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Can Environmental Information Disclosure Improve Energy Efficiency in Manufacturing? Evidence from Chinese Enterprises

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Abstract: Improving the energy efficiency of enterprises is one of the key means to solve the problem of energy shortage. It is of great significance to investigate how environmental information disclosure (EDI) promotes the green total factor energy efficiency (GTFEE) of enterprises. Based on this, this study calculates the GTFEE of enterprises by combining the database of Chinese manufacturing and the pollutant emission of industrial enterprises and investigates the impact of EDI on the GTFEE of manufacturing industries by using a difference-in-difference model. The following is found: (1) EDI can significantly promote the manufacturing enterprises' GTFEE, and the results are still valid after a series of robustness tests; (2) Mechanism analysis shows that EDI can improve the GTFEE of manufacturing enterprises by promoting technological innovation and optimizing energy structure; (3) The heterogeneity analysis shows that EID is more positive on firms' GTFEE in the eastern than western regions. The positive impact is greater for non-state-owned, low-energy consumption, export, and polluting enterprises. The findings of this paper provide a theoretical basis and practical enlightenment for the government to promote the green development transformation of enterprises.

Keywords: environmental information disclosure; manufacturing enterprises' GTFEE; difference-in-difference model; mechanism test

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1. Introduction

Energy is considered critical to social development as the material basis for economic growth [1]. However, extensive energy use exacerbates the supply–demand energy imbalance. It increases greenhouse gas and carbon emissions, exacerbates climate change, and endangers national energy security [2–4]. According to estimated data, by the end of 2050, global energy demand will increase by 50% [5,6]. Reference [7] shows that China's energy consumption grew by 3.1% in 2019, which makes it the world's largest incremental energy consumer for 18 consecutive years [8]. Therefore, achieving efficient energy use is necessary to deal with excessive energy consumption. There are two main ways to achieve it. The first is to change the energy use structure. Most Chinese firms are coal-consumption firms, hindering the green transformation of the economy. Thus, transforming the energy use structure into wind, solar, hydraulic, and other renewable energy sources can reduce environmental damage [1]. However, renewable energy sources are not cheap, and the methods to obtain them are complex and require certain technologies. The second way is to improve energy efficiency (EE). Compared with the first method, improving energy efficiency can reduce energy capital input, mitigate negative externalities, and reduce external dependence. Therefore, it is an inevitable choice to tackle the environmental issues caused by energy consumption and to achieve enterprises' sustainable development [9].

Meanwhile, some research has explored many factors affecting energy efficiency. For instance, previous studies have pointed out that energy consumption structure, technological progress, R&D expenditure, industrial structure, and energy price are the main factors of power efficiency [10,11]. Among them, environmental regulation (ER) has attracted high attention as an effective means to improve energy efficiency and address the external outcomes of environmental pollution [12–15]. The effect of ERs on power efficiency is analyzed through mechanisms such as increasing firms' production costs and promoting technological innovation [16–20]. However, a consensus has not yet been reached within the academic community.

The previous studies have mainly focused on two aspects. The first opinion supports the compliance cost theory. ER increases the costs of enterprise environmental management, thus squeezing production capital and disturbing energy efficiency [12,21,22]. Reference [23] discussed the possible impacts of the Clean Air Law Amendment on EE and claimed that ERs led to reductions in energy efficiency. Reference [9] study showed that the environmental licensing and ban framework launched by the Danish government could not promote energy efficiency. The second opinion supports the Porter hypothesis. ER can make "innovation compensation" possible by offsetting the costs of pollution reduction and achieving the dual dividends of pollution prevention and energy efficiency [23,24]. Reference [25] found that ER enhanced energy efficiency in the Indian cement industry. Reference [26] concluded that the market incentive ER and the command control ER contribute directly to energy efficiency. However, there are heterogeneities among different ERs regarding regulatory costs and models [27], and the influence of various ERs on environmental performance may be different [28]. Most of the literature focuses on the command-and-control influence and market incentive ER on EE, and there is limited discussion regarding the impact of informal regulation and disclosure strategies in environmental aspects, especially on EE at the firm level.

As an effective environmental governance tool, informal ER has become a third-party force to mitigate government and market failures [29,30]. The environmental information disclosure (EID) is a typical type of informal ER that can be used to examine the impact of informal ERs on EE. Increasingly, regulators are supplementing traditional ERs by disclosing public environmental information [31]. Compared to other countries or organizations, the Chinese government has lagged in incorporating environmental information uncovered into environmental laws. Environmental NGOs are increasingly important in environmental governance as a major force and key organization in EID. The Pollution Information Disclosure Index (PITI) contains the first assessment of EID transparency in 113 prefecture-level cities across China, which is jointly hosted by the Public Environment Institute and the Natural Resources Defense Council. Therefore, we apply PITI to measure the intensity of EID by Chinese manufacturing firms.

There are two main channels through which EID can impact an enterprise' energy efficiency. The first is the technological innovation effect. As a typical unofficial ER, EID has an uncertain effect on power efficiency through technology innovation, including a negative "cost loss effect" and a positive "innovation compensation effect". Furthermore, the traditional neoclassical theory holds that ERs increase firms' pollution control costs, squeeze technological innovation funds, and thus inhibit firms' innovation activities [32,33]. Therefore, EID restricts a firm's technological innovation and negatively influences energy efficiency. On the other hand, the "innovation compensation theory" argues that ER can stimulate firms to innovate and achieve the double dividend of pollution prevention and productivity promotion [24]. However, there are no uniform conclusions on the effect of ER on firms' power efficiency.

