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Can customer ESG performance improve corporate carbon emission productivity? --An empirical study from listed companies in China

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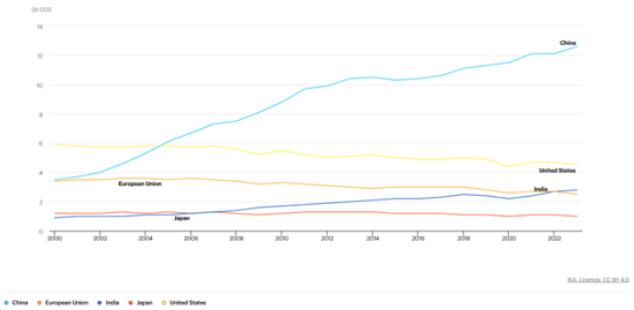
Graphical abstract



Abstract

With the increasing awareness of sustainable development, the ESG performance has become a focal point for both companies and their stakeholders. This study, Chinese A-share listed companies as an example, constructs a sample of paired enterprises and customers to examine the impact of customer ESG performance on corporate carbon productivity and its underlying mechanisms. The research demonstrates a positive relationship between customer ESG performance and corporate carbon productivity, indicating the presence of a supply chain contagion effect. In terms of influencing mechanisms, customer ESG performance primarily enhances corporate carbon productivity by increasing pollution control investments and improving gross domestic product. Further investigation reveals that the improvement in customer ESG performance has a more significant impact on corporate carbon productivity when the company is larger in scale, operates in less-polluting industries, and engages in export activities. This study enriches the relevant research on corporate carbon productivity from an external partner perspective and provides valuable insights for supply chain enterprises on how to enhance carbon productivity and sustainable competitive advantage.

Keywords: ESG performance, carbon productivity, supply chain, environmental awareness

1. Introduction

In recent years, the trend of globalization, environmental pollution, natural disasters, climate change and other issues have made green and sustainable development become the development theme of today's era. According to the International Energy Agency, China surpassed the United States as the world's largest carbon emitter in 2005. In 2023, China's carbon emissions increased by 5.65 million tons to reach 1.19 billion tons, accounting for about 35% of the global total①. As shown in Figure 1, with the changing pattern of emissions, China's total carbon emissions exceeded those of all developed economies combined in 2020 and increased by 15% in 2023①. In the post-COVID-19 era, achieving sustainable development is highly valued, clearly requiring the global economy to become greener over time (Murshed 2023). The increase in carbon emissions (massive emission of greenhouse gases) will lead to global warming, trigger extreme weather, cause loss of biodiversity and result in ecosystem destruction, which has a huge impact on human society and the natural environment. In order to realize harmonious coexistence between human beings and nature and sustainable development, China announced at the 75th United Nations General Assembly that it will strive to peak carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060. Enterprises, however, are both the main creators of social wealth and large consumers of natural resources, and have become the key to harmonizing economic development and ecological protection (Li *et al*. 2019). For a long time, China has mainly utilized its human and resource advantages and embedded itself in the global value chain by undertaking low-end activities characterized by high energy consumption and high pollution, typically outsourced by developed countries (Dai *et al*. 2022). This crude mode of production and development has led to high energy consumption and carbon emissions in China for a long time, posing a huge challenge to China's energy conservation and emission reduction efforts. From an economic point of view, enterprises need to bear a lot of direct financial costs in adopting emission reduction

measures, so they hope to realize low-carbon emission reduction through a new development mode, and promote the coordination of economic growth and environmental protection. Carbon productivity, as a key bridge between economic growth and ecological optimization, can effectively drive traditional high-emission industries to realize green transformation and development. In this new development period, further improving carbon productivity is not only a key measure to accelerate the decoupling of economic growth and carbon emissions but also a powerful driver to promote the overall green and low-carbon transformation of the economy and society (Jin 2024).

