Environmental Information Disclosure, Technology Innovation and Enterprise Competitiveness: Empirical Data Based on Heavily Polluting Listed Companies

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Abstract—China's economy is at a stage of high-quality development, and environmental information disclosure is valued by all sectors of society. This paper selects data on heavily polluting listed companies from 2016-2020 as the research sample to study the relationship between environmental information disclosure, technological innovation, and enterprise competitiveness. The results of the study show that environmental information disclosure and technological innovation are conducive to enhancing enterprise competitiveness, but environmental information disclosure weakens the effect of technological innovation in enhancing enterprise competitiveness. Further analysis found that environmental information disclosure has a more significant impact on the relationship between technological innovation and enterprise competitiveness among non-state enterprises and enterprises in the Eastern region. Based on the above, this paper puts forward three suggestions: Heavy polluting enterprises should improve the level of environmental information disclosure and disclose high-quality information; pay attention to R&D investment to enhance technological innovation; and allocate corporate funds reasonably to avoid the investment in environmental information disclosure crowding out the funds needed for R&D and innovation.

Keywords—Environmental information disclosure; technology innovation; Nature of ownership; enterprise competitiveness

1. Introduction

Outline of the 14th Five-Year Plan (2021-2025) for National Economic and Social Development and Vision 2035 of the People's Republic of China (the "14th Five-Year Plan") points out the need to increase the disclosure of environmental protection information and to strengthen the system of corporate responsibility for environmental governance. In September 2020, China announced its intention to achieve the "emission peak" and "carbon neutrality" targets, and in 2022, a number of departments jointly issued the "Implementation Plan for Synergizing the Reduction of Pollution and Carbon Emissions" to further implement the “carbon peaking and carbon neutrality” deployment. The Environmental Protection Law which came into force in 2015, requires key emission enterprises to disclose their pollutant emissions as well as prevention and control. The Measures for the Administration of Legal Disclosure of Enterprise Environmental Information, which came into effect in 2022, regulate the activities of enterprise environmental information disclosure, increase social supervision and require enterprises to prepare reports on time in accordance with the guidelines, and the presentation and data used in

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disclosing information should comply with the standards and requirements of environmental monitoring and statistics. As the country pays more attention to environmental protection, laws and regulations on environmental information disclosure are being improved, so listed enterprises in heavily polluting industries are required to make timely environmental information disclosure.

Innovation is an important factor for enterprises to enhance their competitiveness. The 14th Five-Year Plan states that we should implement the concept of innovation, reinforce the main position of enterprises in innovation, and enhance the innovation capacity of enterprises through tax incentives, upgrading key common technology platforms and improving the financial support system for innovation. Enterprises need to constantly innovate to maintain their competitive advantage, but innovation is a high-risk activity and there is uncertainty that high investment will be rewarded with high returns. The state, investors and other stakeholders are paying increasing attention to corporate environmental information disclosure, which can affect corporate competitiveness, but there is no consensus on whether the impact of environmental information disclosure on corporate competitiveness is positive. Researching the relationship between environmental information disclosure and corporate competitiveness and improving the quality of corporate environmental information disclosure are conducive to the allocation of resources by enterprises and the enhancement of social welfare of the country. In addition, the fulfilment of the social responsibility of corporate environmental information disclosure will take up some of the resources of enterprises and crowd out the resources needed for innovation input, and whether environmental information disclosure can influence corporate competitiveness by affecting technological innovation needs to be further explored. Based on this, this paper examines the relationship between environmental information disclosure, technological innovation and enterprise competitiveness, and further investigates the differences in the moderating effect of environmental information disclosure on the relationship between technological innovation and enterprise competitiveness among enterprises with different property rights and in different regions.

2. Literature Review and Hypothesis Formulation

2.1 Impact of Environmental Information Disclosure on Enterprise Competitiveness

There is no consensus among scholars as to whether environmental information disclosure enhances corporate competitiveness. Some scholars believe that there is no relationship between the two. Jiang Linfeng (2010) [1] found that stakeholders' demand for environmental information disclosure is not strong, environmental awareness is not sufficient to affect corporate share prices, and there is no relationship between environmental information disclosure and corporate competitiveness. Some scholars argue that environmental information disclosure can have a negative effect on corporate competitiveness. Ren Li and Hong Zhe (2017) [2] explored the impact on corporate value with both soft and hard environmental information disclosure and found that environmental information disclosure has a negative expected cash flow effect that weakens corporate competitiveness. Shen Jianfei and Li Jingjie (2022) [3] argue that environmental information disclosure increases corporate costs and expenditures, reduces operating profit and lowers corporate value. Other scholars believe that environmental information disclosure will enhance corporate competitiveness. Environmental information disclosure can

