



CAFÉ WORKING PAPER NO.42

Centre for Accountancy, Finance, and Economics (CAFE)

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April 2026

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Abstract

This study examines the impact of data factor marketization on the ESG performance of companies listed in the Shanghai and Shenzhen A-share markets in China. An empirical analysis of data from 2009 to 2022 reveals that the marketization of data factors significantly enhances corporate ESG performance, with more pronounced effects observed in heavily polluting and non-high-tech enterprises. The positive influence of data factor marketization on ESG performance is mediated through mechanisms such as promoting digital transformation, alleviating financing constraints, and reducing agency costs. Furthermore, the research uncovers the heterogeneous effects of data factor marketization across different regions and corporate characteristics, with companies in regions with higher marketization levels and the eastern part of China benefiting more significantly. This study fills a gap in the literature regarding the relationship between data factor marketization and corporate ESG performance, constructing a comprehensive analytical framework that extends the application boundaries of ESG theory in the big data era. It provides theoretical and empirical support for government policy-making and corporate strategic planning.

Keywords: Data factor marketization; Corporate ESG performance; Digital transformation; Financing constraints; Agency costs.

JEL classification: Q56; G34; M14

Introduction

In recent years, with the widespread adoption of technologies such as big data, cloud computing, and artificial intelligence, data's potential value-creation capabilities have been thoroughly explored. Data has become a crucial driver for fostering corporate innovation, optimizing resource allocation, and enhancing competitive advantage (Manyika et al., 2011). According to the forecast published in the "Digital Economy Report" by the United Nations Conference on Trade and Development, the value added to the global economy by cross-border data flows is expected to reach \$11 trillion by 2025. This projected value is five times the total contribution of cross-border data flows to the global economy from 2009 to 2018. Meanwhile, governments and regional organizations worldwide are implementing policies to accelerate the market-oriented reform of data elements. For example, China has issued documents such as the "Opinions on Improving the Market-Based Allocation Mechanism of Production Factors" to promote the development of an open, competitive, and well-regulated data market system.

Multiple local governments in China have been actively advancing the development of the data elements market. As of 2022, data exchanges have been established in 29 cities, including Beijing, Shanghai, and Shenzhen, marking the rapid expansion of data marketization practices across the country. These data exchanges have provided a platform for the legal circulation and value realization of data resources. The establishment of these platforms has further unlocked the potential for value creation in data elements, becoming a key force in driving innovation, optimizing resource allocation, and enhancing enterprise competitiveness (Manyika et al., 2011). According to data from the Ministry of Industry and Information Technology, by the end of 2022, the numerical control rate of key processes in industrial enterprises and the penetration rate of digital research and design tools had reached 58.6% and 77.0%, respectively. The "China Data Elements Market Development Report (2022–2023)" highlights that big data applications have deeply penetrated all aspects of research and

development, production, operations, management, and logistics, significantly promoting business growth in industrial enterprises. Against this backdrop, exploring how to leverage the marketization of data elements in resource allocation to further drive enterprise development has become a critical topic of interest for both the government and academic circles in recent years.

Existing research has shown that the marketization of data elements not only facilitates the digital transformation of enterprises but also enhances decision-making efficiency and operational transparency. On the one hand, enterprises leverage big data analytics to optimize supply chain management and improve the customization and environmental sustainability of products and services, thereby demonstrating strong performance in environmental and social dimensions (Porter & Heppelmann, 2014; Gawer, 2009). On the other hand, the open circulation of data drives enterprises to improve internal governance efficiency, strengthen risk identification and response measures, and ensure the scientific and compliant nature of decisions, thereby improving governance practices (Brynjolfsson & McElheran, 2016). These changes are closely linked to the Environmental, Social, and Governance (ESG) framework of enterprises, establishing a logical connection between the marketization of data elements and the enhancement of corporate ESG performance.

Under the dual drivers of global economic integration and sustainable development goals, corporate ESG performance has become a critical indicator for assessing long-term value and risk management capabilities on a global scale. In China, with the accelerated opening of capital markets, regulatory bodies such as the China Securities Regulatory Commission (CSRC) and the Shenzhen Stock Exchange (SZSE) have successively issued normative documents, including the "Code of Corporate Governance for Listed Companies" and the "Assessment Measures for Information Disclosure by Listed Companies," aiming to promote the quality of ESG information disclosure through policy measures. However, while pursuing

shareholder value maximization, enterprises face challenges in improving ESG performance due to the high costs of implementation, lack of professional management experience, and the complexity of data acquisition and management. Additionally, the long-term benefits of ESG initiatives may not be immediately apparent, and insufficient regulatory and market pressure can diminish the internal motivation of enterprises to improve their ESG performance.

This study selects initial data from A-share listed companies on the Shanghai and Shenzhen stock exchanges between 2009 and 2022 as the research sample. Constructing an empirical model, it investigates the impact of data element marketization on corporate ESG performance and explores the mechanisms driving this impact. The study aims to contribute theoretical and empirical support to the advancement of ESG practices in China. Specifically, the research design draws on the approach of Liu Manfeng, Yang Jie and Chen Liang (2023), using the establishment of data trading platforms by local governments as a quasi-natural experiment. The study constructs a data element marketization index through the interaction of regional and temporal dummy variables and empirically tests the impact of data element marketization on corporate ESG performance, ensuring the reliability of the conclusions through a series of robustness checks. In the mechanism analysis, the study empirically examines the role of data element marketization in corporate ESG performance from three perspectives: digital transformation, financing constraints, and agency costs. Additionally, heterogeneity analysis is conducted to reveal the varying impacts of data element marketization on ESG performance across different corporate characteristics and regions with varying degrees of marketization.

The marginal contributions of this study are as follows: First, it innovatively integrates the marketization of data elements with corporate ESG performance, constructing a comprehensive analytical framework. By analysing how data element marketization promotes the deepening and effectiveness of ESG practices, this study extends the application of ESG

theory into the new domain of the big data era and provides enterprises with a new strategic perspective for enhancing sustainable development capabilities. Second, the study delves into the mechanisms by which data element marketization aids corporate ESG performance from the aspects of digital transformation, financing constraints, and agency costs, partially uncovering the "black box" between the two, thereby enhancing its practical significance. Finally, based on differences in corporate characteristics and degrees of marketization, the study conducts a detailed analysis of the heterogeneous impacts of data element marketization on ESG performance, considering factors such as heavy pollution, high-tech industries, marketization levels, and regional attributes between eastern and western China. This further refines the conclusions and provides empirical evidence for government policy-making and corporate strategic planning.