At the same time, with increasing awareness of environmental protection and sustainable development, the concept of Environmental-Social Responsibility-Corporate Governance (ESG) has also been applied (Li *et al*. 2024). ESG is an important system for evaluating the sustainable development of enterprises and a feasible criteria for assessing the level of high-quality development of listed companies. The application and practice of ESG in enterprises align with China's new development concept, and the ESG performance of enterprises has gradually received extensive attention from stakeholders. Scholars have found that corporate ESG performance not only affects its own management decisions and performance, but also influences the management style of stakeholder subjects through the supply chain transmission mechanism. Good ESG performance reduces corporate financing costs (Wu *et al*. 2022), generates new profit growth opportunities through the value creation effect (Yi *et al*. 2022), and contributes to the long-term growth of corporate performance (Bai *et al*. 2022). As ESG is a complementary disclosure to corporate financial performance reporting, bondholders will change their risk premium requirements based on the ESG performance of firms, resulting in an impact on the cost of corporate debt financing (Lian *et al*. 2022). Auditors will also consider the risk-suppressing effect of firms' ESG performance, which may lead to reduce audit fees and standardized audit opinions (Wang *et al*. 2022). Based on the supply chain perspective, the disclosure of ESG performance conveys more internal information to the outside word. Firms, as the main external stakeholders constituting the supply chain, are more likely to be affected by positive and negative information disclosed by customers and make different decisions. Numerous scholars have found that the credit limits (Qian *et al.* 2017) and investment efficiency of enterprises can decrease due to low-quality forward-looking information (Chen *et al*. 2019) or the disclosure of risk factors (Chiu *et al*. 2019) by customers, based on the perspective of negative information disclosure by customers. However, fewer scholars have focused on firms' responses to customers' disclosure of positive information, and Tang *et al* (2023) examined the positive spillover effects of customers' ESG performance. Sun *et al* (2024) focuses on the innovation spillovers from customers' ESG performance, and explores how customers' ESG is transmitted through the supply chain to promote suppliers' green innovation. Research has found that good ESG performance by customers can influence and drive upstream enterprises in the supply chain. Due to the pressure from customers' green development, companies' environmental awareness gradually aligns with that of their customers. They can enhance their own green innovation levels by adopting customers' environmentally friendly practices. Focusing on the context of China's "dual carbon" strategy, carbon productivity—an essential indicator of a low-carbon economy—reflects the economic effects of per unit carbon emissions. Therefore, as corporate green innovation levels rise due to the effects of customer ESG performance, it becomes crucial to investigate whether and how corporate carbon productivity is influenced by customer ESG performance. Currently, few studies focus on the impact and transmission pathways between these two factors. Addressing this issue directly affects the establishment of corporate customer relationships and the utilization of customer resources. Moreover, it extends the understanding of how Chinese enterprises can respond to environmental and social challenges through ESG performance, thereby holding significant practical and social value. Looking around the world, countries are facing the dilemma of harmonizing economic development and carbon emissions. Taking Central Asia as an example, Kyrgyzstan has cooperated with Shanghai in green energy production and consumption for the purpose of energy conservation and emission reduction, and Central Asia as an energy resource-rich region is also affected by ecological fragility (Li *et al*. 2022). Therefore, research on the above issues in the Chinese context can not only help domestic firms to find alternative paths to increase carbon productivity, but also contribute to the green economy, low carbon and sustainable development in Central Asia and the rest of the world.

This study, based on the supply chain perspective, constructs a customer ESG performance index using the sales proportion and ESG performance levels of the top five customers, calculated through unequal weighting. It investigates whether and how the positive externalities generated by customer ESG performance promote enterprises to adopt green cooperation strategies and enhance their carbon productivity through supply chain transmission. Addressing these questions not only helps companies improve their carbon productivity through positive spillovers and transmissions along the supply chain but also supports the implementation of China's "dual carbon" strategy and provides insights for other countries' green policies. The possible marginal contributions of this study are as follows: First, existing research on factors influencing corporate carbon emissions mainly focuses on government regulatory policies such as environmental regulations, with limited attention to the impact of customer ESG performance as a market governance mechanism on corporate carbon emissions. This study further expands the research on factors influencing corporate carbon emissions. Second, previous studies on ESG performance typically examine the impact of a company's own ESG performance on its

financial aspects from a static perspective, without considering the "spillover effect" from an external perspective of supply chain interactions, particularly regarding the impact on corporate carbon emissions. This study highlights the significant role of customer ESG performance on corporate carbon productivity, providing crucial empirical evidence for research on the green ecological impact of ESG performance. Third, past research generally examines the influence of customer integration on corporate management and operational behavior based on the economic importance of customers, such as the proportion of revenue from major customers or the Herfindahl index of customers. Unlike existing literature, which analyzes supply chain characteristics from a concentration perspective, this study explores the interaction between customers and enterprises, expanding the research on the contagion effect of ESG performance in the supply chain. Fourth, by validating that customer ESG ratings can influence corporate carbon emissions, this study further clarifies the pathways through which customer ESG ratings affect corporate carbon emissions. It also reveals that the relationship between customer ESG performance and corporate carbon emissions is influenced by factors such as enterprise size, export intensity, and industry pollution levels. The conclusions of this study provide empirical evidence on how companies can leverage cooperative relationships with upstream and downstream partners for green development under the "dual carbon" initiative. It enriches the research on the mechanisms and influencing factors of how ESG performance promotes corporate carbon productivity from the perspective of external partners.

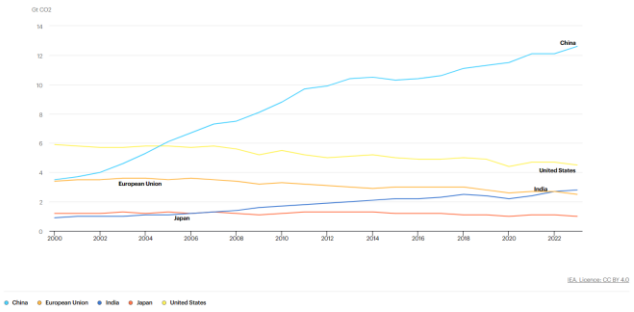


Figure 1. Total CO_2 emissions by region, 2000-2023

2. Materials and methods

2.1. Research objects and data sources

In order to examine the impact of customer' ESG performance on corporate carbon productivity, the article chooses 2009 as the starting point of the study, considering that the Securities Regulatory Commission (CSRC) has encouraged listed companies to disclose the specific names and sales of their top 5 customers and suppliers since 2009. Based on data from Chinese A-share listed companies from 2009 to 2022, this study constructs a one-to-one matched sample of "customer-company-year" through manual collection and screening. The initial sample comprises 158,154 "company-year" observations from 4,708 A-share companies. The sample was then filtered to include only those customers that are listed companies. While the top five customers disclosed by listed companies include both listed and non-listed companies, financial data for non-listed companies are not available. Using the data platform, we identified 2,829 "company-year" observations where customers were listed companies. Subsequently, the data were processed as follows based on the research requirements: (1) 142 observations of ST and *ST companies were excluded; (2) 17 observations from the financial industry were excluded; (3) 26 observations lacking control variable data were excluded; (4) 645 observations lacking customer ESG ratings were excluded; (5) 422 observations lacking necessary weights for the calculation of customer ESG performance values were excluded, as this study uses unequal weights to calculate these values. Ultimately, we obtained 646 matched samples of listed customer-company-year observations. To eliminate the impact of outliers, we performed a 1% winsorization on continuous variables. The supply chain data for this study were sourced from the China Research Data Service Platform (CNRDS), the Huazheng ESG rating data from the Wind Financial Terminal, and other variable data from the China Stock Market & Accounting Research (CSMAR) database.