The second is about the energy structure effect. Improving the energy structure is an accessible method to tackle the current pollution plight of Chinese companies. China has been in a constant state of high energy consumption, especially its reliance on coal, leading to higher pollution emissions. Since traditional energy sources, such as coal, produce large amounts of pollutants, changing the energy structure to new energy sources, such as hydropower, nuclear power, and wind power, can reduce environmental damage. Informal ER can accelerate energy structure optimization, reduce conventional energy consumption, and promote enterprises' energy efficiency [12,16]. For instance, EID's public monitoring and social supervision can force enterprises to disclose more green governance information to protect their reputation. It can encourage enterprises to reduce the consumption of coal and other highly polluting energy in the production process, increase the use of clean energy to reduce pollutant discharge and improve energy efficiency [10]. In addition, EID alleviates resource price distortion and reduces energy overconsumption by revealing energy prices and supply and demand situations. This forces enterprises to transform economic development mode and optimizes the energy structure [8]. These mechanisms generated by EID can effectively improve enterprises' energy efficiency.

Energy efficiency is the service or product that different enterprises produce with the same amount of energy. Higher energy efficiency means more economic output with less energy consumption. Energy efficiency is usually estimated in two ways: single-factor energy efficiency (SFEE) and GTFEE. Single-factor energy efficiency mainly reflects the correlation between energy consumption and economic output. Energy consumption intensity is the most commonly used single-factor indicator, represented by energy consumption per unit of GDP. It makes energy efficiency easier to calculate, but it may overestimate energy consumption's impact on economic output [34]. However, SFEE overlooks the effects of elements of production like capital and labor, as well as the substitutes and structural shifts among different production elements [35]. Therefore, due to integration with various production inputs, GTFEE is considered to be used as the measurement of energy consumption in recent years [36]. GTFEE mainly includes SFA and DEA methods [15,37]. For instance, ref. [38] adopted the SFA model to measure cities' GTFEE in the Yangtze River Economic Belt.

Previous studies have revealed the relationship between EID and energy efficiency. However, the existing literature has the following problems. Firstly, they focus mainly on the national or city level, with less analysis from the firm's perspective. Even when considered at the firm level, previous energy efficiency is only measured by a single factor. Secondly, EID is rarely chosen as the research object to explore its correlation with energy efficiency. Most of the research explores the effect of formal ERs, while few put their view on informal ER. As an unofficial ER, EID has a certain impact on EE. On the contrary, its significance has been neglected. Thirdly, little literature analyzes in depth the influencing mechanisms of energy efficiency. In addition to ERs, various factors still affect energy efficiency. Because of this, we start with GTFEE at the firm level and select EID as the research object to further explore its impact on energy efficiency and potential mechanisms.

Therefore, we employ the manufacturing database in China from 2003 to 2014 (since the data of manufacture enterprises refers to the manufacturing industry with a certain scale, the data of Chinese Industrial Database and Industrial Pollution Database published by the government is only up to 2014, so the data selected in this paper are up to 2014) to explore the impact of EID on manufacturing GTFEE. Firstly, we empirically investigate the impact of EID on manufacturing GTFEE using the DID model. Then, we conduct a series of tests, such as parallel trends, placebo and counterfactual, to consolidate the robustness of the results. Finally, this study further analyzes EID's mechanism on enterprises' EE and analyzes the heterogeneity of enterprises in terms of geographical location and enterprise characteristics.

There are some possible contributions to this paper. Firstly, this study calculates manufacturing firms' GTFEE for the first time. The existing literature only calculates firms' SFEE [10]; however, the manufacturing GTFEE has not been explored. Secondly, this study regards EID as a quasi-natural experiment to discover its relationship with energy efficiency. There are relatively few studies on whether EID can have an impact on energy efficiency. Therefore, we adopt the DID model to empirically analyze the impact of EID on GTFEE and conclude that EID significantly promotes enterprises' GTFEE. Finally, we further discuss the EID's mechanism on GTFEE, and we empirically propose that the implementation of EID can promote GTFEE through improving energy structure and enhancing technological innovation to improve energy efficiency.

The rest of the paper is organized as follows. Section 2 summarizes the research hypothesis. Section 3 presents the methodology and data, which introduces the research design. Section 4 presents the empirical results. Section 5 provides further discussion. Section 6 contains the conclusion and implications.

2. Policy Background and Research Hypothesis

2.1. Policy Background

The Chinese government implemented environmental governance policies and achieved preliminary results in the late 20th century [39]. At the same time, the role of EID in pollution control was gradually emerging. In 2005, the Chinese government launched "Enterprises Environmental Performance Evaluations" to make environmental information more accessible and to promote public supervision of polluting enterprises [30]. In May 2008, the "Measures for EID (Trial)" was officially released and implemented. It stipulated requirements in detail for enterprises and environmental protection authorities regarding the environmental information to be disclosed, marking a more comprehensive and transparent stage of EID in China. To assess the effectiveness of the Measures for EID (Trial) in stimulating public participation in environmental governance, the Public Environment Institute and the Natural Resources Defense Council jointly published the country's PITI [30]. They evaluated the transparency of EID in 113 prefecture-level cities in the same year. The PITI employs eight indicators to evaluate the transparency of pollution information disclosure in 113 pilot cities in China. The PITI also rates and ranks the environmental performance of each city [40]. At the beginning of 2008, the PITI project covered 113 cities in China. Existing research shows that Pilot cities that publish the PITI have a stronger capacity for information disclosure and a higher level of concern about environmental quality than non-pilot cities [10].

