



OPEN ESG ratings empower high-quality development of logistics enterprises through digital transformation and green innovation

Dongyan Liu¹, Ni Sun¹✉ & Xiugang Zhu²

In the context of economic globalization, the logistics industry, as a key link connecting production and consumption, is facing many challenges, and at the same time, ESG scores are gradually becoming a key indicator of the ability to measure the sustainable development of enterprises. Most of the existing literature focuses on a single dimension to explore the impact of ESG on logistics companies, and fewer analyze how ESG scores can empower listed logistics companies to achieve high-quality development from the perspectives of digital transformation and green innovation at the same time. In addition, in terms of research methodology, existing studies in the literature are deficient in systematic data analysis and scientific construction of models, and lack comprehensive robustness tests. This article focuses on how ESG ratings can empower listed logistics companies to achieve high-quality development and explores this issue from two perspectives: digital transformation and green innovation. This paper conducts an empirical analysis based on the data of listed companies in the logistics industry, and the results of the study show that there is a significant positive correlation between ESG scores and both the size and operational efficiency of logistics companies. Further mechanistic tests show that ESG scores can promote innovation in logistics enterprises, and when disaggregated, they are found to be effective in promoting digital transformation and upgrading as well as green innovation. Meanwhile, the robustness and reliability of the study's conclusions are fully demonstrated through a comprehensive robustness test, including various aspects of variable measurement, sample selection, and endogeneity issue treatment. This study not only enriches the theoretical framework about high-quality development and ESG scoring of logistics enterprises at the theoretical level, but also provides a scientific decision-making basis for managers of logistics enterprises in practice. In addition, the research results also provide important reference value for government regulators and investors and help promote sustainable development and standardized management of the logistics industry.

Keywords ESG scores, Logistics enterprises, High-quality development, Digital transformation and upgrading, Green innovation development

In the wave of economic globalization, the logistics industry plays an important role as a key link between production and consumption. Compared with other industries, logistics enterprises have unique characteristics such as heavy assets, extensive network coverage, and multiple and decentralized operations. The logistics process involves a large number of transportation, warehousing, distribution, and other links, with huge energy consumption, and is a major contributor to greenhouse gas emissions, which puts it under greater pressure than other industries in terms of the environment. At the social level, logistics enterprises employ a large number of front-line staff, and social problems such as the working environment and protection of employees' rights and interests are more prominent. At the same time, its operations are widely distributed in various communities, and its relationship with the community is not comparable to that of ordinary enterprises. In terms of corporate governance, due to the complexity of business processes and the high demand for upstream and downstream

¹School of Business, Anhui Xinhua University, Hefei 230601, China. ²School of Economics, Shanghai University, Shanghai 201899, China. ✉email: xinhua.wuli@163.com

coordination of the supply chain, good corporate governance is even more critical to safeguard the stable operation and long-term development of logistics enterprises.

The high-quality development of logistics enterprises signifies the seamless integration of efficiency, sustainability, innovation, and social responsibility in their operations. This not only involves providing fast, accurate, and reliable logistics services but also entails reducing negative environmental impacts, actively fulfilling social obligations, and enhancing corporate governance standards. Currently, logistics companies are experiencing rapid growth globally. With the rise of e-commerce and the acceleration of globalization, the demand for logistics services continues to grow. However, during this development, logistics enterprises also face a series of challenges, such as intense market competition¹, high-cost pressures², prominent environmental issues³, and a lack of awareness regarding corporate social responsibility⁴. High-quality development not only helps logistics companies stand out in the competitive market, attracting more customers and resources, but also promotes the sustainable development of the broader economy. Furthermore, it encourages logistics companies to actively fulfill social responsibilities and prioritize environmental protection, thereby earning social recognition and respect, and enhancing their enterprise image⁵.

The ESG score is a comprehensive evaluation of a company's performance in three key areas: Environmental, Social, and Governance. It reflects a company's ability to achieve sustainable development and fulfill its social responsibilities through quantifiable metrics. The significance of the ESG scores lies in providing investors, enterprise managers, and the public with a holistic tool for assessing a company's value. For investors, ESG scores help identify companies with long-term investment value and reduce investment risks⁶. Through in-depth analysis of five typical cases¹, an empirical chain between ESG performance and investment inflows was constructed from the dimensions of cost, scale, and channel, effectively proving that ESG is the core competitiveness for enterprises to gain capital advantages. For enterprise managers, ESG scores encourage them to place greater emphasis on sustainable development⁷. For the public, ESG scores offer insight into a company's social responsibility practices⁸. Therefore, a strong ESG score can promote the digital transformation of logistics enterprises by driving the development of information systems⁹, fostering the adoption of smart logistics equipment¹⁰, and accelerating supply chain collaboration¹¹. On the other hand, ESG scores can guide logistics enterprises towards green transportation practices, reducing energy consumption¹², supporting the construction of green warehouses with energy-efficient lighting¹³, and promoting research into sustainable packaging solutions¹⁴, thereby advancing green innovation within the logistics industry.

ESG scores also affect logistics companies differently from other types of companies. On the environmental front, logistics enterprises' green energy transition and implementation of emissions reduction measures are directly reflected in the environmental indicators in their ESG scores due to the extensive use of transportation, which is critical to attracting environmentally conscious customers and investors. Other industries may have a greater impact on ESG scores in areas such as pollution treatment in the production chain. On the social front, logistics companies have a large number of employees and work intensively, and employee rights and benefits account for a significant portion of the social dimensions of the ESG score, affecting the social image of the company and the stability of the labor force, which is significantly different from other industries such as knowledge-intensive ones.

Most of the existing research on the high-quality development of logistics enterprises focuses on traditional areas such as cost control and market expansion, and there is a relative lack of research on ESG scoring, which is an emerging and critical factor. Although ESG concepts are mentioned in some of the literature, they have not been explored in depth in terms of the specific ways in which they can empower logistics companies to achieve high-quality development. Research on the impact of ESG scores on logistics enterprises also mostly stays in the description of the phenomenon and lacks in-depth analysis from the perspective of digital transformation and green innovation. This study aims to fill these gaps by analyzing the data of listed logistics companies, exploring in depth how ESG scores empower listed logistics companies to develop in a high-quality manner, and revealing the mechanism of their influence on digital transformation upgrading and green innovation development.

This study aims to explore deeply how ESG scores empower the high-quality development of listed logistics companies. Through data analysis of these companies, the study reveals the mechanisms through which ESG scores influence digital transformation and green innovation. It provides valuable experiences and strategies for the logistics industry, encouraging logistics companies to actively implement ESG principles and achieve high-quality development. Compared with existing literature, this paper offers the following innovations: (1) Innovative Research Perspective: This paper explores the enabling effect of ESG scores on the high-quality development of logistics companies, providing a new research perspective on the sustainable development of logistics enterprises. (2) Innovative Impact Channels: By examining the influence of ESG scores from the perspectives of digital transformation and green innovation, this study identifies new channels through which ESG scores affect the high-quality development of logistics companies, offering a fresh impact mechanism.