2.2. Theoretical analysis and research hypothesis

2.2.1. Customer ESG performance and corporate carbon productivity

Given the weak technological push and market pull characteristics of carbon productivity, companies often lack the motivation to improve it. The decision to undergo comprehensive green reform and enhance carbon productivity heavily depends on the strength of a company's environmental awareness, that is, whether there are endogenous or exogenous drivers guiding the company. The environmental awareness brought about by customers' ESG performance, through a convergence effect, compels corporate management to adopt green development strategies to align with customers' green development ideals (Sun *et al*. 2024). By imitating customers' green development models, companies are also motivated to improve their carbon productivity. On the one hand, modern companies face moral hazard issues arising from information asymmetry and environmental uncertainty in their stakeholder relationships (Demsetz 1964). Outstanding ESG ratings from customers convey their efforts and achievements in environmental, social, and corporate governance to their supply chain partners, reflecting a positive corporate ethos (Rahman *et al*. 2023). This helps companies gain the trust of stakeholders and enhances their profitability (Velte 2017). According to reputation theory, collaborating with high ESG-performing customers can boost a company's brand image and market reputation, attracting more customers and investors. On the other hand, research shows that in the supply chain system, upstream and downstream companies are more willing to collaborate with firms adhering to low-carbon sustainable development principles (Das 2023; Keddie *et al*. 2023). To ensure supply chain stability, customers prefer to partner

with companies that share similar environmental responsibility awareness. This external market incentive drives companies to improve their carbon emission management to secure more business opportunities. Furthermore, the legitimacy conveyed by strong ESG performance can reduce financial risks and increase market attention, making it easier to attract stable and independent institutional investors (Albuquerque *et al*. 2019). As long-term partners, companies observing the competitive advantages of their customers' ESG performance are likely to promptly adjust their strategies to emulate and learn from their customers' green development ideals.

Focusing on the companies themselves, many may lack the necessary technical knowledge or professional talent to implement and manage carbon reduction measures. For some companies, understanding and mastering advanced low-carbon technologies and management practices is itself a challenge. From the perspective of resource dependence theory within the supply chain, the commercial ties between customers and companies facilitate the continuous diffusion of production factors, information, and knowledge among enterprises, making customers crucial sources of heterogeneous resources for companies. The heterogeneous information, capabilities and knowledge acquired by enterprises through the innovation chain and industrial chain transmission will be transformed into complementary elemental resources required for low-carbon innovation activities, enriching the variety of technological metadata while empowering carbon productivity enhancement (Wang *et al*. 2023). High ESG-performing customers, reflecting their commitment to long-term sustainable development, often increase investments in environmental management and technology to address future challenges and uncertainties. They also place greater emphasis on the long-term development of their employees (Wang *et al*. 2023). For instance, such customers actively develop green supply chain management systems that meet low-carbon demands, strive to build circular economy models to reduce raw material consumption, and in the process, accumulate substantial green resource reserves (Li *et al*. 2021). Their experiences and knowledge in green technology and organizational innovation as part of their ESG development practices can be seen as sources of innovation diffusion (Brown 1981). Companies can absorb these abundant green knowledge resources and breakthrough green technologies from their customers through green resource absorption effects and practice sharing pathways (Sun *et al*. 2024). External green knowledge can reshape a company's internal knowledge structure, break green innovation bottlenecks by stimulating innovative thinking, and significantly reduce the costs associated with green innovation in the process of improving carbon productivity (Ben *et al*. 2018). This not only mitigates the instability of green innovation but also ensures a stable improvement in a company's carbon productivity. Based on the above analysis, the following hypothesis is proposed:

Hypothesis 1: Customer ESG performance has a positive correlation with corporate carbon productivity.

