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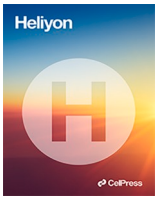

Research article

Environmental information disclosure and green transformation: Evidence from Chinese manufacturing enterprises

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ABSTRACT

Green transformation (GT) is pivotal for global sustainability, with environmental information disclosure (EDI) playing a significant role, especially in the Chinese corporate landscape. This study, spanning 2009 to 2020 and leveraging a comprehensive dataset of listed companies, explores the intricate relationship between EDI and GT in Chinese manufacturing enterprises by constructing a fixed-effect model. Motivated by the imperative to address crucial issues in GT in China, this research utilizes empirical data to uncover the mechanisms through which EDI fosters GT. The study reveals how EDI reinforces environmental consciousness within manufacturing firms. Findings underscore the crucial role of EDI in enhancing GT in manufacturing enterprises, operating through two primary mechanisms. Firstly, EDI alleviates financing constraints towards GT within these firms. Secondly, it facilitates the adoption of enhanced internal governance practices, catalyzing the development of high-quality capital renewal projects. A battery of mechanism tests provides robust evidence that EDI enhances environmental awareness, mitigates financing constraints, and amplifies the motivation and capability of manufacturing enterprises for GT. This multifaceted approach ultimately fosters high-quality GT within companies. Further research reveals that the incentive effect of EDI on GT is more significant among private enterprises and heavily polluting industries. The study reveals the subtle interplay between EDI and GT, highlighting its relevance to policymaking and practical considerations. It provides valuable insights into the ongoing pursuit of sustainability and the integration of green practices into the corporate world.

1. Introduction

The 20th National Congress of the Party emphasized that "promoting green and low-carbon economic and social development is a crucial factor in achieving high-quality development." In recent years, the Chinese government has consistently strengthened environmental protection, consolidated the responsibilities of local governments, and implemented a series of environmental regulatory policies. Traditional environmental regulation consists of two types: command-control environmental regulation and market-incentive environmental regulation. However, empirical evidence demonstrates that traditional environmental regulation incurs significant regulatory costs, while the lack of alignment between the central government and local governments results in a notable decline in the

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efficiency of traditional environmental regulation [1,2].

Environmental information disclosure (EDI) is a crucial communication channel for enterprises to gain recognition from the government and the public, as well as to convey their environmental management and operational status. It represents a new wave of environmental management beyond traditional regulation. EDI refers to the pressure exerted on polluting enterprises to reduce pollution and improve environmental quality by enhancing access to environmental information for the public [3,4]. Although China's adoption of this practice started later than that of developed Western countries, it has gained increasing attention as an important supplementary measure for pollution prevention and control, becoming a hot topic in academic research.

The early literature primarily focused on examining the current state of EDI and its driving factors, predominantly employing qualitative analysis. Recent studies, drawing upon signal display theory and organizational legitimacy theory, have identified regulatory motives, moral motives, and profit motives as the main drivers for EDI [5,6]. Building upon this foundation, several studies have explored the economic implications of EDI from the perspectives of capital cost, corporate risk, and business performance [7–10]. Concurrently, existing research shows that the manufacturing enterprises GT, as a major source of pollution emissions, is the key to promoting the formation of green and low-carbon production and lifestyle [11]. Upon reviewing the aforementioned literature, it becomes apparent that despite being an important tool for environmental regulation through information dissemination, there is a lack of understanding regarding how EDI impacts the manufacturing enterprises GT.

Relevant studies on GT primarily focus on macro policies and the social level, emphasizing traditional environmental regulations, green total factor productivity, green economic growth, and other aspects. These studies argue that achieving GT requires a redesign of production processes, upgrading environmental protection technologies, and adjusting business models [12,13]. However, these transformations often necessitate significant investments in sustainability. Unfortunately, the value generated by such transformations is challenging to demonstrate in the short term. As a result, enterprises tend to passively participate in GT initiatives. Numerous literature studies have indicated that the capital market can provide substantial financial support for enterprises actively disclosing environmental information. In other words, disclosing environmental information enables companies to attract high-quality capital inflows for their GT efforts while creating a stable external financing environment. Consequently, this weakens the constraints imposed by financing limitations on manufacturing enterprises' pursuit of sustainable practices [14,15].

Based on the aforementioned analysis and discussion, this article will focus on the following inquiries: how does EDI impact the manufacturing enterprises' GT? What is the underlying transmission mechanism? In order to address these issues, firstly, by utilizing micro-data from A-share manufacturing listed companies spanning from 2009 to 2020, empirical testing reveals that EDI facilitates the drive towards GT. Subsequently, through a mechanism inspection, it is discovered that alleviating financing constraints and promoting capital renewal serve as transmission mechanisms for EDI to stimulate GT. Lastly, extended analysis results demonstrate that the incentivizing effect of EDI on GT is more pronounced among private enterprises and heavily polluting industries.