Theoretically, this research enriches the theoretical framework of high-quality development and ESG scoring in logistics companies, offering a reference for future studies. By investigating the relationship between ESG scores and the high-quality development of logistics companies, and exploring the role of digital transformation

¹ The five classic cases refer to:

- (1) The first "ESG two-way linked loan" in Shaanxi Province landed at the Xi'an Branch of Shanghai Pudong Development Bank.
- (2) The first "ESG performance-linked loan" in Zhenjiang was implemented.
- (3) The green loan balance of ICBC Shenzhen Branch reached 160.4 billion yuan, with both the total amount and the increase ranking among the top in Shenzhen's banking industry.
- (4) The first "carbon intensity + ESG" dual-linked loan in Hubei's banking industry was issued.
- (5) The Guiyang Branch of Industrial Bank issued the first ESG rating-linked loan of 300 million yuan.

and green innovation, the study provides new directions and insights for academia. Practically, this research offers decision-making guidance for logistics company managers, helping them better understand the importance of ESG scores and develop more scientifically sound and reasonable strategies. It also provides references for government regulatory bodies and investors, encouraging them to pay closer attention to the sustainable development of logistics companies and promote broader economic sustainability.

The remainder of this paper is structured as follows: Sect. 2 reviews and critiques the relevant literature; Sect. 3 presents the theoretical analysis and hypotheses; Sect. 4 describes the research design and data; Sect. 5 discusses the empirical results and analysis; and Sect. 6 concludes with policy recommendations.

Literature review and evaluation

This literature review focuses on the theme of “ESG scores Empowering the High-Quality Development of Logistics Enterprises — From the Perspectives of Digital Transformation and Green Innovation.” It emphasizes the analysis of the factors influencing the high-quality development of logistics enterprises and their significant impacts, especially about economic considerations. By reviewing numerous high-quality studies, this review provides a solid theoretical foundation for a deeper understanding of the high-quality development of logistics enterprises and the role of ESG scores.

The first category of literature pertains to the high-quality development of logistics enterprises. This body of research primarily addresses the factors that influence high-quality development and its significant impacts.

Firstly, high-quality development is primarily influenced by technological innovation, management level, market demand, and the policy environment. (1) Technological Innovation: The rise of digital technologies has brought new opportunities for the development of logistics enterprises¹⁵, while continuous upgrades in smart logistics equipment have provided strong support for the high-quality development of logistics companies⁵. (2) Management Level: An efficient management system is key to achieving high-quality development in logistics enterprises¹⁶. Additionally, a strong leadership team and a highly skilled workforce are critical factors in enhancing management quality¹⁷. (3) Market Demand: Consumer demand for logistics services continues to grow, placing higher requirements on the high-quality development of logistics companies¹⁸. Moreover, the rapid expansion of e-commerce presents both significant opportunities and challenges for logistics companies¹⁹. (4) Policy Environment: Government policies have played an important role in driving the high-quality development of logistics enterprises²⁰. At the same time, increasingly stringent environmental regulations are pushing logistics companies to adopt more environmentally friendly operational practices²¹. Secondly, high-quality development has a significant impact on the economy, society, and the environment. (1) Economic Impact: The high-quality development of logistics enterprises plays a crucial role in driving economic growth. At the same time, the growth of logistics enterprises can stimulate the development of related industries, such as transportation, warehousing, and packaging, creating an industry-wide synergy that promotes regional economic prosperity⁵. (2) Social Impact: High-quality logistics companies can provide more convenient and efficient logistics services, meeting the growing consumption demands of society¹¹. Additionally, logistics companies can enhance their social image and credibility by actively participating in public welfare activities and focusing on employee welfare²². (3) Environmental Impact: The high-quality development of logistics enterprises involves adopting environmentally friendly operational practices, reducing energy consumption and carbon emissions, and contributing to environmental protection. Moreover, the development of green logistics not only helps to reduce environmental pollution but also improves resource utilization efficiency, thereby achieving sustainable development²³.

The second category of literature pertains to ESG scores, primarily focusing on the construction of ESG score indicators and their significant impacts.

Firstly, the construction of ESG score indicators can be divided into three dimensions: environmental indicators, social indicators, and governance indicators. (1) Environmental Dimension Indicators, the environmental dimension indicators in ESG scores usually include the enterprise's energy consumption, carbon emissions, waste management, resource utilization efficiency, and other aspects. At the same time, the responsibility of enterprises in addressing climate change, includes the enterprise's climate risk management, greenhouse gas emission reduction targets, and actions in the environmental dimension indicator system²⁴. (2) Social Dimension Indicators, the Social Dimension Indicators in the ESG Scores cover the enterprise's employee rights and interests, community relations, product responsibility, and consumer rights and interests' protection. At the same time, the responsibility of enterprises in human rights protection, the enterprise's human rights policy, supply chain human rights management, employee human rights training, etc., are included in the social dimension indicator system²⁵. (3) Governance Dimension Indicators, the governance dimension indicators in ESG scores involve the board structure, executive compensation, risk management, and information disclosure of the enterprise. Meanwhile, the responsibility of enterprises in anti-corruption and compliance, the anti-corruption policy, internal audit, and compliance management of enterprises are included in the system of governance dimension indicators²⁶. Secondly, ESG scores significantly impact investor decision-making, corporate sustainability, and innovation capabilities. (1) Investor decision-making, more and more investors include ESG factors in the investment decision-making process. Enterprises with higher ESG scores are usually favored by investors because they have better long-term investment value and risk-resistant ability; ESG scores can be used as an important tool for investors to assess the risk and return of a company. Good ESG performance reduces risk and improves financial performance, resulting in higher returns for investors²⁷. (2) Corporate Sustainability: Enterprises with higher ESG ratings typically have better long-term sustainability. Good ESG performance can help companies reduce risk, improve reputation, attract investors and talent, and thus promote sustainable development. At the same time, ESG scores can be used as an important indicator of corporate sustainability to help companies assess their own sustainability performance and formulate sustainable development strategies²⁸. (3) Enterprises with higher ESG scores usually have stronger innovation capabilities.

Good ESG performance can promote technological innovation, management innovation, and business model innovation of enterprises and improve their competitiveness. In addition, ESG scores can be used as an important indicator of an enterprise's innovation capability to help enterprises assess their own innovation performance and formulate innovation strategies²⁹.

By reviewing the existing literature, it can be concluded that the studies on the high-quality development of logistics enterprises have clarified their connotation and influencing factors, providing a theoretical foundation for further research. These studies emphasize the importance of technological innovation, management level, market demand, and policy environment in the high-quality development of logistics enterprises, while also exploring the significant impacts of this development on the economy, society, and environment, thus offering directions for sustainable corporate development. However, there are limitations such as relatively singular research methods and a lack of interdisciplinary studies; insufficient attention to the dynamic changes in the high-quality development of logistics enterprises, making it challenging to adapt to rapidly changing market conditions; and inadequate in-depth research on the high-quality development of different types of logistics enterprises, resulting in a lack of targeted policy recommendations.