2.2.2. Intrinsic mechanisms of client ESG performance affecting corporate carbon productivity

Improving carbon productivity usually requires technological upgrades, equipment replacement, and production process improvements, all of which require substantial capital investment. For many companies, especially small and medium-sized enterprises, these high initial investment costs can be challenging to bear. In the supply chain network, customers with excellent ESG performance can help Chinese companies overcome the high ongoing investment costs and initial economic pressures associated with improving their carbon productivity. The social responsibility signals conveyed by good ESG performance of customer companies enable them to stand out in the judgment of social status and moral capital by external investors, thereby increasing green credit investment and cooperation (Shi *et al.* 2024). While accumulating social capital for themselves, customer companies also expand the sources of external resources for the supply chain and network (Xu *et al*. 2016), thus providing more external funding support for associated enterprises in the supply chain. From the stakeholder perspective, stakeholders, driven by the pursuit of higher returns, are responsible for overseeing corporate operations (Xue *et al*. 2023), demanding higher standards in the production and sale of green products, green technology, and green management concepts. The supervision mechanisms and informal regulations imposed by stakeholders internalize external costs, compelling companies to increase pollution control expenditures to improve carbon productivity and maintain their quality customer resources. Secondly, according to the theory of peer learning, companies in the same industry with similar operational scopes and product structures tend to engage in strategic imitation of peer companies (Cao *et al*. 2019). Companies are more inclined to strategically imitate their customers within the supply chain to avoid potential ESG development failure risks. In this context, companies, based on their close cooperative relationships with customers, significantly reduce the search costs for green knowledge by obtaining green production technologies and green development concepts from their customers (Wu *et al*. 2022). The improvement in green development efficiency significantly enhances the internal gross product of companies. Green innovation, through the green knowledge spillover effect, can lead to green technology upgrades, energy efficiency improvements, green product development, and the empowerment of circular economy models, thereby improving the internal gross product of companies. The enhancement of carbon productivity relies on long-term investment of substantial resources, and resource constraints are the primary challenge faced by companies. Collaborating with customers with excellent ESG performance strengthens a company's ability to acquire resources from the supply chain, alleviating green resource constraints by improving the company's own

gross product. Based on the above analysis, the following hypothesis is proposed:

Hypothesis 2: Customer ESG performance influences corporate carbon productivity through increased pollution control investments and improved gross product.

2.3. Variables selection

2.3.1. Explained variables

Carbon productivity refers to the economic output generated per unit of carbon dioxide emissions (Yang *et al*. 2015). It is a core metric for balancing economic benefits and carbon emissions under environmental resource constraints. Currently, there is no unified standard for measuring and calculating carbon productivity. This paper draws on the research of Xie *et al*. (2018) and Yao *et al*. (2023), uses single-factor productivity to measure the carbon productivity of manufacturing enterprises, which aligns with China's emission reduction targets and plans.

$$cp_{it} = goutput_{it} / co_{2it} \quad (1)$$

In equation (1), $goutput_{it}$represents the total output of the enterprise, and co_{2it} represents the enterprise's carbon dioxide emissions. A higher cp_{it} indicates a higher level of carbon productivity for the enterprise; conversely, a lower cp_{it} indicates a lower level of carbon productivity. Since there is currently no official statistic for carbon emission intensity at the enterprise level, this paper adopts the estimation method of Liu *et al*. (2020). Using data from the China Tax Survey Database, the carbon dioxide emissions of enterprises are calculated based on the consumption of three major energy sources: coal, oil, and electricity.

2.3.2. Explanatory variables

The selection of client ESG performance indicators in this paper draws on the studies of Lian *et al*. (2023) and Shi *et al*. (2024), utilizes the Huazheng ESG rating data to measure customer ESG performance. The Huazheng Index incorporates the core principles of international ESG standards, references mainstream international methods and practices, and considers the characteristics of China's national conditions and capital markets. It rates listed companies across three dimensions: environmental, social, and corporate governance. Compared to other rating systems, the Huazheng Index features a wide coverage, high update frequency, and large sample size, making it more conducive to large-scale empirical research in this paper. The rating results are divided into 9 levels from low to high: C, CC, CCC, B, BB, BBB, A, AA, AAA. In this paper, these ratings are assigned values from 1 to 9, with higher values indicating better ESG performance for the company. After collecting the ESG performance values corresponding to the companies' customers, to mitigate the impact of undisclosed data, further measurement of the customer ESG performance for the enterprise is required. Previous research indicates variations in the economic importance of the top five customers to the enterprise. Therefore, we calculate the customer ESG performance using unequal-weighted weighting based on the proportion of sales revenue from major customers. The specific calculation method is as follows: First, we determine whether each of the top five customers disclosed in the company's annual report is a listed company. If any of the disclosed customers are listed companies, the sample is retained. Secondly, if the customer is a listed company, the customer's ESG performance is calculated using unequal-weighted weighting based on the proportion of their sales revenue. Finally, if the same enterprise includes multiple customer ESG values in the same year, the values are averaged to obtain a unique customer ESG performance value.

Table 1. Variable description

Type	Name	Definition
Dependent Variable	CP	Gross enterprise value divided by enterprise CO_2 emissions
Independent Variable	Cus_ESG	Customer ESG scores obtained from CSI Ratings and then weighted unequally based on the sales share of the top five customers
Control Variable	Trans	Evaluation of disclosure quality of enterprises
	Inv	Ratio of net inventory to total assets
	Size	Natural logarithm of total assets for the year
	Lev	Total liabilities at year-end divided by total assets at year-end
	Cashflow	Net cash flows from operating activities divided by total assets
	Cus_Firmage	The year of the client's company minus the year of the company's founding plus one, and then take the logarithm of that number
	Cus_ROA	Net profit of client companies divided by the average balance of total assets
	ROA	Net profit divided by average balance of total assets
	Growth	Growth rate of operating income, the enterprise's operating income for the current year divided by the operating income of the previous year minus one
	FirmAge	The current year of the company minus the year of incorporation plus one, and then take the logarithm of that number
	Inver	Investment spending ratio, total cash paid for fixed assets, intangible assets and other long-term assets to total assets

2.3.3. Control variables

Drawing on the studies by Di *et al*. (2020) and Zhang *et al*. (2024), this paper selects control variables, including firm size (Size), firm leverage (Lev), return on assets (ROA), firm age (Firmage), growth capability (Growth), cash flow (Cashflow), inventory ratio (INV), investment expenditure ratio (Inver), information disclosure quality, customer firm return on assets (Cus_ROA), and customer firm age (Cus_Firmage). Additionally, the paper controls for year, industry, and city fixed effects. Table 1 provides definitions for the main variables.