Literature Review

(1) Research on the Marketization of Data Elements

The marketization of data elements refers to the process of promoting the circulation and utilization of data resources through market mechanisms, which has significant implications for both regional economic development and corporate growth. The role of data element marketization in regional economic development is evident in two key aspects:

First, the circulation of data resources greatly enhances innovation activities within regions. The openness of data platforms is closely linked to regional innovation outputs. By enabling data sharing and openness, companies can more easily access external data resources, thereby improving their research and development (R&D) efficiency and innovation capabilities.

Second, data element marketization contributes to balanced regional economic development. The market-driven allocation of data resources can break down informational

barriers between regions, reducing the digital divide and promoting economic growth in less developed areas. Effective allocation of data resources allows enterprises in remote regions to access the same level of data support as those in developed areas, fostering more balanced regional economic growth. The role of data marketization in narrowing the digital divide is particularly pronounced in developing countries.

The impact of data element marketization on enterprises can be summarized in the following areas:

Enhancing Operational Efficiency: Data element marketization enables companies to more efficiently acquire and utilize data resources, optimizing production processes and operational management. For example, data-driven decision support systems help companies accurately predict market demand, thereby reducing inventory and logistics costs (Brynjolfsson & McElheran, 2016). Additionally, the application of data analytics can increase market responsiveness and competitiveness (Manyika et al., 2011) while boosting productivity in manufacturing.

Promoting Innovation and R&D: The marketization of data elements provides enterprises with abundant data resources and technical support for innovation. Through data mining and analysis, companies can identify new market demands and technological trends, leading to the development of innovative products and services. Moreover, data marketization fosters collaborative innovation among companies, with data sharing playing an increasingly crucial role in cross-industry innovation. Companies can collaborate on R&D and market expansion through data sharing and cooperation (Chesbrough, 2003).

Enhancing Market Competitiveness: Data element marketization enables companies to better understand consumer needs and market dynamics, allowing for more precise marketing strategies. By analysing consumer behaviour data, companies can implement personalized

marketing, enhancing customer satisfaction and loyalty (Rust & Huang, 2014). Additionally, data marketization helps shorten the time for supply chain management, improving operational efficiency and response times, and reducing the risk of inventory buildup and supply chain disruptions (Christopher, 2016).

Driving Digital Transformation: Data element marketization is a crucial driver of digital transformation in enterprises. Through the market-driven allocation of data resources, companies can more easily access digital technologies and services, accelerating the process of digital transformation (Westerman et al., 2014). This transformation not only enhances operational efficiency but also strengthens the ability to respond to market fluctuations. Data marketization significantly propels digital transformation and fosters the emergence of new business models. For instance, companies can enhance the flexibility and scalability of their IT infrastructure by purchasing cloud computing services, thereby better adapting to market changes and business needs (Marston et al., 2011).

(2) Research on the Factors Influencing ESG Performance

Corporate ESG performance is shaped by a variety of micro and macro factors. At the micro level, several key influences stand out. First, corporate governance structures play a crucial role; companies with independent and diverse boards tend to exhibit stronger ESG performance. This is because such boards bring a range of perspectives and expertise, which enhances the oversight and guidance of ESG activities. Recent studies confirm that gender diversity and board independence are particularly effective in boosting ESG outcomes.

Second, the culture and values of a company are strongly linked to its ESG performance. Companies that prioritize sustainability and social responsibility often perform better in environmental protection, social responsibility, and governance (Eccles et al., 2014). Third, stakeholder pressure significantly influences ESG performance. As demands from

investors, customers, suppliers, and employees for higher ESG standards grow, companies respond by adopting more proactive ESG strategies to improve their image and competitiveness (Freeman et al., 2010). Fourth, a company's financial performance also affects its ESG efforts. Financially strong companies are better equipped to invest in ESG initiatives, which in turn can enhance their reputation, reduce risks, and improve financial sustainability (Friede et al., 2022).

At the macro level, government incentives play a significant role in promoting ESG performance. Governments can drive corporate ESG initiatives by offering tax incentives, subsidies, and other rewards. For example, many countries provide tax breaks and financial support to companies that adopt clean energy and energy-saving technologies, thereby encouraging environmentally friendly production methods. Additionally, regulations mandating ESG disclosures have a profound impact on corporate transparency and accountability. The EU's Non-Financial Reporting Directive (NFRD) is a prime example of how legislation can compel large companies to disclose ESG information, thereby enhancing their transparency and responsibility (KPMG, 2020).

Market competition is another macro-level factor that influences ESG performance. In highly competitive industries, companies are motivated to adopt higher ESG standards to differentiate themselves and attract more consumers and investors. Moreover, social culture plays a crucial role, especially in societies where there is a strong awareness of environmental issues and social responsibility. In such contexts, companies are more likely to prioritize ESG performance, as seen in Nordic countries where corporate strategies frequently align with societal demands for sustainability (Hofstede et al., 2001).

Finally, international standards and guidelines, such as those set by the UN Global Compact and the Global Reporting Initiative (GRI), provide clear frameworks for ESG

practices. Adherence to these international standards can significantly enhance a company's global competitiveness and sustainability (UN, 2000; GRI, 2016).

While it is clear that data element marketization has profound effects on corporate behaviour—enhancing operational efficiency, fostering innovation, increasing market competitiveness, and driving digital transformation—the direct impact of data marketization on ESG performance has been relatively underexplored in academic research. This study, therefore, aims to investigate the specific mechanisms and pathways through which data element marketization influences corporate ESG performance, offering valuable insights for both theoretical understanding and practical application.

Theoretical Analysis and Hypothesis

As a crucial production factor, data drives corporate innovation, resource optimization, and competitive advantage (Manyika et al., 2011). The widespread adoption of big data, cloud computing, and AI has made data marketization essential for fostering innovation and optimizing resources. Beyond economic benefits, data marketization also significantly impacts a company's Environmental, Social, and Governance (ESG) performance.

(1) The Role of Data Marketization in Enhancing ESG Performance

Data marketization facilitates the efficient allocation of data resources, providing companies with unprecedented opportunities to excel in environmental, social, and governance dimensions.

On the environmental front, data marketization offers companies access to abundant data resources and analytical tools, enabling them to optimize resource allocation and improve energy efficiency. This drives the adoption of more efficient production methods, reduces resource consumption and environmental pollution, and enhances green supply chain management (Porter & Heppelmann, 2014). Additionally, data-driven environmental

management systems allow companies to monitor and manage their environmental impact in real time, supporting green production and sustainable development.