The linear research method was adopted, the bidirectional fixed effect model was used for large sample estimation analysis, and the results were verified by the two-stage least squares (2SLS) method. The key contributions of this study are as follows. Firstly, it enriches the existing research on the economic outcome of EDI. The current literature predominantly examines the economic consequences of EDI from the perspectives of capital costs, enterprise risks, and business performance [6,16,17]. This article extends the research scope to encompass GT, which holds significant practical significance. It confirms that environmental information's green transformation possesses a substantial incentive effect and represents a valuable extension to understanding the economic implications of EDI. Secondly, it unveils the mechanism through which environmental information influences manufacturing enterprises' GT. Considering EDI as an informational regulatory policy [18], this article employs signal display theory and resource dependence theory to reveal how environmental information impacts production and operation aspects such as financing constraints and capital renewal. This provides favorable empirical evidence for fully implementing mandatory policies regarding EDI. Thirdly, the index system of EDI is constructed based on the three dimensions of significance, comparability and reliability, which provides empirical data for empirical analysis of green governance effect and deepens the theoretical cognition of EDI policies' operational effect.

2. Hypothesis

China is currently experiencing a significant period of strategic potential for industrial transformation and upgrading. Relying on green transformation, it is likely for manufacturing enterprises to generate significant value and achieve leapfrog development. Environmental information disclosure policy, as an essential disclosure-based environmental regulatory tool, is a crucial information channel for manufacturing enterprises to win the recognition of stakeholders and convey their environmental management and operation status, which has a significant impact on the green transition [19,20].

EDI is favorable for reducing information asymmetry, increasing the cost of environmental violations, and weakening the constraints of financing constraints on firms' GT. The high risk, high investment and long cycle characteristics of GT activities have enhanced the sensitivity of stakeholders to information asymmetry, leading to increased external financing pressure [21,22]. On the contrary, EDI is an important information channel for enterprises to win the recognition of the government and the public, and to pass on the environmental management and operation status, which is conducive to reducing the information disadvantage and expected risk of stakeholders. Besides, it also enhances the willingness of stakeholders to provide funds to enterprises and reduces the cost of capital, thereby improving the external financing environment as well as the efficiency of capital flow and mitigating financing constraints [23,24].

Limited by detailed environmental disclosure regulation, manufacturing businesses have incentives to realize GT through capital renewal. On the one hand, such regulation, as a formal system of environmental supervision, clarifies the specific content and quality of EDI and also stipulates the quantification and comparability of information, which to some extent increases the cost of

environmental violations and inhibits the opportunistic behavior to hide pollution information and avoid environmental inspections [25,26]. It can be seen that manufacturing enterprises, as the "main force" of environmental pollution and energy consumption, bear enormous social pressure and legal threat. On the other hand, the institutional theory holds that environmental information, subject to the dual supervision of law enforcement departments and the capital market, can not only help to internalize environmental externalities, but can also incentivize manufacturing enterprises to invest in capital renewal by introducing more advanced environmentally friendly equipment and creating green processes, so as to drive manufacturing enterprises to change their green transformation from passive governance to active prevention and control [23,24].

To sum up, as non-financial information, environmental information is conducive to the realization of green development, which is specifically attributed to the following advantages: Alleviating the problem of information asymmetry, reducing the expected risk and cost of capital, alleviating the financial constraints in the process of GT, and accelerating the renewal of capital. On the basis of the theoretical analysis presented above, we formulate the following hypothesis.

Hypothesis H1. EDI is beneficial to GT in manufacturing enterprises.

3. Methodology

3.1. Sample selection and data sources

Considering that the manufacturing enterprises are a major source of pollutants, this study focuses on A-share manufacturing listed companies exchanges from 2009 to 2020. The selected sample interval spans from 2009 to 2020 for two reasons: Firstly, China implemented new accounting standards in 2007 and issued a Notice on Strengthening the Social Responsibility of Listed Companies in 2009, which strongly advocated for the disclosure of social responsibility reports by listed companies. This provided an opportunity to obtain environmental responsibility information from these companies, hence why 2009 was chosen as the starting year. Secondly, in 2020, China committed to achieving its "dual carbon" goal, imposing new requirements on corporate environmental information disclosure and green transformation. Therefore, in order to eliminate any interference caused by this significant national strategy, we have taken 2020 as the end year. Regarding the current body of knowledge, the data underwent the following processing steps to ensure quality. Initially, the data pertaining to companies operating in the financial industry were eliminated. This was due to the adoption of distinct accounting standards in China's financial and non-financial sectors, and the inclusion of the financial industry in the statistical sample would increase the data error. Further, data from organizations exhibiting aberrant observations were deleted to prevent any potential interference caused by data errors. Next, the data on ST and ST*companies were excluded. ST category firms represent the existence of two consecutive fiscal years with net profits in the red, ST*category firms represent the existence of three consecutive fiscal years with net profits in the red. All three types of companies would affect the quality of the sample data. Finally, all continuous variables were applied to a 1 % shrinkage, and the final sample contained 17,826 observations. Among them, EDI data is manually collected and processed from social responsibility reports, sustainable development reports, environmental reports, corporate annual reports, listed company systems, other major issues and the website of the Environmental Protection Bureau. GT data is calculated based on the green transformation indicators disclosed in manufacturing enterprises' annual reports, corporate social responsibility reports and official websites. Green patent data is obtained by matching patent numbers from the website of the State Intellectual Property Office and the World Intellectual Property Organization (WIPO). Other data mainly comes from China Stock Market & Accounting Research Database (CSMAR) and Wind databases. Additionally, Stata 17.0 was used to process and analyze the data.