On the other hand, existing literature on ESG scores introduces the definition, indicator system, and applications of ESG scores, providing references for businesses and investors. It highlights the importance of ESG scores in investment decision-making, corporate management, and regulatory policy formulation while exploring the impact of ESG scores on corporate sustainability and providing guidance for the fulfillment of corporate social responsibilities. However, there are also issues such as the absence of a unified indicator system for ESG scores, with variations in scoring standards among different organizations. A lack of in-depth research on the effectiveness and reliability of ESG scores makes it difficult to accurately assess a company's sustainability capabilities. And insufficient research on the application of ESG scores in emerging industries and small- to medium-sized enterprises, leading to a lack of targeted solutions.

This study explores the role of ESG scores in promoting the high-quality development of logistics enterprises against the backdrop of existing research. Unlike previous cross-industry studies, it delves into the unique characteristics of the logistics sector, such as capital intensity, policy sensitivity, and high carbon emissions. For the first time, it reveals the industry-specific path where ESG scores drive new productive forces through digital and green innovations. It also constructs a theoretical model that fits the logistics industry, filling a theoretical gap. In terms of transmission mechanisms, this study puts forward the logic that "ESG score improvement drives digital transformation of logistics enterprises, thereby enhancing new productive forces". It clarifies the mediating role of digital transformation and builds a "ESG-green innovation-new productive forces" mechanism. By treating digital transformation and green innovation as core channels, it breaks the limitation of single-innovation-dimension research. This highlights the logistics industry's need for dual-transformation in the "dual-carbon" and digital economy era, offering precise theoretical support for industry policy-making and making contributions in both theoretical and practical aspects.

Theoretical analysis and hypotheses

ESG scores and high-quality development of logistics enterprises

ESG scores facilitate the high-quality development of logistics enterprises. A high ESG score signifies that a company performs well across multiple dimensions, including economic, social, and environmental aspects, which enhances its competitiveness and long-term value. This, in turn, promotes the high-quality development of the company. Additionally, strong ESG performance can attract investors, customers, and employees, creating a favorable development environment that drives the company toward high-quality growth²⁹.

ESG Scores help upgrade logistics enterprise strategy. By establishing a clear ESG strategy, companies can better manage environmental, social, and governance risks, improving resource utilization efficiency and overall performance and competitiveness. When formulating strategies, companies should fully integrate ESG factors with their long-term development goals to achieve balanced growth across economic, social, and environmental dimensions³⁰.

ESG Scores optimize logistics enterprise risk management. Through the evaluation of ESG factors, companies can assess their risk profiles in these areas and develop corresponding risk management strategies to reduce exposure. Moreover, strong ESG performance can enhance a company's reputation and credit rating, lowering financing costs and insurance premiums, thus strengthening its risk management capabilities³¹.

ESG Scores strengthen the logistics enterprise's social responsibility. A high ESG score indicates that a company has made positive contributions in areas such as environmental protection, employee welfare, and community development, reflecting a strong sense of social responsibility. Companies that actively fulfill their social responsibilities can gain societal recognition and support, enhancing their reputation and brand image, which in turn brings long-term economic benefits and social value³².

In summary, we propose the first hypothesis of this paper:

Hypothesis 1 Ceteris paribus, an increase in ESG Scores is conducive to the high-quality development of logistics enterprises; that is, the higher the ESG scores, the more it promotes logistics enterprises to improve efficiency and expand their scale.

ESG scores, digital transformation and upgrading, and high-quality development of logistics enterprises

ESG Scores play a significant role in promoting the digital transformation and upgrading of logistics enterprises. Through the impetus of the environmental dimension, the motivation from the social dimension, and the assurance provided by the governance dimension, companies pursuing higher ESG scores must leverage digital

technologies to optimize production processes, enhance management efficiency, and meet social demands, thereby facilitating the high-quality development of logistics enterprises.

First, ESG scores promote logistics enterprises digital transformation and upgrading from the environmental dimension. To achieve the energy-saving and emission-reduction goals within the ESG framework, companies need to adopt digital technologies to optimize production processes, reduce energy consumption, and lower carbon emissions. Additionally, companies must use digital technologies to enhance supply chain transparency and traceability, enabling information sharing and collaboration among all stakeholders³³.

Second, ESG scores motivate logistics enterprises digital transformation and upgrading from the Social Dimension. To meet the social goals of ESG and improve their social scores, companies are likely to increase investment in digital training and employee development, attracting and cultivating digital talent. At the same time, through digital transformation, companies can better understand customer needs, offer personalized products and services, and fulfill the demand for sustainable consumption³⁴.

Finally, ESG scores safeguard logistics enterprise digital transformation and upgrading from the governance dimension. Digital technologies provide companies with more accurate and timely information, improving the scientific rigor and accuracy of decision-making. These technologies also enhance internal communication and collaboration, boosting efficiency and helping companies meet the governance goals of the ESG framework³⁵.

In summary, we propose the second hypothesis of this paper:

Hypothesis 2 Ceteris paribus, an increase in ESG Scores contributes to the high-quality development of logistics enterprises through the channel of digital transformation and upgrading.

ESG scores, green innovative development, and high-quality development of logistics enterprises

ESG Scores play a crucial role in driving the green innovation development of enterprises. Through mechanisms such as access to funding and resource support, internal management and operational optimization, as well as technological innovation and collaborative exchanges, ESG Scores promote the green innovation efforts of logistics enterprises, thereby helping them achieve high-quality development goals.

First, Higher ESG Scores Facilitate Access to Funding and Resource Support.

Logistics enterprises with higher ESG scores are more attractive to investors, drawing in greater capital investment and securing more favorable interest rates, which reduces financing costs. Additionally, these companies are more likely to gain government recognition, qualifying for relevant policy incentives and financial support. As a result, companies can allocate more resources to green innovation and improve the efficiency of capital utilization³⁶.

Second, Higher ESG Scores Promote Internal Management and Operational Optimization.

On the one hand, companies with high ESG Scores emphasize scientific, transparent, and responsible decision-making, helping them formulate more rational and effective green innovation strategies, creating a favorable internal environment for sustainable growth. On the other hand, these companies focus on the efficient use of resources and environmental protection, leading to optimized resource allocation, reduced energy consumption, and lower waste emissions during production and operations. This resource optimization provides a solid foundation for green innovation³⁷.

Finally, Higher ESG Scores Enhance Technological Innovation and Collaborative Exchange.

Companies with strong ESG performance tend to increase investment in green technology research and development, collaborating with universities and research institutions to jointly advance green technologies and improve their innovation capabilities. Furthermore, the promotion of ESG principles fosters increased collaboration and knowledge sharing among companies on green development, allowing them to exchange experiences, share resources, and innovate together³⁸.

In summary, we propose the third hypothesis of this paper:

Hypothesis 3 Ceteris paribus, an increase in ESG Scores contributes to the high-quality development of logistics enterprises through the channel of green innovation development.

