RESEARCH ON THE IMPACT OF DIGITAL TRANSFORMATION ON ENTERPRISE ESG PERFORMANCE

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This paper analyzes the impact of digital transformation on corporate ESG (environmental, social, and governance) performance based on the dynamic capability theory of enterprises and the stakeholder theory perspective and conducts empirical tests based on the data of Chinese A-share listed companies in Shanghai and Shenzhen from 2009 to 2022. Before, researchers mostly looked at overall ESG performance. This paper, on the other hand, starts by looking at overall ESG performance and then goes on to look at each of the three ESG dimensions (E, S, and G). It then does a subdimensional refinement to see how digital transformation affects the different dimensions of ESG performance and then checks how the company's ability to innovate in green technology affects the subdimension of ESG performance. This paper puts digital transformation and ESG performance in the same analytical framework, and from the perspective of digital transformation, it puts forward targeted insights and suggestions to improve the ESG performance of Chinese enterprises, providing theoretical support and empirical evidence to promote the practice of ESG development in Chinese enterprises.

Keywords: ESG; enterprise ESG performance; digital transformation; green technology innovation

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Introduction

In recent years, the concepts of sustainable development and green development have gradually taken root in the hearts of people. Global climate issues have made the world further reflect on the relationship between human beings and nature.

The performance of enterprises in environmental, social, and corporate governance (ESG) has received extensive attention from all walks of life. The ESG value management concept that pursues sustainable economic development has gradually become the consensus of all mankind, and the scope of enterprise value creation has also extended from economic value to external environment and social value. ESG requires corporate managers to take into account economic, social, and environmental benefits and provide social and environmental responsibility and governance information that meets the needs of stakeholders.

Enterprises need to proactively adapt to the development trend of ESG, practice the concept of ESG, continuously enhance their vitality, competitiveness, innovation, and risk-resistance, further improve their sustainable development capability, and promote the high-quality development of enterprises.

At the same time, in the context of the digital economy era, under the pattern of economic “double cycle” development, the digital economy, including big data, cloud computing, the Internet of Things, blockchain, artificial intelligence, 5G communications, and other emerging technologies, is becoming a key force in reorganizing global factor resources, reshaping the global economic structure, and changing the pattern of global competition. The digital transformation is also gradually becoming a breakthrough for the development and growth of enterprises.

Digital technology greatly reduces costs and improves the operational efficiency and perceptual ability of enterprises in information collection, decision-making support, and operation management; enhances the authenticity, comprehensiveness, and timeliness of ESG information disclosure; improves the efficiency and convenience of ESG information management and operation; strengthens the ability of corporate ESG practice and improves corporate ESG performance; and has become an important path to empower the new dynamics of corporate development. Some scholars have proposed that the green innovation capability of enterprises is closely related to the environmental, social, and governance impacts of enterprises (Xu et al., 2022) and that green technological innovation is an important path for realizing the goal of sustainable development of enterprises (Huang & Li, 2017).

Digital transformation improves the efficiency of enterprise resource allocation through the application of digital technology, which effectively promotes the green technology innovation of enterprises (Song et al., 2022; Wang et al., 2022), reduces environmental pollution in the production process and the emission of production terminal waste, and improves the enterprise's ESG (environmental) performance.

In summary, this paper integrates digital transformation and enterprise ESG performance into the same analytical framework. Based on the analysis of the overall performance of digital transformation on enterprise ESG, this paper further explores the role of digital transformation in improving enterprise ESG (E-Environment) performance from the perspective of enterprise green technology innovation ability and expands the research ideas of enterprise ESG performance in the digital economy era.
The possible marginal contribution of this paper compared to the established research literature is reflected in the following aspects:

First, existing research mainly explores the impact of digital transformation on the economic value of enterprises, i.e., financial performance, and less on the impact of non-economic values such as environment, society, governance, etc., and there is a lack of literature that directly establishes the association between digital transformation and the ESG performance of enterprises. In this paper, digital transformation and ESG performance are integrated into the same analytical framework, which expands the research ideas of corporate ESG concepts in the era of the digital economy, provides new perspectives for enterprises to improve ESG performance, and enriches the related research in this field.

Second, the existing literature is mainly based on the perspective of external influencing factors to study the impact on corporate ESG performance. This paper is based on the theory of the dynamic capabilities of enterprises, considering, in addition to external driving factors, how the digital transformation is achieved through the stimulation of the internal motivation of the enterprise, so as to enhance the ability of corporate ESG practice and improve ESG performance.

Thirdly, different from the existing literature, this study takes the overall performance of ESG as the research object. Based on the research on the overall performance of ESG, this study opens the three dimensions of the overall performance of ESG to carry out detailed analysis of sub-dimensions (E, S, and G) and deeply discusses the overall impact of digital transformation on the performance of ESG and the impact of different dimensions, which provides new ideas for research in this field.