3.2. Conception and quantification of variables

(1) Green transformation (GT): GT refers to intensive use of energy and resources, reduction of pollutant emissions, reduction of environmental impact, improvement of labor productivity, and enhancement of sustainable development capability. Some scholars have used corporate financial indicators to measure GT, whereas others have used questionnaires. Recent research employs textual analysis to measure GT more comprehensively. As corporate social responsibility reports provide details on organizations' environmental governance policies, including their green initiatives, readability, and ton, this method is considered appropriate for this study. Drawing on existing literature [27], this study constructs a green transformation evaluation system by using textual analysis method from seven dimensions of green culture transformation, green strategy transformation, green innovation transformation, green input transformation, green production transformation and green emission transformation, so as to measure the manufacturing enterprise's GT.

(2) Environmental information disclosure (EDI): Text analytics and content analysis method have revealed new paths for the measurement of EDI [28,29]. EDI was measured according to the following steps: First, the quantitative classification of EDI involves two kinds of mandatory and non-mandatory disclosure. Second, according to the Measures for the Management of Information Disclosure of Listed Companies, that is subdivided into three parts: significance, comparability and reliability. Third, the scores were based on the criteria available in the literature [30–32], and if it is a qualitative indicator, it was assigned a value of 1. If the indicator was not disclosed, it was assigned a value of 0. If the indicator combines quantitative and qualitative disclosure, it was assigned a value of 2. Among them, there is an independent social responsibility, sustainability report or environmental report assigned a value of 2, otherwise 0. This article summarized the scores of EDI indices according to the

above steps, and then divided the actual scores of EDI level by the highest possible scores of all indices to obtain the relative indices, that is, EDI index. The formula is as follows.

$$EDI = \frac{\sum_{j=1}^{17} Scid_{i,j,t}}{34} \tag{1}$$

where i refers to the enterprise. t is the year. j means Grade II index of EDI, and $Scid_{i,j,t}$, the score of Grade II index for enterprise i in year t. In addition, the indicate of EDI are shown in Table 1.

(3) ***Control variable***: To ensure the accuracy of the estimation results and prevent the omission of variables, considering the relevant scholarly sources [33,34], the following variables were selected as control variables (control): enterprise size (Size), which is expressed by the natural logarithm of the total assets; enterprise Age (Age), which is calculated by the natural logarithm of the number of years between the year of establishment and that of listing; enterprise capital density (Fixed), which is demonstrated by the natural logarithm of the per capita net fixed assets; enterprise' labor productivity (Sales), which is represented by the natural logarithm of the per capita operating income; enterprise growth (Growth), which is measured by the year-on-year growth rate of business revenue; asset liability ratio (Lev), which is used to control the impact of the enterprise's capital structure; cash assets ratio (Cash), which is expressed by the ratio of cash assets to total assets, and used to control the impact of existing cash on enterprise innovation; return on assets (ROA), which is used to measure the profitability; board size (Board), which is expressed by the natural logarithm of the number of board members; R&D expenditure (RD), which is measured by the proportion of R&D expenditure of the current year to total assets at the end of the period; shareholding ratio of institutional investors (INT), which is calculated by the ratio of institutional investors' shareholding to the total number of shares; product market competition (HHI), which is measured by the Herfindahl-Hirschman Index; external information environment (IE), which is expressed by the natural logarithm of the number of analysts plus 1. According to the nature of the ultimate controller, if it is a state-owned enterprise, Own was assigned a value of 1. If not, Own was assigned a value of 0.

3.3. Model specification

In order to investigate the impact of EDI on the manufacturing enterprises' GT, referring to the existing literature [33,34], this study used ordinary least squares (OLS) regression to set the following model based on panel data:

$$GT_{it} = \alpha_0 + \alpha_1 EDI_{it} + \alpha_2 control_{it} + \sum Year_t + \sum ID_i + \varepsilon_{it} \tag{2}$$

Where GT represents the dependent variable, denoting the extent of green transformation. Similarly, EDI serves as an independent variable, representing environmental information disclosure. Control is a set of control variables. i denotes enterprises and t stands for years. α_0 refers to the intercept term, then $\alpha_1 \sim \alpha_2$ indicate the regression coefficient of the corresponding variable. If α_1 is significantly positive, it indicates that EDI positively affects GT and supports hypothesis H1. Fixed effects are considered. Year and ID are included to account for potential annual and industry effects. ε_{it} represents a random error term. Moreover, all regression analyses employ company code clustering and robust adjustment for standard errors.

Table 1
Indices for enterprises' environmental information disclosure.