Figure 1 illustrates the relationships among ESG score, innovation and development, and high - quality development of enterprises. It clearly demonstrates how ESG score, by promoting innovation (digital transformation and green innovation), contributes to the high - quality development of enterprises, specifically manifested as productivity improvement and expansion of enterprise scale. It comprehensively showcases all the hypotheses and their action mechanisms in this paper, providing a more intuitive and rigorous visual analysis framework for understanding the interplay of various factors.

Research methods and data processing

Model settings

Considering that the core variables in this study are all continuous variables that dynamically change across both firm - level and time - series dimensions, and that the research data involve complex information from multiple levels, including firms, cities, and time, in order to effectively control the unobserved heterogeneity at different levels and minimize the interference of endogeneity issues on the research conclusions, this study ultimately employs a high - dimensional fixed - effects model to test the proposed hypotheses. The specific regression model (1) is specified as follows:

$$DEV_{ict} = \alpha_0 + \alpha_1 ESG_{ict} + \alpha_2 Z_{ict} + \nu_i + \nu_{ct} + \epsilon_{ict} \quad (1)$$

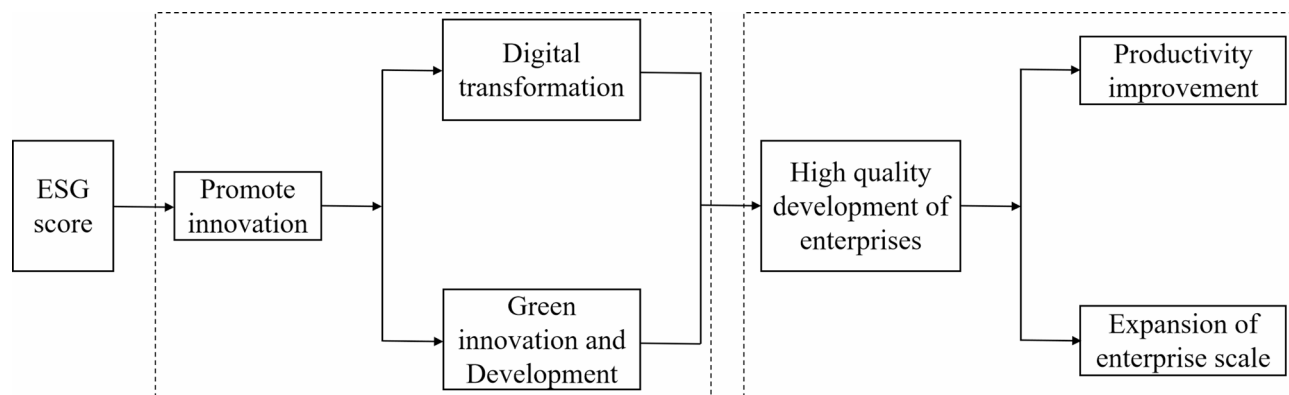


Fig. 1. Theoretical mechanism.

Where the subscripts i , c , and t denote the enterprises, city, and year, respectively. DEV represents the level of high-quality development of the firm, which is considered from both qualitative and quantitative perspectives. The qualitative aspect is measured by enterprise efficiency, while the quantitative aspect is measured by enterprises scale. ESG denotes the firm's ESG scores. Z represents the control variables, as detailed in the variable descriptions. v_i indicates the firm fixed effects, v_{ct} represents the city-year effects, and ε denotes the random error term. It is particularly worth emphasizing that the level of high-quality development of firms is likely to be strongly interfered by factors such as the level of development, the level of the labor force, and the policy regime at the city-year level, and therefore this paper further strengthens the year fixed effects as city-year level fixed effects.

Variable description

High-quality development. The high-quality development of enterprises is a multidimensional concept, essentially encompassing extensive dimensions such as economic benefits, social benefits, and environmental performance. As defined by Sun Qixiang and Zhou Xinfu³⁹, its core connotation includes improving production efficiency on the basis of emphasizing the synergistic enhancement of economic and social benefits — enhancing factor allocation efficiency through pathways such as technological transformation and management optimization, pursuing reasonable profit growth, cost control, and return on assets optimization at the economic benefit level, and manifesting the fulfillment of responsibilities such as social employment absorption and environmental protection at the social benefit level. In view of the complexity of reverse causality that may be triggered by the high interweaving of the connotation of broad-sense high-quality development and ESG (Environmental, Social, Governance) factors, this study adopts a narrow definition, focusing on the direct impact mechanism of traditional economic indicators on the high-quality development of enterprises. This restrictive definition aims to: ① avoid endogeneity interference among multi-dimensional indicators by isolating the core driving effects of enterprise size (SIZE) and total factor productivity (TFP); ② highlight the fundamental roles of factor efficiency and scale expansion through a model simplification strategy, so as to construct a theoretical anchor for the subsequent introduction of complex dimensions such as ESG. Accordingly, this study operationalizes corporate high-quality development as a dual evolution process of production efficiency optimization represented by the improvement of total factor productivity and enterprise scale expansion measured by indicators such as asset scale and revenue scale, which not only maintains the connection with the existing economic theoretical framework but also reserves multi-dimensional integration space for follow-up expansion research.

ESG scores. This paper evaluates and scores the performance of listed companies in the three dimensions of environment (E), society (S), and corporate governance (G) by referring to the introduction of Shanghai CSI Index Information Service Co., Ltd. and learning from the international mainstream methodology and practical experience, and combining the Chinese national conditions and the characteristics of the capital market. This system includes three primary indicators, 14 secondary indicators, and 26 tertiary indicators, with more than 130 data indicators at the fourth level. The ratings are divided into nine tiers from AAA to C, where BBB and above are considered leading levels, BB-CCC are categorized as average levels, and CC and below are classified as lagging levels. Accordingly, this paper uses the annual mean and median of Huazheng ESG scores as independent variables.

Digital transformation. Following the approach of Zhao Chenyu (2021)⁴⁰, this paper collects the annual reports of listed companies and counts the frequency of keyword disclosures in four aspects: application of digital technology, internet business models, intelligent manufacturing, and modern information systems. This reflects the degree of transformation of enterprises in these areas. Based on this, the frequency data are standardized, and the entropy method is used to determine the weights of each indicator, ultimately yielding an index of the degree of digital transformation. This paper uses the degree of digital transformation as a channel variable.

Green innovation. Based on patent classification numbers, this paper utilizes the WIPO green patent list to filter green patents of enterprises, selecting the total number of green patents applied as a channel variable.

