Can green technology innovation improve corporate environmental social governance performance?

---Mediating effects based on product differentiation

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Abstract. In the context of the strategic objectives of carbon peak and carbon neutrality, the ESG performance system has become one of the important indicators for enterprises to realize high-quality development. In the new development stage, whether green technological innovation can promote enterprises' ESG performance deserves in-depth study. This paper utilizes the data of China's A-share listed manufacturing companies from 2012 to 2022 to explore the impact of green technology innovation on ESG performance. The study finds that: inventive green technology innovation can promote ESG performance; product differentiation plays a part of the mediating effect in this driving process; heterogeneity analysis reveals that, in the development of enterprises in China's central and western regions, the promotion effect of green technology innovation on corporate ESG performance is more significant. Therefore, the government should actively guide enterprises to enhance their investment in to help realize the high-quality economic and social development.

Keywords: green technology innovation; ESG performance; fixed-effects modeling

1 Introduction

In recent years, ESG has become an important reference system for measuring the high-quality development of enterprises[1]. With the deepening of the concept of high development, green technological innovation has become an important way to improve quality and increase efficiency[2].Therefore, this paper selects China's manufacturing enterprises as samples from 2012 to 2022, empirically analyzes the impact of green technological innovation on the ESG performance of enterprises, and focuses on exploring product differentiation as a mediating variable and enterprise scale as a moderating variable, and the role of the mechanism in the process of the impact. Based on the above analysis, the research contribution of this paper is to further deepen the research on the causes of ESG performance, and the measurement index of independent variable is enriched.

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2 Theoretical analysis and research hypotheses

2.1 Green technology innovation and ESG performance

Enterprises should reduce corporate pollution and waste emissions, and increase their investment in environmental technology innovation [3]. Based on signaling theory, when an enterprise participates in evaluating the relationship between stakeholders and the environment, continuously improves the quality of innovative products, it will establish reputational advantages[4].

H1a: Inventive green technology innovation has a significant positive effect on ESG performance.

H1b: Utility-based green technology innovation has a significant positive effect on ESG performance.

2.2 The mediating role of product differentiation

The products produced by green technology innovation are more environmentally friendly, which satisfies consumers' demand for differences in product quality[5]. In addition, based on the national green policy, enterprises implementing green technology innovation should improve the customer and product management mechanism, and form the management advantage of differentiated products[6].

H2a: Inventive green technology innovation affects firms' ESG performance through the mediating effect of product differentiation.

H2b: Utility model green technology innovation affects firms' ESG performance through the mediating effect of product differentiation.

2.3 The moderating role of enterprise size

Relevant studies show that under normal circumstances, the larger enterprise, the more conducive to attracting and retaining high-level scientific and technological talent, and thus more equipped with the human resource reserves[7].

H3a: Firm size moderates the relationship between inventive green technology innovation and firm ESG performance.

H3b: Firm size plays a moderating role in the relationship between utility-based green technology innovation and firm ESG performance.

3 Research design

3.1 Data sources and sample selection

This paper uses the data of all A-share listed manufacturing companies from 2012-2022 as samples, and the data are mainly obtained from CSI ESG rating database, China Research Data Service Platform (CNRDS), and Cathay Pacific database (CSMAR). Among them, the CSI ESG Rating Database provides ESG scores; CNRDS provides

green patent application data and total patent application data; CSMAR provides basic information and financial statement data of listed companies. In addition, this study has treated the variables as follows: (1) excluding samples with listing statuses of ST, *ST and PT; (2) excluding samples with excessive missing data of relevant indicators; and (3) for the problem of heteroskedasticity, the raw data are treated by adding one to take the logarithm of the original data.

3.2 Variable design

Explained variable: ESG performance. Since the ESG data of Huazheng has a wide coverage and high timeliness, this paper takes its data as the explained variable. Explanatory variable: green technology innovation. Referring to the research of Qi Huaijin, green technological innovation is further subdivided into green invention patents(GTI1)and green utility model patents(GTI2)[8]. Mediating variable: product differentiation. Referring to Xiao Zuoping(2004)[9], through the relationship between selling expenses and operating expenses, the degree of differentiation is related to the investment of the enterprise. Moderating variable: firm size. The specific variables are shown in the following Table 1.

