 102–113.
Li, G., Wu, H., Jiang, J., & Zong, Q. (2023). Digital finance and the low-carbon energy transition (LCET) from the perspective of capital-biased technical progress. *Energy Economics, 120*, Article 106623.
Libby, R., & Rennekamp, K. (2012). Self-serving attribution bias, overconfidence, and the issuance of management forecasts. *Journal of Accounting Research, 50*(1), 197–231.
Luo, C., Wei, D., & He, F. (2023). Corporate ESG performance and trade credit financing–Evidence from China. *International Review of Economics & Finance, 85*, 337–351.
Richardson, S. (2006). Over-investment of free cash flow. *Review of Accounting Studies, 11*, 159–189.
Singh, K., & Pillai, D. (2022). Corporate governance in small and medium enterprises: A review. Corporate governance. *The international journal of business in society, 22*(1), 23–41.
Wang, E. Z., & Lee, C. C. (2022). The impact of clean energy consumption on economic growth in China: Is environmental regulation a curse or a blessing? *International Review of Economics & Finance, 77*, 39–58.
Zhang, W., & Zhao, J. (2023). Digital transformation, environmental disclosure, and environmental performance: An examination based on listed companies in heavy-pollution industries in China. *International Review of Economics & Finance, 87*, 505–518.

ABOUT UMT FACULTY

SDI

Selective Dissemination of Information (SDI) service is a current-awareness service offered by the PSNZ for UMT Faculty Members. The contents selection criteria include current publications (last 5 years), highly cited and most viewed/downloaded documents. The contents with pdf full text from subscribed databases are organized and compiled according to a monthly theme which is determined based on the topics of specified interest.

For more information or further assistance, kindly contact us at 09-6684185/4298 or email to psnz@umt.edu.my/sh_akmal@umt.edu.my

Thank you.

Perpustakaan Sultanah Nur Zahirah
Universiti Malaysia Terengganu
21030 Kuala Nerus, Terengganu.

Tel. : 09-6684185 (Main Counter)
Fax : 09-6684179
Email : psnz@umt.edu.my