Control variables. Referencing existing literature, this paper selects indicators such as cash flow, long-term debt ratio, cash holdings, return on net assets, and enterprise credit ratings as control variables. The explanations, measurements, and descriptive statistics of the variables are presented in Table 1 below:

Sample selection

Due to the imperfect data statistics system in the current logistics industry, there is no authoritative database specifically focusing on ESG indicators of logistics enterprises, which leads to objective difficulties in obtaining samples and collecting key indicators for non-listed enterprises; At the same time, the ESG rating system of third-party institutions relied on for research has strict independence and is limited by its internal evaluation rules, making it temporarily unable to conduct additional evaluations of non-listed companies. From the perspective of research design, the digital transformation and green innovation that this article focuses on have high requirements for enterprise resource reserves, technological capabilities, and strategic vision. Compared to small and medium-sized enterprises that focus on survival issues, stronger listed companies have more advantages in terms of capital investment, technological research and development, and long-term planning, and therefore have more motivation and ability to achieve high-quality development through innovation. In addition, the sample selection is consistent with mainstream research in the logistics field, and its scientific and reliable nature has been verified by academic practice. The sample data in this study primarily comes from listed company data and reports, as well as patent data, with specific details outlined as follows:

Data Time Frame: Considering data availability, this paper selects 2015–2022 in the baseline regression and extends it to 2010–2022 in the robustness.

Listed Company Data: First, this study filters out 109 logistics enterprises based on industry classification, including 9 in the warehousing category, 5 in the postal category, 85 in the transportation category, and 10 in the agency category. Subsequently, relevant variables are calculated based on different indicators.

Listed Company Reports: This study follows the methodology of Zhao Chenyu (2021) by utilizing textual analysis to calculate the frequency of keyword occurrences, which serves as a measure of the digital transformation level of listed companies⁴⁰.

Patent Data: On one hand, the presence or absence of patent applications is used to determine whether listed companies exhibit innovative behavior. On the other hand, the number of green patents applied for is filtered to assess the level of green innovation development among listed companies.

Empirical results and analyses

Baseline test results

Based on the econometric model (1), we test Theoretical Hypothesis 1. Table 2 presents the test results for Hypothesis 1, where columns (1) and (2) examine the impact of ESG scores on the scale of logistics enterprises, while columns (3) and (4) validate the effect of ESG scores on the efficiency of logistics enterprises. The dependent variable represents the level of high-quality development of logistics enterprises, measured by both the scale and efficiency of these enterprises, with ESG scores as the core explanatory variable.

On the one hand, to exclude unobservable factors that vary with the enterprise, this study controls for individual (enterprise) fixed effects. On the other hand, considering that the development of the logistics industry is significantly influenced by different city policies, this study further controls for city-year joint effects to account for the impact of variations in city support policies.

First, in columns (1) and (3) of Table 2, we examine the impact of ESG scores on the scale of logistics enterprises. In column (1), without adding control variables, the results show that the coefficient of ESG1 is significantly positive at the 5% confidence level. Considering that the scale of logistics enterprises may be influenced by other factors, we further included control variables in column (2) and (3), and the results indicate that the coefficient of ESG1 remains positive, with the confidence level rising to 1%. The regression results suggest

Var	Definition	Formula	Obs	Mean	SD	Min	Max
SIZE1	Enterprise scale	Enterprise scale = ln (total assets)	763	23.2781	1.441	20.06	26.96
SIZE2		Enterprise scale = ln(operating receipt)	763	22.2469	1.487	18.61	26.69
TFP1	Enterprise efficiency	Total factor productivity: the LP method	617	8.6803	1.079	5.81	11.28
TFP2		Total factor productivity: OP method	617	6.9959	0.891	4.67	9.49
ESG1	ESG scores	Annual average ESG scores of Huazheng Securities	763	3.8135	0.974	1.00	6.75
ESG2		Annual median ESG scores of Huazheng Securities	763	3.8316	1.016	1.00	7.00
INNO	Whether innovation	Whether to apply for a patent or not	763	0.1075	0.310	0.00	1.00
DIGI	Digital transformation	Degree of digital transformation	763	3.0010	1.165	0.00	6.55
GREEN	Green innovation	Total number of green patent applications	763	0.4705	1.941	0.00	25.00
C1	Cash flow	Cash flow = net operating cash flow / total assets	763	0.0726	0.061	-0.22	0.41
C2	Long-term debt ratio	Long-term debt ratio = total long-term liabilities / total assets	698	0.1826	0.143	0.00	0.70
C3	Cash holdings	Cash holdings = (monetary funds + trading financial assets) / total assets	763	0.1466	0.103	0.00	0.73
C4	Return on Equity (ROE)	ROE = Net Profit/Shareholder Equity Balance	760	-0.0117	1.709	-46.66	0.58
C5	Credit rating	Enterprise (main body) credit rating	763	1.7969	2.149	0.00	5.00

Table 1. Interpretation of variables and descriptive statistics.

VAR	(1)	(2)	(3)	(4)	(5)	(6)
	Enterprise scale			Enterprise efficiency		
	SIZE1	SIZE1		TFP1	TFP1	
EGS1	0.0706** (2.162)	0.1149*** (3.624)	0.0827*** (2.891)	0.1621*** (3.942)	0.1497*** (2.932)	0.1459*** (2.912)
Control	N	Y	Y	N	Y	Y
New Control	N	N	Y	N	N	Y
Enterprises	Y	Y	Y	Y	Y	Y
City-Year	Y	Y	Y	Y	Y	Y
OBS	561	490	479	426	364	357
SR2_A	0.965	0.964	0.967	0.902	0.904	Y

Table 2. Testing of hypothesis 1. Note: The values in parentheses () represent t-values; ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$. It is worth noting that columns (2) and (5) are the benchmark results of this article, and columns (3) and (6) are intended to mitigate the potential issue of omitted variables, with additional robustness results added later.

VAR	(1)	(2)	(3)
	Whether innovation	Digital transformation and upgrading	Green Innovative Development
	INNO	DIGI	GREEN
EGS1	0.0492* (1.889)	0.1687** (2.543)	0.2492* (1.848)
Control variables	Y	Y	Y
Enterprises	Y	Y	Y
City-Year	Y	Y	Y
OBS	490	490	490
R2_A	0.418	0.795	0.521

Table 3. Testing of hypothesis 2 and hypothesis 3. Note: The values in parentheses () represent t-values; ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

that all else being equal, there is a positive correlation between ESG scores and the scale of logistics enterprises, meaning that an increase in ESG scores is conducive to promoting the expansion of logistics enterprises and achieving high-quality development.

Next, in columns (4) and (6) of Table 2, we examine the impact of ESG scores on the efficiency of logistics enterprises. In column (4), without adding control variables, the results show that the coefficient of EGS1 is significantly positive at the 1% confidence level. Considering that the efficiency of logistics enterprises may also be influenced by other factors, we further included control variables in column (5) and (6), and the results indicate that the coefficient of EGS1 maintains its positive sign and significance. The regression results suggest that all else being equal, there is a positive correlation between ESG scores and the efficiency of logistics enterprises, meaning that an increase in ESG scores is beneficial for enhancing the efficiency of logistics enterprises and achieving high-quality development.

In summary, the analysis indicates that an increase in ESG scores is favorable for logistics enterprises to expand their scale and enhance their efficiency, thus achieving high-quality development, which validates Hypothesis 1 of this study.