Fourth, for the definition of digital transformation characteristic words, compared with the existing literature on the dummy variable method of constructing digital transformation by hand-arranging the annual reports and announcements of listed companies (He & Liu, 2019), the ratio of the amount related to the digital transformation of enterprises to the total amount of intangible assets (Qi et al., 2020), the questionnaire survey method (Liu et al., 2020), the textual analysis and the word frequency statistics method (Zhao et al. 2021; Yuan et al. 2021; Wu et al. 2021), this paper combines the word frequencies of Wu et al. (2021) and Zhao et al. (2021), retains the same words as a single one, and adds the words that are not found in each other's studies to the evaluation indexes, so that we can get the total characteristic words of this study on "digital transformation". The total characteristic words of this study on "digital transformation" are obtained, thus forming a comprehensive digital transformation index, which is more comprehensive and scientific.

Fifth, different from the existing literature from the green patent and R&D investment perspective to measure enterprise green technology innovation, this paper from the independent innovation and joint innovation two modes to measure the enterprise green innovation capacity, more detailed enterprises in the exploration of green technology innovation of different paths on the differences.

Finally, the selection of control variables in the empirical test section is more comprehensive and scientific, and it is proposed to select control variables from "two perspectives and three dimensions" with "two perspectives" including internal perspective and external perspective and "three dimensions" including financial perspective, non-financial perspective, and three dimensions of external control, so that the research conclusions are more scientific and robust.
Literature review

As digital transformation and enterprise ESG development continue to deepen, research on the value function of digital transformation in the context of comprehensive benefits that take into account the economy, the environment, and society can better highlight the improvement of enterprise sustainable development performance and capabilities brought about by digital transformation. Digital transformation is of great significance in the areas of cost reduction and efficiency enhancement, process reshaping, operation mode change, business model innovation and reshaping, and improvement of enterprise competitiveness, thus enhancing the economic and non-economic values of enterprises, and the research in this field will provide a more theoretical basis and practical experience for the sustainable and high-quality development of enterprises and society.

Compared with traditional technological innovation, green innovation refers to the innovative approaches adopted by industries to transform traditional business into sustainable operations (Fazal-e-Hasan, 2023), which have environmental attributes in product design, production process, production products, consumer experience, market positioning, etc. (Schiederig et al., 2012).

With the development of the economy and the improvement of people's living standards, society pays more and more attention to the environmentally friendly attributes of products, and products with green production technology can better meet the new era value orientation of consumers due to the advantages of environmental protection, safety, high efficiency, environmental friendliness, and low cost of use (Su & Li, 2021). In light of the strict technical barriers to green trade in developed countries, products produced by green technology can better open the door to the market (Schiederig et al., 2012). Technology can better open up the market under the strict green trade technical barriers of developed countries.

Digital technology can play an important role in clean production, recycling, energy conservation, emission reduction, and carbon reduction. For example, in high-carbon industries such as iron and steel, building materials, petrochemicals, and non-ferrous metals, digital technology can realize the centralization of production factors and intelligent decision-making. As for digital carbon reduction, the use of 5G, big digital twins, and other technologies can realize carbon footprint monitoring, carbon data analysis, carbon neutral deduction, help enterprises and industries realize carbon transformation and carbon asset value-added, and provide strong technical support and a feasible path for enterprises to fulfill their ESG responsibilities.

Therefore, green technological innovation by enterprises reflects their concern for the natural environment and human society, highlights their sense of social responsibility, enhances their image of business ethics, and creates a unique advantage in the social dimension of their products, which in turn enhances their ESG performance. In addition, government subsidies to consumers for green consumption policies can increase customers' sustainable consumption behaviors, and enterprises can strengthen customer management, supply chain management, and product management in this process, forming unique advantages in product management and thus enhancing ESG performance.

In summary, there are relatively few studies on the relationship between digital transformation, green technology innovation, and corporate ESG performance, and the
breadth and depth of the research needs to be improved in discussing the impact of digital transformation on corporate ESG performance.

The existing literature on ESG mainly focuses on the external drivers of ESG and the micro impacts generated by ESG, while there are fewer studies on how to improve corporate ESG performance and less research on how to improve the internal drivers of corporate ESG performance. Meanwhile, the existing literature mainly explores the impact of digitization on the economic value of enterprises, i.e., financial performance, but less on the impact of non-economic values such as environment, society, governance, etc., and there is a dearth of literature that directly establishes the correlation between digitization and the performance of enterprises' ESG performance. At present, there are few systematic studies on ESG performance, especially on ESG sub-dimensions.

In the context of the country's vigorous promotion of the digital economy, ESG performance has increasingly become an important part of enterprises efforts to build sustainable competitive advantages. Theoretically, digital transformation can optimize the allocation of resources inside and outside the enterprise, enhance the ability of sustainable development, and achieve green and inclusive growth.

Driven by a new round of scientific and technological revolutions and the industrial revolution, digital transformation has also become an important starting point for countries to enhance their competitiveness and cultivate new driving forces. According to the data from the "2021 Chinese Enterprise Digital Transformation Index Research" released by Accenture, the proportion of successful digital transformation in Chinese enterprises will increase to 16% in 2021.

Then, while realizing the transformation and upgrading of enterprises at the micro level, can digital transformation also enhance the sustainable development ability of enterprises and form support for the national "double carbon" strategy at the macro level? Therefore, this paper attempts to propose the impact of digital transformation on enterprise ESG performance based on the three sub-dimensions of enterprise ESG performance: E (environment), S (society), and G (government). In order to improve the ESG performance of Chinese enterprises and promote the development path of China's ESG, this paper attempts to provide theoretical support and empirical evidence.