In the social dimension, data marketization significantly enhances corporate transparency, encouraging greater attention to employee welfare, community engagement, and consumer rights protection. By leveraging data analytics, companies can better predict and manage labour rights issues within the supply chain, thereby strengthening their social responsibility (Gawer & Cusumano, 2019). Furthermore, companies can use data to better understand customer needs and societal expectations, leading to the development of products and services that offer greater social value. The transparency afforded by data marketization also improves the disclosure of corporate social responsibility information, thereby enhancing social performance.

In terms of governance, data marketization improves internal information flow and management efficiency. Data-driven decision support systems enable corporate management to make more informed strategic decisions, reducing information asymmetry and increasing the scientific rigor of internal governance. This also enhances external oversight, ensuring fairness and compliance in decision-making processes (Brynjolfsson et al., 2017). Moreover, data analytics can assist companies in identifying and managing risks, optimizing internal control mechanisms, and ultimately improving governance performance.

H1: The marketization of data elements enhances corporate ESG performance.

(2) Mechanisms of Data Marketization's Impact on Corporate ESG Performance

Data marketization influences corporate ESG performance through three key mechanisms:

1. Data Marketization, Digital Transformation, and ESG Performance

Data marketization accelerates corporate digital transformation, enabling companies to adopt advanced information technologies that optimize production processes, enhance operational efficiency, and foster innovation in product design and supply chain management (Porter & Heppelmann, 2014). Digital transformation allows companies to better monitor and control environmental impacts, improve energy efficiency, and reduce waste, thereby enhancing their environmental performance. For example, smart sensors can provide real-time data on energy consumption, enabling companies to adjust production plans and achieve energy-saving goals. Moreover, digital technologies aid in enhancing social responsibility practices by predicting and managing labour rights issues in the supply chain, ensuring transparency and compliance (Gawer & Cusumano, 2019). Digital transformation also improves corporate governance by increasing decision-making transparency, strengthening risk management, and optimizing governance performance. Big data analytics, for instance, can help companies identify potential operational risks and adjust strategies to prevent crises (Brynjolfsson et al., 2017).

H2: Data marketization promotes corporate ESG performance by facilitating digital transformation.

2. Data Marketization, Financing Constraints, and ESG Performance

Data marketization lowers the barriers to financing, particularly for small and medium-sized enterprises (SMEs). Through credit assessments and risk analyses on data platforms, companies can more easily secure support from financial institutions, easing financing constraints. Reduced financing constraints allow companies to allocate more resources to ESG initiatives, such as developing environmental technologies or implementing social responsibility projects, thereby enhancing their ESG performance. For example, companies can invest in green energy projects with the obtained funds, reducing carbon emissions and

improving environmental performance. Additionally, strong ESG performance can further lower a company's financing costs, creating a virtuous cycle. Investors and financial institutions increasingly favor companies with strong ESG credentials, viewing them as more stable and sustainable in the long term.

H3: Data marketization positively impacts corporate ESG performance by alleviating financing constraints.

3. Data Marketization, Agency Costs, and ESG Performance

Data marketization increases information transparency, reducing information asymmetry and, consequently, agency costs (Jensen & Meckling, 1976). In a data-rich environment, the information gap between shareholders and management narrows, enabling shareholders to better monitor managerial actions and prevent self-serving behaviours, thus improving corporate governance (Shleifer & Vishny, 1997). For instance, real-time access to financial and operational data allows shareholders to stay informed about the company's performance and effectively oversee management decisions, ensuring the long-term interests of the company. Additionally, data marketization enhances communication with external stakeholders and strengthens social oversight, prompting companies to focus more on ESG performance to maintain a positive corporate image and reputation. By proactively disclosing ESG information, companies can build trust and support from the public, attracting more socially responsible investors.

H4: Data marketization positively impacts corporate ESG performance by reducing agency costs.

Data

This study focuses on Chinese A-share listed companies from 2009 to 2022, with financial data sourced from the CSMAR database by GTA. To ensure the stability of the results,

the data was processed as follows: 1) Financial industry companies were excluded; 2) Companies classified as ST, ST*, or PT were removed; 3) Companies registered in the Cayman Islands and Hong Kong were excluded; 4) Samples with negative net assets were removed; 5) Samples with missing data were excluded; 6) To ensure the integrity of the panel data, companies listed after 2015 were excluded. A 1% Winsorization was applied to all variables, resulting in a total of 30,340 observations.

Variable Definitions

Dependent Variable

Corporate ESG Performance (ESG): This study uses the ESG rating system of Huazheng as the dependent variable due to its more comprehensive data compared to other companies' ESG indicators. The ESG ratings are assigned values ranging from 1 to 9. For robustness checks, the ESG performance score (0-100) provided by Huazheng is used as an alternative dependent variable to ensure the consistency of the conclusions.

Independent Variable

Marketization of Data Factors (did): Following the research of Liu Manfeng et al., the establishment of data trading platforms led by local governments in China is regarded as a key event marking the marketization of data factors. The year a platform is established is taken as the starting point of data factor marketization in the region, creating a quasi-natural experiment. The effect of data factor marketization is evaluated through an interaction term between regional dummy variables and the time dummy variables for the platform's establishment. Cities that have established data trading platforms are assigned a value of 1 (experimental group), while those that have not are assigned 0 (control group). Time dummy variables are also assigned based on the year of platform establishment, with years prior to establishment assigned 0 and years following establishment assigned 1. The focus is on the coefficient of the

did variable: a value greater than 0 indicates a positive impact of data factor marketization on corporate ESG performance, while a value less than 0 suggests a negative impact.

Control Variables

Based on existing literature, the following control variables are included in this study: company size (Size), debt-to-asset ratio (Lev), return on assets (ROA), Tobin's Q (TobinQ), cash flow ratio (Cashflow), R&D expenditure (RD), revenue growth rate (Growth), shareholding ratio of the top five shareholders (TOP5), board size (Board), proportion of independent directors (Indep), CEO duality (Dual), as well as time, city, and firm fixed effects. Additionally, city-level control variables include per capita GDP (Pgdp), balance of loans from financial institutions (finance), and the ratio of local government expenditure on science and technology to regional GDP (rd).

Mechanism Variables

Based on the theoretical analysis, the mechanism variables include the following: (1) Digital Transformation (digital): Following Wu Fei et al. (2021), this is measured by the logarithm of the frequency of digital transformation-related terms in the company's annual reports. (2) Financing Constraints (WW): Using the nonlinear GMM method to estimate Euler equation parameters, as described by White & Wu (2006), the firm-level financing constraint is calculated. (3) Agency Costs (agency): This is measured by the ratio of the sum of management expenses and selling expenses to operating income.