Grade I Index	Grade II Index
J1 Pollutant Discharge of Enterprises	J11 Pollutant Types
	J12 Tailpipe Emission
	J13 Wastewater Discharge
	J14 Pollutant emission compliance
J2 Environmental Accidents and Violations	J21Expenditure on Major Environmental Issues
	J22 Punishment by Environmental Protection Department
J3 Environmental Protection Objectives and Measures	J31 Clear Targets and Plans for Energy Conservation and Emission Reduction
	J32 Environmental Protection Measures in Daily Office
	J33 Energy Saving and Emission Reduction Measures in Production
J4 Environmental Management and Agency Certification	J41 Energy saving and emission reduction into the management system
	J42 Environmental Information Disclosure System
	J43 Publicity and Education Activities on Energy Conservation and Emission Reduction
	J44 Whether to execute the past certification Benefits from Energy Conservation and Emission Reduction
J5 Enterprise Environmental Protection Income and Expenditure	J51 Benefits of energy conservation and emission reduction
	J52 Environmental grant
J6 Other	J61 Honors of Energy Conservation and Emission Reduction
	J62 Low Carbon Services or Products

4. Results

4.1. Descriptive statistics

A heteroskedasticity test revealed that the sample did not have a heteroskedasticity problem. To improve the applicability of the model to the sample, we performed a Hausman test, which indicated that the fixed-effects model is better.

The descriptive statistics for all variables are presented in Table 2. For EDI, the SD was 0.185, the mean value was 0.279, the lowest value was 0.046, and the peak was 0.928, which suggests deficits in the level of EDI among firms and huge discrepancies between businesses [35]. For GT, the SD was 1.252, the mean value was 0.425, the lowest value was 0.00, and the peak was 1.923, indicating that the level of GT in Chinese enterprises was generally low, and there were large differences in AI levels among different firms. It is urgent to accelerate manufacturing enterprises' GT. For Own, the mean value was 0.585, indicating that 58.5 % of the sample companies are state-owned. In addition, the remaining statistical results are basically consistent with the existing research, indicating that the selection of control variables in this article is reasonable.

4.2. Correlation analysis

Pearson's correlation analysis was conducted for all variables. In Table 3, the correlation coefficient between EDI and GT was 0.118, which passes the 5 % significance level threshold. A substantial and strong connection exists between EDI and GT. This finding initially supports H1, but further investigation is required. The correlations of the other variables were all below 0.5, which highlights a tenuous association among additional variables; this can aid the model in better discerning the impact of EDI on GT. To avoid covariance interference, the VIF is employed to calculate multicollinearity. In a word, the results reveal indicates the absence of multicollinearity.

4.3. Regression results and analysis

The regression results are reported in Table 4. The results of column (1) and column (2) show that the coefficient of EDI is significantly positive at the level of 1 %, demonstrating that EDI has a beneficial impact on GT. Meanwhile, in order to enhance the reliability of the research conclusion, the test results based on the fixed effect model are further reported, as shown in columns (3) and (4). The outcomes show that after controlling a series of related variables, the coefficient of EDI is 0.179 and it is significant at the level of 1 %, which means that the promotion effect of EDI on GT is significant both statistically and economically. Besides, considering the obvious "left truncation" feature of the dependent variable, Tobit regression model was further used for empirical testing, and the results are shown in columns (5) and (6). It is evident that the regression results based on Tobit model does not change substantially. It can be seen that EDI is conducive to driving GT, that is, hypothesis H1 is verified.

In fact, the above conclusions are consistent with previous literatures. Specifically, Wang & Feng discovered that EDI could stimulate green technology innovation, which is a crucial aspect of achieving GT [37]. Therefore, this article not only refines the research focus from a governmental level to a micro-enterprise level but also broadens the scope for evaluating the actual impact of EDI from green technology innovation to GT. Additionally, Shi et al. found that increasing the intensity of government-led EDI would encourage enterprises to undertake remedial actions towards reducing total pollutant emissions [38]. Clearly, pollution reduction is another key measure for realizing enterprise-level GT. This article not only confirms the viewpoint of the previous literature [36–38], but also expands the research scope of the existing literature.

Table 2
Descriptive statistics and definition.

Variable	Observations	Mean	SD	Max.	Min.
GT	17826	0.425	1.252	1.923	0.000
EDI	17826	0.279	0.185	0.928	0.046
Size	17826	21.249	1.492	29.227	17.526
Age	17826	2.724	0.318	3.524	1.652
Fixed	17826	379.529	542.229	987.289	75.278
Sales	17826	797.425	197.264	7887.325	65.528
Growth	17826	0.265	1.458	0.752	0.025
Lev	17826	0.452	1.152	0.885	0.015
Cash	17826	0.215	0.645	0.514	0.012
ROA	17826	0.0582	0.165	0.436	−0.258
Own	17826	0.585	0.517	1.000	0.000
Board	17826	2.235	0.216	2.824	1.721
RD	17826	8.126	6.725	21.125	0.000
INT	17826	0.073	0.145	0.452	0.000
HHI	17826	0.086	1.267	0.364	0.012
IE	17826	2.246	1.342	4.252	0.000

Table 3
Correlation analysis.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1.GT	1												
2.EDI	0.118**	1											
3.Size	0.011*	0.023*	1										
4.Age	0.019*	0.112*	0.021	1									
5.Fixed	0.013	0.024	0.015	0.014*	1								
6.Sales	0.036*	0.013*	0.012*	0.011*	0.286*	1							
7.Growth	0.152*	0.287*	0.018	0.058*	0.365*	0.076*	1						
8.Lev	−0.212*	−0.013	−0.085	−0.124	−0.363*	−0.058	−0.038	1					
9.Cash	0.296**	0.154*	0.386*	0.109	0.185**	0.136*	0.209**	0.011*	1				
10.ROA	0.178*	0.034*	0.292*	0.054*	0.042*	0.038*	0.295*	0.016*	0.282*	1			
11.Own	−0.161*	−0.091	0.202*	−0.022	−0.008*	−0.016*	−0.042*	−0.017	−0.016	−0.142	1		
12.Board	0.021*	0.109*	0.089*	0.129*	0.027*	0.032*	0.108*	−0.133	0.208*	0.209*	−0.142	1	
13.HHI	−0.265*	−0.145	−0.019	−0.076	−0.032*	0.026*	−0.038*	0.046	−0.225	−0.076	0.128*	−0.105	1

Note: ***, **, * indicate significance at 1 %, 5 %, and 10 % levels.