**Theoretical framework and hypotheses**

**Digital transformation and enterprise ESG performance**

Stakeholder theory requires that enterprises should not only be responsible to shareholders but also to creditors, employees, suppliers, customers, the government, the community, and the environment (Freeman, 1984), focusing more on the external governance of the enterprise, paying attention to more stakeholders, and maximizing the overall interests of stakeholders.

However, the ESG practices of enterprises have certain externalities, and the investment of enterprises in environmental and social responsibility will increase the additional expenditure of enterprises, so enterprises have the problems of insufficient investment and excessive cost (Friedman, 2007, Garcia & Orsato, 2020), which in turn leads to insufficient incentives for enterprise ESG.

However, the mutual embedding of new-generation digital information technology and the traditional production mode of enterprises is the core strategy for Chinese enterprises to
realize high-quality development in the digital economy era. The digitization of the real economy and the materialization of digital technology have had a great impact on current production and lifestyle.

At the same time, green sustainable development and balanced development have become the themes of the new era, and the value of digital transformation is not only reflected in the improvement of the economic performance of enterprises but also in their non-economic performance.

Firstly, digital transformation can promote enterprise technological innovation, especially green technological innovation and application, so as to enhance the enterprise's contribution to the environment and sustainable development;

Secondly, digital transformation enables enterprises to improve interaction with core stakeholders through technological advances, such as better understanding of customer needs through big data technology and optimizing the relationship with suppliers through supply chain management, so as to enhance the enterprise's core stakeholder management capabilities and better fulfill their social responsibilities;

Third, digital technology is conducive to reducing information asymmetry and transaction costs, improving the transparency of corporate information, and helping enterprises improve their internal control capabilities and governance level. At the same time, the application of digital technology is conducive to improving the efficiency of corporate resource allocation and use, enhancing corporate decision-making and operational management efficiency, enhancing the ability of corporate ESG practice, and reducing the cost of corporate ESG practice.

Thus, digital transformation is not only conducive to reducing the "negative effect" of corporate ESG but also enhances the intrinsic motivation of corporate ESG investment, which in turn improves the overall ESG performance, ESG (environmental) performance, ESG (social) performance, and ESG (government) performance of the enterprise.

Therefore, this paper proposes the hypothesis:

H1: Digital transformation can improve overall corporate ESG performance.
H1a: Digital transformation can improve corporate ESG (e-environmental) performance.
H1b: Digital transformation can enhance corporate ESG (social) performance.
H1c: Digital transformation can improve corporate ESG (G-Governance) performance.

**Digital transformation, green technology innovation, and ESG (E-Environmental) performance**

A large number of existing empirical studies have shown that the digital transformation of enterprises can effectively promote green technology innovation (Song et al., 2022; Wang et al., 2022). On the one hand, by utilizing digital technologies such as big data and artificial intelligence, enterprises can accurately grasp the current difficulties in environmental governance and carry out R&D and innovation of green technologies targeting environmental problems.

On the other hand, by utilizing the interconnection of digital technologies, enterprises can accelerate the internal exchange of information and knowledge technologies and can also form a collaborative innovation and knowledge co-creative network with external enterprises (Subramaniam & Young, 2005), further accelerating the green technology innovation of enterprises.
In the process of production and use of products with environmentally friendly characteristics produced by enterprises using green technological innovation, they can comply with the environmental policies (such as green procurement policy, green credit policy, and green subsidy policy) formulated and implemented by the national strategy, reduce energy and resource consumption and pollutant emissions, reduce greenhouse gas emissions to cope with climate change, protect biodiversity, and form the unique advantage of environmentally friendly products.

In addition, the enhancement of green innovation technology also reduces energy intensity, reduces energy consumption in the production chain, and positively impacts the environment by reducing extensive dependence on energy and improving environmental quality. Therefore, digital transformation lays the foundation for enterprises’ green technology innovation capability, and the increasing level of enterprises' green technology has led to a reduction in the cost of conducting green production and an increase in efficiency, which has prompted enterprises to better practice their environmental responsibility and improve their corporate reputation (Peattie & Ratnayaka, 1992), thus enhancing their ESG (E-Environmental) performance.

Therefore, the hypothesis of this paper is proposed:

H2: Digital transformation can positively contribute to corporate ESG (e-environmental) performance by enhancing corporate green technology innovation capability.

The green technology innovation capacity of listed companies is an important factor in promoting green development and sustainable development. Chinese enterprises have mainly taken two paths in innovation and technology upgrading: introducing foreign technologies or conducting their own R&D (Zhang et al., 2023).

In addition, the green technology innovation capability of listed companies can also be embodied in independent innovation and joint innovation, both of which are key ways to enhance the green technology innovation capability. Independent innovation enables enterprises to realize technological breakthroughs and obtain independent intellectual property rights through their own efforts. In the field of green technology innovation, independent innovation can help enterprises reduce their dependence on external technologies and improve their autonomy in product and technology upgrading.

The increase in the intensity of enterprises’ independent R&D investment has a significant positive impact on China’s technological progress (Liu, 2011) and productivity improvement (Wu, 2006), which can effectively promote the development of green technological innovation (Bi et al., 2011).