Table 1. Main variables, variable measures and data sources

Variable	Name	Symbol	Definition
explanatory variable	ESG	ESG	Adoption of the internationally recognized CSI ESG score
explanatory variable	Green Invention Patent	$LnGTI_1$	Log of Green Invention Patent applications filed by firms, Year-End 2012-2022
	Green Utility Patent	$LnGTI_2$	Log of Green Utility Patent applications filed by Firms, Year-End 2012-2022
Intermediary variable	Product differentiation	PD	Selling expenses/operating income
Moderator variable	Enterprise size	Size	ln (total business assets)
control variable	gearing	Lev	Total liabilities at end of period/total assets at end of period
	Total number of patent applications	LnTPA	Logarithm of Patent Filings by Firms, Year-End 2012-2022
	Percentage of independent directors	Indep	Number of independent directors/total number of directors
	Percentage of shares held by institutional investors	INST	Percentage of shares held by outside investors
	Nature of business	SOE	State-owned enterprises =1, non-state-owned enterprises = 0
	Nature of area	East	Company is registered in the East = 1, otherwise = 0

3.3 Modeling

The theoretical framework model of this paper is shown in Figure 1.

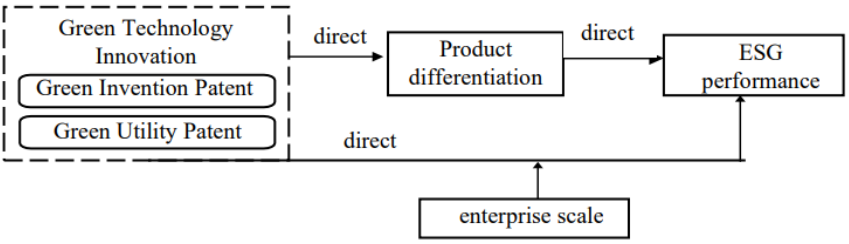

Fig. 1. Schematic diagram of the study model

At the same time, this paper constructs the following five models.

$$ESG_{it} = \beta_0 + \beta_1 LnGTI_{1it} + \beta_2 LnGTI_{2it} + \beta_3 Control_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

$$PD_{it} = \beta_0 + \beta_1 LnGTI_{1it} + \beta_2 LnGTI_{2it} + \beta_3 Control_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (2)$$

$$ESG_{it} = \gamma_0 + \gamma_1 LnGTI_{1it} + \gamma_2 LnGTI_{2it} + \gamma_3 PD_{it} + \gamma_4 Control_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (3)$$

$$ESG_{it} = \alpha_0 + \alpha_1 lnGTI_{1it} + \alpha_2 SCA_{it} + \alpha_3 lnGTI_{1it} \times SCA_{it} + \alpha_4 Control_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (4)$$

$$ESG_{it} = \alpha_0 + \alpha_1 lnGTI_{2it} + \alpha_2 SCA_{it} + \alpha_3 lnGTI_{2it} \times SCA_{it} + \alpha_4 Control_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (5)$$

4 Empirical results and analysis

4.1 Descriptive statistics

In Table 2, it can be seen that the mean values of the number of green patent applications are 1.115 and 1.149, indicating that the degree of green technological innovation of enterprises is relatively high. The standard deviation of ESG is 4.818, indicating that the ESG performance are differences among enterprises.

Table 2. Descriptive statistical analysis of variables

Variable	N	Mean	p50	SD	Min	Max
LnGIT1	6073	1.115	0.693	1.155	0	4.477
LnGIT2	6073	1.149	1.099	1.059	0	3.970
ESG	6073	73.91	74.09	4.818	59.98	83.92
PD	6073	0.0600	0.0410	0.0580	0	0.469
Size	6073	22.64	22.51	1.239	20.20	25.87
Lev	6073	0.431	0.437	0.179	0.0720	0.786
LnTPA	6073	4.140	4.127	1.378	0.693	7.416
Indep	6073	37.37	33.33	5.357	33.33	57.14
INST	6073	46.27	48.09	23.71	0.396	90.84
SOE	6073	0.389	0	0.488	0	1
East	6073	0.688	1	0.463	0	1

Note: All continuous variables in the table are indented at 1% and 99%.