Table 4
The basic regression results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Mixed Effect Model		Fixed Effect Model		Tobit Regression Model	
EDI	0.215***	0.184***	0.224***	0.179***	0.226***	0.203***
	(8.29)	(5.59)	(4.92)	(4.12)	(3.64)	(3.26)
Size		0.626***		0.428***		0.342**
		(3.62)		(5.66)		(2.06)
Age		0.463**		0.379*		0.329**
		(2.28)		(1.75)		(2.05)
Fixed		0.172**		0.187**		0.168**
		(2.14)		(2.35)		(2.17)
Sales		0.021*		0.039**		0.026*
		(1.82)		(2.04)		(1.74)
Growth		0.044		0.107*		0.053*
		(1.46)		(1.74)		(1.82)
Lev		−0.412***		−0.262***		−0.293*
		(-4.52)		(-3.46)		(-1.76)
Cash		0.253***		0.221**		0.301***
		(4.26)		(2.07)		(8.72)
ROA		0.524**		0.416***		0.169*
		(2.23)		(10.21)		(1.72)
Own		−0.011*		−0.004*		−0.013*
		(-1.73)		(-1.85)		(-1.72)
Board		0.335**		0.295**		0.279*
		(2.21)		(2.25)		(1.75)
RD		0.367*		0.332**		0.314**
		(1.82)		(2.32)		(2.09)
INT		0.063***		0.057***		0.045**
		(3.29)		(2.79)		(2.05)
HHI		−3.416**		−3.016***		−1.172**
		(-2.21)		(-3.17)		(-2.01)
IE		0.236***		0.228***		0.232***
		(5.39)		(4.79)		(4.34)
Constant	0.523***	0.617***	0.426***	0.432***	0.465***	0.452***
	(3.28)	(4.75)	(3.37)	(6.29)	(3.86)	(3.59)
Industry/Year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17826	17826	17826	17826	17826	17826
R^2	0.236	0.237	0.234	0.236	0.235	0.237

Note: ***, **, * indicate significance at 1 %, 5 %, and 10 % levels. Robust t-statistics are in parentheses. Herfindahl-Hirschman Index is the reverse index.

Table 5
Endogenous problem handling: Instrumental Variable Method.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Mixed Effect Model		Fixed Effect Model		Tobit Regression Model	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
	EDI	GT	EDI	GT	EDI	GT
IMEDI	0.102**		0.095***		0.118***	
	(2.09)		(3.46)		(5.28)	
Weak IV: Shea's partial $R^2 = 0.435$; $F = 325.56$; $p = 0.0001$						
PEDI		0.327**		0.324***		0.335**
		(2.02)		(4.07)		(2.26)
The year, industry effect and control variables were controlled but omitted here for space limitation.						
Constant	0.472***	0.431***	0.406***	0.386***	0.392***	0.374***
	(4.81)	(3.08)	(5.17)	(4.13)	(7.94)	(3.98)
Observations	17826	17826	17826	17826	17826	17826
R^2	0.216	0.225	0.221	0.224	0.218	0.226
F value	461.81	121.07	379.37	84.78	121.39	115.68
Hansen J value	–	0.387	–	0.416	–	0.452
P value	–	0.521	–	0.432	–	0.394

Note: ***, **, * indicate significance at 1 %, 5 %, and 10 % levels. Robust t-statistics are in parentheses.

4.4. Robustness test

Company characteristic variables that did not be controlled in the model may affect EDI and GT [39–41]. The robustness of the finding would also be impacted by certain unobservable elements concurrently. Therefore, the instrumental variable method was adopted to solve such endogenous problem. Based on the research [29], the mean of EDI of the same industry excluding the target enterprises (IMEDI) was selected as the instrumental variable. In fact, IMEDI is somehow similar to the EDI of a single enterprise, but is less likely to directly affect the GT of a single enterprise.

The test results of the "weak instrument" in Table 5 show that the F value is 325.56, far greater than the experience value of 10, and the P value is close to 0, indicating that there is no "weak instrument" problem. The values of Hansen J statistics are significantly greater than 10 %, indicating that the null hypothesis of "no overidentification" is accepted. Therefore, IMEDI meets the requirements of correlation and exogenous. The specific test results are shown in Table 5. The outcomes demonstrate that the environmental information disclosure prediction variable (PEDI) obtained from the first stage of regression analysis is significantly positive with GT, which is consistent with the previous results. It can be seen that the previous conclusion is still robust after controlling endogenous problems.