Focusing on technological innovation capability, some scholars conducted empirical tests using panel data from large and medium-sized industrial enterprises in China and found that independent R&D has a significant positive impact on technological innovation (Li & Shen, 2011). Under the background of digital transformation, corporate independent innovation plays an important role in enhancing the digitalization capability and green technology innovation capability of listed companies, which can also reflect the R&D strength of listed companies.

Therefore, this paper proposes the hypothesis:

H2a: Digital transformation can positively contribute to the ESG (environmental) performance of enterprises by enhancing autonomous innovation capability.
Some scholars, in their research exploring different paths of enterprise technological innovation, distinguish the innovation mode into two types: independent innovation and collaborative innovation, according to the initiating body of technological innovation (Xie & Zhang, 2023). Compared with independent innovation, co-innovation is equally important in the field of green technology.

Co-innovation is a way to realize innovation through cooperation, which can effectively integrate resources, improve innovation efficiency, share resources, technologies, and markets, and reduce innovation risks through cooperation among enterprises, between enterprises and scientific research institutions, and internationally. In the field of green technology innovation, co-innovation can help enterprises share resources, technologies, and markets and reduce innovation risks.

At present, Chinese listed companies have made some progress in green technology joint innovation, such as establishing industrial technology innovation strategic alliances and jointly carrying out green technology R&D projects. In order to enhance the ability of green technology joint innovation, enterprises need to actively seek partners, establish stable cooperative relationships, and strengthen information communication and resource sharing.

At the same time, the government should actively build cooperation platforms between enterprises and enterprises, enterprises and universities, and enterprises and research institutes to promote multi-party cooperation and win-win cooperation, enhance the joint innovation ability of enterprises, and then improve the ESG (e-environment) performance of enterprises. Therefore, this paper proposes the hypothesis:

H2b: Digital transformation can positively promote the ESG (environmental) performance of enterprises by enhancing joint innovation capability.

The theoretical model diagram is shown in Fig. 1 below.

Figure 1 - Conceptual framework of this study
(Source: made by the author)
Data and methodology

Sample and data
This study empirically examines the data of Chinese A-share listed companies in Shanghai and Shenzhen from 2009 to 2022 and analyzes the three dimensions of corporate ESG performance (E-Environmental), (S-Social), and (G-Governance), respectively.

The explanatory variables are overall corporate ESG performance and different dimensions (E, S, and G) performance; the explanatory variable is digital transformation; the mediator variable is selected based on the corporate capability perspective, mainly based on the corporate green innovation capability (Independent Innovation and Joint Innovation) perspective; the control variables are considered from various aspects of the enterprise, mainly based on the enterprise's financial perspective, non-financial perspective, and internal and external factors to design and the control variables are considered from various aspects of enterprises and are mainly designed and selected based on the enterprises' financial perspective, non-financial perspective, internal perspective, and external perspective.

Among them, the financial data of listed companies comes from the database of Cathay Pacific (CSMAR), the green technology innovation data comes from the databases of China Research Data Service Platform (CNRDS) and the World Intellectual Property Organization (WIPO), and the data on ESG performance is selected from the total score and sub-score of CSI's ESG rating. The variable data on digital transformation, corporate culture, and other aspects are calculated by extracting materials from the text analysis of listed companies' annual reports, and the text database of listed companies' annual reports is from Juchao Information Network.

In the analysis, this paper carries out a 1% level of bilateral shrinkage of the data as a way to achieve a certain degree of elimination of the impact of outliers. After the final data cleaning, the total sample size is 25,200, involving a total of 3,532 listed companies, and the final data is unbalanced panel data.

Measures

Dependent variables
Enterprise ESG performance (ESG) Based on the consideration of the comprehensiveness of the data volume and the time span to meet the research needs, this study adopts the CSI ESG rating data.

Comprehensive research by scholars found that a number of scholars (Hu et al., 2023; Xie & Lu, 2022; Song et al., 2022; Fang & Hu, 2023) have used CSI ESG ratings data in their ESG ratings studies. In the CSI ESG data, considering the priority of specific values for model fitting, this paper chooses to use the specific scores of the CSI ESG ratings for the analysis. Referring to the idea of Hu et al. (2023), this paper chooses to use the C-AAA evaluations of the CSI ESG ratings, respectively, and sets the values of 1–9 for replacing the variables to conduct the robustness test.

Finally, in the specific analysis, because E, S, and G in ESG have different focuses and connotations, respectively, and the CSI ESG ratings provide sub-scores of E, S, and G, this paper will simultaneously take E, S, and G as the explanatory variables, respectively, for parallel research.
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Independent variables
Digital Transformation (Digital). This paper combines the studies of Wu et al. (2021) and Zhao (2021) to measure digital transformation and obtains the total characteristic words about "digital transformation" in this study so as to form a comprehensive digital transformation index.

After obtaining all the word frequencies, this paper uses the summation method to calculate the number of word frequencies used to measure the degree of enterprise digital transformation in this paper.