Mechanism test results

To examine how ESG scores influence the high-quality development of enterprises through various channels, this study replaces the high-quality development variable DEV in the econometric model (1) with the channel variable CHA. Based on the previous analysis, this channel variable is likely related to enterprise innovation, which can be further divided into digital transformation and upgrading (DIG) and green innovation development (GREEN). The specific results of this examination are presented in Table 3. To maintain consistency and rigor in the research, this section also controls for individual (enterprise) fixed effects and city-year joint effects, and the control variables remain consistent with those mentioned earlier.

First, in column (1) of Table 3, the explained variable is whether the enterprise has innovated (INNO). If the enterprise applied for a patent in that year, then INNO = 1; otherwise, INNO = 0. The explanatory variable remains the ESG scores. As shown in the table, the coefficient of EGS1 is significantly positive, but the confidence level is only 10%, indicating that an increase in ESG scores can promote innovation in logistics enterprises, thereby achieving high-quality development. However, the significance is not high, suggesting that the comprehensive indicator of whether an enterprise has innovated does not precisely indicate specific channels of influence. To further analyze the specific channels of influence, this study will categorize enterprise innovation.

Next, considering that digital transformation and upgrading are core directions for current enterprise development, this study further narrows logistics enterprise innovation down to the direction of digital transformation and upgrading. Column (2) of Table 3 reports the relevant regression results, where the explained variable changes the degree of digital transformation and upgrading of logistics enterprises (DIGI). A larger value indicates a higher degree of digital transformation and upgrading. The explanatory variable remains the ESG scores. As shown in the table, the coefficient of ESG1 is still significantly positive, and the confidence level rises to 5%. This indicates that an increase in ESG scores can promote the digital transformation and upgrading of logistics enterprises, thereby achieving high-quality development. The significance has improved, suggesting that the indicator of digital transformation and upgrading in logistics enterprises can better explain the channel through which the increase in ESG scores promotes high-quality development.

Finally, recognizing that green innovation development is an important goal for current enterprise development, this study further narrows logistics enterprise innovation down to the direction of green innovation development. Column (3) of Table 3 reports the relevant regression results, where the explained variable changes the degree of green innovation development in logistics enterprises (GREEN). A larger value indicates a higher degree of green innovation development. The explanatory variable remains the ESG scores. As shown in the table, the coefficient of ESG1 is still significantly positive, with the confidence level maintained at 10%, indicating that an increase in ESG scores can promote green innovation development in logistics enterprises, thereby achieving high-quality development. However, the significance has not changed, which may be related to the measurement indicators used for assessing green innovation development in logistics enterprises. Since logistics enterprises primarily engage in logistics and transportation-related activities, their patent research and development direction tend to focus more on transportation rather than energy conservation and emission reduction. Therefore, using the number of green patents applied for as a measure of the degree of green innovation development in logistics enterprises may involve some bias. Nevertheless, overall, the indicator of green innovation development in logistics enterprises still explains the channel through which the increase in ESG scores promotes high-quality development. Thus, this study verifies Hypothesis 3.

Robustness test

Variable measurement problem and treatment

First, we consider the impact of measurement error in the dependent variable. As described in the previous section regarding variable definitions, this study measures enterprise scale using the logarithm of total assets and calculates enterprise efficiency using the LP method in the baseline regression. In contrast, this section uses the logarithm of operating income to measure enterprise scale and calculates enterprise efficiency using the OP method.

Next, we consider the impact of measurement error on the independent variable. In the baseline regression, this study used the annual average of Huazheng ESG scores to measure enterprise ESG scores. To enhance the credibility of the results, this study now chooses the annual median of Huazheng ESG scores to measure enterprise ESG scores.

Table 4 reports the relevant regression results. Columns (1) and (2) replace the measurement method of the dependent variable; columns (3) and (4) replace the measurement method of the independent variable, and columns (5) and (6) simultaneously replace the measurement methods of both the dependent and independent variables. As shown in Table 4, the coefficients of ESG1 and ESG2 are significantly positive, with confidence levels reaching 1%. This indicates that the regression results are consistent with those presented earlier, demonstrating that the results remain robust.

VAR	(1)	(2)	(3)	(4)	(5)	(6)
	Replace the dependent variables		Replace the independent variables		Replace dependent and independent variables	
	SIZE2	TFP2	SIZE1	TFP1	SIZE2	TFP2
ESG1	0.2366*** (5.085)	0.1504*** (3.068)				
ESG2			0.0926*** (3.368)	0.1256*** (2.997)	0.1996*** (5.076)	0.1303*** (3.111)
Control variables	Y	Y	Y	Y	Y	Y
Enterprises	Y	Y	Y	Y	Y	Y
City-Year	Y	Y	Y	Y	Y	Y
OBS	490	364	490	364	490	364
R2_A	0.945	0.852	0.964	0.904	0.944	0.852

Table 4. Results of robustness test on replacing cores variable measurement. Note: The values in parentheses () represent t-values; ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

Sample selection problem and treatment

Considering that the baseline sample includes certain special samples, the high-quality development levels of these enterprises may be significantly influenced by special factors such as economic policies rather than directly by ESG scores. This study excludes the following special samples:

Exclude ST and ST stock samples*: These specially treated stock samples often have financial conditions or other anomalies, and thus they are more focused on addressing existing problems rather than high-quality development.

Exclude ChiNext stock samples: Stocks in this category are characterized by high growth potential, high risk, strong innovation drive, and easy financing, with price fluctuation limits of $\pm 20\%$. They inherently lean more towards high-quality development.

Extend the sample period: The study selects enterprise samples from 2010 to 2022 to validate the impact of ESG scores on the high-quality development of logistics enterprises from a longer-term perspective.

Table 5 reports the relevant regression results. Columns (1) and (2) report regressions excluding ST and ST* samples; columns (3) and (4) report regressions excluding ChiNext samples; and columns (5) and (6) report regressions with the extended sample period. As shown in Table 5, the coefficient of ESG1 is significantly positive, with confidence levels not less than 5%, indicating that the regression results are consistent with those presented earlier.

Endogeneity issues and treatment

On one hand, in order to mitigate the issue of bidirectional causality, this study lags the explanatory variable (ESG1) by one period (ESG1_1). On the other hand, to thoroughly avoid endogeneity issues, this study employs an instrumental variable approach. Drawing from the work of Benlemlih and Bitar (2018)⁴¹, it selects the average ESG ratings of all publicly listed companies in the same county where each company is registered (ESG1_IV) as the instrumental variable. The ESG score of each logistics firm is affected by the ESG performance of other firms in the same county and therefore satisfies the correlation. The ESG scores of other firms are not directly correlated with the high quality development of this logistics firm, thus satisfying exogeneity. This study employs the two-stage least squares method (2SLS) for instrumental variable regression.

Table 6 reports the relevant regression results. Columns (1) and (2) present the results after lagging the variable, where the coefficient of ESG1_1 is significantly positive with a confidence level reaching 5%. This indicates that the regression results are consistent with those presented earlier, suggesting that the results are robust.

Columns (3) to (6) report the IV test results. Columns (3) and (5) provide the first-stage regression results, while columns (4) and (6) present the second-stage regression results. The table indicates that the weak instrument variable test has been passed, and the coefficients of both ESG1 and ESG1_IV are significantly positive, confirming that the study's conclusions withstand the instrumental variable test, thereby validating the robustness of the research findings.