4.5. Mechanism analysis

As mentioned above, environmental information, as non-financial information, is an essential index for stakeholders to evaluate the attitude to fulfill social responsibilities and their environmental governance level [31]. In particular, China's financial system dominated by the bank has set up a green barrier for enterprises to guide capital flows to green industries. EDI is conducive to obtaining bank loans with lower interest rates and longer maturities [42], thus easing the pressure of financing constraints [43]. At the same time, EDI would attract signification attention from stakeholders. Driven by the pressure of stakeholders, manufacturing enterprises usually rely on technological transformation on the production side to achieve GT. For example, in the production process, advanced and environmentally-friendly new machinery and equipment are added, that is, accelerating the process of productive capital renewal [34]. Based on the above analysis, the mechanism would be tested from financing constraints and capital renewal.

(1) Financing constraints

In order to test that EDI may drive manufacturing enterprises to achieve GT by easing the pressure of financing constraints, this article referred to the previous research [44] and selected SA index to measure the financing constraints. The calculation method is shown in Formula (3):

$$SA_{it} = \left| -0.737 \times Size_{it} + 0.043 \times Size_{it}^{2} - 0.04 \times Age_{it} \right| \tag{3}$$

where Size represents the company size, which is expressed by the natural logarithm of the total assets. Age refers to the age of the company, expressed by the natural logarithm of the number of years between the year of establishment and the year of listing. The SA index is positive.

The results of column (1) in Table 6 show that the impact of EDI on financing constraints. The results show that the coefficient of EDI is negative and significant at the level of 1 %, indicating that EDI is conducive to easing the pressure of financing constraints. At the same time, easing the pressure of financing constraints can provide a financial guarantee for GT [45]. It can be seen that easing financing constraints is an intermediate transmission mechanism for EDI to drive manufacturing enterprises to achieve GT.

(2) Capital renewal

The research concepts of Wan et al. were used as a guide to capture and reflect the capital renewal from the perspective of investment, depreciation, and capital productivity in order to test the hypothesis that EDI may promote manufacturing enterprises to achieve GT through capital renewal [34]. Table 6 displays the test results.

Table 6
Mechanism analysis.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Financing constraints	Capital renewal					
	SA	INV	MFIX	NFIX	DEP	DEPR	KEF
EDI	−0.372***	0.547***	0.219***	0.396*	0.275***	1.242***	0.022***
	(-12.35)	(4.98)	(7.02)	(1.74)	(11.79)	(12.08)	(7.43)
The year, industry effect and control variables were controlled but omitted here for space limitation.							
Constant	−0.238***	0.304**	0.382***	0.348***	0.273***	0.374***	0.354***
	(-2.88)	(2.02)	(4.22)	(4.61)	(4.86)	(6.54)	(5.24)
Observations	17826	17826	17826	17826	17826	17826	17826
R^2	0.251	0.317	0.311	0.293	0.286	0.276	0.282

Note: ***, **, * indicate significance at 1 %, 5 %, and 10 % levels. Robust t-statistics are in parentheses.

The results of column (2) in Table 6 show that the coefficient of EDI is significantly positive, indicating that EDI helps manufacturing enterprises significantly increase total investment in fixed assets. On this basis, the total investment in fixed assets was further divided into two categories: production and operation (MFIX) and non-production and operation (NFIX). The results are shown in columns (3) and (4). The outcomes demonstrate that EDI is more conducive to significantly increasing the total investment in fixed assets for the production and operation. The results of columns (5) and (6) show that EDI can not only significantly increase the depreciation (DEP), but also significantly accelerate the depreciation (DEPR). In addition, the results of column (7) display that EDI helps improve capital productivity (KEF).

As mentioned above, the findings demonstrate that EDI boosts capital productivity while also assisting industrial businesses in accelerating capital investment and depreciation. In other words, EDI speeds up capital renewal. A key strategy for China's manufacturing productivity improvement and GT has always been upgrading production equipment to adopt sophisticated production technology [19,34,46]. As can be seen, capital renewal is another intermediate transmission mechanism that enables manufacturing businesses to achieve a green transformation that is motivated by the disclosure of environmental information.

4.6. Heterogeneous analysis

(1) Nature of property right

The focus of academic research lies in examining the differential behavior of enterprises with varying property rights under environmental regulation. Therefore, this study divides the samples into two sub-samples based on the nature of their final controller: state-owned enterprises and private enterprises. Regression analyses are conducted separately for each group. The results, as presented in Table 7, indicate that in column (1), the coefficient of EDI for state-owned enterprises is 0.164, which is significant at the 10 % level. Similarly, in column (2), the coefficient of EDI for private enterprises is 0.201, significant at the 1 % level. Additionally, Chow test was performed with an empirical P-value of 0.012, indicating significance at the 5 % level. These findings suggest that EDI plays a more beneficial role in facilitating GT among private enterprises compared to state-owned counterparts. This could be attributed to private enterprises actively shaping a positive corporate image and enhancing social recognition through environmentally friendly product production and certification of their environmental management systems; thereby establishing green brands to attract customers and secure government funds and policy support.