Model

First, to examine the impact of data factor marketization on corporate ESG performance, this study adopts the approach of Zheng Guoqiang et al. (2023) and uses the establishment of big data comprehensive experimental zones in various Chinese cities as a quasi-natural experiment. The following model is constructed:

$$ESG_{ict} = \alpha_0 + \alpha_1 did_{ict} + \beta_j Controls_{ict} + \gamma_i + \mu_c + \tau_t + \varepsilon_{it} \quad (\text{Equation 1})$$

In this model, the subscripts i , c and t represent firm i in city c in year t . The dependent variable ESG_{ict} measures the ESG performance of the firm. The key independent variable did_{ict} represents the policy effect. If city c establishes a big data comprehensive experimental zone in year t , the variable did take the value 1; otherwise, it takes 0. The model also includes a set of control variables $Controls_{ict}$. The terms γ_i , μ_c and τ_t represent firm, city and time effects, respectively and ε_{it} is the random error term.

Second, to explore the indirect mechanisms through which data factor marketization affects corporate ESG performance, a two-step mechanism test is conducted:

$$M_{ict} = \delta_0 + \delta_1 did_{ict} + \lambda_j Controls_{ict} + \gamma_i + \mu_c + \tau_t + \varepsilon_{it} \quad (\text{Equation 2})$$

Here, M_{ict} represents the mechanism variables, specifically digital transformation, financing constraints, and agency costs. The other variables remain consistent with Model (1).

Empirical analyse.

(1) Descriptive Statistics

Table 1 presents the descriptive statistics for all variables. The dependent variable, ESG, has a mean value of 4.0644, a median of 4, and a standard deviation of 1.0740, indicating a normal distribution and significant variation in ESG performance across companies, which meets the conditions for this study. The independent variable did have a mean value of 0.2630, suggesting that 26.30% of the listed companies in this study are in regions with data trading platforms. The control variables show no significant deviations compared to existing literature, contributing positively to the accuracy and reliability of the research results.

Table 1. Descriptive Statistics of Key Variables

	count	mean	sd	min	p50	max
ESG	30340	4.0644	1.0740	1.0000	4.0000	6.0000
did	30340	0.2630	0.4403	0.0000	0.0000	1.0000
Size	30340	22.3461	1.3289	19.8319	22.1710	26.3685
Lev	30340	0.4450	0.2063	0.0510	0.4425	0.8956
ROA	30340	0.0363	0.0638	-0.2315	0.0350	0.2145
TobinQ	30340	2.0382	1.3248	0.8370	1.6087	8.5446
Cashflow	30340	0.0459	0.0695	-0.1631	0.0445	0.2434
RD	30340	0.0171	0.0184	0.0000	0.0131	0.0906
Growth	30340	0.1643	0.4192	-0.5724	0.1003	2.7075
TOP5	30340	0.5161	0.1534	0.1932	0.5134	0.8730
Board	30340	2.1373	0.1987	1.6094	2.1972	2.7081
Indep	30340	0.3751	0.0541	0.3333	0.3333	0.5714
Dual	30340	0.2410	0.4277	0.0000	0.0000	1.0000
pgdp	30340	11.3692	0.5377	9.9166	11.4323	12.2234
finance	30340	18.4495	1.4190	15.1215	18.6251	20.6772
rd	30340	0.0062	0.0045	0.0006	0.0047	0.0207

(2) Baseline Regression

Table 2 presents the baseline regression results. Column (1) of Table 2 shows the regression results for the core independent variable, **data factor marketization (did)**, without including the control variables at the prefecture-level city dimension, while keeping other control variables constant. The regression coefficient for **did** is 0.0554, which is positive and significant at the 5% level. In Column (2), after adding three prefecture-level city control variables, the regression coefficient for **did** increases to 0.0643 and remains positively significant at the 5% level.

This indicates that, regardless of whether additional control variables are included, data factor marketization has a significant positive effect on corporate ESG performance, and the

impact is robust. The primary reasons for this positive effect are twofold: First, as data factor marketization progresses, it increases corporate transparency and compliance with policies, incentivizing companies to improve ESG behavior to attract investment and protect their reputation. Second, more accurate data analysis helps companies develop environmentally friendly products and proactively identify and mitigate potential environmental and social risks, resulting in better ESG performance. In conclusion, **Hypothesis 1** of this study is validated.

Table 2. Regression Results

	(1)	(2)
VARIABLES	ESG	ESG
did	0.0554**	0.0643**
	(2.1680)	(2.4585)
Size	0.2427***	0.2435***
	(12.9655)	(12.9121)
Lev	-0.7740***	-0.7735***
	(-11.0447)	(-11.0582)
ROA	1.0443***	1.0452***
	(7.5886)	(7.6035)
TobinQ	-0.0122*	-0.0119
	(-1.6706)	(-1.6294)
Cashflow	-0.3752***	-0.3752***
	(-3.9909)	(-3.9950)
RD	3.1324***	3.1379***
	(3.9917)	(3.9959)
Growth	-0.0474***	-0.0472***
	(-3.5396)	(-3.5141)
TOP5	0.2999***	0.2950***
	(3.1184)	(3.0662)
Board	0.0951	0.0949

	(1.3045)	(1.3040)
Indep	1.4435***	1.4416***
	(6.7669)	(6.7615)
Dual	-0.0440**	-0.0441**
	(-2.0713)	(-2.0696)
pgdp		0.0080
		(0.1500)
finance		0.0557
		(0.9387)
rd		-6.8070*
		(-1.8860)
Constant	-1.9607***	-3.0547**
	(-4.3338)	(-2.4602)
Adjusted R-squared	0.4719	0.4720
Firm FE	YES	YES
Year FE	YES	YES
City FE	YES	YES

*** p<0.01, ** p<0.05, * p<0.1, Robust t-statistics in parentheses

(3) Parallel Trend Test

The use of a Difference-in-Differences (DID) model requires that, prior to policy implementation, the experimental group and control group follow a consistent trend—known as the parallel trend assumption. Since the establishment times of data exchanges vary across cities, a fixed year cannot be universally used as the event point to set time dummy variables. Instead, a relative time dummy variable must be assigned to each city based on the year their data exchange was established.