2.2. Research Hypothesis

The impact of EID on firms' energy efficiency can be thoroughly analyzed from both micro and macro perspectives. At the macro level, governments can achieve environmental governance through regulation and economic means. Specifically, the government can promote social monitoring through EID, alleviate resource price distortions, reduce excessive energy consumption, and thus stimulate enterprises to improve energy efficiency, thereby reducing environmental pollution. At the micro level, the influence mechanism of EE facilitates the improvement of enterprises' EE through various ways, including technological innovation and energy structure effects. Technological innovation can push companies to adopt more energy-efficient and environmentally friendly production technologies, thereby improving overall energy efficiency. In addition, by adjusting the energy structure, enterprises can allocate and use various energy resources more effectively and achieve a higher level of energy efficiency. Therefore, we propose the following:

Hypothesis 1: EID has positive effects on manufacturing enterprises' GTFEE.

EID can also influence enterprises' EE through the energy structure mechanism. Improving the energy structure is an efficient way to address the current pollution situation of Chinese enterprises. China's reliance on coal generates many pollutants and leads to higher pollution emissions. Therefore, transforming the energy structure into new energy sources, such as hydropower, nuclear power, and wind power, can reduce environmental damage. EID can bring public supervision and force enterprises to disclose more green governance information for their reputation, reducing firms' consumption of polluting energy sources, such as coal, promoting the use of clean energy, and optimizing the energy structure. In addition, EID alleviates the price distortion of resources by revealing energy prices and reducing excessive energy consumption. This forces enterprises to change their economic development mode and optimize the energy structure, thus improving energy efficiency. In summary, EID can promote the enterprises' energy efficiency by accelerating the optimization of energy structure. Therefore, we propose the following:

Hypothesis 2: EID promotes manufacturing enterprises' GTFEE by optimizing energy structure.

EID can affect enterprises' EE through the technological innovation mechanism. EID will generate a negative "cost loss effect" or positive "innovation compensation effect", thus indirectly affecting energy efficiency through technological innovation. Furthermore, the "cost loss effect" means implementation of EID regulations will raise the expenses associated with enterprise pollution control and limit capital investment in technology innovation. Therefore, EID limits the firm's technological innovation and negatively affects energy efficiency. On the other hand, the "innovation compensation theory" suggests that scientific ER can encourage companies to innovate and achieve the dual benefit of preventing pollution and improving productivity [24], contributing to the improvement in firms' energy efficiency. In conclusion, there is no convincing conclusion regarding the extent and direction of EID's impact on the energy efficiency of enterprises. Based on this, we propose the following research hypotheses:

Hypothesis 3a: EID has a positive impact on manufacturing enterprises' GTFEE by promoting technological innovation.

Hypothesis 3b: EID has a negative impact on manufacturing enterprises' GTFEE by inhibiting technological innovation.

The influencing mechanisms of the research hypothesis can be summarized in Figure 1. EID can influence the energy efficiency of enterprises by influencing technological innovation and optimizing the energy structure. The impact of technological innovation on EE is uncertain and the improvement in energy structure can effectively improve energy efficiency.

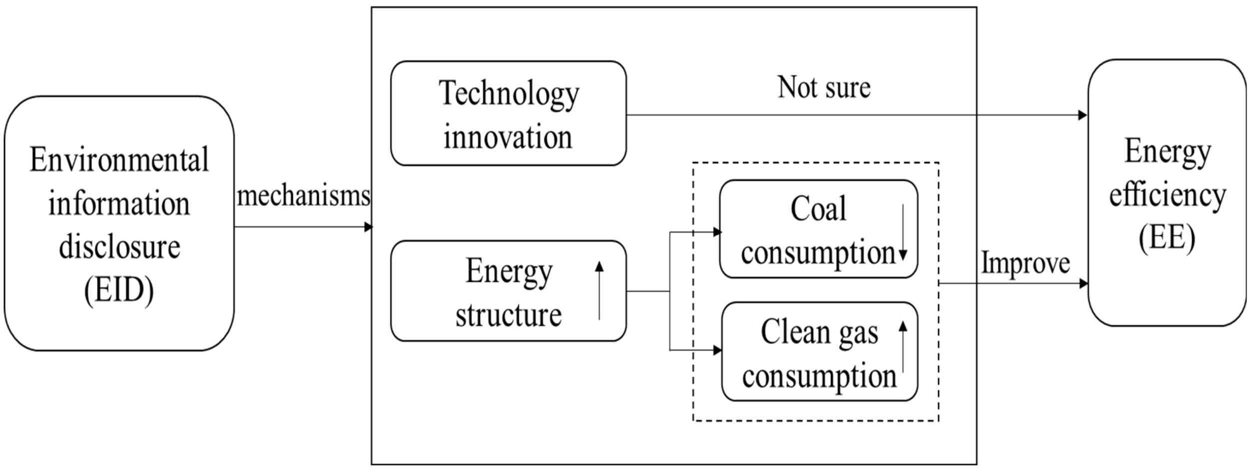

Figure 1. Mechanisms of EID impact the manufacturing enterprises' energy efficiency.