reduce information asymmetry between companies and relevant stakeholders, increase investors' understanding of companies, and change investors' perceptions that companies do not disclose environmental information due to poor environmental governance, and environmental information disclosure can have a positive impact on corporate performance. China's requirements for environmental information disclosure are becoming increasingly stringent, and the environmental performance of heavily polluting enterprises has a significant impact on their own survival and development. Wu Hongjun et al. (2017)[4] argue that environmental information disclosure can demonstrate strong environmental management capabilities and environmental performance to investors, mitigate the risks faced by investors, and thus attract investment to enhance corporate value. Iatridis (2013)[5] finds that environmental information disclosure affects investors' perceptions and reduces the difficulties of firms in accessing capital market. Zhao Dandan (2021)[6] finds that environmental information disclosure can also signal to outsiders that a company's environmental performance is good, eliminating the concerns of external capital investors and reducing external financing constraints. When the benefits from environmental information disclosure are higher than the costs, it is conducive to improving firm competitiveness. This paper proposes hypothesis 1. Hypothesis H1: Environmental information disclosure is positively related to corporate competitiveness.

2.2 The Impact of Technological Innovation on The Competi-tiveness of Enterprises

R&D investment is an important indicator for evaluating technological innovation capability, and technological innovation plays an important role in enhancing the competitiveness of enterprises. chan et al. (2001)[7] argue that R&D intensity is positively correlated with return volatility, and the higher the R&D intensity of enterprises, leading to higher excess returns. Li Wenqian and Liu, Yi (2017) [8]argue that innovative R&D results obtained by firms investing large amounts of R&D funds contribute to a competitive advantage in the industry. Firms with more innovative R&D results are more likely to promote them in the market and gain consumer recognition, and are better able to attract customers to gain a stronger competitive edge. Zou Ying and Xie Heng (2020)[9] argue that efficient technological innovation activities of enterprises can continuously increase their new knowledge and capabilities, clarify their advantages, gain a head start in the competition, and enable them to achieve significant growth in profits. Wu lichao et al. (2021)[10] argue that the R&D results obtained after R&D investment will reduce unnecessary wastage, improve the efficiency of the enterprise's resource use, reduce the cost of products to enhance the unit production value, accelerate the rate of capital accumulation of the enterprise, grow business performance and thus improve market position. Based on this, the second research hypothesis is as follows. Hypothesis H2: Technological innovation has an enhancing effect on the competitiveness of enterprises.

2.3 The impact of environmental information disclosure on the relationship between technological innovation and enterprise competitiveness

Environmental information disclosure can increase costs and expenses for companies and have a crowding-out effect on innovation output. On the one hand, in order to meet the standard requirements set by government departments and to satisfy the information needs of stakeholders, companies must regularly and compliantly disclose information on environmental liabilities, environmental performance and governance, which can increase disclosure expenses. On the other hand, companies undertaking environmental information disclosure assume social responsibility and help to build a good reputation and a positive image. The public's perception of a

company's brand image does not change easily. Establishing the public perception of an environmentally friendly company through environmental information disclosure deepens the public's perception of the legitimacy of the company's actions and helps to improve its performance. For this purpose, some companies with poor environmental performance even increase their exposure costs and whitewash their environmental behavior through false publicity (Zhang Kechin and Pan An'e, 2018)[11]. With limited funds held by the company, these inputs can crowd out the R&D and innovation expenditure, thus discouraging corporate innovation. In addition, China's environmental information disclosure system is not perfect, and the content and form of information disclosure do not ensure comparability (Cui Xiumei et al., 2021)[12]. Some enterprises make selective disclosures and do not provide detailed disclosures of important information such as pollutant emissions and governance, so that users of the report cannot obtain valuable information through the environmental information disclosure report and are unable to know the environmental value brought about by the enterprise's "green innovation", making environmental information disclosure unable to have a positive impact on innovative R&D results. This prevents environmental information disclosure from having a positive impact on innovative R&D results. Based on this, the third hypothesis of this paper is proposed. Hypothesis H3: Environmental information disclosure can weaken the effect of technological innovation on corporate competitiveness.