Following the method of Beck et al. (2010), this study uses an event study approach to conduct the parallel trend test. The following model is constructed:

$$ESG_{ict} = v_0 + v_1 dis\ tan\ t_{ict} + \beta_j Controls_{ict} + \gamma_i + \mu_c + \tau_t + \varepsilon_{it} \quad (\text{Equation 3})$$

In equation (3), the variable $dis\ tan\ t_{ict}$ represents the observations for each city from n years before to n years after the establishment of the data exchange. For cities without a data exchange, the dummy variable takes the value of 0. The range of n is set from $[-7,7]$, meaning the test period includes 7 years before and after the event.

The results, illustrated in Figure 1, show that prior to the establishment of data exchange, there is no significant difference in ESG values between the experimental and control groups, confirming the parallel trend assumption. After the establishment of the data exchange, the ESG values in the treatment group are higher than those in the control group, further validating the positive impact of data exchange establishment on corporate ESG performance. Moreover, the effect increases gradually over time, indicating a growing influence as the data exchange becomes more established.

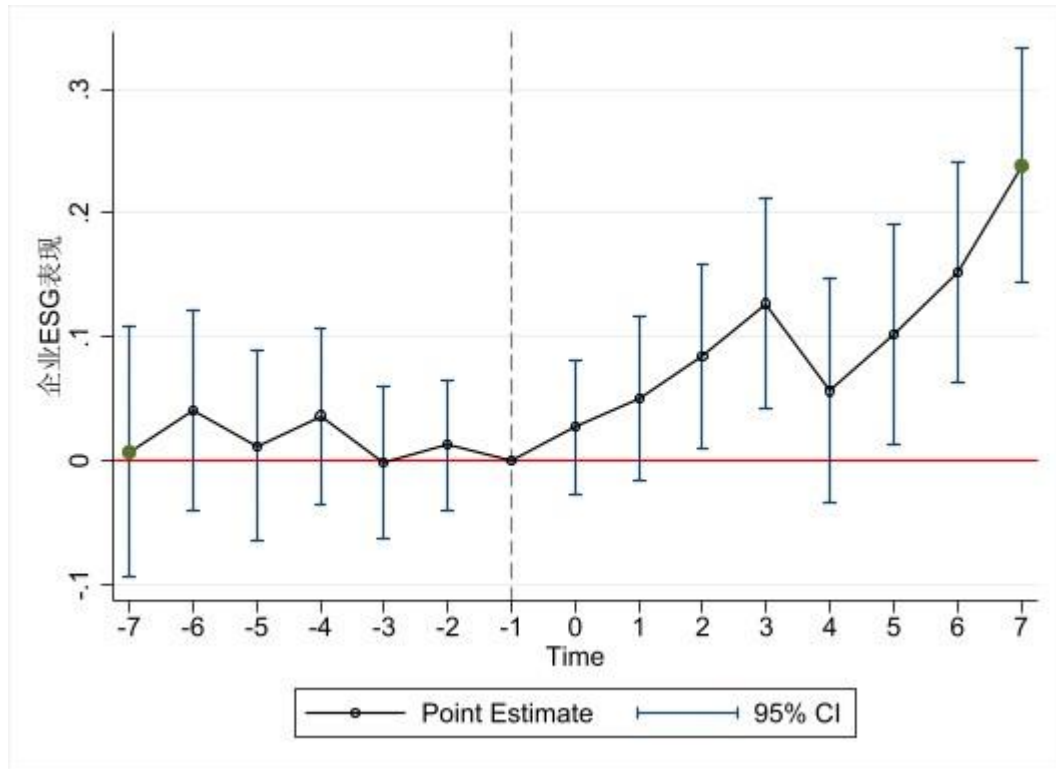


Figure 1. Parallel Trend Test

(4) Robustness Tests

Replacing the Dependent Variable:

To ensure the reliability of the regression results, the ESG performance score (ESG_Score) provided by Huazheng was used as an alternative dependent variable. This allowed for a remeasurement of the impact of data exchange establishment from different ESG dimensions. According to the regression results in Column (1) of Table 3, when using the ESG performance score, the estimated coefficient of the core independent variable did remains significantly positive. This indicates that data factor marketization still has a significant positive impact on the ESG performance of listed companies, demonstrating the robustness of the findings.

Considering Other Policy Impacts:

During the sample period, the Chinese government implemented various policies, such as "Broadband China," which could influence the development of the regional digital economy and potentially affect the results of this study. To account for this, a dummy variable for the "Broadband China" policy (kuandai) was introduced to control for the effects of other policies on the estimates. The regression results in Column (2) of Table 3 show that, after controlling for the effects of other policies, the direction and significance of the core independent variable did remain consistent with the baseline regression, confirming the robustness of the conclusions.

Addressing Endogeneity:

Considering the potential lagged effects of corporate ESG performance and to mitigate endogeneity issues caused by reverse causality, all independent variables were lagged by one period. The regression results in Column (3) of Table 3 indicate that the direction and

significance of the coefficient for *did* remain unchanged, alleviating concerns about endogeneity to some extent. This further supports the robustness of the conclusions.

Propensity Score Matching Regression:

To eliminate differences in characteristic variables between the experimental and control groups and reduce bias in the regression results, propensity score matching was employed, using all control variables as matching variables. The difference-in-differences method was applied to ensure the robustness of the conclusions. Column (4) of Table 3 presents the regression results based on kernel matching in the propensity score matching estimation. The core independent variable *did* remains significantly positive at the 5% level. This suggests that the influence of individual characteristics across cities is relatively small, further confirming the robustness of the study's conclusions.

Table 3. Robustness Tests Results

VARIABLES	(1) ESG_Score	(2) ESG	(3) F.ESG	(4) ESG
did	0.3415*** (2.6703)	0.0678*** (2.5824)	0.0986*** (3.5306)	0.0616** (2.3042)
Size	1.2415*** (13.4811)	0.2436*** (12.9213)	0.1479*** (7.1679)	0.2457*** (12.4986)
Lev	-3.9223*** (-11.5592)	-0.7738*** (-11.0612)	-0.5979*** (-7.7330)	-0.7773*** (-10.6218)
ROA	5.3016*** (7.9172)	1.0446*** (7.5977)	2.9478*** (19.3915)	1.0621*** (7.4171)
TobinQ	-0.0350 (-0.9889)	-0.0119 (-1.6271)	-0.0152* (-1.9520)	-0.0116 (-1.5397)
Cashflow	-1.7185*** (-3.8589)	-0.3764*** (-4.0078)	-0.3341*** (-3.3596)	-0.3856*** (-4.0110)
RD	16.2699***	3.1355***	1.4964*	3.1969***