2.4. Model construction and variable interpretation

In order to assess the impact of customers' ESG performance on firms' carbon productivity, the following model was developed based on the hypotheses presented earlier and with reference to the findings of Lei *et al.* (2024):

$$cp_{i,t} = \beta_0 + \beta_1 Cus\_ESG_{i,t} + \beta_2 Controls_{i,t} + Year_{i,t} + Ind_{i,t} + City_{i,t} + \varepsilon_{i,t} \quad (2)$$

where, $cp_{i,t}$ is the explanatory variable, denoting the carbon productivity of firms in period t. $Cus\_ESG_{i,t}$ denotes the ESG performance value of firm i's customers in year t. Controls is the control variables for both firms and customers, Year is the year fixed effect, Ind is the industry fixed effect, City is the fixed effect of the firm's city, and $\varepsilon_{i,t}$ is the residuals. This paper focuses on whether and how client ESG performance affects firms' own carbon productivity levels. If hypothesis 1 holds, i.e., expected customer ESG performance does improve firms' carbon productivity, the sign of β_1 in the model should be significantly positive and significant.

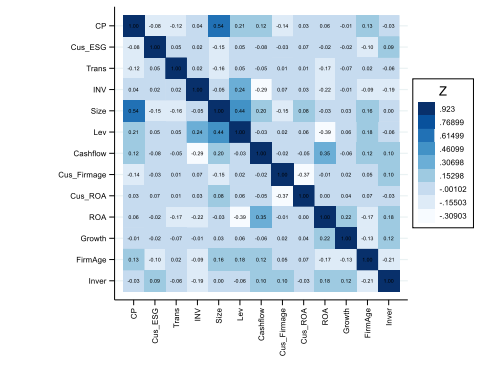


Figure 2. Correlation heat map

3. Results and discussion

3.1. Descriptive statistics

Table 2 presents the descriptive statistics results of each variable under the full sample. The analysis results show that the mean value of customer ESG performance Cus_ESG is 0.317, indicating that the overall level of customer ESG performance of enterprises listed in Shanghai and Shenzhen A-share companies is not high. The mean value of carbon productivity is 13.21, indicating that the carbon productivity of most enterprises is in the lower middle level. At the level of control variables, the mean value of enterprise size (Size) is 21.80, the mean value of enterprise gearing ratio (Lev) is 0.39, the mean value of enterprise growth capacity (Growth) is 0.13, and the mean value of enterprise investment expenditure rate (Inver) is 0.057, which is not significantly different from the existing literature.

Table 2. Descriptive statistics of the main variables

Variable	Obs	Mean	SD	Min	Max
CP	646	13.2186	1.9320	8.0556	19.3654
Cus_ESG	646	0.3179	0.3522	0.228	2.076
Trans	646	2.0116	0.5652	1	4
Inv	646	0.1306	0.0829	0.0058	0.4122
Size	646	21.8060	1.2609	19.7400	25.7996
Lev	646	0.3922	0.2076	0.0352	0.9202
Cashflow	646	0.0381	0.0586	-0.1362	0.2115
Cus_Firmage	646	0.0474	0.0442	-0.0640	0.1843
Cus_ROA	646	0.5483	0.1641	0.1040	0.8540
ROA	646	0.0446	0.0536	-0.1744	0.1851
Growth	646	0.1346	0.3117	-0.4923	1.8002
FirmAge	646	2.7067	0.3832	1.3862	3.4657
Inver	646	0.0575	0.0459	0.0019	0.2308

3.2. Correlation analysis

Figure 2 shows the results of the correlation analysis for each variable. As can be seen from the figure, the correlation coefficients of all variables are around 0.5, indicating that there is no serious problem of multicollinearity.

3.3. Results of regression tests

Table 3 presents the test results for Hypothesis 1, which examines whether there is a positive correlation between customers' ESG performance and firms' carbon productivity. To investigate the impact of customers' ESG performance on firms' carbon productivity, this paper examines the overall transmission effect of customers' ESG performance on firms' carbon productivity after controlling for industry, year, and city fixed effects. The regression results of Model (1) provided in Table 3 show

that the coefficient for customers' ESG performance is 0.268, which is significantly positive at the 5% level. This result indicates that an improvement in customers' ESG performance enhances firms' carbon productivity levels. Additionally, the estimated ESG coefficient is economically significant, suggesting that for every one standard deviation increase in customers' ESG rating, firms' carbon productivity levels increase by 26.8%. This finding suggests that improvements in major customers' ESG performance can motivate firms to undertake more green emission reduction initiatives. In other words, the higher the ESG rating of customers, the higher the firms' carbon productivity levels, thereby confirming Hypothesis 1 of this paper.