(2) Environmental attribute

Heavy polluting enterprises are the primary sources of pollution emissions and naturally exhibit higher sensitivity towards environmental regulations. Therefore, we anticipate an asymmetrical impact of EDI on GT between heavy polluting enterprises and non-heavy polluting enterprises. To validate these theoretical expectations, we classify the sample based on environmental attributes into two sub-samples: heavy polluting enterprises and non-heavy polluting enterprises. We then conduct separate regressions for each sub-sample. The results presented in Table 7 indicate that in column (3), the coefficient of EDI is 0.173, which is significant at a 1 % level for heavy polluting enterprises; while in column (4), the coefficient of EDI is 0.135, which is significant at a 10 % level for non-heavy polluting enterprises. Additionally, the empirical P-value from Chow test is found to be 0.023, indicating significance at a 5 % level. These findings suggest that EDI contributes more effectively to the GT of heavy polluting enterprises compared to their non-heavy counterparts-implying that heavy polluters demonstrate stronger motivation towards green governance when faced with EDI.

Table 7
Further analysis.

Variable	(1)	(2)	(3)	(4)
	Nature of property right		Environmental attribute	
	state-owned enterprise	private enterprise	heavily polluting	non-heavily polluting
EDI	0.164*	0.201***	0.173***	0.135*
	(1.82)	(7.68)	(5.48)	(1.74)
The year, industry effect and control variables were controlled but omitted here for space limitation.				
Constant	0.424***	0.434***	0.628***	0.456***
	(11.44)	(8.45)	(7.28)	(6.89)
Observations	10428	7398	10695	7131
R^2	0.234	0.235	0.236	0.237
P value	0.012**		0.023**	

Note: ***, **, * indicate significance at 1 %, 5 %, and 10 % levels. Robust t-statistics are in parentheses. The experience P value is used to test the coefficient difference between groups and obtained after 1000 bootstraps.

5. Discussion and conclusions

5.1. Discussion

This study reveals that EDI significantly incentivizes GT. Upon reviewing pertinent research on EDI, it becomes evident that social and political theory, as well as voluntary disclosure theory, serve as the primary theoretical foundations for hypothesis development. However, neither of these theories holds superiority, and there is insufficient support for the existing literature's theoretical framework. Addressing this issue, this article argues that enterprises, being active market participants, will be influenced by stakeholders' demands for environmentally friendly practices regardless of whether they are compelled to disclose environmental information due to legitimacy concerns or actively choose to disclose such information to attract investor attention. Consequently, clarifying the motivation behind EDI emerges as a critical necessity.

As for the reasons behind EDI, previous literature offers different explanations based on signal display theory and legitimacy management theory. According to the signal display theory, EDI serves as a means of transmitting signals, helping to mitigate the issue of information asymmetry. Specifically, when external evaluations of corporate environmental performance impact corporate value, enterprises are strongly motivated to actively disclosure environmental information in order to differentiate themselves from those with poor environmental performance [47,48]. On the other hand, legitimacy management theory posits that disclosing environmental information is a tool employed by enterprises to manage their own legitimacy. Therefore, from this perspective, it can be seen as a passive behavior driven by the desire for obtaining legitimacy [16,17]. However, this article argues that factors such as production resources and bank credit are prerequisites for normal business operations and survival of enterprises whereas maintaining a legitimate status merely represents one resource among others.

In fact, EDI serves as a crucial mechanism for enterprises to communicate their environmental performance to external stakeholders, thereby impacting the cost of financing through the internalization of pollution expenses. Consequently, it influences financial institutions' decision-making in extending credit facilities to companies with commendable environmental records [9,49]. Evidently, this aligns with the theory of resource dependence. From this perspective, compared to legitimacy management theory, resource dependence theory offers a more robust explanation for the impetus behind EDI. Therefore, this study adopts signal display theory and resource dependence theory as its theoretical foundation and elucidates the motivation driving EDI from both external pressures and internal incentives.

Based on the theories of signal display and resource dependence, this study reveals that easing financing constraints and capital renewal serve as the mechanisms through which EDI encourages manufacturing enterprises to achieve GT. From an external perspective, green low-carbon practices have become a social consensus, with all sectors of society increasingly advocating for GT. EDI is a crucial measure for enterprises to gain legitimacy [10], representing a passive environmental governance behavior driven by non-economic motives in order to meet legitimacy goals. From an endogenous motivation standpoint, EDI serves as an effective means for enterprises to communicate their environmental management efforts and establish a low-carbon environmental protection image, thereby eliciting positive feedback from the capital market. In other words, it represents an active environmental governance behavior driven by economic motivations aimed at obtaining competitive resources.

On the basis of the aforementioned analysis, this article asserts that EDI is driven by both economic and non-economic motives. Therefore, in contrast to existing literature, this study incorporates signal display theory and resource dependence theory to consider both external pressures and internal motivations. Consequently, it reveals that EDI encompasses both economic and non-economic incentives. This not only serves as a valuable complement to prior research but also enhances our comprehension of the motivation behind EDI.