4.2 Correlation analysis

As shown in Table 3, there is a significant positive correlation between the two types of green technology innovation, as well as between green technology innovation and corporate ESG.

Table 3. Correlation analysis of total sample data

Variable	$LnGIT_1$	$LnGIT_2$	ESG	Size	Lev	LnTPA	Indep	INST	SOE	East
$LnGIT_1$	1									
$LnGIT_2$	0.682***	1								
	0									
ESG	0.167***	0.132***	1							
	0	0								
Size	0.471***	0.441***	0.202***	1						
	0	0	0							
Lev	0.249***	0.280***	-0.0180	0.565***	1					
	0	0	0.166	0						
LnTPA	0.635***	0.616***	0.171***	0.567***	0.291***	1				
	0	0	0	0	0					
Indep	0.066***	0.050***	0.087***	0.054***	0.00200	0.040***	1			
	0	0.000100	0	0	0.864	0.00190				
INST	0.155***	0.100***	0.112***	0.422***	0.196***	0.217***	-0.030**	1		
	0	0	0	0	0	0	0.0208			
SOE	0.165***	0.083***	0.091***	0.361***	0.294***	0.178***	0.00500	0.408***	1	
	0	0	0	0	0	0	0.692	0		
East	0.039***	0.040***	0.036***	-0.093***	-0.110***	0.040***	0.022*	-0.059***	-0.208***	1
	0.00220	0.00160	0.00460	0	0	0.00200	0.0885	0	0	

Note: *, **, and *** indicate significant at the 10%, 5%, and 1% levels, respectively.

4.3 Baseline regression analysis

In Table 4, this study adopts the progressive regression strategy, as shown in column (1), the regression coefficient of inventive green technology innovation on enterprise ESG performance is 0.633 and passes the 1% significance test; in column (2), the regression coefficient narrows to 0.249, but it still passes the 1% significance test. In columns (3)-(4), the promotion effect is still significant at 1% significance level, which indicates that the more inventive green technology patents, the better the ESG performance of enterprises, and the two present a significant positive relationship, i.e., the core hypothesis of this paper is established. According to the data of substantive green technology innovation in Column (1)-(2), the influence coefficient is reduced to 0.046 after adding control variables, and the promotion effect is no significant. In the two-way fixed effects model of columns (3)-(4), the impact coefficient of substantive green technological innovation is not significant or even negative regardless of adding control variables, which proves that substantive green technological innovation does not

effectively improve the comprehensive score of ESG indicators. The reason may be due to the fact that a utility model patent can only be used to protect products and has a lower level of inventiveness than an invention patent[10].

Table 4. Benchmark regression results

Variable	（1）	(2)	（3）	(4)
	Individual fixation effect	Individual fixation effect	Bidirectional fixed effect	Bidirectional fixed effect
LnGIT1	0.633***	0.249***	0.360***	0.272***
	(9.40)	(3.26)	(4.71)	(3.19)
LnGIT2	0.153**	0.046	-0.038	-0.131
	(2.07)	(0.56)	(-0.50)	(-1.56)
Size		0.909***		1.363***
		(12.34)		(8.44)
Lev		-5.107***		-4.773***
		(-12.50)		(-8.12)
LnTPA		0.114*		-0.042
		(1.80)		(-0.48)
Indep		0.062***		0.049***
		(5.56)		(3.42)
INST		0.004		-0.009*
		(1.33)		(-1.76)
SOE		0.454***		1.147***
		(3.23)		(2.93)
East		0.440***		1.313
		(3.34)		(1.20)
Constant	73.001***	51.782***	74.022***	43.478***
	(851.69)	(34.36)	(482.97)	(12.23)
Observations	6,732	6,073	6,732	6,073
R-squared	0.033	0.081	0.020	0.042
Number of Scode			612	609

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

4.4 Robustness tests

To further ensure the reliability of the study, the results is tested through the following ways: (1) Changing the measure of green technological innovation to the share of green patent applications; (2) Adopting green product innovation as an instrumental variable, and estimating by 2SLS in order to solve the omitted variables; (3) Since 2019 is affected by the New Crown epidemic, this study excludes the sample of 2020 for the test.