3. research design

3.1 Sample selection and data sources

The data of listed companies in the heavy pollution industry for 2016-2020 were studied, excluding *ST and ST, companies listed after 2016, companies with outliers and incomplete key data, and a total of 261 observations of listed companies were obtained. The data is sourced from the CSMAR database.

3.2 Definition of variables

3.2.1 Explained variables

Enterprise competitiveness (COMP). The competitiveness of an enterprise can reflect its development status and financial management status. With reference to the existing evaluation bases of enterprise competitiveness, this paper chooses to build an enterprise competitiveness evaluation system based on the competitive results and using financial indicators. The financial indicators calculated based on the financial data from the annual reports of enterprises are reliable, and the external public reports of enterprises have been audited by accounting firms to meet the requirements of accounting information, with high quality and credible data. This paper builds up the enterprise competitiveness evaluation system as shown in Table 1, and obtains the comprehensive score of enterprise competitiveness through factor analysis.

Table 1 Enterprise competitiveness evaluation system

Tier 1 indicators	Tier 2 Indicators	Tier 3 Indicators
Corporate Competitiveness	Profitability Indicators	Rate of return on total assets(X1), Return on equity(X2), Net operating margin(X3)
	Development capacity indicators	Total assets growth rate(X4), Operating income growth rate(X5), Operating profit growth rate(X6)
	Operating Capacity Indicators	Inventory turnover rate(X7), Current asset turnover ratio(X8)
	Solvency indicators	Net cash flow/current liabilities (X9), Gearing ratio (X10), Current ratio(X11)

3.2.2 Explanatory variables

Environmental information disclosure (EDI). Scholars mainly adopt the content analysis method to evaluate the level of environmental information disclosure, selecting indicators related to environmental information disclosure to establish an evaluation system, and then finding public reports of enterprises, scoring the indicators according to the criteria, with the high or low score represents the level of environmental information disclosure of enterprises. This paper refers to the "Evaluation Report on Disclosure of Environmental Responsibility Information of Chinese Listed Companies Environmental Responsibility Information Disclosure Evaluation Report of Chinese Listed Companies" to construct the evaluation index system as shown in Table 2, and score the indicators according to descriptive information and numerical information respectively to obtain the score of a single sample (EDIS) and the maximum score of 34, and the Environmental Disclosure Index (EDI) can be obtained by comparing the two values with the formula EDI = EDIS/34.

Technological innovation (RD). Referring to the research of Wang Yuze et al. (2019)[13], Ln(R&D input +1) is chosen to measure enterprise technological innovation (RD).

Table 2 Environmental Information Disclosure Indicator System

Categories	Item Name	Scoring Criteria
Disclosure vehicles	Annual Reports of Listed Companies	0 points for failure to disclose relevant information 1 point for disclosure of relevant information
	Social Responsibility Report	
	Environmental Reports	
Environmental Management	Environmental philosophy	
	Environmental objectives	
	Environmental Education and Training	
	Environmental honours or awards	
	The "three simultaneous" system	
Environmental regulation and certification	Pollutant discharge compliance	
	Environmental violations	
	ISO14001 certified or not	
	ISO9001 certified or not	
Environmental liabilities	Wastewater discharge	0 marks for non-disclosure of relevant information 1 mark for qualitative
	SO2emissions	
	CO2emissions	
	Soot and dust emissions	
	Industrial solid waste generation	

Environmental performance and governance	Cleaner Production Implementation	disclosure of relevant information 2 marks for quantitative disclosure of relevant information
	Wastewater abatement treatment	
	Waste gas abatement treatment	
	Fume and dust control	
	Treatment of noise, light pollution, radiation, etc.	
	Solid waste utilization and disposal	

3.2.3 Control variables

Table 3 Variable definitions

Nature of variables	Variable name	Variable symbols	Variable Description
Explained variables	Corporate Competitiveness	COMP	Factor analysis to calculate score
Explanatory variables	Environmental Information Disclosure	EDI	Constructing a system of indicators and assigning values
	Technological innovation	RD	Ln(R&D investment+1)
Control variables	Asset structure	LEV	Gearing ratio
	Concentration of shareholding	SC	Total number of shares held by the top ten shareholders
	Growth capacity	GROW	Operating income growth rate

To better investigate the relationship between environ-mental information disclosure, technological innovation and enterprise competitiveness, asset structure (LEV), Concen-tration of shareholding (SC) and growth capacity (GROW) were selected as control variables.