5.2. Conclusions

This study utilized a two-way fixed-effect model and specifically focused on Chinese A-share listed companies to determine the implementation effects of EDI policies from the perspective of GT. This study selects listed manufacturing companies from 2009 to 2020 as the research subjects. The research reveals the following findings: (1) EDI is conducive to driving manufacturing enterprises' GT, indicating EDI can stimulate the internal motivation for GT, improve their internal governance, and subsequently enhance the quality of their GT. This suggests that EDI should not be viewed as a mere cost but rather an effective means of value investment and competitiveness improvement. (2) Mechanism analysis indicates that easing financing constraints and capital renewal serve as transmission channels for EDI to drive manufacturing enterprises towards achieving GT. This reveals that EDI strengthens the environmental awareness, stimulates their intrinsic motivation for GT, weakens their "greenwashing" behavior, and promotes high-quality GT. The signaling effect generated by EDI can effectively alleviate the financing constraints faced by manufacturing enterprises, thereby reducing the resource pressure on enterprises in the R&D process, allowing enterprises to invest more resources in innovation activities and carry out high-quality GT. Therefore, EDI can help enterprises obtain financial support from the government and financial institutions, overcome financing constraints, renew their capital, and ultimately promote GT. (3) Heterogeneity analysis reveals that the incentive effect of EDI on GT is more pronounced in private enterprises and heavily polluting industries, thus, understanding the heterogeneity and causes of property rights nature and environmental protection attributes in the context of the green governance effect will enable regulatory authorities to adopt targeted policies and measures for orderly promoting enterprise's quality improvement in terms of disclosing environment-related data. After conducting a series of robustness tests, the above research conclusions remain unchanged.

The recommendations of the research conclusions are primarily manifested in the following three aspects. Firstly, government

departments should enhance EDI standards and evaluation criteria, enhance the quality of EDI, and fully unleash the green governance impact of EDI. In terms of EDI standards, it is imperative to further enhance the depth and breadth of such disclosures, ensuring coverage throughout a product's entire life cycle and encompassing all business operations conducted globally by enterprises. Particularly noteworthy is encouraging enterprises to actively disclose environmental information through market-oriented means, thereby transitioning from voluntary to mandatory disclosure and reducing government supervision costs.

Secondly, promote the legal establishment of EDI and guide enterprises in promoting green and intelligent transformation. Enhance the collection and regulation of environmental supervision data, integrate pollution source information, environmental supervision and law enforcement data, as well as dynamic punishment information. Construct a "one-stop," "comprehensive coverage," and "convenient" environmental data service platform to disclose high-quality environmental supervision information. Establish cross-departmental and cross-regional mechanisms for sharing and linking environmental information, utilizing emerging digital technologies such as 5G, big data, and artificial intelligence to deliver timely environmental information while eliminating the issue of "information islands" in relation to environmental data.

Thirdly, facilitate comprehensive development of green finance to alleviate financing difficulties faced by enterprises during their green transformation process. Financial institutions should establish a long-term driving mechanism that promotes enhanced EDI by enterprises along with conducting activities related to green technology innovation. Support the growth of green securities funds while encouraging social capital flow towards green industries in order to better serve the real economy's transition towards sustainability. Simultaneously, financial institutions should implement policies regarding green credit while establishing an improved exit mechanism for funding polluting projects.

5.3. Implication

This study has significant theoretical and practical implications. First, this study enhances existing knowledge on the connection between EDI and GT. This confirms the practical implementation of the EDI and green enterprise practices. The conclusion drawn from the data is typical and based on listed enterprises in the Chinese context. Second, while research on EDI outcomes currently focuses on the macro level [47,49,50], the inclusion of the corporate perspective completes the multifaceted study of EDI outcomes and enhances the research on the micro perspective-based antecedents of corporate GT. Third, while most research measuring corporate GT uses financial indicators or questionnaire surveys [51,52], this study uses text analysis to collect data. This enhances the use of machine-learning techniques in empirical research and advances the field of corporate GT measurement. Further, the conclusion serves as a guide for policymakers to create environmentally friendly laws. Moreover, this study establishes an effective connection between EDI and GT, which promotes the green and low-carbon development of enterprise products, improves resource utilization, and enhances enterprise economic value. This research is conducive to the adjustment and optimization of public policy on GT, especially under the guidance of environmental regulation policy. Additionally, this study contributes to the body of knowledge on green development and improves the research on the dimensions of EDI.

5.4. Research limitations and future prospects

The measurement of EDI level can be further improved in the future. Firstly, this article currently assesses the quality of EDI based on three dimensions: significance, comparability, and reliability. However, this approach is limited as it relies solely on publicly available information, which may not provide a comprehensive understanding of a company's environmental performance. With advancements in digital technology, future research could explore the use of emerging digital tools to access non-public channels and compare real-time data on corporate environmental performance with disclosed information. This would enable a more accurate assessment of companies' motivations for disclosing environmental information. Secondly, considering the time lag issue, this article focuses only on manufacturing enterprises that regularly release social responsibility reports as its sample scope. To enhance future studies, it is recommended to expand the selection criteria beyond these enterprises and include those without social responsibility reports by utilizing annual reports and other relevant materials. Finally, given China's increasingly stringent environmental regulations, regulatory authorities play a crucial role in influencing companies' behavior regarding EDI. Future research could compare the green quality effect of EDI under different regulatory levels to gain deeper insights into heterogeneous outcomes.

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Data availability statement

The raw data supporting the conclusions of this article will not be made publicly available. However, the data can be made available upon reasonable request to the corresponding author.

CRediT authorship contribution statement

Hui Xu: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Yue Fu:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Yi Li:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Gong Zhang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Shulei Bi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

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