3. Methodology and Data

3.1. Data Source

Using data on industrial pollution emissions from the China Industrial Enterprise Environmental Statistics Database, this paper considers other economic indicators from the China Industrial Enterprise Database. To ensure the accuracy and consistency of the data, we merged the different databases above. Then, according to standard processing method of China's industrial enterprise database, we cleaned the data. After processing it according to [10], we obtained 155,237 samples during the period from 2003 to 2014. Table 1 presents the descriptive statistics.

Table 1. Descriptive statistics.

VarName	Obs	Mean	SD	Min	Max
Firm GTFEE	155,237	0.02	0.05	0.000	1.000
Firm age	155,237	2.39	0.73	0.000	7.606
Whether state-owned firm	155,237	0.11	0.32	0.000	1.000
Whether export firm	155,237	0.45	0.50	0.000	1.000
Firm assets	155,237	10.84	1.24	6.953	15.957
Firm asset-liability ratio	155,237	0.60	0.32	1.104	15.116
Total profits	155,237	5.23	6.73	−13.817	15.878
R&D expenditure	155,237	0.86	2.17	0.000	12.161

3.2. Variable Definition

3.2.1. Explained Variable

To calculate firms' GTFEE, we conduct the undesirable-SBM model, which is the same as [40]. We assume that $x \in R^m$, $y^g \in R^{S_1}$, $y^b \in R^{S_2}$, and define three matrices: input matrix $X = [x_1, x_2, \ldots\ldots, x_n] \in R^{m\times n}$; expected output matrix $Y^g = \left[y_1^g, y_2^g, \ldots\ldots, y_n^g\right] \in R^{S_1\times n}$; undesirable output matrix $Y^b = \left[y_1^b, y_2^b, \ldots\ldots, y_n^b\right] \in R^{S_2\times n}$, X, Y^g, and Y^b are all greater than 0. Therefore, it can be defined as follows:

$$P = \left\{ \left(x, y^g, y^b\right) | x \geq \sum_{j=1}^{n} \lambda_j x_j, y^g \leq \sum_{j=1}^{n} \lambda_j y_j^g, y^b \geq \sum_{j=1}^{n} \lambda_j y_j^b, y^g \geq 0, \lambda \geq 0 \right\} \quad (1)$$

For $DMU_0\left(x_0, y_0^g, y_0^b\right)$, if there is no vector $\left(x_0, y_0^g, y_0^b\right) \in P$ make inequality $x_0 \geq x$, $y_0^g \leq y^g, y_0^b \geq y^b$ founded, and at least one inequality strictly, then $DMU_0\left(x_0, y_0^g, y_0^b\right)$ is on the front surface and the decision unit is valid. The undesirable-SBM model with undesirable outputs is as follows:

$$\tau^* = min \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{S_i^-}{x_{i0}}}{1 + \frac{1}{S_1+S_2}\left(\sum_{r=1}^{S_1} \frac{S_r^g}{y_{r0}^g} + \sum_{l=1}^{S_2} \frac{S_l^b}{y_{l0}^b}\right)}$$

$$s.t. \begin{cases} y_0^b = \sum\limits_{j=1, j\neq j_0}^{n} \lambda_j y_j^g - S^b \\ y_0^g = \sum\limits_{j=1, j\neq j_0}^{n} \lambda_j y_j^g - S^g \\ x_0 = \sum\limits_{j=1, j\neq j_0}^{n} \lambda_j x + S^-, \lambda \geq 0 \end{cases} \quad (2)$$

where S is the relaxation of input and output, S^- is redundancy of input, S^b is undesirable output, S^g is desired output, and λ is the weight vector, if $\lambda \geq 0$, *then*, $S^- \geq 0, S^g \geq 0, S^b \geq 0$; τ^* represents the target efficiency value, a larger τ^* means that the DMU has a higher efficiency. When $0 < \tau^* < 1$, the measured DMU belongs to the low efficiency and can be further optimized to improve the efficiency. When $\tau^* \geq 1$, $S^- = S^g = S^b = 0^*$, the measured DMU is valid.

3.2.2. Explanatory Variable

The EID_{ct} represents environmental information disclosures, where c is city and t is the year. It reveals differences in core variables between pilot and non-pilot cities. It equals 1 when enterprises are located in the 113 PITI pilot cities and the year greater than or equal to 2008; otherwise, its value equals 0. This measures whether a company discloses environmental information.

3.2.3. Mechanism Variables

EID affects energy efficiency mainly through two mechanisms: green technological innovation and the energy structure of enterprises. Referring to [5], we introduce the new product share as the measurement of technological innovation, which is calculated by the ratio of the new product output value to the total output value of enterprises. For the energy structure, we use the consumption of coal and clean gas as the agency of energy structure. The energy structure improves as the proportion of clean gas consumption increases.