	(4.2608)	(3.9918)	(1.7836)	(3.8742)
Growth	-0.2619***	-0.0471***	0.0825***	-0.0445***
	(-4.1150)	(-3.5128)	(6.0707)	(-3.0880)
TOP5	1.3035***	0.2946***	0.0196	0.3074***
	(2.7689)	(3.0618)	(0.1961)	(3.0467)
Board	0.3951	0.0948	0.0293	0.0938
	(1.1311)	(1.3015)	(0.3819)	(1.2054)
Indep	6.6569***	1.4411***	0.8816***	1.4840***
	(6.3662)	(6.7603)	(3.9483)	(6.5146)
Dual	-0.1777*	-0.0440**	-0.0338	-0.0418*
	(-1.7121)	(-2.0631)	(-1.5051)	(-1.8872)
pgdp	0.0965	0.0068	0.0078	-0.0087
	(0.3725)	(0.1267)	(0.1455)	(-0.1521)
finance	0.1025	0.0575	0.0925	0.0502
	(0.3522)	(0.9645)	(1.4830)	(0.7889)
rd	-32.8632*	-6.7519*	-6.8060*	-4.7727
	(-1.8967)	(-1.8692)	(-1.8516)	(-1.2744)
kuandai		-0.0174		
		(-0.6370)		
Constant	39.7262***	-3.0696**	-1.2401	-2.8426**
	(6.5114)	(-2.4685)	(-0.9508)	(-2.1614)
Observations	30,334	30,334	26,872	28,412
Adjusted R-squared	0.5098	0.4720	0.4954	0.4734
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
City FE	YES	YES	YES	YES

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(5) Mechanism Test

The baseline regression results demonstrate the direct effect of data factor marketization on corporate ESG performance. Next, this study further explores the indirect mechanisms of this effect through three dimensions: digital transformation, financing constraints, and agency costs.

Existing research provides extensive evidence on the relationships between digital transformation, financing constraints, agency costs, and corporate ESG performance. Studies have shown that digital transformation enhances corporate ESG performance by improving transparency, strengthening data analytics, and optimizing resource management (Kiron et al., 2017). When facing financing constraints, companies often improve their ESG practices to enhance their financing conditions (Boubakri et al., 2010; Cheng et al., 2014; Dhaliwal et al., 2014). Additionally, when agency costs are low, firms are more motivated to enhance their ESG performance to gain recognition in the capital markets (McWilliams et al., 2000; Barnea et al., 2010; Ferrell et al., 2016). Therefore, this study does not separately analyse the relationships between these mechanism variables and corporate ESG performance.

The regression results for the mechanism tests are as follows:

Digital Transformation:

Column (1) of Table 4 shows the regression results for the effect of data factor marketization on digital transformation. The coefficient for the digital transformation variable is 0.1193, which is significantly positive at the 1% level, indicating that data factor marketization promotes corporate digital transformation.

Financing Constraints:

Column (2) of Table 4 presents the regression results for the effect of data factor marketization on financing constraints. The coefficient for the financing constraint variable is

-0.0026, significantly negative at the 1% level, suggesting that data factor marketization alleviates corporate financing constraints.

Agency Costs:

Column (3) of Table 4 displays the regression results for the effect of data factor marketization on agency costs. The coefficient for agency costs is -0.0054, significantly negative at the 5% level, indicating that data factor marketization reduces corporate agency costs.

In summary, data factor marketization enhances corporate ESG performance through the mechanisms of promoting digital transformation, alleviating financing constraints, and reducing agency costs. Thus, Hypothesis 2, Hypothesis 3, and Hypothesis 4 are confirmed.

Table 4. Mechanism Test Results

	(1)	(2)	(3)
VARIABLES	digital	WW	agency
did	0.1193*** (4.0209)	-0.0026*** (-3.3883)	-0.0054** (-2.1625)
Size	0.3050*** (13.8013)	-0.0475*** (-80.3479)	-0.0166*** (-7.0620)
Lev	-0.2143*** (-2.6180)	0.0249*** (10.4258)	-0.0489*** (-5.5158)
ROA	-0.1715 (-1.3430)	-0.1138*** (-24.3320)	-0.3030*** (-19.1452)
TobinQ	0.0324*** (3.9881)	0.0008*** (2.9815)	0.0036*** (3.9131)
Cashflow	-0.2399*** (-2.7128)	-0.0975*** (-29.4443)	-0.0334*** (-3.2624)
RD	4.6999*** (5.3212)	0.0042 (0.1830)	0.3381*** (3.3581)

Growth	0.0260**	-0.0435***	-0.0240***
	(2.1081)	(-47.4840)	(-14.5315)
TOP5	-0.4484***	-0.0258***	0.0374***
	(-3.8634)	(-8.1002)	(3.2979)
Board	0.2903***	0.0001	0.0073
	(4.0089)	(0.0536)	(1.1046)
Indep	-0.1004	0.0032	-0.0007
	(-0.4894)	(0.5201)	(-0.0383)
Dual	0.0045	-0.0004	0.0013
	(0.2005)	(-0.7409)	(0.6297)
pgdp	-0.0706	0.0023	0.0054
	(-1.2222)	(1.4404)	(1.0490)
finance	0.0254	-0.0039**	-0.0079
	(0.4000)	(-2.0988)	(-1.2080)
rd	10.9736***	0.1106	-1.2149***
	(2.9144)	(1.0509)	(-3.3951)
Constant	-5.6629***	0.1054***	0.6144***
	(-4.1923)	(2.6699)	(4.4893)
Observations	30,304	27,439	30,136
Adjusted R-squared	0.7555	0.8826	0.7813
Firm FE	YES	YES	YES
Year FE	YES	YES	YES
City FE	YES	YES	YES

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(6) Heterogeneity Test

Heterogeneity Analysis Based on Industry Characteristics

Given that industry characteristics may influence the motivation behind data factor marketization and corporate ESG performance, this study conducts an industry-level

heterogeneity analysis by adding dummy variables for heavy pollution and high-tech attributes to the baseline regression model (1).

Heavy Pollution Industries:

The results in Columns (1) and (2) of Table 5 show that the coefficient for *did* in heavy pollution industries is 0.1046, which is significantly positive at the 5% level. However, for non-heavy pollution industries, the coefficient for *did* is 0.0426 and not significant. This indicates that the impact of data factor marketization is more pronounced for heavy pollution enterprises. The main reason is that data factor marketization increases corporate transparency, and heavy pollution enterprises, compared to non-heavy pollution enterprises, are more driven by environmental compliance and the need to maintain their public image. As a result, they are more likely to improve their ESG performance in response to data factor marketization.

High-Tech Industries:

The results in Columns (3) and (4) of Table 5 reveal that the *did* coefficient for high-tech enterprises is 0.0499, but it is not statistically significant. In contrast, the *did* coefficient for non-high-tech enterprises is 0.0669, which is significantly positive at the 10% level. This suggests that data factor marketization can promote ESG performance in both high-tech and non-high-tech enterprises, but the effect is more significant for non-high-tech enterprises. The primary reason is that non-high-tech enterprises, typically in traditional labour-intensive industries, have a larger gap in their integration of digital technology compared to high-tech enterprises and thus possess more room for improvement. Consequently, data factor marketization, by incorporating relevant digital technologies and optimizing operational management processes, has a more substantial effect on enhancing ESG performance for non-high-tech enterprises.

Table 5. Heterogeneity Test Results

	(1)	(2)	(3)	(4)
VARIABLES	ESG	ESG	ESG	ESG
did	0.1046** (2.0637)	0.0426 (1.3704)	0.0499 (1.3738)	0.0669* (1.7432)
Size	0.2579*** (7.0442)	0.2477*** (10.7756)	0.2721*** (10.6690)	0.2455*** (7.9943)
Lev	-0.8363*** (-6.7986)	-0.7639*** (-8.6084)	-0.7731*** (-8.2460)	-0.6939*** (-6.1878)
ROA	0.7698*** (3.1281)	1.1785*** (6.8985)	0.9139*** (5.1526)	1.2125*** (5.4545)
TobinQ	-0.0062 (-0.4889)	-0.0152* (-1.6761)	-0.0110 (-1.2069)	-0.0044 (-0.3468)
Cashflow	-0.5671*** (-3.3272)	-0.2358** (-2.0912)	-0.3474** (-2.5632)	-0.4355*** (-3.3629)
RD	4.0902*** (2.8467)	3.1784*** (3.4993)	2.9158*** (3.4460)	7.0430*** (4.0529)
Growth	-0.0792*** (-2.9796)	-0.0320** (-2.0202)	-0.0847*** (-4.0793)	-0.0083 (-0.4816)
TOP5	0.1538 (0.8308)	0.3095*** (2.6735)	0.3681*** (2.6811)	0.1585 (1.0709)
Board	0.1320 (1.0241)	0.0240 (0.2749)	0.1849* (1.8704)	-0.0094 (-0.0848)
Indep	1.7065*** (4.5017)	1.1936*** (4.7235)	1.1726*** (4.0275)	1.6047*** (5.0548)
Dual	-0.0311 (-0.7746)	-0.0407 (-1.5914)	-0.0410 (-1.4219)	-0.0502 (-1.5071)
pgdp	0.1616* (1.8113)	-0.0747 (-1.0848)	-0.0042 (-0.0603)	0.0163 (0.1947)
finance	0.0142 (0.1687)	0.0286 (0.3400)	0.0246 (0.2974)	0.0684 (0.7666)
rd	-10.9880	-4.6372	-8.3663*	-4.3694

	(-1.5480)	(-1.0973)	(-1.7781)	(-0.7630)
Constant	-4.4302**	-1.4677	-3.0989*	-3.2660*
	(-2.5392)	(-0.8117)	(-1.7979)	(-1.6969)
Observations	10,053	20,231	16,966	13,331
Adjusted R-squared	0.4558	0.4834	0.4453	0.5109
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
City FE	YES	YES	YES	YES

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Heterogeneity Analysis Based on Marketization Levels

To explore whether corporate ESG performance differs across varying levels of marketization, this study conducts a heterogeneity analysis from two dimensions: marketization level and regional characteristics. Marketization data is sourced from the China Marketization Index, compiled by Fan Gang and Wang Xiaolu. If the marketization level of a company's province is greater than or equal to the sample median, the value is set to 1; otherwise, it is set to 0. Regional characteristics are divided into eastern and western regions of China.

Marketization Levels:

The results in Columns (1) and (2) of Table 6 show that for companies in provinces with higher levels of marketization, the regression coefficient for *did* is 0.0990, which is significantly positive at the 1% level. For companies in provinces with lower marketization levels, the coefficient for *did* is -0.0474 and not significant. This indicates that the positive effect of data factor marketization on corporate ESG performance is more pronounced in regions with higher marketization levels. The reasons for this are twofold:

In provinces with higher marketization, mechanisms for data circulation and trading are more developed, and regulatory policies are more comprehensive. Companies can more easily access high-quality data, such as environmental monitoring and social responsibility project assessments, helping them improve ESG performance to meet higher standards.

In highly marketized environments, competition among companies is more intense, and ESG performance becomes a key differentiator that attracts more investors and consumers. Therefore, in regions with higher marketization, data factor marketization has a more significant impact on improving corporate ESG performance.

Regional Characteristics:

The results in Columns (3) and (4) of Table 6 show that for companies in eastern China, the regression coefficient for *did* is 0.1244, which is significantly positive at the 1% level. In contrast, for companies in western China, the coefficient for *did* is 0.0171 and not significant. This suggests that while data factor marketization can promote ESG performance in both eastern and western regions, its impact is stronger in the east. The main reasons are:

Eastern China has a more developed economy and stronger government fiscal capabilities, providing more policy and financial support (e.g., tax incentives) for companies with outstanding ESG performance, encouraging them to improve.

The higher marketization level in the east allows companies to more efficiently utilize and share data, further driving their efforts to improve ESG performance. In contrast, western China, though experiencing a "catch-up effect," lags in financial maturity, marketization, and technological development, limiting the extent to which data factor marketization can enhance corporate ESG performance.

Table 6. Heterogeneity Test Results (2)

	(1)	(2)	(3)	(4)
VARIABLES	ESG	ESG	ESG	ESG
did	0.0990*** (3.1333)	-0.0474 (-1.0088)	0.1244*** (3.1422)	0.0171 (0.4564)
Size	0.2412*** (10.1730)	0.2542*** (8.3862)	0.2779*** (9.4153)	0.2297*** (8.5183)
Lev	-0.7850*** (-9.1470)	-0.7682*** (-6.4817)	-0.8259*** (-7.5013)	-0.6903*** (-6.9390)
ROA	1.0278*** (6.3099)	1.0919*** (4.2650)	0.8884*** (4.5657)	1.0154*** (4.8323)
TobinQ	-0.0127 (-1.4355)	-0.0137 (-1.0444)	-0.0196* (-1.7702)	-0.0080 (-0.7803)
Cashflow	-0.2862** (-2.5541)	-0.5778*** (-3.3928)	-0.1656 (-1.2441)	-0.4734*** (-3.4648)
RD	2.5324*** (2.7427)	4.9387*** (3.3196)	1.7599 (1.4951)	4.6684*** (4.2189)
Growth	-0.0369** (-2.1916)	-0.0637*** (-2.8825)	-0.0109 (-0.5162)	-0.0793*** (-4.4791)
TOP5	0.4561*** (3.9449)	-0.0967 (-0.5512)	0.5119*** (3.6066)	-0.1256 (-0.8533)
Board	0.0199 (0.2227)	0.2495** (1.9906)	0.0670 (0.5823)	0.1284 (1.2604)
Indep	1.2177*** (4.6071)	1.9338*** (5.4603)	1.0172*** (3.3035)	1.7219*** (5.8317)
Dual	-0.0595** (-2.4063)	-0.0023 (-0.0549)	-0.0186 (-0.6139)	-0.0662** (-2.0332)
pgdp	-0.0128 (-0.1869)	-0.0079 (-0.0857)	-0.0843 (-0.9407)	0.0399 (0.5022)
finance	0.0586 (0.6817)	0.2039** (2.3697)	0.0532 (0.4514)	0.1094 (1.4112)
rd	-13.6290***	6.5460	-12.8581**	4.8302

	(-2.9871)	(0.9397)	(-2.5379)	(0.6939)
Constant	-2.5871	-6.1281***	-2.5339	-4.1032***
	(-1.3962)	(-3.5683)	(-0.9440)	(-2.6524)
Observations	21,002	9,316	14,922	14,947
Adjusted R-squared	0.4774	0.4569	0.4906	0.4849
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
City FE	YES	YES	YES	YES

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Conclusion

(1) Research Findings

This study focuses on the impact of data factor marketization on the ESG performance of Chinese A-share listed companies on the Shanghai and Shenzhen stock exchanges, analysing data from 2009 to 2022. The empirical results reveal that higher levels of data factor marketization significantly enhance corporate ESG performance. These findings remain robust after a series of tests. Mechanism analysis demonstrates that data factor marketization positively affects ESG performance through three key channels: promoting corporate digital transformation, alleviating financing constraints, and reducing agency costs. Further heterogeneity analysis shows that the positive impact of data factor marketization is particularly pronounced in heavy pollution industries and non-high-tech firms. Additionally, firms in regions with higher marketization levels and those in eastern China benefit more from this process.

(2) Theoretical Significance

This study fills a gap in the research on the relationship between data factor marketization and corporate ESG performance. It innovatively constructs a comprehensive analytical framework, revealing how data factor marketization deepens and enhances corporate ESG practices. The findings extend the application boundaries of ESG theory in the era of big data and provide theoretical support for corporate sustainable development strategies. Furthermore, by analysing the mechanisms of digital transformation, financing constraints, and agency costs, this research offers new insights into ESG theory and practice.

(3) Practical Implications

The results of this study enrich the theoretical research on data factor marketization and also provide important practical guidance:

At the macro level: Governments should actively promote the development of the digital economy by implementing relevant policies and establishing data trading platforms and market mechanisms. This will create a favourable environment for the circulation and marketization of data factors, accelerating corporate digital transformation in production, sales, and management, thus improving the efficiency of the entire economic system. Moreover, governments should provide policy guidance and incentives to encourage companies to integrate ESG principles into their operations, fostering corporate participation in data marketization to enhance ESG capabilities.

At the micro level: Companies need to adapt to this trend by viewing digital transformation as a key strategy for enhancing competitiveness. By engaging in data factor marketization, companies can accelerate their digital transformation, alleviate financing constraints, and reduce agency costs, thereby improving operational efficiency and ESG performance. Heavy pollution and non-high-tech firms, in particular, should respond proactively to policy initiatives, participate in data marketization, and emphasize ESG practices

to improve production processes, reduce environmental pollution, and increase energy efficiency, gradually transitioning toward green, low-carbon development. Firms in highly marketized and eastern regions should leverage their data advantages to enhance ESG capabilities, build a positive corporate image, and strengthen their social responsibility brand.

(4) Research Limitations and Future Directions

Although this study provides valuable insights into the relationship between data factor marketization and corporate ESG performance, several limitations remain:

Sample limitations: This research is limited to A-share listed companies in China, and the external validity of the findings requires further verification. Future studies could consider corporate samples from different countries and regions to validate the universality of the impact of data factor marketization on ESG performance and explore how international data flows affect multinational corporations' ESG performance in a global context. Comparative analysis could offer a more comprehensive understanding of the unique characteristics of data factor marketization in different countries and regions and its specific impact on corporate ESG performance.

Industry characteristics and firm size: The impact of data factor marketization on ESG performance may vary by industry characteristics and firm size. This study primarily focuses on overall trends, but future research could explore the specific effects in sub-sectors, such as differences between high-tech industries and traditional manufacturing in data utilization and ESG performance. Additionally, firm size may influence the mechanisms of data factor marketization, as large and small firms differ significantly in resource allocation, risk management, and innovation capacity. Understanding how these differences translate into ESG performance improvements warrants further investigation. Moreover, the long-term value and market competitiveness of ESG improvements require deeper exploration to assess whether the

positive effects of data factor marketization can be converted into core competitive advantages and sustained growth drivers for firms.

Potential mediating and moderating variables: The complexity of data factor marketization necessitates attention to additional mediating and moderating variables. While this study has preliminarily revealed the link between data factor marketization and corporate ESG performance, the role of micro and macroeconomic factors, policy environments, and technological advancements remains to be fully uncovered. Future research could focus on building more refined analytical frameworks to examine the dynamic feedback mechanisms between data factor marketization, ESG performance, and corporate performance, and how institutional and cultural factors influence this process.

Data security and privacy concerns: The issue of data security and privacy protection cannot be ignored in the context of data factor marketization. As data becomes a core resource for corporate operations and innovation, balancing data utilization with privacy rights and data sovereignty is critical. Companies must avoid data misuse and breaches, making data governance an essential component of their ESG responsibilities. Future research could delve deeper into data governance strategies under data factor marketization, including legal frameworks, technical safeguards, and corporate social responsibility practices, to promote the healthy and sustainable development of the data factor market.

In summary, while this study provides valuable insights into the relationship between data factor marketization and corporate ESG performance, achieving a comprehensive understanding will require further research from multiple perspectives. By continuously accumulating and integrating new evidence, we can expect to build a more systematic and comprehensive theoretical framework to guide businesses and society toward sustainable and responsible development in the wave of data factor marketization.

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