Conclusions and policy recommendations

Conclusions

In the context of economic globalization, the logistics industry is crucial but faces challenges related to environmental, social, and governance (ESG) issues. ESG ratings have become important indicators for measuring a company's sustainable development capabilities. Studying the relationship between ESG ratings and the high-quality development of logistics enterprises is of practical significance. High-quality development in logistics requires a blend of efficiency, sustainability, innovation, and social responsibility. Currently, the industry faces challenges related to market competition, costs, environmental concerns, and awareness of social responsibilities. ESG ratings provide evaluation tools for investors, managers, and the public, promoting the digital transformation and green innovation development of logistics enterprises.

This paper, on the one hand, explores the empowering role of ESG ratings in the high-quality development of logistics enterprises, offering new perspectives. On the other hand, it investigates the mechanisms of influence from the perspectives of digital transformation and green innovation, enriching the theoretical framework and

VAR	(1)	(2)	(3)	(4)	(5)	(6)
	Exclude ST and ST* samples		Exclude samples from the ChiNext board		Extend the sample period	
	SIZE1	TFP1	SIZE1	TFP1	SIZE1	TFP1
ESG1	0.1134*** (3.582)	0.1515*** (2.930)	0.1124*** (3.447)	0.1472** (2.640)	0.1149*** (3.624)	0.1497*** (2.932)
Control variables	Y	Y	Y	Y	Y	Y
Enterprises	Y	Y	Y	Y	Y	Y
City-Year	Y	Y	Y	Y	Y	Y
OBS	482	356	464	338	490	364
R2_A	0.964	0.901	0.962	0.901	0.964	0.904

Table 5. Results of robustness test on sample replacement. Note: The values in parentheses () represent t-values; ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

VAR	(1)	(2)	(3)	(4)	(5)	(6)
	Variables lag		stage I	stage II	stage I	stage II
	SIZE1	TFP1	ESG1	SIZE1	ESG1	TFP1
ESG1_1	0.0817** (2.134)	0.1384** (2.631)				
ESG1				0.5223*** (3.314)		0.5555*** (3.916)
ESG1_IV			0.6024*** (6.395)		0.6346*** (4.883)	
Control variables	Y	Y	Y	Y	Y	Y
Enterprises	Y	Y	Y	Y	Y	Y
City-Year	Y	Y	Y	Y	Y	Y
OBS	413	317	480	480	364	364
R2_A	0.975	0.916		-0.821		-0.610
Cragg-Donald Wald F				29.60 {16.38}		25.10 {16.38}
Kleibergen-Paap Wald rk F				40.90 {16.38}		27.86 {16.38}
Kleibergen-Paap rk LM				8.87 [0.00]		9.07 [0.00]

Table 6. Results of robustness test on instrumental variables. Note: ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively. The regression coefficients are accompanied by t-values calculated using clustered robust standard errors in parentheses; the p-values are indicated in brackets [], and the values in braces { } represent the critical values from the Stock-Yogo test at the 10% level.

providing new ideas for research. The research conclusions indicate that improved ESG ratings are beneficial for the high-quality development of logistics enterprises, promoting increases in efficiency and scale through the channels of enterprise digital transformation and green innovation.

Policy recommendations

The policy implications of this study's conclusions are reflected in three aspects.

Recommendations for logistics enterprises. On the one hand, logistics companies need to deeply integrate ESG concepts into the core of their corporate strategy and formulate clear, quantifiable, and stage-by-stage ESG targets and implementation plans based on their operational characteristics and market positioning. For example, setting a target to reduce carbon emissions by a specific percentage (e.g. 5%) in the short term (1–2 years), improving employee welfare satisfaction to a certain level (e.g. 80%) in the medium term (3–5 years), and achieving a 10% reduction in costs due to the application of green technologies in the long term (more than 5 years) ensures that there is a clear path to sustainable development for the enterprise. On the other hand, increase investment in digital technology and green innovation to promote digital transformation and upgrading of enterprises and green innovation development, such as adopting digital technology to optimise production processes and increasing investment in green technology research and development. In addition, we should optimise the internal management of enterprises and improve the scientific, transparent and responsible decision-making in order to better respond to ESG-related risks and opportunities.

Recommendations for investors. On the one hand, a comprehensive investment appraisal system has been constructed to take ESG score of logistics enterprises as one of the core indicators and organically combine it with financial indicators (e.g. net profit growth rate, return on assets), market competitiveness indicators (market share, customer satisfaction), etc. to comprehensively judge the long-term investment value of the enterprise and the level of risk, so as to avoid investment decision-making from a single financial perspective. On the other hand, we continue to pay attention to the digital transformation process and green innovation achievements of logistics enterprises, such as regularly examining the upgrading of intelligent logistics technology, green patent applications and application effectiveness of enterprises; analysing the innovation potential of enterprises in emerging logistics modes (e.g. construction of urban green distribution network, application of green technology in cold chain logistics), and giving priority to investing in ESG performers with high innovation ability to obtain long-term stable returns.

Recommendations for government regulatory bodies. On the one hand, we have accelerated the construction of a regulatory framework for ESG in the logistics industry, and refined the standards for environmental emissions, employee labor protection, and corporate governance compliance. We will strengthen regulatory enforcement, establish a regular inspection and special audit mechanism, and seriously deal with non-compliant enterprises in accordance with the law, so as to ensure that the industry's ESG practices are promoted in an orderly manner. On the other hand, it has introduced diversified policy incentives, giving preferential policies such as tax breaks (e.g., a certain percentage of their green investment will be offset against their taxable amount), financial subsidies (for the purchase of green technology and equipment), and preferential project approvals to ESG-leading logistics

enterprises. Setting up an ESG industry fund to guide social capital to invest in green innovation and digital upgrading projects in logistics, and promote sustainable development and transformation of the industry.

Data availability

Empirical data will be furnished in accordance with the requirements. Should you have any need, please feel free to obtain the empirical data from Ni Sun (xinhua.wuliu@163.com).