3.3 Model construction

This paper constructs the following three empirical models to empirically test and analyze the impact of environmental information disclosure on corporate competitiveness of heavily polluting listed companies, the impact of technological innovation on corporate competitiveness and the moderating effect of environmental information disclosure on the relationship between technological innovation and enterprise competitiveness.

$$COMP=\alpha_0+\alpha_1 EDI+\alpha_2 \sum Control+\varepsilon \quad (1)$$

$$COMP=\alpha_0+\alpha_1 RD+\alpha_2 \sum Control+\varepsilon \quad (2)$$

$$COMP=\alpha_0+\alpha_1 EDI+\alpha_2 RD+\alpha_3 EDI\times RD+\alpha_4 \sum Control+\varepsilon \quad (3)$$

Control represents the control variable.

4. Empirical Analysis

4.1 Overall corporate competitiveness score

Table 4 Explanation of total variance

Ingredients	Initial Eigenvalue		
	Total	**Variance%**	**Cumulative%**
1	2.834	25.766	25.766
2	2.070	18.817	44.582
3	1.532	13.928	58.510
4	1.211	11.007	69.517
Ingredients	**Extraction Sums of Squared Loadings**		
	Total	**Variance%**	**Cumulative%**
1	2.834	25.766	25.766
2	2.070	18.817	44.582
3	1.532	13.928	58.510
4	1.211	11.007	69.517
Ingredients	**Rotation Sums of Squared Loadings**		
	Total	**Variance%**	**Cumulative%**
1	2.148	19.528	19.528
2	2.110	19.179	38.707
3	1.724	15.677	54.385
4	1.665	15.132	69.517

This paper constructs an enterprise competitiveness evaluation system as shown in Table 1, and conducts factor analysis on the indicators concerning enterprise competitiveness scores. Table 4 shows that the initial eigenvalues of the four principal components are 2.834, 2.070, 1.532 and 1.211 are all greater than 1, indicating that they have sufficient influence, all of them are extracted as public factors, and their cumulative contribution rate of variance reaches 69.517%, which is a strong proxy for enterprise competitive-ness. As can be seen from Table 5, the public factor F1 has higher weights in X9, X10 and X11, naming it as a solvency indicator, which has the greatest influence on the competitiveness of enterprises. Public factor F2 has a higher weight in X1, X2 and X3, and the indicator reflects the earnings of the enterprise, so it is named as profitability indicator. Public factor F3 has a higher weight in X4, X5 and X6, and the indicator reflects the development of the enterprise, so it is named development capability indicator. Public factor F4 has a higher weighting in X7 and X8, and the indicator reflects the operating conditions of the enterprise, so it is named the operating capacity indicator. The SPSS software was used to calculate the individual factor scores and the composite score of corporate competitiveness with the formula (0.19528F1+0.19179F2+0.15677F3+0.15132F4)/0.69517. The indicators related to corporate competitiveness of listed companies in the heavy pollution industry for 2016-2020 were substituted into the formula to obtain the composite score of corporate competitiveness of each company.

Table 5 Rotated component matrix

Indicators	1	2	3	4
Rate of return on total assets(X1)	0.289	0.866	0.149	0.068
Return on equity(X2)	0.060	0.834	0.121	0.076
Net operating margin(X3)	0.027	0.729	-0.015	-0.137
Total assets growth rate(X4)	-0.043	0.014	0.879	-0.085
Operating income growth rate(X5)	-0.047	0.080	0.905	0.029
Operating profit growth(X6)	0.093	0.193	0.308	0.211
Inventory turnover rate(X7)	-0.079	-0.033	0.009	0.863
Current asset turnover ratio(X8)	-0.154	-0.003	0.016	0.862
Net cash flow from operating activities/current liabilities(X9)	0.769	0.228	0.003	0.123
Gearing ratio(X10)	-0.809	-0.178	0.033	0.209
Current ratio(X11)	0.879	-0.059	0.002	-0.191

4.2 Descriptive statistics

Table 6 Descriptive statistics

Variables	Sample size	Average value	Standard deviation	Minimum value	Median	Maximum value
COM-P	1305	0.0000	0.5033	-3.1900	-0.0291	4.8356
EDI	1305	0.3541	0.1976	0.0294	0.3529	0.9118
RD	1305	18.3294	1.8166	0.0000	18.4243	22.1912
LEV	1305	0.3972	0.1865	0.0143	0.3809	0.9732
SC	1305	0.5731	0.1460	0.1462	0.5581	0.9507
GRO-W	1305	0.1560	0.4752	-0.5968	0.0957	11.8426