Mediator variables
Green innovation capability perspective: independent innovation (Grelnv_ia) and joint innovation (Grelnv_ja).
Referring to studies such as Xie et al. (2023), Brockman et al. (2018), Wang et al. (2021), and Li et al. (2022), for the measurement of independent innovation and co-innovation, their two capabilities are evaluated separately, and in this paper, we use the natural logarithm of the total of the number of green patents independently developed by listed firms in terms of technology (the sum of the number of green inventions and the number of green utility models in both cases added up) for the measurement of the ability to independently innovate, and we use the natural logarithm of the total of the number of green patents developed by listed firms in terms of co-innovation in terms of technology (the sum of the number of green inventions and the number of green utility models in both cases added up) for measuring the co-innovation capabilities.

Control variables
In order to better set the control variables, this paper considers many aspects of the enterprise. It is mainly based on the financial, non-financial, internal, and external perspectives of the enterprise to be considered. The main control variables are as follows:
Age (age of enterprise), Big1 (ownership concentration), Cash (cash holdings), Dual (two-position integration), Growth (enterprise growth rate), IndepDir (proportion of independent directors), Leverage (assets-liability ratio), M_hold (executive shareholding ratio), MTB (book-market ratio), Size (size of enterprise).

In addition, in order to eliminate the problem of omitted variables, this paper also controls for the year effect. Since there are control variables in this paper that consider sub-provinces, there is no control for the province effect.

Model development
Combined with the knowledge of econometric tests, this paper determines the fixed effect model as the optimal model for this study through the F-test, BP-test, and Hausman test. The specific model settings are as follows:
The main effect of this paper is mainly to test all the hypotheses of Hypothesis 1 series (H1, H1a, H1b, and H1c), i.e., to analyze the impact of digital transformation on the overall ESG performance and dimensional performance of enterprises. In the analysis of the model, considering the heteroskedasticity problem of the model, the model is estimated with robust standard errors in this paper.

Next, the regression formula for digital transformation on ESG performance is organized as follows:
In the above four models, ESG is the overall ESG performance, E, S, and G are the three dimensions of ESG performance, is the constant term of the regression model, is the error perturbation term, is the year control, and \((n=1, 2, 3\ldots)\) are the regression coefficients of the corresponding variables. When the above model presents significance and the regression coefficient is greater than 0, it means that the hypothesis (H1, H1a, H1b, H1c) verification of this paper is valid.

**Empirical results**

*Descriptive statistical analysis*

Full-sample Descriptive statistics were analyzed for all variables in the sample, as shown in Table 1: The mean of overall corporate ESG performance was 73.459, the standard deviation was 5.028, and the coefficient of variation was 0.068.

This indicates that the ESG performance of Chinese corporations is generally good, with a high mean value. Further, among the three ESG dimensions (E, S, and G), ESG (G-Governance) performance has the highest mean value (79.37), followed by ESG (S-Social) performance (74.851), and ESG (E-Environmental) performance is the lowest (60.663).

The mean value of digital transformation is 2.899, with a standard deviation of 1.271 and a coefficient of variation as high as 0.439. This high coefficient of variation points to a very high degree of inter-firm variability in digital transformation, suggesting that there is a clear polarization in the degree of digital transformation among Chinese firms.

The mean value of autonomous green innovation capability is 0.329, with a standard deviation of 0.734 and a high coefficient of variation of 2.234. This indicates that the fluctuation of enterprises in autonomous green innovation capability is extremely large, suggesting that some enterprises may be outstanding in this aspect while most enterprises may be relatively backward.

The mean value of joint green innovation capability is 0.102, the standard deviation is 0.396, and the coefficient of variation is even as high as 3.888, indicating that enterprises are generally weak in joint green innovation and that there are great variations among enterprises.