Received: 11 February 2025; Accepted: 5 June 2025

Published online: 02 July 2025

References

- Du, F. et al. Price and distribution range of logistics service providers considering market competition. *Asia Pac. J. Mark. Logistics*. **30** (4), 762–778 (2018).
- Marcin et al. Identification and measurement of logistics cost parameters in the Company - ScienceDirect. *Transp. Res. Procedia*. **16**, 490–497 (2016).
- Lin, C. Y. A review of research on environmental issues in the logistics industry. *Inform. Manage. Bus. Rev.* **3** 1 (2011) 19–26.
- Solovjova, J. & Sivolapova, E. Corporate social responsibility in transport and logistics sector. *Transp. Res. Procedia* (2022).
- Zhang, M. L., Jiang, M. & Wang, W. B. Sustainable development of modern logistics industry under the condition of industrial cluster. In: *16th International Conference on Industrial Engineering and Engineering Management*. IEEE, (2009).
- Giese, G. et al. Performance and risk analysis of Index-Based ESG portfolios. *J. Index. Invest.* **4** (2019).
- Zhou, G. & Liu, L. Sustainable development, ESG performance and company market value: mediating effect of financial performance. *Bus. Strategy Environ.* **31** (7), 3371–3387 (2022).
- Gillan, S. L., Koch, A. & Laura, T. Starks. Firms and social responsibility: A review of ESG and CSR research in corporate finance. *J. Corp. Finance*. **66**, 101889 (2021).
- Ma, Y. et al. Firms' multi-sided platform construction efforts and ESG performance: an information processing theory perspective. *Ind. Mark. Manage.* **115**, 455–469 (2023).
- Liu, H. & **-Sup, J. Impact of digital transformation on ESG management and corporate performance: focusing on the empirical comparison between. *Korea China Sustain.* **16** (7), 2817 (2024).
- Andreevna, P. P. Building sustainable supply chains: collaboration capacity in emerging markets. (2023).
- Pham, T. et al. The effects of ESG combined score on business performance of enterprises in the transportation industry. *Sustainability* **14**.14 : 8354. (2022).
- Błaszczuk, A. & Milena Le Viet-Błaszczuk. and. The role of social media marketing of ESG in warehouse logistics. *Zeszyty Naukowe Organizacja I Zarządzanie/Politechnika Śląska* (2024).
- Altunina, V., Voytyuk, V. & Li, N. Ensuring sustainable development of the food packaging industry. *International conference Ecosystems without borders*. (Springer Nature Switzerland, 2023).
- Wang, L. & Shao, J. Can digitalization improve the high-quality development of manufacturing? An analysis based on Chinese provincial panel data. *J. Knowl. Econ.* **15** (1), 2010–2036 (2024).
- Volkov, V. et al. Determining the efficient management system for a specialized transport enterprise. *Scientific Bull. Natl. Min. University* **4** (2020).
- Liu, Lu, S., Si & Li Research on the effect of regional talent allocation on high-quality economic development—Based on the perspective of innovation-driven growth. *Sustainability* **15** 7 6315. (2023).
- Yan, B., Yao, B., Cheng & Zhang Industrial structure, high-quality development of logistics industry and the economy. *Plos One*. **18**, e0285229 (2023).
- Liu, Chen, D. & Cai, J. The operation of the cross-border e-commerce logistics in China. *Int. J. Intell. Inform. Syst.* **4** (2), 15–18 (2015).
- He, D. et al. Has the manufacturing policy helped to promote the logistics industry? *Plos One*. **15**, e0235292 (2020).
- Richnák, P. & Gubová, K. Green and reverse logistics in conditions of sustainable development in enterprises in Slovakia. *Sustainability* **13**.2 : 581. (2021).
- Quan, C. et al. Comprehensive efficiency evaluation of social responsibility of Chinese listed logistics enterprises based on DEA-Malmquist model. *Oper. Manage. Res.* **15** (3), 1383–1398 (2022).
- Khan, S. A. et al. Environmental, social and economic growth indicators spur logistics performance: from the perspective of South Asian association for regional Cooperation countries. *J. Clean. Prod.* **214**, 1011–1023 (2019).
- Šević, A. et al. Sustainability indices nexus: green economy, ESG, environment and clean energy. *Int. Rev. Financial Anal.* **96**, 103615 (2024).
- Gerard, B. ESG and socially responsible investment: A critical review. *Beta* **33**, 1 61–83. (2019).
- Mooneeapen, O., Abhayawansa, S. & Naushad Mamode Khan. The influence of the country governance environment on corporate environmental, social and governance (ESG) performance. *Sustain. Acc. Manage. Policy J.* **13** (4), 953–985 (2022).
- Van Duuren, Emiel, A., Plantinga & Bert Scholtens. ESG integration and the investment management process: fundamental investing reinvented. *J. Bus. Ethics.* **138**, 525–533 (2016).
- Yang, P. et al. Moving toward sustainable development: the influence of digital transformation on corporate ESG performance. *Kybernetes* **53**, 2 669–687. (2024).
- Ge, G. et al. Does ESG performance promote high-quality development of enterprises in China? The mediating role of innovation input. *Sustainability* **14**, 7 3843. (2022).
- Khudyakova, T. et al. Improving approaches to strategic enterprise management in the context of sustainable development. *Sustainability* **12**, 20 8375. (2020).
- Chen, F., Liu, Y. & Xue-zhao Chen ESG performance and business risk—empirical evidence from china's listed companies. *Innov. Green. Dev.* **3** (3), 100142 (2024).
- Nugroho, Deinera, P. D. et al. Investigating the interconnection between environmental, social, and governance (ESG), and corporate social responsibility (CSR) strategies: An examination of the influence on consumer behavior. *Sustainability* **16**, 2 614. (2024).
- Su, Wang, S. & Li, F. The impact of digital transformation on ESG performance based on the mediating effect of dynamic capabilities. *Sustainability* **15**, 18 13506. (2023).
- Hussain, M. et al. ESG in the digital age: unraveling the impact of strategic digital orientation. *Available SSRN* **4543836** (2023).
- Zhu, X. & Ye, Y. Economic policy uncertainty and enterprise export resilience in china: does the digital economy matter? *Heliyon* **10**, 10 (2024).
- Kotsantonis, S., Pinney, C. & Serafeim, G. ESG integration in investment management: Myths and realities. *J. Appl. Corp. Finance.* **28** (2), 10–16 (2016).
- Yin, D. How environmental, social, and governance (ESG) impacts the facility managers and the facilities management profession. MS thesis. (Pratt Institute, 2023).

38. Zhang, C. and Shanyue **. What drives sustainable development of enterprises? Focusing on ESG management and green technology innovation. *Sustainability* 14, 18 11695. (2022).
39. Jia, H. & Zhang, W. Scientific and technological innovation, industrial structure upgrading, and High-Quality economic development. *China Economic Transition = Dangdai Zhongguo **gi Zhuaxing Yanjiu*. 5 (3), 388–407 (2022).
40. Zhao, C., Wang, W. & Li, X. How does digital transformation affect the total factor productivity of enterprises. *Finance Trade Econ.* 42 (7), 114–129 (2021).
41. Benlemlih, M. & Bitar, M. Corporate social responsibility and investment efficiency. *J. Bus. Ethics.* 148, 647–671 (2018).

Author contributions

D.L. is mainly responsible for the theory, writing, and funding of the paper; N.S. is mainly responsible for the concepts, methods, and analysis of the paper; X.Z. is mainly responsible for the writing, data and methods of the paper.

Funding

Anhui Province Higher Education Revitalization Plan (Logistics Management) (No. 2013ZXS01), Anhui Province Higher Education Science Research Project (No. 2024AH052538), Anhui Province Quality Engineering Project (No. 2021sx065), University level Doctoral Talent Research and Training Project (No. bs2025kyqd025).

Declarations

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to N.S.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

© The Author(s) 2025