3.2.4. Control Variables

To increase the accuracy of empirical results and avoid omitting variables that may affect energy efficiency, referring to [8], we add the following control variables: (1) Firm age: taking the logarithm of the enterprise established year minus the current year; (2) Whether state-owned firm: when the enterprise is state-owned, the dummy variable equals 1 and equals 0 otherwise; (3) Whether export firm: when the enterprise belongs to the exporting firm, the dummy variable that is 1 and is 0 otherwise; (4) Firm assets: taking the logarithm of enterprises' total fixed assets; (5) Firm asset-liability ratio: the ratio of total liabilities to total assets of an enterprise; (6) Total profits: taking the logarithm of the total profits of the firm; (7) R&D expenditure: measured by taking the enterprise's logarithm of new product research and development expenses.

3.3. Econometrics Model

To evaluate the impact of disclosing environmental information on EE, we conduct a quasi-natural experiment using the Pollution Information Transparency Index of 113 prefecture-level cities to distinguish whether a firm is making EID or not, and construct difference-in-differences (DID) model to analyze how EID affects enterprise GTFEE. The treatment group is the enterprises in 113 cities selected for the PITI list and the control group is the enterprises in the cities not selected in PITI. The DID model is designed as follows:

$$GTFEE_{ijtc} = \alpha_0 + \alpha_1 EID_{ct} + \varphi X_{ijtc} + \mu_i + \eta_j + \tau_t + \gamma_c + \varepsilon_{ijtc} \tag{3}$$

In Formula (3), $GTFEE_{itc}$ represents the energy efficiency where i, j, t, and c represent firm, industry, year, and city separately. The core explanatory variable EID_{ct} is the dummy variable. X_{ijtc} is a series ofvariables controlled at the enterprise level, μ_i, η_j, τ_t, γ_c are fixed effects, and ε_{ijtc} is the error term. This model mainly focuses on the significance of the coefficient α_1, which represents the impact of the environmental information disclosure on GTFEE.

4. Empirical Results

4.1. Basical Result

The empirical results of benchmark regression are presented in Table 2. We can conclude from columns (1) and (3) that city and industry fixed effects and disclosure of the information environment significantly promote firms' GTFEE at the 1% significance level, regardless of whether the control variables are added. The results remain unchanged after further controlling firm-fixed and year-fixed effects. The firms' GTFEE is significantly higher compared to firms located in cities that do not make environmental disclosures. These results indicate that EID significantly contributes to the firm's GTFEE. Hypothesis 1 is also verified.

Table 2. Benchmark regression results.

	(1)	(2)	(3)	(4)
Variables	**GTFEE**	**GTFEE**	**GTFEE**	**GTFEE**
EID	0.050 ***	0.048 ***	0.032 ***	0.030 ***
	(6.233)	(6.197)	(4.051)	(4.011)
_cons	4.365 ***	4.316 ***	2.119 ***	2.131 ***
	(6.301)	(3.794)	(2.835)	(2.155)
Control	N	N	Y	Y
Firm FE	N	Y	N	Y
Year FE	N	Y	N	Y
City FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
N	155,237	155,237	155,237	155,237
Adj-R^2	0.391	0.312	0.556	0.617

Notes: *** $p < 0.01$, and the t-value is in parentheses.

4.2. Parallel Trend Result

The basic premise of the DID model is to satisfy the parallel trend hypothesis test, which means that the control and experimental groups' GTFEE had the same trend before the PITI was released, and there was a different trend between the GTFEE of the control and experimental groups after the PITI released. Referring to [24], we conduct a model to further test the parallel trend as shown in Formula (4):

$$GTFEE_{ijtc} = \beta_0 + \sum_{k \geq -5, \neq -1}^{5} \beta_k EID_{c,t_0+k} + \delta X_{ijtc} + \eta_j + \tau_t + \gamma_c + \varepsilon_{ijtc} \quad (4)$$

where t_0 is the policy implementation year. $k < 0$ means k years before the policy's implementation and $k > 0$ represents k years after the implementation of the policy. EID_{c,t_0+k} equals 1 if the enterprise is in k^{th} (k = −2, −3, −4, −5) the year before policy implementation and 0 otherwise. EID_{c,t_0+k} equals 1 if the enterprise is in k^{th} (k = 1, 2, 3, 4, 5) year after the implementation and equals 0 otherwise. β_k represents the difference between the treatment and control groups in the k^{th} year. The results of this are shown in Figure 2.

The regression coefficients for the five years before the policy implementation are insignificant. They indicate that there is no significant difference between the energy efficiency of enterprises in the treatment and control groups before the release of PITI, satisfying the parallel trend test. The regression coefficients are positive in the 5 years after the release of PITI, which means EID starts to significantly improve the enterprises' energy efficiency in the first year of the policy implementation. This shows that enterprises' energy efficiency improvement is due to the EID rather than previous trends. In summary, the DID model of this study satisfies the parallel trend test and can be considered to analyze the effect of EID.

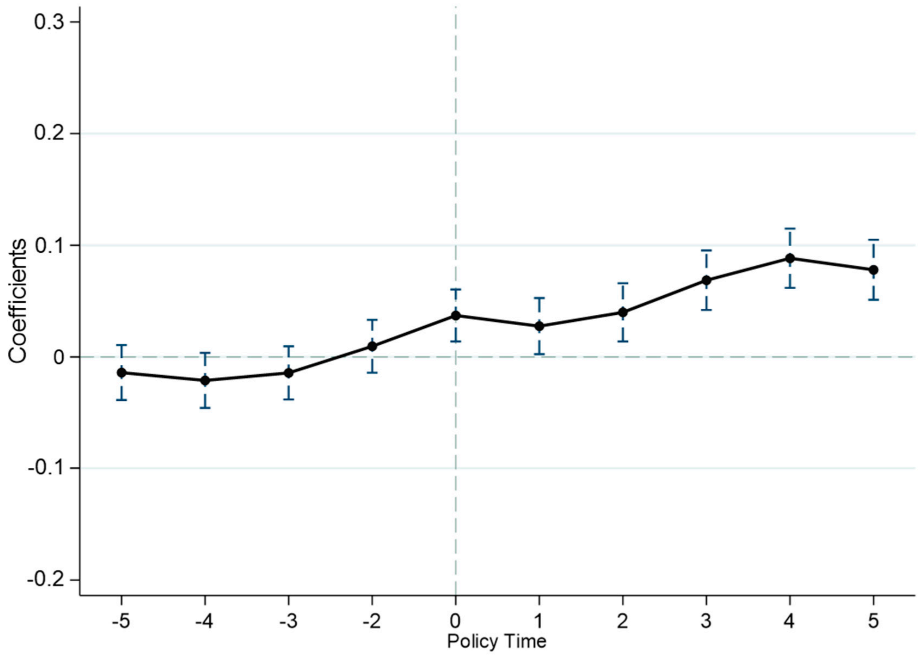

Figure 2. Parallel trend test.

4.3. Robustness Test

4.3.1. Placebo Test

To exclude the potential effect of omitted variables and potential non-observable elements on baseline results, this paper conducts a placebo test. This process involves a new random selection of 113 pilot cities and 500 randomized bootstrap samples to eliminate random elements. We conduct a dummy variable $EID_{placebo}$ in the placebo test. Figure 3 shows that the average value of $EID_{placebo}$ is characteristic of a normal distribution. However, the empirical result equals 0.05, the line is noticeably distant from this distribution (which is not plotted in this paper). These findings suggest that there is no major bias in the estimation results and that the promotion impact of EID on enterprises' EE is not influenced by random. The conclusion of the baseline regression is robust.

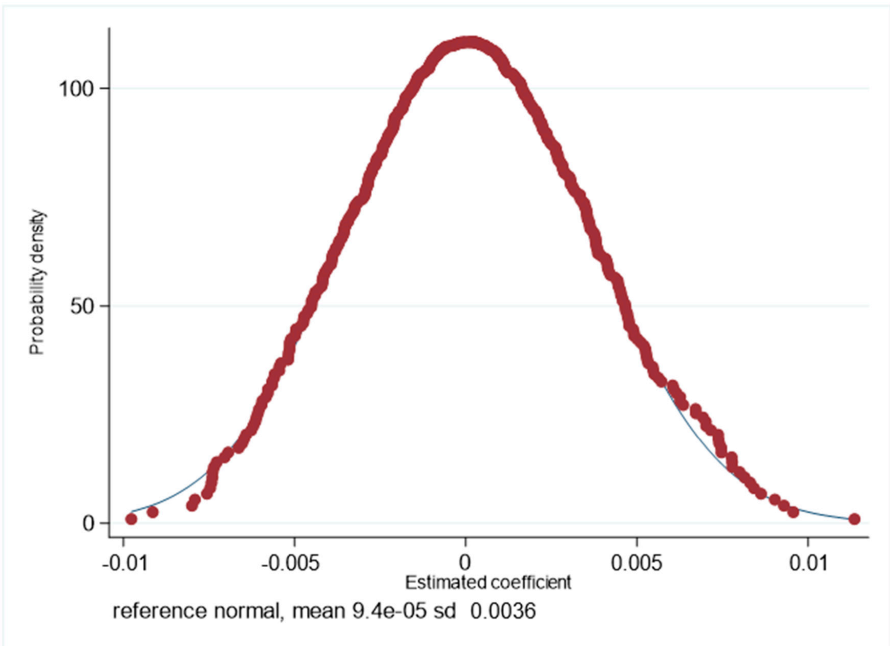

Figure 3. Placebo test.

4.3.2. A Series of Robustness Tests

To further verify the reliability of our findings, we perform a series of additional robustness tests, including advancing the policy year, replacing the single-factor energy efficiency indicator, excluding the four municipalities' samples, and expanding the sample interval.

Firstly, we conduct the counterfactual test by advancing the year of PITI release by one year, setting the year of dummy policy implementation as "adv", and generating "EID_adv" as the alternative interaction item, which represents the year of dummy policy implementation and the treatment group. As can be seen from column (1) of Table 3, the interaction term's coefficient "EID_adv" is not significant, indicating that the new interaction term cannot significantly affect enterprises' energy efficiency if the implementation year of the policy is advanced by one year. Thus, the results of the benchmark regression are robust.

Table 3. Robustness test.