In addition, the descriptive statistics of the control variables are highly consistent after comparing the existing relevant references. Specifically, it is shown in Tab. 1.
Table 1 - Descriptive statistical analysis
(Source: made by the author)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>p50</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESG</td>
<td>25200</td>
<td>54.52</td>
<td>85.54</td>
<td>73.459</td>
<td>5.028</td>
<td>73.67</td>
<td>0.068</td>
</tr>
<tr>
<td>ESG_E</td>
<td>25200</td>
<td>43.57</td>
<td>84.81</td>
<td>60.663</td>
<td>7.629</td>
<td>60.375</td>
<td>0.126</td>
</tr>
<tr>
<td>ESG_S</td>
<td>25200</td>
<td>39.34</td>
<td>100</td>
<td>74.851</td>
<td>9.625</td>
<td>75.516</td>
<td>0.129</td>
</tr>
<tr>
<td>ESG_G</td>
<td>25200</td>
<td>43.64</td>
<td>93.67</td>
<td>79.37</td>
<td>6.391</td>
<td>80.509</td>
<td>0.081</td>
</tr>
<tr>
<td>digital</td>
<td>25200</td>
<td>0</td>
<td>6.248</td>
<td>2.899</td>
<td>1.271</td>
<td>2.833</td>
<td>0.439</td>
</tr>
<tr>
<td>Grelnv_ia</td>
<td>25200</td>
<td>0</td>
<td>3.829</td>
<td>0.329</td>
<td>0.734</td>
<td>0</td>
<td>3.888</td>
</tr>
<tr>
<td>Grelnv_ja</td>
<td>25200</td>
<td>0</td>
<td>2.708</td>
<td>0.102</td>
<td>0.396</td>
<td>0</td>
<td>3.888</td>
</tr>
<tr>
<td>size</td>
<td>25200</td>
<td>19.652</td>
<td>26.414</td>
<td>22.195</td>
<td>1.312</td>
<td>21.993</td>
<td>0.059</td>
</tr>
<tr>
<td>leverage</td>
<td>25200</td>
<td>0.027</td>
<td>0.892</td>
<td>0.411</td>
<td>0.205</td>
<td>0.402</td>
<td>0.499</td>
</tr>
<tr>
<td>Cash</td>
<td>25200</td>
<td>0.009</td>
<td>0.838</td>
<td>0.172</td>
<td>0.136</td>
<td>0.131</td>
<td>0.791</td>
</tr>
<tr>
<td>growth</td>
<td>25200</td>
<td>-0.642</td>
<td>3.004</td>
<td>0.178</td>
<td>0.368</td>
<td>0.121</td>
<td>2.069</td>
</tr>
<tr>
<td>IndepDir</td>
<td>25200</td>
<td>0.25</td>
<td>0.571</td>
<td>0.375</td>
<td>0.053</td>
<td>0.333</td>
<td>0.141</td>
</tr>
<tr>
<td>dual</td>
<td>25200</td>
<td>0</td>
<td>1</td>
<td>0.287</td>
<td>0.452</td>
<td>0</td>
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<tr>
<td>Big1</td>
<td>25200</td>
<td>0.08</td>
<td>0.77</td>
<td>0.349</td>
<td>0.148</td>
<td>0.328</td>
<td>0.425</td>
</tr>
<tr>
<td>MTB</td>
<td>25200</td>
<td>0.055</td>
<td>8.868</td>
<td>1.002</td>
<td>1.168</td>
<td>0.621</td>
<td>1.166</td>
</tr>
<tr>
<td>age</td>
<td>25200</td>
<td>1.099</td>
<td>3.584</td>
<td>2.880</td>
<td>0.349</td>
<td>2.944</td>
<td>0.121</td>
</tr>
<tr>
<td>M_hold</td>
<td>25200</td>
<td>0</td>
<td>0.716</td>
<td>0.141</td>
<td>0.202</td>
<td>0.007</td>
<td>1.436</td>
</tr>
</tbody>
</table>

Regression analysis

The analysis of the results of the impact of digital transformation shows that the regression results demonstrate the relationship between digital transformation and corporate ESG and its sub-dimensions (E, S, and G).

The regression coefficient between digital transformation and overall ESG performance is 0.350 and is highly significant (p<0.01), indicating a positive and strong relationship between digital transformation and corporate ESG performance. In terms of ESG (E-Environmental) performance, the regression coefficient is 0.620 with a standard error of 0.049, also showing a highly significant positive relationship, which indicates that digital transformation has a more significant positive impact on corporate ESG (E-Environmental) performance than on overall ESG performance.

That is to say, improving digitalization is particularly effective in improving firms' environmental performance. The regression coefficient of ESG (S-Social) performance is 0.508, with a standard error of 0.058, indicating that digital transformation also has a significant positive relationship with firms' ESG (S-Social) performance, which means that the improvement of digitalization also has a positive impact on firms' ESG (S-Social) performance.

The regression coefficient for ESG (G-Governance) performance is relatively small at 0.115, but the standard error of 0.041 is also statistically significant. Although this suggests that the positive impact of digital transformation on firms' ESG (governance) performance is small relative to environmental and social performance, it is still positive.

In summary, digital transformation has a positive relationship with corporate ESG and its sub-dimensions (E, S, and G) performance, and all of them are statistically significant. This suggests that as firms' digitalization capabilities improve, their corporate ESG performance tends to improve as well. In particular, digital transformation seems to have a more significant positive impact on ESG (e-environmental) performance.
These results reflect that digital transformation can positively impact corporate sustainability practices by improving efficiency, promoting information transparency, and enhancing regulatory compliance.

Table 2 - Fixed effects regression results
(Source: made by the author)

<table>
<thead>
<tr>
<th></th>
<th>ESG</th>
<th>ESG_E</th>
<th>ESG_S</th>
<th>ESG_G</th>
</tr>
</thead>
<tbody>
<tr>
<td>digital</td>
<td>0.350***</td>
<td>0.620***</td>
<td>0.508**</td>
<td>0.115***</td>
</tr>
<tr>
<td>(0.033)</td>
<td>(0.049)</td>
<td>(0.058)</td>
<td>(0.041)</td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>32.314***</td>
<td>12.709***</td>
<td>29.632***</td>
<td>45.023***</td>
</tr>
<tr>
<td>(1.026)</td>
<td>(1.567)</td>
<td>(1.845)</td>
<td>(1.285)</td>
<td></td>
</tr>
<tr>
<td>control variables</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>year</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>N</td>
<td>25200</td>
<td>25200</td>
<td>25200</td>
<td>25200</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.176</td>
<td>0.158</td>
<td>0.252</td>
<td>0.219</td>
</tr>
</tbody>
</table>

Note: Values in parentheses are robust standard error statistics; * p<0.1 ** p<0.05 *** p<0.01

Robustness test

In this paper, the model is tested based on replacement variables, and the analysis is conducted from the perspective of replacing the explanatory variables, using the 9-level score assignment 1-9 of the CSI ESG, and using the variables generated by the scores (ESG1, ESG_E1, ESG_S1, and ESG_G1) instead of the original variables (ESG, ESG_E, ESG_S, and ESG_G), respectively, in the regression analysis, and once again, using the fixed effects regression model analysis, and the results were collated as follows:

Table 3 - Regression results with the replacement of explanatory variables
(Source: made by the author)

<table>
<thead>
<tr>
<th></th>
<th>ESG1</th>
<th>ESG_E1</th>
<th>ESG_S1</th>
<th>ESG_G1</th>
</tr>
</thead>
<tbody>
<tr>
<td>digital</td>
<td>0.067</td>
<td>0.100</td>
<td>0.069</td>
<td>0.023</td>
</tr>
<tr>
<td>(0.007)</td>
<td>(0.008)</td>
<td>(0.007)</td>
<td>(0.008)</td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>-4.171***</td>
<td>-5.241***</td>
<td>-4.110***</td>
<td>-1.533***</td>
</tr>
<tr>
<td>(0.217)</td>
<td>(0.263)</td>
<td>(0.222)</td>
<td>(0.259)</td>
<td></td>
</tr>
<tr>
<td>control variables</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>year</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>N</td>
<td>25200</td>
<td>25200</td>
<td>25200</td>
<td>25200</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.164</td>
<td>0.129</td>
<td>0.194</td>
<td>0.220</td>
</tr>
</tbody>
</table>

Note: values in parentheses are robust standard error statistics; * p<0.1 ** p<0.05 *** p<0.01

The results of the analysis show that the positive impact of digital transformation on overall ESG performance and its dimensions (E, S, and G) is significant, but the degree of impact varies across dimensions. Specifically, the impact coefficient of digital transformation on overall ESG performance (ESG1) is 0.067, which is significant at the 1% significance level, indicating that digital transformation plays a positive role in improving the overall performance of corporate ESG.

Among the three ESG dimensions, the most significant impact on ESG (environmental) performance (ESG_E1) has a coefficient of 0.100, suggesting that digital transformation is the most effective in promoting corporate environmental responsibility.
The impact coefficient of 0.069 for ESG (S-Social) performance (ESG_S1) is also significant, suggesting that digitization is also effective in improving social relations and responsibility. In contrast, the impact on ESG (G-Governance) performance (ESG_G1) is smaller, with a coefficient of 0.023, which, although still significant at the 1% significance level, suggests that digital transformation is relatively weak in improving corporate governance.

These results as a whole reveal that digital transformation has a positive impact on improving firms' ESG performance, especially most significantly in terms of environmental responsibility and relatively weakly in terms of corporate governance. Taken together, the H1, H1a, H1b, and H1c hypotheses are all significantly valid, indicating that the model is relatively robust.

Further analysis
In the previous study, this paper analyzed that digital transformation has a significant positive impact on the overall performance of enterprise ESG and the performance of each sub-dimension. In addition, it was found that digital transformation has the greatest impact on enterprise ESG (E-Environmental) performance in the impact of each sub-dimension of enterprise ESG (E, S, and G) performance, and this part of the paper is based on this study, focusing on the impact of digital transformation through what paths can strengthen the impact on enterprise ESG (E-Environmental) performance.

Based on this research, this part focuses on the path through which digital transformation can enhance the impact on the ESG (environmental) performance of enterprises.

Based on this, this paper further explores the impact of enterprises' green innovation capability enhancement on ESG (e-environmental) performance. In this paper, we refer to the research results of Wen (2004–2022),, and apply the stepwise regression method to verify the mediation effect, and use the fixed effect model to analyze and collate the results as follows (Tab. 4).

Table 4 - Mediated effects regression results (Green Technology Innovation Capacity)
(Source: made by the author)

<table>
<thead>
<tr>
<th></th>
<th>Grelnv_ia</th>
<th>Grelnv_ja</th>
<th>ESG_E</th>
</tr>
</thead>
<tbody>
<tr>
<td>digital</td>
<td>0.054**</td>
<td>0.019***</td>
<td>0.539***</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.003)</td>
<td>(0.049)</td>
</tr>
<tr>
<td>Grelnv_ia</td>
<td></td>
<td></td>
<td>1.145***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.071)</td>
</tr>
<tr>
<td>Grelnv_ja</td>
<td></td>
<td></td>
<td>0.971***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.124)</td>
</tr>
<tr>
<td>_cons</td>
<td>-3.735***</td>
<td>-1.678**</td>
<td>18.613***</td>
</tr>
<tr>
<td></td>
<td>(0.176)</td>
<td>(0.104)</td>
<td>(1.571)</td>
</tr>
<tr>
<td>control variables</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>year</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>N</td>
<td>25200</td>
<td>25200</td>
<td>25200</td>
</tr>
<tr>
<td>R²</td>
<td>0.159</td>
<td>0.100</td>
<td>0.172</td>
</tr>
</tbody>
</table>

Note: values in parentheses are robust standard error statistics; * p<0.1 ** p<0.05 *** p<0.01
In analyzing the impact of digital transformation on ESG (environmental) performance, autonomous green innovation capability and joint green innovation capability are considered as mediating variables, and the regression results show that digital transformation has a significant impact on ESG performance at both direct and indirect levels.