Table 3. Empircial test results of regression model

Variable	(1)	(2)	(3)	(4)
	CP	CP	CP	CP
Cus_ESG	0.268**		0.236*	0.280*
	(2.00)		（1.80）	（1.74）
Cus_ESG1		0.006*		
		(1.84)		
Trans	-0.095	-0.091	-0.067	
	(-1.55)	(-1.49)	(-1.13)	
Inv	1.746**	1.694**	0.996	
	(2.49)	(2.42)	(1.37)	
Size	0.522***	0.493***	0.578***	
	(3.98)	(3.78)	(4.46)	
Lev	0.934**	0.940**	1.956***	
	(2.38)	(2.40)	(4.07)	
Cashflow	0.599	0.566	1.095*	
	(1.07)	(1.01)	(1.94)	
Cus_Firmage	-0.337	-0.444	-0.380	
	(-0.42)	(-0.55)	(-0.48)	
Cus_ROA	-0.419	-0.413	-0.303	
	(-1.51)	(-1.49)	(-1.11)	
ROA	1.771*	1.918**	1.330	
	(1.92)	(2.10)	(1.47)	
Growth	0.337***	0.326***	0.347***	
	(3.48)	(3.36)	(3.66)	
Firmage	-0.097	-0.086	-0.437	
	(-0.17)	(-0.15)	(-0.78)	
Inver	1.214	1.197	0.904	
	(1.53)	(1.50)	(1.16)	
NWC			1.421***	
			(3.56)	
Combined leverage			0.015	
			(1.28)	
Imr				1.702***
				(3.63)
Constant	1.173	1.776	0.408	11.224***
	(0.40)	(0.61)	(0.14)	(26.16)
Year/Industry/City	Yes	Yes	Yes	Yes
Observations	646	646	646	599
R-squared	0.562	0.560	0.590	0.359

3.4. Discussion of robustness tests

3.4.1. Replace core variable measurement

ESG performance values help companies build a positive social image and reputation. To convey a positive signal of good management to the public, companies may have the motivation to exaggerate their ESG performance (Shi *et al*. 2024). To avoid the potential inaccuracy of ESG ratings due to possible "greenwashing" by companies, this paper draws on the research of Lian *et al*. (2023) and reconstructs the alternative explanatory variable (Cus_ESG1) based on the Huazheng ESG rating. When a company receives an ESG rating of A, AA, or AAA, it is assigned a value of 3; when the rating is B, BB, or BBB, it is assigned a value of 2; and when the rating is C, CC, or CCC, it is assigned a value of 1. After processing the basic data, a new customer ESG performance indicator is calculated using unequal weights. Model (1) is then re-estimated, and the regression results are presented in the second column of Table 3. These results indicate that customer

ESG performance has a significant positive impact on firms' carbon productivity, consistent with the main test, further confirming the robustness of the paper's conclusions.

3.4.2. Endogeneity test

In the baseline regression, controlling for fixed time, year, and industry effects can mitigate endogeneity issues to some extent. Since the China Securities Regulatory Commission only encourages listed companies to disclose the names and sales figures of their top five customers, the disclosure of major customer information by Chinese listed companies is voluntary. This may lead to sample self-selection bias. Therefore, following the methods of Ellis *et al*. (2012) and Wang *et al*. (2014), this paper employs the Heckman two-stage regression to address this sample self-selection issue. First, in the first stage, the variable "whether customer information is disclosed" (Disclosure) (a dummy variable, 1 if customer information is disclosed, 0 otherwise) is used as the dependent variable. Next, firm size (Size), leverage (Lev), return on assets (ROA), growth ability (Growth), and firm age (Firmage) are used as explanatory variables in the first-stage Probit regression. The inverse Mills ratio (IMR) estimated in the first stage is then included in the second-stage regression model. The results presented in the fourth column of Table 3 indicate a significant positive correlation between customer ESG performance and firms' carbon productivity, consistent with the conclusions of the main analysis. This demonstrates that the study's conclusions remain robust even after accounting for sample self-selection issues.

Table 4. Mechanism testing

Variable	(1)	(2)
	Pollution control inputs	Gross enterprise product
Cus_ESG	0.163**	0.249***
	(2.23)	(4.22)
Trans	0.071**	0.003
	(1.98)	(0.11)
Inv	1.016**	0.372
	(2.49)	(1.21)
Size	0.577***	0.752***
	(6.93)	(13.01)
Lev	0.167	0.275
	(0.74)	(1.59)
Cashflow	0.493	0.560**
	(1.55)	(2.28)
Cus_Firmage	0.066	-0.304
	(0.14)	(-0.85)
Cus_ROA	-0.075	0.038
	(-0.43)	(0.31)
ROA	-0.182	1.456***
	(-0.34)	(3.59)
Growth	-0.034	0.271***
	(-0.62)	(6.35)
Firmage	-0.829**	0.655***
	(-2.46)	(2.61)
Inver	0.025	0.251
	(0.05)	(0.72)
Constant	7.659***	2.549**
	(4.23)	(1.99)
Year/Industry/City	Yes	Yes
Observations	529	552
R-squared	0.548	0.542

3.4.3. Omitted variable issue

Considering that omitted variables may also cause endogeneity issues, this paper further includes firm-level net working capital (NWC) and comprehensive leverage. The regression results addressing the omitted variable issue are reported in the third column of Table 3. As shown in the third column of Table 3, customer ESG performance still positively impacts firms' carbon productivity, indicating that the baseline regression results are robust.

3.5. Mechanism test

The paper verifies in Model (2) that customer ESG performance significantly improves firms' carbon productivity. Drawing on the theoretical analysis presented earlier, the paper posits that customer ESG performance can enhance firms' carbon productivity by

increasing pollution control investment and improving gross domestic product (GDP). Building on the study by Jiang (2022), when the causal relationship between the mediator and the outcome variable is relatively direct in theory, it is sufficient to examine the impact of the explanatory variable on the mediator variable to validate the mediating mechanism. Therefore, based on Model (2), Model (3) is constructed to examine how customer ESG performance affects firms' carbon productivity. In Model (3), the mediator variable, denoted as $Media_{i,t}$, includes both firm management expenses and gross domestic product. To test the impact mechanism, the following model is constructed based on Equation (2):

$$Media_{i,t} = \beta_0 + \beta_1 Cus\_ESG_{i,t} + \beta_2 Controls_{i,t} + Year_{i,t} + Ind_{i,t} + City_{i,t} + \varepsilon_{i,t} \quad (3)$$

To verify whether customer ESG performance drives the improvement of firms' carbon productivity through cost compliance effects, this paper follows the approach of Zhu *et al*. (2022) by using the logarithm of firm management expenses as a proxy variable for firms' compliance costs (pollution control investment). Given that the impact of customer ESG performance on firms' carbon productivity has been presented in Table 3, this section only provides the regression results of the explanatory variables on the mediator variable, as shown in Table 4. In the first column of Table 4, the coefficient of customer ESG performance is significantly positive at the 1% level, indicating that good customer ESG performance indeed increases firms' environmental governance costs and pollution control costs. In the second column, the coefficient of customer ESG performance is also significantly positive, suggesting that good customer ESG performance can stimulate the increase of firms' internal gross domestic product (GDP), ultimately leading to the improvement of carbon productivity.

3.6. Heterogeneity analysis

3.6.1. Heterogeneity of firm size

To further investigate whether customer ESG performance generates heterogeneous green effects across different types of firms, this paper conducts sub-sample tests on firms of different size categories. Firms are divided into large-sized and small-sized groups based on whether their total assets are above or below the sample mean, respectively, and group regression analysis is performed. The estimation results, as shown in Table 5, indicate that in the small-sized group, the coefficient of customer ESG performance is positive and significant at the 10% level. However, for the large-sized group, the ESG coefficient is negative but not significant. This suggests that the improvement in customer ESG performance does indeed have heterogeneous effects on firms' carbon productivity at the firm size level. One possible reason is that large-scale firms have stronger path dependence and are not subject to significant financing constraints, which reduces their attention to changes in external customer ESG performance and the corresponding application of green technologies. In a competitive market environment, small-scale firms, unlike large-scale firms, can obtain higher-quality heterogeneous resources. To maintain their competitive advantage, small-scale firms have a stronger willingness to search for external market resources and information to enhance their carbon productivity. Therefore, in small-sized firms, the impact of improving customer ESG performance on enhancing firms' carbon productivity is more significant.

3.6.2. Heterogeneity in industry pollution levels

To examine the differential impact of customer ESG performance on firms' carbon productivity across industries with different pollution levels, this paper follows the approach of Fu *et al*. (2021) by dividing the sample data into industries with high emission intensity and those with low emission intensity. Industries with high emission intensity include the top six high-energy-consuming industries defined by China and eight traditional industries with high energy consumption. The remaining industries are classified as low emission intensity industries. According to the clear definition in the 2010 Statistical Bulletin of China's National Economic and Social Development, the six high-energy-consuming industries include chemical raw materials and chemical product manufacturing, non-metallic mineral product manufacturing, black metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry, petroleum processing, coking, and nuclear fuel processing industry, and electricity, heat production, and supply industry. The eight traditional industries include agricultural and sideline food processing industry, food manufacturing industry, paper and paper products industry, textile industry, chemical fiber manufacturing industry, rubber and plastic products manufacturing industry, metal products and other manufacturing industries. The estimation results, as shown in Table 5, indicate that in the low pollution intensity industry group, the ESG coefficients are all significantly positive at the 1% level. However, in the high pollution intensity industry group, although customer ESG performance is positively related to firms' carbon productivity, the relationship is not significant. One possible reason is that firms in high pollution intensity industries have high energy consumption and are mostly low-tech-intensive enterprises, typically engaging in extensive production with low-cost advantages. When customers in the supply chain improve their ESG ratings, they may undergo significant green technology and mode transformations, increasing their own costs while also imposing higher product transformation costs on partner firms through supply chain contagion effects. In such cases, firms in high pollution intensity industries may be more inclined to seek new customer partners or allocate surplus capital to pollution control to maintain basic production and operation activities. However, these approaches only reduce carbon emissions and do not fundamentally improve production efficiency. On the other hand, firms in low pollution intensity industries, as technology-intensive enterprises with low carbon emission intensity, typically view the improvement in

customer ESG performance as a positive market signal. They are more motivated to engage in green development models to maintain high-quality customers and enhance their market competitiveness. Therefore, customer ESG performance has a more significant impact on firms' carbon productivity in low pollution intensity industries.

3.6.3. Heterogeneity in market orientation

To further investigate the heterogeneity of market orientation, this paper follows the approach of Ye *et al*. (2022) by selecting export scale as a proxy variable for export intensity. Based on the degree of export scale, the sample is divided into two groups: firms with an export intensity of 0 are categorized as domestic-oriented enterprises, while firms with an export intensity greater than 0 are categorized as export-oriented enterprises. The regression results, as shown in Table 5, indicate that in the domestic-oriented enterprise group, the coefficient of customer ESG performance is significantly positive at the 1% level. However, in the export-oriented enterprise group, although the coefficient of customer ESG performance is positive, it is not significant. One possible reason is that customer relationships in export-oriented enterprises are influenced by export taxation policies, national policies, and international situations, which may not remain stable, and the interoperability of green information is not as strong as in domestic-oriented enterprises. In contrast, domestic-oriented enterprises can balance cooperation in innovation talents and technological equipment, fully utilizing the domestic market to respond to changes in the market environment, thereby reducing the interference of external environmental policies. Therefore, in domestic-oriented enterprises, customer ESG performance is more conducive to enhancing firms' carbon productivity.

Table 5. Heterogenelty analysis

Variable	(1) Large scale	(2) Small scale	(3) High emission intensity	(4) Low emission intensity	(5) Export-oriented	(6) Domestic-oriented
	CP	CP	CP	CP	CP	CP
Cus_ESG	-0.048	0.304*	0.362	0.367***	0.182	0.542***
	(-0.16)	(1.70)	(0.74)	(3.04)	(0.99)	(2.80)
Trans	0.104	-0.240**	0.016	-0.011	-0.113	-0.125
	(1.04)	(-2.56)	(0.19)	(-0.18)	(-1.40)	(-1.27)
Inv	1.421	1.138	0.574	1.156	1.740**	-0.146
	(0.76)	(1.25)	(0.49)	(1.59)	(2.05)	(-0.09)
Size	1.113**	0.535***	0.364	0.616***	0.519***	0.623
	(2.56)	(2.74)	(1.03)	(4.47)	(3.28)	(1.61)
Lev	0.190	1.153**	0.336	1.334***	1.245**	0.178
	(0.18)	(2.07)	(0.45)	(2.91)	(2.53)	(0.25)
Cashflow	0.140	0.564	0.880	0.294	1.517*	0.240
	(0.13)	(0.76)	(1.13)	(0.53)	(1.79)	(0.32)
Cus_Firmage	-3.166**	-0.214	-0.700	0.977	0.400	0.697
	(-2.37)	(-0.18)	(-0.44)	(1.19)	(0.32)	(0.58)
Cus_ROA	-0.676	-0.465	-0.481	-0.336	-0.380	0.073
	(-0.93)	(-1.26)	(-1.14)	(-1.23)	(-0.96)	(0.22)
ROA	2.230	3.007**	2.673*	0.646	2.441*	1.309
	(1.17)	(2.24)	(1.86)	(0.76)	(1.93)	(0.93)
Growth	0.011	0.326**	0.305*	0.381***	0.153	0.461***
	(0.07)	(2.43)	(1.88)	(4.22)	(1.10)	(3.46)
Firmage	-1.646*	0.953	-2.989	-0.083	-0.385	0.240
	(-1.99)	(0.85)	(-1.37)	(-0.17)	(-0.40)	(0.33)
Inver	0.039	2.386**	1.683*	-0.798	2.276**	-0.625
	(0.03)	(2.21)	(1.92)	(-0.93)	(2.06)	(-0.50)
Constant	-7.316	-1.693	10.770	-0.676	1.833	-1.886
	(-0.79)	(-0.34)	(0.99)	(-0.23)	(0.46)	(-0.26)
Year/Industry/City	Yes	Yes	Yes	Yes	Yes	Yes
Observations	259	387	310	336	488	158
R-squared	0.633	0.567	0.803	0.376	0.533	0.841

4. Conclusions and recommendations

In order to examine the impact of clients' ESG performance on firms' carbon productivity under partnership, this paper selects statistics from 2009-2022, centering on the Chinese capital market. The research findings indicate that customer ESG performance significantly enhances firms' carbon productivity levels. This not only confirms the supply chain contagion effect of ESG performance but also expands the environmental impact of corporate ESG performance. Secondly, customer ESG performance affects firms' carbon productivity levels through two main mechanisms of action, namely, improving pollution control costs and improving firms' gross domestic product. Heterogeneity analysis reveals that the impact of customer ESG performance is more significant in smaller-sized firms,

industries with low pollution intensity, and domestic-oriented market-oriented firms. From a global perspective, this study provides managerial insights for companies striving to improve their carbon productivity.

Based on the conclusions above, this study offers the following insights: Firstly, from the perspective of the government, the government should strengthen the guarantee of the service-oriented layout of the enterprise supply chain, and fully realize the influence of customer relationship. Governments can facilitate the construction of green supply chain networks by leveraging core enterprises in the supply chain, formulate reasonable environmental regulations to strengthen market environmental supervision, stabilize the external environment for green collaborative innovation, and ensure the sharing of green technology innovation knowledge among enterprises. At the same time, Chinese government agencies need to strengthen oversight of ESG rating agencies by supervisory bodies, as well as introduce forensic services to issue official ESG ratings. Most of the "greening" at the corporate level is related to corporate green marketing, and it is necessary to strictly review and increase penalties to curb from the root the behavior of corporations that gain gains by exaggerating or over-embellishing the fulfillment of their environmental and social responsibilities, so as to promote the ESG ratings to truly reflect the green development and sustainable activities of the corporations.

Secondly, from the perspective of enterprises, strengthening ESG concepts and practices is essential under the background of sustainable development. Managers play a critical role in formulating green strategies for enterprises and should integrate ESG concepts into business philosophies to form new management concepts, integrating ESG thinking throughout the governance process of enterprise development. Enterprises should improve relevant governance mechanisms, pay close attention to international trends in green strategies, and guide managers to pay attention to the environmental demands of external stakeholders by actively organizing conferences and lectures on the theme of green sustainable development.

Lastly, from the perspective of supply chain management, the transmission mechanism of ESG performance in the supply chain cannot be ignored. Constructing green supply chain networks can stimulate green collaborative effects. The realization of national green transformation goals relies on the collaboration of single enterprises. To achieve green governance, it is crucial to promote green collaboration among upstream and downstream enterprises in the supply chain.

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