The conclusions of the above methods are all consistent with the previous paper, verifying the robustness of the benchmark regression.

4.5 Analysis of impact mechanisms

Analysis of mediating effects.

This paper starts from the perspective of product differentiation (PD) and refers to the recursive equation of Wen Zhonglin[11] to carry out the research. In Table 5, it is found that the regression coefficient of inventive green technological innovation on enterprise ESG through the mediating effect of product differentiation is positive and highly significant, which implies that inventive green technological innovation products have unique value, which can satisfy the green preference of consumers, and help to improve the enterprise's ESG performance.

Table 5. Mediating role of product differentiation

Variable	（1）PD	（2）ESG
LnGTI1	-0.008**	0.272***
	(-2.0726)	(3.19)
PD		0.308***
		(4.3447)
Control variable	YES	YES
industry	YES	YES
Year	YES	YES
Observations	6,234	6,234
R-squared	0.064	0.166

z-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Analysis of moderating effects.

However, is this positive contribution of inventive green technology innovation to ESG performance affected by the different sizes of different firms? In Table 6, LnGTI1 × SCA is 0.380 and passes the 1% significance level, which indicates that the moderator variable of firm size strengthens the relationship between inventive green technological innovations on firms' ESG.

Table 6. Analysis of regulatory effects

Variable	(1)ESG
LnGIT1	-8.472***
	(-8.20)
LnGTI1 ×SCA	0.380***
	(8.51)
Lev	-3.026***
	(-5.51)

Variable	(1)ESG
LnTPA	0.069
	(0.86)
Indep	0.037***
	(2.58)
INST	-0.003
	(-0.54)
SOE	1.138***
	(2.91)
East	1.162
	(1.07)
Constant	72.644***
	(70.46)
Observations	6,073
Number of Scode	609
R-squared	0.042

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

Heterogeneity analysis.

In Table 7, the empirical results show that, compared with the eastern enterprises, the non-eastern enterprises shows a positive impact on their ESG and passes the 1% significant level, which has a greater degree of influence.

Table 7. Heterogeneity analysis regression results

Variable	(1)Full sample	(2)eastern	(3)Non-eastern
LnGIT1	0.228***	0.178*	0.414***
	(2.84)	(1.90)	(2.67)
Size	1.387***	1.450***	1.398***
	(8.73)	(7.65)	(4.65)
Lev	-4.876***	-5.125***	-4.331***
	(-8.52)	(-7.64)	(-3.92)
LnTPA	-0.0926	-0.215**	0.104
	(-1.14)	(-2.12)	(0.75)
Indep	0.0460***	0.0604***	0.0267
	(3.24)	(3.45)	(1.08)
INST	-0.00796	-0.00812	-0.0104
	(-1.53)	(-1.35)	(-1.02)
_cons	44.48***	43.30***	43.67***
	(13.12)	(10.65)	(6.90)
N	6234	4297	1937
R2	0.041	0.041	0.056
adj. R2	-0.066	-0.069	-0.059
F	14.99	10.19	6.372

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

5 Conclusions and insights

5.1 Conclusions of the study

This paper found that when enterprises focus on inventive green technology innovation, it can significantly promote their ESG performance, and product differentiation plays a part of the mediating effect. In further analysis, this paper investigate whether the contribution of green technology innovation to ESG performance varies according to the region of the enterprise.

5.2 Policy implications

Sound external incentive mechanism for green technology innovation.

The government can reduce the R&D costs of enterprises and alleviate the external financing constraints by improving the subsidies and tax incentives for enterprises' green technological innovation.

Improving the internal power mechanism of green technology innovation.

By improving the protection of green technology property, we can help enterprises apply their technological achievements in production practice more efficiently, and continuously promote their R&D investment.

Increase stakeholder interest in ESG evaluation systems.

When measuring the performance of enterprises, senior managers should not only measure their economic performance, but also consider environmental, social and corporate governance, so as to strengthen the attention of all parties to the ESG.

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