Specifically, the coefficient of the impact of digital transformation on autonomous green innovation capacity is 0.054, which is significant at the 1% significance level, indicating that as firms become more digitized, their autonomous green innovation capacity increases significantly. Similarly, the impact coefficient of digital transformation on joint green innovation capacity is 0.019, which is also significant at the 1% significance level, indicating that digital transformation promotes joint green innovation cooperation with other entities.

Further analyzing the mediating effect, the coefficient of autonomous green innovation capability on ESG (environmental) performance is 1.145, which is significant at the 1% significance level. This indicates that autonomous green innovation capability plays an important and significant mediating role between digital transformation and ESG (environmental) performance. Similarly, the coefficients of joint green innovation capability on ESG (E-Environmental) performance are 0.971, respectively, which are also significant at the 1% significance level, showing that joint green innovation capability is likewise an important mediator of digital transformation in influencing firms' ESG (E-Environmental) performance.

Taken together, these results reveal that digital transformation has a significant positive impact on ESG (environmental) performance by enhancing firms' autonomous and joint green innovation capabilities.

As mediating variables, autonomous and joint green innovation capabilities play a bridging role in transmitting the impact of digital transformation on ESG (environmental) performance, reflecting the far-reaching impact of digital transformation on corporate sustainability.

**Conclusions and discussion**

**Conclusions**

The hypotheses of this paper are all significantly valid, and digital transformation has a significant positive impact on firms' ESG performance, ESG (environmental) performance, ESG (social) performance, and ESG (government) performance. Digital transformation employs information technology to improve corporate business processes, promote innovation, and enhance decision-making capabilities. This enables firms to make smarter environmental, social, and governance (ESG) choices.

For example, big data analytics are used to optimize resource use reduce waste, and lower environmental footprints. From a resource-based viewpoint, digital transformation can be seen as a unique strategic resource that improves an organization's core competencies and enables it to respond more effectively to ESG challenges.

In conclusion, the positive impact of digital transformation on firms' ESG performance is supported by multiple theories, reflecting the role of information technology as a strategic resource in improving firms' ESG performance, especially ESG (environmental) performance.
RESEARCH ON THE IMPACT OF DIGITAL TRANSFORMATION

The mediating effect of corporate green innovation capability is significantly established and partially mediated by the impact of digital transformation on corporate ESG performance.

Therefore, in the context of digital transformation, green innovation capability becomes a key bridge connecting the enterprise's technological capability with the overall ESG performance and environmental (E) performance, which is both a manifestation of the dynamic capability and part of the enterprise's core resources and can effectively enhance the enterprise's ESG performance. In the path of digital transformation's impact on an enterprise's ESG (environmental) performance, the autonomous green innovation capability shows a more significant positive mediating effect than the joint green innovation capability. In contrast, the joint green innovation capability, although also important, involves cooperation with external partners and may be limited by the vision, goals, and capability of the partner, which leads to a relatively weaker mediating effect on its impact on ESG (environmental) performance.

The mediating role is relatively weak. Therefore, autonomous green innovation capabilities are more significant in mediating the digital transformation due to their deeper internal integration and unique use of resources.

Suggestions

At the macro-government level, on the one hand, it should take various measures to encourage the integration of the digital economy with the real economy, create a positive external market environment for enterprises to carry out digital transformation, vigorously advocate and actively promote the concept of ESG, and guide enterprises to utilize digital technology to enhance their ESG capabilities and actively engage in ESG practices.

At the microenterprise level, enterprises should seize the opportunities brought by the digital economy, actively introduce cutting-edge new-generation digital information technology, and apply digital technology in all aspects of production and operation as far as possible, so as to improve their green technology innovation capability, core stakeholder capability, internal control and decision-making capability, and operation management capability, and thus improve their overall ESG performance and various dimensions of ESG performance.

Performance: Actively implement the digital transformation of enterprises, respond to the call of national policies, and then actively implement and carry out the practice of enterprise ESG to achieve high-quality and sustainable development of enterprises.

Emphasize the cultivation of a green innovation culture, establish an enterprise culture that encourages innovation, strengthen the patent application and protection of green technology innovation achievements, safeguard the technological advantage of the enterprise in competition, and raise awareness of intellectual property protection among all staff.

In short, the enterprise should not only enhance its independent green technology innovation capability but also strengthen its connection with external resources through cooperation and alliance so as to jointly promote the development of green technology.

This requires enterprises to have forward-looking strategic planning as well as to build an ecosystem that supports innovation both internally and externally, so as to enhance their ESG (environmental) performance.
Limitations and future research

This study is innovative in terms of the impact of digital transformation on corporate ESG performance, but there are some shortcomings, such as: there is no unified definition and measurement of "digital transformation" which may lead to inconsistency in the results and make it difficult to compare the degree of digital transformation of different enterprises more accurately. This may lead to inconsistency in research results and make it difficult to more accurately compare the degree of digital transformation of different enterprises.

Therefore, in future research, the selection of the research object aspect can be further refined in terms of grouping, and the specific impact and degree of impact of digital transformation on corporate ESG performance can be investigated.

It is possible to test the different degrees of impact of digital transformation on corporate ESG performance in different industries, regions, and life cycle stages, such as clean energy, low-carbon transportation, green manufacturing, agricultural science and technology, and other industries that have become the main direction of ESG investment and therefore are the key areas for future research.

References:


