Can customer enterprises' digital transformation improve suppliers' ESG performance? An Empirical Study

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Abstract

This paper examines the impact of customer enterprises' digital transformation on the ESG performance of their supplier enterprises. The findings are as follows: (1) Digital transformation in customer firms significantly improves the ESG performance of their suppliers. (2) This improvement occurs through green innovation-driven effects and financial support. (3) The positive impact is more significant when the business relationship between the supplier and customer is closer, the supplier is state-owned, or both firms belong to high-pollution industries. These findings offer important practical implications, especially in the context of economic transition and green development. Customer firms, through digital transformation, can lead their suppliers toward greater sustainability, promote their own green transformation, and enhance the overall ESG performance of the supply chain. Policymakers and business managers could recognize the key role of digital transformation in driving supply chain sustainability and actively seek ways to integrate digitalization with green innovation to foster balanced social, environmental, and economic development.

Keywords: Customer enterprises; Supplier enterprises; digital transformation; ESG performance

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Can customer enterprises' digital transformation improve suppliers' ESG performance? An Empirical Study

1. Introduction

As digital transformation progresses, digital technologies are increasingly recognized as key drivers of industrial optimization and high-quality economic development (Qin et al., 2024; Zhao and Wang, 2025). In China, digital transformation has not only had a profound impact on the development of individual firms but has also generated significant externalities for both upstream and downstream companies in the supply chain (Franco et al., 2024; Lei et al., 2024; Geng et al., 2024). In recent years, with the tightening of environmental regulations, corporate Environmental, Social, and Governance (ESG) performance has garnered increasing attention from the public, investors, and governments (Yang et al., 2024; Peng and Kong, 2024; Cao et al., 2024). Against this backdrop, whether digital transformation can enhance the ESG performance of suppliers has become an urgent issue.

Customer enterprises' digital transformation, through mechanisms such as information sharing, green innovation, and supply chain collaboration, may positively influence supplier enterprises' ESG performance in areas like environmental protection, social responsibility, and governance. However, existing research has yet to provide sufficient theoretical and empirical evidence on how digital transformation flows through supply chains to enhance supplier ESG performance. A solid empirical investigation into whether and how digital transformation impacts the ESG performance of companies within the supply chain is crucial for understanding and promoting sustainable supply chain development.

Existing literature has explored the relationship between corporate digital transformation and ESG performance (Xu et al., 2025; Li et al., 2024; Qiao et al., 2025), but most studies focus on the effects at the individual firm level. Research on the interaction of digital transformation between upstream and downstream firms in the supply chain remains limited. Most studies emphasize how digital transformation improves a firm's own ESG performance (Ding et al., 2024; Khalid et al., 2024; Wang and Esperança, 2023), neglecting its transmission effects across the supply chain. This gap hinders a comprehensive understanding of the role digital transformation plays in supply chain management and sustainable development. Specifically, suppliers' ESG performance is influenced by multiple factors, with customer companies' digital transformation potentially affecting suppliers through channels like green innovation and financial flow, thus driving improvements in ESG.

Additionally, some literature explores how the financial or managerial characteristics of listed companies influence those of their upstream or downstream supply chain partners, which can provide insights for this paper on the impact of

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customer companies' digital transformation on suppliers' ESG performance. For example, Jiang and Yang (2024) investigated the effect of client companies' ESG disclosures on the cost stickiness of their suppliers, while Yan et al. (2024) examined how the ESG performance of downstream client companies affects green innovation in midstream firms. These studies highlight how upstream and downstream interactions within the supply chain influence the ESG performance of suppliers, shedding light on the broader implications of customer companies' digital transformation.

In this context, studying the impact of customer companies' digital transformation on suppliers' ESG performance not only enriches the theoretical frameworks of digital economy and supply chain management but also provides valuable insights for policymakers, industry regulators, and business decision-makers. This paper aims to examine, using data from Chinese A-share listed companies and their top five suppliers (2009-2023), the impact of customer digital transformation on suppliers' ESG performance and its underlying mechanisms. The study will also analyze the heterogeneity of these effects across different supplier-customer characteristics, contributing to a deeper understanding of how digital transformation drives sustainable supply chain development.

The contributions of this article are as follows: First, from the perspective of supply chain transmission effects, this paper examines the impact of customer companies' digital transformation on suppliers' ESG performance. While existing literature primarily focuses on the internal effects of digital transformation within individual firms, there has been less attention on the mechanisms of influence between upstream and downstream entities in supply chains. This study not only enriches the theoretical link between digital transformation and supply chain management but also provides a new theoretical framework for understanding inter-firm interdependencies and synergies.

Second, this paper identifies two key channels through which customer companies' digital transformation enhances supplier ESG performance: the green innovation-driven effect and the financial liquidity support effect. While previous research has explored the relationship between digital transformation and corporate performance, limited focus has been placed on how customer companies drive green innovation and provide financial support to improve the ESG performance of their suppliers. By fostering green innovation and supporting financial flows, customer companies can significantly enhance the overall green development of the supply chain, thereby contributing to national sustainable development goals.

Third, this paper clarifies how the impact of customer companies' digital transformation on supplier ESG performance varies according to the degree of business contact between suppliers and clients, the ownership structure of suppliers, and the industry characteristics of both parties. These findings offer important policy implications and managerial strategies for practice, helping guide future efforts in sustainable supply chain management and digital transformation initiatives.

The remainder of this article is structured as follows: Section 2 develops the research hypotheses; Section 3 introduces samples, data, variable definitions, and

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econometric model settings; Section 4 investigates the impact of customer enterprises' digital transformation on supplier's ESG performance, explores its influence channels, and further examines the heterogeneous effects; Section 5 provide conclusions and implications.

2. Hypothesis development

2.1. The effects of CDT on SESG

The digital transformation of customer enterprises plays a crucial role in improving the ESG performance of their suppliers. First, as key players in the supply chain, customer enterprises increasingly leverage digital technologies to optimize their operations and enhance sustainability. This transformation extends beyond their internal processes and influences their relationships with suppliers. For example, digital platforms enable customer companies to set higher standards for suppliers in areas like environmental protection, resource efficiency, and governance (Yan et al., 2024). This interaction encourages suppliers to enhance their ESG performance to maintain a strong partnership with their customer companies.

Second, the digital transformation of customer enterprises fosters collaboration and communication with suppliers, thereby enhancing the potential for green innovation. Digital tools enable customer companies to share advanced environmental technologies and green production processes with their suppliers, helping them achieve sustainable production and environmental goals (Feliciano-Cestero et al., 2023). This innovation-driven effect motivates suppliers to adopt more eco-friendly production methods, reduce pollution, and improve their overall environmental performance (Zekhnini et al., 2022). Moreover, the collaborative nature of digital transformation promotes joint research and development efforts between customer enterprises and suppliers, advancing sustainable practices across the supply chain. This collaboration not only strengthens the environmental dimension of suppliers' ESG performance but also positively influences their social responsibility and governance, boosting corporate transparency and accountability (Zhang et al., 2019).

Finally, customer enterprises' digital transformation improves suppliers' financial liquidity by optimizing cash flow and providing greater access to funding opportunities (Itzkowitz, 2013). Digital platforms enable customer companies to manage cash flows more efficiently, alleviating financing constraints for suppliers and offering them more financial support for ESG-related investments.With improved financial liquidity, suppliers can invest in green technologies, environmental facilities, and clean energy, further enhancing their environmental performance (Zhang et al., 2019). Additionally, increased liquidity allows suppliers to implement social responsibility initiatives and optimize their governance structures, thereby improving their social and governance performance (Attig, 2024; Chen et al., 2013). Based on the above analysis, the following research hypotheses can be proposed.

Hypothesis 1: Customer enterprises' digital transformation is beneficial to improve supplier enterprises' ESG performance.

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2.2. The mechanism of CDT on SESG

2.2.1 Green innovation-driven enhancement effect

The digital transformation of customer companies not only enhances their own green innovation capabilities but also drives progress in green innovation among their suppliers. First, customer companies may require suppliers to adopt more efficient and less polluting production processes or to provide raw materials that meet green standards. As customer companies advance their digital transformation, suppliers must accelerate the development and innovation of green technologies to meet these demands (Liu et al., 2021). Second, through digital platforms, customer companies can share the latest environmental technologies and green production practices with suppliers, helping them achieve green production and environmental protection goals (Feliciano-Cestero et al., 2023).

Third, digital transformation facilitates collaborative innovation between customer companies and suppliers (Kamalaldin et al., 2021). By leveraging digital tools, customer companies can collaborate more effectively with suppliers on technology integration and joint research, driving the co-development of green technologies (Zekhnini et al., 2022). These platforms enable real-time data exchange and information sharing, accelerating green innovation and reducing the risks and costs associated with the innovation process. Through these channels, the digital transformation of customer companies plays a key role in enhancing suppliers' ESG performance.

Green innovation plays a crucial role in enhancing a company's ESG performance. First, it directly impacts the environmental performance of supplier companies by improving resource efficiency, reducing pollution, and enhancing the environmental quality of products. These improvements boost their ESG scores, particularly in the environmental dimension (Niu et al., 2024; Zhao et al., 2024). Second, green innovation often has indirect effects on social responsibility and corporate governance (Liu et al., 2024), such as fostering a stronger sense of social responsibility within the company and increasing trust from the public and investors. In summary, advancements in green innovation contribute to improved ESG performance. Based on this, Hypothesis 2.1 is proposed.

Hypothesis 2.1: Customer enterprises' digital transformation improves supplier enterprises' ESG performance by green innovation-driven enhancement effect.

2.2.2. Financial liquidity support effect

Digital transformation enhances the financial management capabilities of customer companies and, through digital platforms, provides suppliers with greater funding support and financing opportunities (Itzkowitz, 2013), thereby improving suppliers' ESG performance. First, digital transformation enables customer companies to manage cash flows more efficiently and connect with suppliers for financial transactions via digital platforms. By leveraging digital technology, customer companies can optimize the flow of funds within the supply chain, easing financing constraints for suppliers.

Second, customer companies' digital transformation helps suppliers assess the returns on ESG-related investments through data analysis and intelligent decision-making (Gao et al., 2024). Digital tools provide suppliers with real-time market data and ESG performance metrics, enabling them to make more informed investment

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decisions. This not only reduces the financial risks associated with investments in environmental protection and social responsibility but also improves the efficiency of capital allocation in these areas.

The financial liquidity of supplier companies directly impacts their ESG performance. First, higher financial liquidity enables suppliers to invest in green technologies, environmental facilities, and clean energy, thereby enhancing their environmental performance (Zhang et al., 2019). For example, suppliers with more liquid assets can adopt eco-friendly technologies in their production processes, reducing pollutant emissions and promoting sustainable production methods.

Second, increased financial liquidity allows suppliers to better implement social responsibility initiatives (Attig, 2024), such as improving employee welfare, supporting social welfare activities, and contributing to community development. Adequate liquidity empowers companies to take on more social responsibilities, thereby enhancing their social performance. Third, greater financial liquidity provides suppliers with more opportunities to optimize their governance structures (Chen et al., 2013). For instance, suppliers can hire more professionals to improve internal controls, increase transparency, and enhance decision-making efficiency, thus strengthening corporate governance and reputation. Based on these points, Hypothesis 2.2 is proposed.

Hypothesis 2.2: Customer enterprises' digital transformation improves supplier enterprises' ESG performance by financial liquidity support effect.

3. Material and methods

3.1. Model specification

3.1.1. The effects of CDIG on SESG

To assess the impact of agricultural mechanization on agricultural green total factor productivity, we construct the following benchmark model:

$$SESG_{it} = \alpha_0 + \alpha_1 CDT_{jt} + \boldsymbol{X\phi} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where subscripts i, j and t represent the supplier enterprise, customer enterprise and year, respectively. Under the inclusion of enterprise-fixed effect μ_i、year-fixed effect δ_t and control variables vector $\boldsymbol{X}$, α_1 measures the impact of customer enterprises' digital transformation on the ESG performance of supplier enterprises. α_0 denotes the intercept coefficient, ϕ represents the coefficients vector of control variables，and ε_{it} is the random error term.

3.1.2. The channels of CDIG on SESG

To examine the channels through which customer enterprises' digital transformation affects the ESG performance of supplier enterprises, we construct the following stepwise regression model based on the baseline regression model (1):

$$M_{it} = \beta_0 + \beta_1 CDT_{jt} + \boldsymbol{X\phi}' + \mu_i' + \delta_t' + \varepsilon_{it}' \quad (2)$$

$$SESG_{it} = \gamma_0 + \gamma_1 CDT_{it} + \gamma_2 M_{it} + \boldsymbol{X\phi}'' + \mu_i'' + \delta_t'' + \varepsilon_{it}'' \quad (3)$$

The mediating variables used in this paper are the level of green innovation of

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supplier enterprises (SGI), and the financing constraints of supplier enterprises (SFS). Equations (1) to (3) collectively form the stepwise regression model for testing the mediating effect. Equation (2) reflects the influence of CDT on the mediating variable M, with the corresponding coefficient denoted as β_1. Equation (3) represents both the impact of M on $SESG$ and the direct effect of CDT on $SESG$, apart from the influence of M. Regression coefficients α_1 and γ_1 respectively denote the total effect and direct effect of CDT on $SESG$, while $\beta_1 \times \gamma_2$ represents the indirect effect. If α_1, β_1, and θ_2 are all significant, it indicates the existence of the mediating effect. Otherwise, if α_1 is significant and either β_1 or γ_2 is not, further Sobel tests are needed to determine the presence of the mediating effect.

3.2. Variable election and data source

3.2.1. Dependent variable

The dependent variable in this paper is the ESG performance of supplier enterprises (SESG). We use the Huazheng ESG ratings to represent the ESG performance of these suppliers. The Huazheng ESG rating is widely recognized for its comprehensive data coverage and extensive applicability in China, which significantly enhances the robustness of the sample (Zhao and Chen, 2024). The rating system consists of nine categories: AAA, AA, A, BBB, BB, B, CCC, CC, and C, ranked from highest to lowest. Each category is assigned a numerical value ranging from 9 (highest) to 1 (lowest) to quantify the ESG rating. To measure enterprise-level ESG performance on an annual basis, we calculate the average annual ESG rating by using the quarterly ESG scores for each year.

3.1.2. Independent variable

The key independent variable in this paper is the degree of digital transformation of customer enterprises (CDT). Referring to the studies of Hao et al. (2025), we construct an indicator of digital transformation using text analysis and word frequency statistics. First, we manually review relevant national policy documents addressing digitalization, selecting 139 high-frequency terms related to digitalization, such as artificial intelligence, big data, smart marketing, digital finance, and virtual reality, to create a digital transformation lexicon. Second, based on this lexicon, we conduct a word frequency analysis of annual reports from publicly listed companies between 2009 and 2023, counting the occurrences of these high-frequency terms relative to the total word count. Finally, to standardize the measurement, we use the proportion of digitalization-related terms to the total word count as a proxy variable for the enterprise's digital transformation.

3.1.3. Control variables

Referring to Yan et al. (2024), Ding et al. (2024), Lu et al. (2024), Cai et al. (2023), and Wu et al. (2024), we control both financial and governance characteristics at the supplier and customer enterprise levels. The financial characteristics include: (1) Book-to-Market Ratio (BM), the ratio of shareholders' equity to market value; (2) Return on Assets (ROA), the ratio of net profit to total assets; (3) Debt-to-Asset Ratio (DAR), the ratio of total liabilities to total assets; (4) Tobin's Q (TQ), the ratio of market value to total assets; (5) Revenue Growth Rate (RGR), the percentage change in operating

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revenue between the current and previous quarters; and (6) Asset Growth Rate (AGR), the percentage change in total assets between the current and previous year-end.

Governance characteristics include: (7) Ownership Concentration (OC), the combined shareholding of the top three largest shareholders; (8) Duality (DUA), whether the roles of Chairman and CEO are held by the same individual; and (9) Board Size (BS), the number of members on the board of directors. Additionally, we include a variable for digital transformation (DT) at the supplier company level. To distinguish between supplier and customer-level variables, those at the supplier level are prefixed with "S", and those at the customer level with "C".

3.1.4 Mediating variables

The two mediating variables in this paper are as follows: First, the innovation-driven enhancement effect, measured by the number of green patent applications filed by the enterprise (SGI). Existing literature typically uses the number of green patents filed or granted as a proxy for a company's green innovation level (He and Qiu, 2024; Liu et al., 2025; Wang et al., 2025). Given the influencing factors and time lags in the granting process of green patents for listed companies (Bai et al., 2024), this paper adopts the number of green patent applications as a more immediate measure of green innovation capability.

Second, the financial liquidity support effect, measured by the company's cash holdings (SCH), which include cash and cash equivalents, net short-term investments, and trading financial assets. Digital transformation in customer companies typically enhances operational efficiency and optimizes capital allocation, enabling them to provide greater liquidity support to upstream suppliers through cash flow, cooperation, or other means.

3.1.5 Instrumental variable

This paper selects the proportion of digital intangible assets in total intangible assets (CPDIA) as the instrumental variable. Digital intangible assets, such as intellectual property, software systems, and data resources, are key investments in a firm's digital transformation, reflecting strategic decisions and resource allocation. The ratio of digital intangible assets is closely linked to the extent of digital transformation and effectively captures the intensity of such investments, satisfying the relevance condition for an instrumental variable. Moreover, there is no direct causal relationship between the customer's digital intangible asset ratio and the ESG performance of supplier enterprises, ensuring the exogeneity condition of the instrument.

3.1.6. Sample and data source

We obtained data on Chinese A-share listed companies and their top five suppliers from the CSMAR database for the period 2009-2023. The data were processed as follows: (1) samples of non-listed suppliers among the top five suppliers were excluded; (2) samples of customer or supplier enterprises with ST or *ST designations (indicating operational anomalies) were removed; (3) samples with missing data for customer or supplier variables were excluded. The final dataset consists of unbalanced panel data on the digital transformation, financial characteristics, and corporate governance of Chinese A-share listed companies from 2009 to 2023. ESG data were sourced from the

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Huazheng ESG Rating Database. Descriptive statistics of the main variables are in Table 1.

Table 1

Descriptive statistics

Variables	Symbols	Obs.	Mean	S.D.	Min.	Max.
Dependent Variable	$SESG$	1425	4.4184	0.9625	1	7
Key Independent Variable	CDT	1425	0.0674	0.1553	0	1.4017
Control variable of supplier enterprises	SDT	1416	0.0743	0.1855	0	3.5153
	SBM	1415	0.3492	0.1666	-0.0668	1.1081
	$SROA$	1425	0.0442	0.0625	-0.4272	0.6019
	$SDAR$	1425	0.5016	0.1953	0.0438	1.1178
	STQ	1404	1.7095	1.3954	0.6704	21.2958
	$SRGR$	1422	0.1561	0.6866	-2.6833	19.5689
	$SAGR$	1425	0.1909	0.3247	-0.2721	4.2287
	SOC	1425	53.4356	17.6857	7.2447	98.1825
	$SDUAL$	1385	0.2585	0.4380	0	1
	SBS	1425	9.3242	2.2374	4	18
Control variables of customer enterprises	CBM	1367	0.3596	0.1730	-0.1256	0.9346
	$CROA$	1418	0.0293	0.0706	-0.8044	0.3987
	$CDAR$	1418	0.4448	0.2162	0.0206	1.3034
	CTQ	1362	1.8662	1.3618	0.7488	18.7203
	$CRGR$	1405	85.01	2240.73	-	59411.55

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			58	30	2.0167	00
	$CAGR$	1423	0.3997	4.0993	-0.5856	151.9874
	COC	1425	50.0691	14.8951	11.6626	95.8218
	$CDUAL$	1393	0.2505	0.4335	0	1
	CBS	1418	8.604	1.735	4	18
Instrument Variable	$CPDIA$	1113	0.0677	0.1160	0.0000	0.5000
Mediator Variable	SGI	1166	10.8842	38.9064	0	708
	SCH	1404	21.4401	1.6483	17.7071	26.3483

4. Results analysis

4.1. The effect of CDT on SEGS

4.1.1. Baseline regression results

Table 2 reports the baseline regression results on the impact of customer enterprises' digital transformation on their suppliers' ESG performance. Column (1) presents the univariate regression of customer enterprises' digital transformation on suppliers' ESG performance. Columns (2) to (4) progressively control for firm and year fixed effects, supplier firm control variables, and customer firm control variables, respectively. All results show that customer firms' digital transformation improves suppliers' ESG performance at least at the 5% significance level, providing preliminary support for Hypothesis 1.

Table 2

The results of baseline regression

	(1) $SESG$	(2) $SESG$	(3) $SESG$	(4) $SESG$
CDT	0.4232***	0.5446***	0.4541**	0.5692**
	(0.1462)	(0.1879)	(0.1907)	(0.2248)
Control variables of supplier enterprises	NO	NO	YES	YES
Control variables of customer enterprises	NO	NO	NO	YES
Year FE	NO	YES	YES	YES
Enterprise FE	NO	YES	YES	YES
Intercept	4.3899***	4.4181***	4.4453***	4.4411***

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	(0.0272)	(0.0207)	(0.3676)	(0.4443)
N	1425	1167	1098	1029
R^2	0.0047	0.7133	0.7168	0.7206

Notes: (1) The values in parentheses represent t-statistics. (2) ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively. (3) The regression adopted robust standard error. (4) Year FE and Enterprise FE respectively indicate year-fixed effects and enterprise-fixed effects.

4.1.2. Robustness

Although the baseline model has established a positive relationship between customer enterprises' digital transformation and supplier enterprises' ESG performance, the regression results may still be influenced by factors such as variable measurement methods, sample selection, and random shocks. To assess the robustness of the baseline model, we examine it from seven perspectives:

(1) We include province and industry fixed effects to account for potential significant differences across provinces in terms of technological development, market environment, and regulatory policies, as well as variations in business models, management structures, and development stages across industries.

(2) We incorporate industry-year interaction effects to mitigate potential interference from policy changes, technological advancements, or shifts in market conditions across industries and years.

(3) We replace robust standard errors with industry-clustered standard errors to address potential correlations within the same industry, such as shared industry policies or market competition.

(4) We apply winsorization at the 1% level for all continuous variables to reduce the impact of outliers.

(5) We replace the key dependent variable to minimize selection bias or measurement error by using the SynTao Green Finance ESG score instead of the Huazheng ESG score and re-estimate the regression results.

(6) We exclude observations where the duration of the relationship between customer enterprises and supplier firms is less than two years. This ensures the reliability and representativeness of the results by focusing on longer-term relationships, avoiding noise and bias from short-term ties.

(7) We exclude suppliers ranked third or lower, as these suppliers often have smaller shares in the customer firms' supply chains and are subject to higher operational volatility, such as order fluctuations or supply chain disruptions, which could interfere with the regression results.

The results of these robustness tests, shown in columns (1) to (7) of Table 3, indicate that customer enterprises' digital transformation significantly improves supplier enterprises' ESG performance, confirming the robustness of the baseline regression results.

Table 3

The results of robustness test

	(1)	(2)	(3)	(4)	(5)	(6)	(7)

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	SESG	*SESG*	*SESG*	*SESG*	*SESG*1	*SESG*	*SESG*
CDT	0.5656***	0.8689**	0.5692***	0.5675**	1.0424*	0.6269**	0.6621**
	(0.2432)	(0.3788)	(0.1944)	(0.2553)	(0.5609)	(0.2638)	(0.2651)
Controls	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
Enterprise FE	YES	YES	YES	YES	YES	YES	YES
Intercept	3.9858***	4.2170***	4.4411***	4.3874***	5.6111***	4.1049***	4.7293***
	(0.5189)	(0.7501)	(0.3490)	(0.6248)	(1.1487)	(0.5880)	(0.6977)
N	1023	871	1029	1029	288	889	622
R2	0.7405	0.8475	0.7206	0.7221	0.8247	0.7290	0.7105

Notes: (1) The values in parentheses represent t-statistics. (2) ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively. (3) The regression adopted robust standard error. (4) Year FE and Enterprise FE respectively indicate year-fixed effects and enterprise-fixed effects.

4.1.3. Endogeneity

To mitigate estimation bias due to omitted variables and endogeneity, CPDIA is employed as an instrumental variable to re-estimate the baseline model, as shown in Table 4. The first column presents the outcome of the first-stage regression, while the second column lists the results of the second stage, estimated using 2SLS methods. Despite addressing potential endogeneity concerns, a positive correlation between CDT and SESG persists, thereby confirming the robustness of the baseline regression results. Furthermore, the LM statistic for the under-identification test is 59.58, exceeding the 1% significance threshold, which rejects the null hypothesis of insufficient instrument variable identification. The Kleibergen-Paap rk Wald F statistic for the weak instrument test is 58.03, surpassing the 10% critical value of 16.38, thus dispelling concerns about weak instrument issues and validating the use of CPDIA as an instrumental variable. Therefore, Hypothesis 1 is supported.

Table 4

The results of endogenous test

	First Stage	Second Stage
	(1)	(2)
	OLS	2SLS
	CDT	*SESG*
CPDIA	0.312***	
	(0.041)	
CDT		1.957**
		(0.975)
Controls	YES	YES

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Year FE	YES	YES
Industry FE	YES	YES
Intercept	0.085	1.654
	(0.138)	(1.032)
N	994	994
R^2	0.505	0.174
Under-identification test—Kleibergen-Paap rk statistic: 59.5820***		
Weak identification test (Cragg-Donald Wald F statistic): 58.0250		
Stock-Yogo weak ID test critical values (10% critical value): 16.3800		

Notes: (1) The values in parentheses represent t-statistics. (2) ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively. (3) The regression adopted robust standard error. (4) Year FE and Industry FE respectively indicate year-fixed effects and industry-fixed effects.

4.2 Channel analysis

4.2.1. Green innovation-driven enhancement effect

Columns (1) and (2) of Table 5 present the channel of the green innovation-driven enhancement effect through which customer firms' digital transformation improves supplier enterprises' ESG performance. At the 10% significance level, customer firms' digital transformation enhances supplier firms' green innovation levels, which, in turn, leads to a significant improvement in their ESG performance, supporting Hypothesis 2.1. This mediating channel suggests that customer firms' digital transformation is not only a technological change but also has a profound impact on supplier behavior, business models, and environmental responsibility. Digital transformation enables suppliers to make significant strides in improving efficiency, reducing resource waste, and fostering green technological innovation, thereby driving overall improvements in ESG performance.

Table 5

The channels of agricultural mechanization affecting agricultural green total factor productivity

	Green innovation-driven enhancement effect		Financial liquidity support effect	
	SGI	*SESG*	*SCH*	*SESG*
	(1)	(2)	(3)	(4)
CDT	29.0491*	0.4563*	0.6169*	0.5275*
	(16.1617)	(0.2598)	(0.3170)	(0.2699)
SGI		0.0022**		
		(0.0010)		
SCH				0.0837***
				(0.0296)
Controls	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Enterprise FE	YES	YES	YES	YES

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Intercept	57.2265*	3.7368***	19.7819***	2.5160***
	(29.2038)	(0.6307)	(0.8304)	(0.7815)
N	838	838	1029	1029
R^2	0.6248	0.7122	0.8436	0.7236

Notes: (1) The values in parentheses represent t-statistics. (2) ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively. (3) The regression adopted robust standard error. (4) Year FE and Enterprise FE respectively indicate year-fixed effects and enterprise-fixed effects.

4.2.2. Financial liquidity support effect

Columns (3) and (4) of Table 5 report on the channel of the financial liquidity support effect through which customer firms' digital transformation improves the ESG performance of supplier firms. At the 10% significance level, customer firms' digital transformation enhances supplier firms' financial liquidity, which, in turn, leads to a 1% significant improvement in their ESG performance, supporting Hypothesis 2.2. This process highlights the positive effect of digital transformation on the financial health of supplier enterprises. As their financial liquidity improves, suppliers gain better access to capital, enabling them to invest in key areas such as environmental sustainability, social responsibility, and corporate governance, thereby enhancing their overall ESG performance.

4.3. The heterogeneity of CDIG on SESG

Based on the baseline model, we use a subsample regression approach to examine the heterogeneity in the impact of customer enterprises' digital transformation on supplier enterprises' ESG performance, considering different characteristics of the customer-supplier relationship.

4.3.1. Business contact degree

The impact of customer enterprises' digital transformation on supplier enterprises' ESG performance may vary depending on the degree of business contact between upstream suppliers and midstream customer firms. Theoretically, a stronger commercial relationship between supplier and customer firms would amplify the effect of digital transformation on supplier ESG performance throughout the supply chain. In this paper, we use the median of the ratio of a supplier's purchase amount to its annual total revenue as a threshold. Samples with a ratio greater than the median are assigned a value of 1, indicating a higher degree of commercial relationship, while those below the median are assigned a value of 0, indicating a lower degree of commercial relationship. The heterogeneity analysis results, presented in columns (1) and (2) of Table 6, show that when the business contact degree is higher, the effect of customer firms' digital transformation on improving supplier firms' ESG performance is more significant.

Table 6

The results of heterogeneity analysis

	Business contact degree	Enterprises' property rights	Heavy pollution industries

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	High	Low	State-owned	Nonstate-owned	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
CDT	1.1627***	-0.1410	1.1623***	0.2610	1.3488***	0.5771**
	(0.3017)	(0.3327)	(0.4421)	(0.3001)	(0.4518)	(0.2455)
Controls	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Enterprise FE	YES	YES	YES	YES	YES	YES
Intercept	4.0331***	4.3397***	4.7687***	3.4413***	4.4342***	3.3692***
	(0.8515)	(0.9274)	(0.6937)	(0.7668)	(0.7562)	(0.7107)
N	484	448	556	411	484	510
R2	0.7679	0.7987	0.6956	0.7833	0.7580	0.7789

Notes: (1) The values in parentheses represent t-statistics. (2) ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively. (3) The regression adopted robust standard error. (4) Year FE and Enterprise FE respectively indicate year-fixed effects and enterprise-fixed effects.

4.3.2. enterprise's property rights

The impact of customer enterprises' digital transformation on supplier enterprises' ESG performance may vary depending on the enterprises' property rights. Specifically, state-owned enterprises (SOEs) are typically subject to stronger government regulation and policy incentives, have better access to resources, and are more strategically focused on long-term sustainability. As a result, SOEs can more effectively leverage digital transformation to achieve ESG goals. In contrast, non-state-owned enterprises (NSOEs) may face different strategic priorities, resource constraints, and market conditions, leading to a weaker impact of digital transformation on their ESG performance. Therefore, this paper divides suppliers into SOEs and NSOEs and estimates the heterogeneous effect of customer firms' digital transformation on supplier enterprises' ESG performance. The results, shown in columns (3) and (4) of Table 6, indicate that when the suppliers are state-owned enterprises, the positive impact of customer firms' digital transformation on supplier firms' ESG performance is more significant.

4.3.3 Heavy pollution industries

A potential concern with this paper's results is that if both supplier and customer firms belong to heavy-pollution industries, the improvement in ESG performance may be attributed to government environmental regulations rather than the effect of digital transformation within the supply chain. To address this, we assign a value of 1 when both the supplier and customer firms belong to heavy-pollution industries, and 0 otherwise. The heterogeneity analysis results, shown in columns (5) and (6) of Table 6,

indicate that, regardless of whether both firms belong to heavy-pollution industries, customer firms' digital transformation significantly improves supplier firms' ESG performance. However, when both companies belong to heavy-pollution industries, the impact is more pronounced, thereby ruling out the potential interference of government environmental regulations in the regression results.

5. Conclusions and implications

This paper examines the impact of customer enterprises' digital transformation on the ESG performance of supplier enterprises, using data from Chinese A-share listed companies between 2009 and 2023. The baseline regression results show that customer enterprises' digital transformation significantly enhances the ESG performance of their suppliers. Channel analysis reveals that this effect is driven by increased green innovation and improved financial liquidity, both of which contribute to enhancing suppliers' ESG performance. Heterogeneity analysis indicates that the positive impact is particularly strong when the business relationship between the customer and supplier is closer, when the supplier is a state-owned enterprise, or when both the supplier and customer operate in high-pollution industries.

These findings have important practical implications for Chinese companies and other developing countries. As China accelerates its digital transformation efforts, customer companies play a crucial role in driving the sustainable development of firms across the supply chain, particularly suppliers. This study also provides valuable insights for other countries seeking to improve supplier ESG performance through digital transformation initiatives.

The findings of this paper offer important implications for suppliers, customer companies, and policymakers. First, supplier enterprises should prioritize digital collaboration with customer companies and actively engage in the adoption of green innovation and digital technologies during the customer enterprises' digital transformation process. This approach will not only enhance their competitiveness but also improve their ESG performance, fostering greater social and environmental responsibility.

Second, customer enterprises should continue to advance their own digital transformation efforts and, through collaboration with suppliers, promote green innovation and sustainable development within the supply chain. Specifically, when selecting and supporting suppliers, customer companies can enhance ESG standards across the entire supply chain by strengthening ESG requirements and offering ongoing support.

Lastly, governments should introduce policy incentives and regulatory measures to encourage digital transformation, particularly in green innovation and low-carbon development. Additionally, governments can support small and medium-sized enterprises (SMEs) by providing access to data resources and offering policy guidance to enhance their digital transformation capabilities, thereby promoting broader societal sustainability.

It is important to note that, due to data availability constraints, the analysis of the

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impact of customer enterprises' digital transformation on supplier enterprises' ESG performance is based solely on Chinese A-share listed companies. This may not fully represent all types of firms, particularly small and medium-sized enterprises (SMEs) and non-state-owned companies. As a result, this limitation may affect the generalizability of the findings. Future research, using more comprehensive data, could explore these effects further, thereby enhancing the broader applicability and external validity of the conclusions.

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