As can be seen from Table 6: (1) COMP reflects the relative strength of the competitiveness of listed enterprises in the heavy pollution industry, with higher scores indicating stronger competitiveness. From the sample data, it can be seen that there is a large difference in competitiveness between enterprises. (2) The large difference between EDI values indicates that there is a large difference in the level of environmental information disclosure among enterprises. (3) There is also a large difference between the RD values, indicating that although they belong to the same heavily polluting industry there is a large difference in the degree of attention paid to technological innovation by different companies.

4.3 Correlation analysis

As can be seen from Table 7, environmental information disclosure, technological innovation and the control variables of growth capacity, concentration of shareholding are all significantly positive at the 1% level and asset structure is negative at the 1% level of significance.

Table 7 Descriptive statistics

Variables	COMP	EDI	RD	Lev	SC	xxsr
COMP	1					
EDI	0.075***	1				
RD	0.087***	0.178***	1			
LEV	-0.444***	0.186***	0.160***	1		
SC	0.164***	0.160***	0.177***	0.092***	1	
GROW	0.436***	-0.009	0.064**	0.052	0.120***	1

Note: ***, ** and * represent significant at the 1%, 5% and 10% levels respectively, same below.

4.4 Regression analysis

Table 8 Regression results

Variables	Model 1	Model 2	Model 3
EDI	0.386*** (7.180)		1.676*** (3.104)
RD		0.032*** (5.398)	0.058*** (4.146)
LEV	-1.369*** (-24.235)	-1.342*** (-23.682)	-1.401*** (-24.859)
SC	0.458*** (6.333)	0.472*** (6.468)	0.411*** (5.684)
GROW	0.474*** (21.628)	0.464*** (20.984)	0.468*** (21.526)
EDI×RD			-0.072*** (-2.462)
Constant	0.071 (1.521)	-0.392*** (-3.628)	-0.932** (-3.682)
N	1305	1305	1305
R^2	0.453	0.444	0.464
Adj.R^2	0.452	0.442	0.462

From Table 8: In model 1, the EDI coefficient is significantly positive at 0.386, indicating that the higher the level of environmental information disclosure, the stronger the level of competitiveness of the company, consistent with the hypothesis that environmental information disclosure is positively related to corporate competitiveness. In model 2, the RD coefficient is 0.032, which is positive at 1% significance level, indicating that when the level of technological innovation of a company is higher, its competitiveness is also stronger, which is consistent with the hypothesis that technological innovation has an enhancing effect on the competitiveness of a company. In Model 3, the coefficients of EDI and RD are significantly positive, but the coefficient on the cross product of the two is significantly negative at -1.401, indicating that environmental information disclosure plays a negative moderating role in the impact of technological innovation on enterprise competitiveness, consistent with the hypothesis that environmental information disclosure weakens the effect of technological innovation on enterprise competitiveness.

4.5 Robustness tests

In order to improve the robustness of the research results and to avoid the impact of different competitiveness scoring indicators chosen to have an unrobust effect on the empirical results, this paper chose to use a replacement explanatory variable for the test, and to use the indicator of total net asset margin as a proxy for corporate competitiveness. As can be seen from the results of the robustness analysis in Table 9, the main variables as well as the model are significantly correlated and the findings are consistent with those above, indicating that the analysis is reliable.

Table 9 Robustness analysis

Variables	Model 1	Model 2	Model 3
EDI	0.041*** (4.570)		0.411*** (4.673)
RD		0.007*** (7.480)	0.016*** (6.858)
LEV	-0.149*** (-15.893)	-0.151*** (-16.452)	-0.157*** (-17.055)
SC	0.082*** (6.815)	0.076*** (6.387)	0.070*** (5.924)
GROW	0.028*** (7.789)	0.027*** (7.440)	0.027*** (7.528)
EDI×RD			-0.021*** (-4.326)
Constant	0.047*** (6.079)	-0.065*** (-3.702)	-0.225*** (-5.440)
N	1305	1305	1305
R2	0.215	0.235	0.254
Adj.R2	0.213	0.233	0.251

5. Further analysis

5.1 Consideration of the nature of ownership

Taking into account the influence of the form of ownership, this paper divides the sample enterprises into two sub-samples of state-owned and non-state-owned enterprises for further analysis, and the regression results are shown in Table 10.

As can be seen from Table 10, the coefficients of EDI in Model 1 for the two samples of state-owned enterprises and non-state enterprises are 0.363 and 0.415 respectively, both of which are positive at the 1% level of significance, indicating a positive effect of environmental information disclosure on enterprise competitiveness. The results of model 2 show that the coefficients between technological innovation and enterprise competitiveness for state-owned and non-state enterprises are 0.038 and 0.024 respectively, which are significantly positive at the 1% level of significance, indicating that technological innovation is conducive to enhancing enterprise competitiveness. The results of model 3 for state-owned enterprises show that the coefficient of the interaction term between environmental information disclosure and technological innovation is 0.008 but the results are not significant. The results of model 3 for non-state enterprises show that the coefficient of the interaction term between environmental information disclosure and

technological innovation is negative -0.143, which is significant at the 1% level, indicating that environmental information disclosure in non-state enterprises is not conducive to technological innovation in enhancing the competitiveness of enterprises. Therefore, the above analysis suggests that environmental information disclosure has a more significant impact on the relationship between technological innovation and corporate competitiveness in non-state enterprises. Possible reasons for this are that compared to state-owned enterprises, non-state enterprises receive less policy support and subsidies, face more financing constraints and have less stable sources of funding. The excessive financial resources taken up by the environmental disclosure work of non-state enterprises can lead to a reduction in investment in R&D and innovation, which in turn weakens their competitiveness.

Table 10 Robustness analysis

Variables	**State-owned enterprises**		
	Model 1	**2Model 2**	**Model 3**
EDI	0.363*** (4.435)		0.172 (0.193)
RD		0.038*** (4.124)	0.030 (1.501)
LEV	-1.213*** (-14.482)	-1.236*** (-14.576)	-1.261*** (-14.972)
SC	0.331*** (3.021)	0.345*** (3.147)	0.277** (2.524)
GROW	0.468*** (17.363)	0.457*** (16.901)	0.460*** (17.185)
EDI×RD			0.008 (0.165)
Constant	0.100 (1.379)	-0.467*** (-2.742)	-0.382 (-1.043)
N	634	634	634
R2	0.447	0.444	0.457
Adj.R2	0.443	0.441	0.452
Variables	**Non-state enterprises**		
	Model 1	**Model 2**	**Model 3**
EDI	0.415*** (5.847)		2.958*** (4.135)
RD		0.024*** (3.275)	0.089*** (4.350)
LEV	-1.601*** (-19.314)	-1.541*** (-18.484)	-1.613*** (-19.709)
SC	0.483*** (4.806)	0.487*** (4.748)	0.455*** (4.560)
GROW	0.496*** (11.994)	0.483*** (11.488)	0.486*** (11.870)
EDI×RD			-0.143*** (-3.601)
Constant	0.112 (1.672)	-0.217 (-1.521)	-1.453*** (-3.946)
N	671	671	671
R2	0.470	0.452	0.486
Adj.R2	0.647	0.449	0.482

5.2 Consideration of regional differences

To further investigate the relationship between EDI, RD and COMP, this paper divides the study sample into two sub-samples, Eastern region and Central, Western and North-eastern regions, based on the regional distribution of enterprises. The results of the analysis are shown in Table 11.

From Model 1 in Table 11, it can be seen that there is a significant positive correlation between environmental information disclosure and enterprise competitiveness in the Eastern region and Central, Western and North-eastern regions, with coefficients of 0.444 and 0.335 respectively, from Model 2, it can be seen that the coefficients of technological innovation in the two samples are 0.031 and 0.037 respectively, both of which are significant at the 1% level, indicating that both environmental information disclosure and technological innovation are conducive to enhancing enterprise competitiveness . From model 3, the coefficient of EDI×RD in the eastern region is -0.139 and the result is significant, while the coefficient of EDI×RD in the Eastern region and Central, Western and North-eastern regions is 0.052 but the result is not significant, indicating that the moderating role of environ-mental information disclosure in the relationship between technological innovation and enterprise competitiveness differs between the eastern region and the Central and west and Northeast regions. The effect of environmental information disclosure is more significant in the eastern region. This may be due to the higher level of economic development and better financial regulatory system in the Eastern region, which means that companies are subject to more stringent regulations and must make more compliant environmental disclosures. In order to meet the standards set by the government, companies will spend more on environmental disclosure, which will crowd out the resources needed for innovation and thus negatively affect their competitiveness.

Table 11 Regression results for regional groupings

Variables	**Eastern region**		
	Model 1	**Model 2**	**Model 3**
EDI	0.444*** (6.867)		2.947*** (4.687)
RD		0.031*** (4.446)	0.090*** (5.195)
LEV	-1.319*** (-18.869)	-1.286*** (-18.175)	-1.346*** (-19.496)
SC	0.387*** (4.636)	0.427*** (5.054)	0.325*** (3.916)
GROW	0.656*** (17.224)	0.638*** (16.513)	0.651*** (17.364)
EDI×RD			-0.139*** (-4.049)
Constant	0.048 (0.906)	-0.395*** (-3.088)	-1.528*** (-4.914)
N	825	825	825
R2	0.437	0.419	0.458
Adj.R2	0.435	0.416	0.454
Variables	**Central, Western and North-eastern regions**		
	Model 1	**Model 2**	**Model 3**
EDI	0.335*** (3.624)		-0.664 (-0.640)

RD		0.037*** (3.498)	0.013 (0.545)
LEV	-1.462*** (-15.405)	-1.462*** (-15.364)	-1.519*** (-15.838)
SC	0.566*** (4.224)	0.543*** (4.018)	0.494*** (3.655)
GROW	0.397*** (14.079)	0.388*** (13.708)	0.391*** (13.933)
EDI×RD			0.052 (0.927)
Constant	0.079 (0.904)	-0.467** (-2.417)	-0.074 (-0.170)
N	480	480	480
R2	0.499	0.498	0.509
Adj.R2	0.495	0.494	0.503

Note: Grouping is based on the division of economic zones published by the National Statistics Office.

6. Conclusions and Recommendations

6.1 Conclusion

This paper analyzes the relationship between environmental information disclosure, technological innovation and enterprise competitiveness by constructing a multiple regression model with heavily polluting listed companies from 2016-2020, and obtains the following research conclusions: Firstly, environmental information disclosure is significantly and positively related to enterprise competitiveness. It indicates that listed companies in the heavy pollution industry should improve their environmental information disclosure to provide more valuable information to stakeholders in order to promote the competitiveness of enterprises. Secondly, technological innovation has a significant positive impact on enterprise competitiveness. Technological innovation enables enterprises to gain cost advantages, and enterprises should pay attention to innovation and R&D investment to continuously enhance their core competitiveness. Thirdly, environmental information disclosure can weaken the effect of technological innovation in enhancing enterprise competitiveness. This suggests that heavily polluting enterprises, especially those in the Eastern region and non-state enterprises, should improve the efficiency of environmental information disclosure, so as not to take up too many resources to ensure that enterprises can better carry out technological innovation, so that they can both assume social responsibility and achieve economic benefits.

6.2 Recommendations

At the level of government departments, the public understands the environmental protection status of enterprises through their environmental information disclosure, and government departments should strengthen guidance and supervision on the content and manner of environmental information disclosure, so that enterprises can disclose more standardized and high-quality environmental information and the public can better monitor the environmental protection work of enterprises; The penalties imposed on enterprises for violating the regulations are relatively light, and the benefits gained by some enterprises through violating the environmental information disclosure guidelines are far greater than the amount of fines. The excessively low

cost of violating the law and the high revenue cannot serve as a warning to enterprises. The government departments should increase penalties and raise the cost of violations to reduce the possibility of false disclosure of environmental information by enterprises; The government should reward enterprises that actively disclose information and have good environmental benefits, so as to realize the exemplary role of high-quality enterprises. Government departments should develop selection criteria by industry and select enterprises with excellent environmental information disclosure quality for relevant coverage in the mainstream media to enhance their brand awareness and set an example for other enterprises.

At the enterprise level, enterprises should actively disclose environmental information to show the public that they are actively working on environmental protection. Enterprises should establish a good corporate image with a sense of social responsibility, so that investors will recognize the development concept of enterprises to invest in them, so as to obtain more development funds. The company should establish a professional environmental protection department, which can provide targeted advice on environmental protection for each production step to improve the company's environmental management and environmental performance; Companies need to improve their environmental information disclosure workflow, allocate resources rationally, reduce the loss of human and material resources, and reduce the crowding out of resources for innovative R&D by environmental disclosure efforts, so that companies can better innovate and develop products with both high economic and environmental benefits.

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