	(1) Advancing the Policy Year	(2) Replacing the Single-Factor Energy Efficiency	(3) Excluding the Four Municipalities' Sample	(4) Expanding the Sample Interval
EID_adv	0.021			
	(0.857)			
EID		0.034 **	0.032 ***	0.035 ***
		(2.569)	(3.964)	(4.517)
Control	Y	Y	Y	Y
Firms FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
City FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
N	155,237	155,237	155,237	155,237
Adj-R^2	0.514	0.586	0.618	0.543

Notes: *** $p < 0.01$, ** $p < 0.05$, and the *t*-value is in parentheses.

Secondly, replace the explained variable. This paper examines the GTFEE of 113 pilot city enterprises of PITI as a proxy for EE by using data envelopment analysis. Therefore, similar to [5], we utilize single-element EE as the measurement. As shown in column (2), the estimations are still significant when replacing the dependent variable, indicating the benchmark results are robust. Thirdly, considering the specificity of municipalities, this study excludes the sample of enterprises in four municipalities: Beijing, Tianjin, Shanghai, and Chongqing. Column (3) shows that the results are still significant after eliminating the special samples, further indicating the robustness of the results. Fourthly, we extend the research period from 2003–2014 to 2001–2014. The results are shown in column (4), and after changing the time range, the results remain significant, further testing the robustness.

5. Further Discussion

5.1. Mechanism Analysis

Table 4 presents the mechanism tests. Columns (1)–(4) reveal the energy structure mechanism of EID on energy efficiency. EID significantly reduces the consumption of coal, a highly polluting energy, and significantly increases the use of clean gas, a low-polluting energy. The results suggest that EID can promote energy efficiency by optimizing enterprises' energy structures. The economic explanation for this may lie in the fact that EID can bring about public scrutiny and force companies to disclose more information about their green governance. Therefore, enterprises would reduce their consumption of high-polluting energy sources, such as coal, and add up their use of low-polluting energy sources, such as clean energy. This helps reduce the emission of pollutants, optimizing their power structure, and promoting EE within firms. The above result is similar to that of [5], confirming Hypothesis 2 and proving the validity of energy structure.

Table 4. Mechanisms test.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**Coal**	**Coal**	**Clean Gas**	**Clean Gas**	**Technology Innovation**	**Technology Innovation**
EID	−0.025 **	−0.022 **	0.066 **	0.058 **	0.065 **	0.060 **
	(−2.265)	(−1.972)	(2.408)	(2.506)	(1.990)	(1.970)
_cons	7.284 ***	5.499 ***	0.125 ***	1.159 **	1.808 ***	1.893 ***
	(3.504)	(2.904)	(2.125)	(1.359)	(2.054)	(2.322)
Control	N	Y	N	Y	N	Y
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
N	155,237	155,237	155,237	155,237	155,237	155,237
Adj-R^2	0.206	0.307	0.152	0.252	0.453	0.563

Notes: *** $p < 0.01$, ** $p < 0.05$, and the *t*-value is in parentheses.

Columns (5) and (6) reveal the technological innovation channels of EID on enterprises' GTFEE. The results show that the influence of EID on the firms' technology innovation is at a 5% level, indicating that EID can positively improve energy efficiency by promoting firms' technology innovation. The possible reason is that EID generates a positive "innovation compensation effect". It stimulates enterprises to improve technological innovation to prevent pollution and promotes the productivity of enterprises, which facilitates the improvement of GTFEE. The above analysis is similar to that of [41], proving the validity of energy structure, and Hypothesis 3a is also confirmed.

5.2. Heterogeneity Analysis

5.2.1. Regional Heterogeneity

Since there are obvious regional imbalances in China's economic development, the impacts of EID on EE are discrepant in different economic zones. This paper divides cities into three areas: eastern, central, and western regions, and further conducts heterogeneity analysis separately. Just as the results in Table 5, EID positively influences firms' energy efficiency in eastern and central regions compared to western regions. This may be because eastern cities are located in the coastal areas, which are greatly developed and rich in resources due to the proximity to international trade opportunities. As a result, enterprises in eastern and central cities have advanced their energy use technologies, significantly reduced excessive energy consumption, and effectively improved their energy efficiency.

Table 5. Regional heterogeneity.

	(1)	(2)	(3)
	Eastern	**Central**	**Western**
EID	0.049 ***	0.032 *	0.060
	(4.555)	(1.758)	(1.452)
_cons	2.407 ***	1.701 ***	2.054 ***
	(3.244)	(1.035)	(1.412)
Control	Y	Y	Y
Firms FE	Y	Y	Y
Year FE	Y	Y	Y
City FE	Y	Y	Y
Industry FE	Y	Y	Y
N	93,921	38,011	23,305
Adj-R^2	0.612	0.417	0.598

Notes: *** $p < 0.01$, * $p < 0.10$, and the *t*-value is in parentheses.

5.2.2. Enterprise-Type Heterogeneity

The GTFEE of enterprises with different characteristics will have discrepant behavioral responses to EID. Therefore, we test different types of manufacturing enterprises affected by EID according to whether they are state-owned enterprises, exporting enterprises, high energy consumption enterprises, and polluting enterprises.

As shown in Table 6, column (1) explains that EID plays a smaller role in promoting GTFEE in state-owned enterprises than in non-state-owned enterprises. This may be because, under the policy shock, state-owned enterprises have been accustomed to EID, making the marginal impact of energy efficiency improvement lower than that of non-state-owned enterprises. Therefore, they have greater social responsibility and must pay more attention to environmental issues.

Table 6. Enterprise-type heterogeneity.

	(1)	(2)	(3)	(4)
	State-Owned	**Export**	**High Consumption**	**Polluting**
EID	0.045 ***	0.031 ***	0.075 ***	−0.279 ***
	(5.413)	(3.520)	(8.335)	(−8.069)
EID × State owned	−0.144 ***			
	(−8.030)			
EID × Export		0.022 **		
		(1.987)		
EID × High cons			−0.091 ***	
			(−10.820)	
EID × Polluting				0.318 ***
				(9.261)
_cons	2.114 ***	2.127 ***	1.815 ***	1.142 ***
	(5.246)	(4.514)	(3.284)	(3.826)
Control	Y	Y	Y	Y
Firms FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
City FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
N	155,237	155,237	155,237	145,327
Adj-R^2	0.382	0.416	0.217	0.336

Notes: *** $p < 0.01$, ** $p < 0.05$, and the *t*-value is in parentheses.

Column (2) shows that EID improves firms' GTFEE more for export firms than non-export firms. This may be because export enterprises face stricter international green export standards. As a result, with EID, export enterprises are more motivated to prevent energy consumption and use clean energy. Therefore, EID has a more significant promotion in export enterprises' GTFEE. Columns (3) and (4) demonstrate that the EID has a better impact on the firms' GTFEE with low consumption and high pollution. This may be because the government's ERs have a more positive effect on low-energy-consuming enterprises rather than high-energy-consuming ones. The production process of enterprises in high-pollution industries consumes a significant amount of highly polluting energy, while enterprises in clean industries mostly use new energy sources having lower emissions. However, EID aims to monitor the excessive use of highly polluting energy materials, such as coal, which limits the productivity of enterprises in highly polluting industries. An effective way to restore productivity is to improve the energy mix or increase energy efficiency [42]. Therefore, EID can more effectively promote GTFEE in polluting enterprises than in clean enterprises.

6. Conclusions and Policy Implications

Improving energy efficiency is a necessary step to achieve enterprises' green sustainable development, and the implementation of EID is beneficial for governments to make more environmentally friendly decisions and help enterprises effectively improve the GTFEE. This study uses the DID method and evaluates the effect of EID on manufacturing GTFEE. The empirical estimations show that the release of PITI can significantly improve manufacturing enterprises' GTFEE. This finding remains robust after a series of robustness tests, such as parallel trend, placebo, and counterfactual. An in-depth analysis of the mechanisms reveals that EID can significantly improve firms' GTFEE by promoting technological innovation and energy structure. In addition, considering that regional and enterprise-type heterogeneity may lead to different effects of EID on energy efficiency, we conduct heterogeneity tests to verify the regional and enterprise-type heterogeneity analyses which indicate that, compared to the western regions, EID has a more positive effect on firms' GTFEE in the eastern and central regions. The positive impact is greater for non-state-owned, low energy consumption, export, and polluting enterprises.

Although this study has proposed that EDI has a positive role in promoting enterprise green total factor energy efficiency and investigated the role channels from the two dimensions of technological innovation and energy structure, the boundary conditions affecting the relationship between EDI and enterprises' GTFEE have not been further revealed. Future directions can further investigate the boundary conditions affecting the relationship between the two based on the theoretical basis. For example, from the perspective of internal and external enterprises, the regulatory role of environmental regulations and the level of digitalization of enterprises can be investigated to further enrich relevant studies.

Based on these conclusions, we propose the following policy implications. Firstly, increasing the intensity and scope of EID. The core finding shows that EID can achieve the dual effect of reducing emissions and improving energy efficiency. Therefore, it is vital to expand the scope of EID by increasing PITI cities and further improving the intensity and quality of EID. At the same time, the government should intensify the supervision of EID for enterprises to realize long-term sustainable development. Secondly, the government should make full use of the influencing mechanisms of EID on EE. Considering green innovation's role in promoting energy efficiency, it is feasible for the government to adopt incentive policies to stimulate enterprises' green innovation. For enterprises, they need to invest capital in technology innovation and realize enterprise technical cooperation to improve their energy efficiency. At the same time, firms should reduce their high-pollution energy consumption, such as coals, and increase their use of clean energy, optimizing the energy structure to promote energy efficiency. Thirdly, the government can implement targeted regional strategies. To achieve regional energy conservation, it is important to implement relevant policies that are tailored to the specific energy efficiency situation in each region. Due to the obvious regional imbalance in China's economic development, the effects of EID on energy efficiency are discrepant in different areas. Considering the empirical fact that the impact of promoting EID in eastern cities on enterprises' EE is better than that in the other two regions, it should play a leading role in the eastern region to improve the overall energy efficiency level in China. Fourthly, at the enterprise level, this study shows that EID has a greater positive impact on non-state-owned enterprises, low-energy enterprises, export enterprises, and polluting enterprises. Therefore, such enterprises should make use of their unique advantages, actively respond to EID policies, and improve their own GTFEE. In particular, enterprises should proactively, regularly, and accurately disclose their environmental information, including energy consumption, pollutant discharge, and waste treatment, and establish a sound internal environmental management system to ensure the authenticity and integrity of environmental information to achieve sustainable development.

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