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Can Informal Environmental Regulation Promote Urban Green Economy Efficiency? A Quasi-natural Experiment from Environmental Information Disclosure

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Abstract

In this article, we construct the Green Economy Efficiency Index to evaluate the efficiency of the green economy in Chinese prefectural cities and above from 2006 to 2021. This evaluation employs the non-radial directional distance function within the framework of super-efficiency Data Envelopment Analysis (DEA). We empirically analyze the impact of environmental information disclosure on urban green economy efficiency using Difference-in-Differences (DID) and Propensity Score Matching-Difference-in-Differences (PSM-DID) methods in a quasi-natural experiment. This experiment involves the Institute of Public and Environmental Affairs (IPE), which disclosed information regarding pollution source regulation in selected cities in 2008. The results indicate that: (1) Environmental information disclosure significantly enhances urban green economy efficiency, and this conclusion demonstrates strong robustness; (2) The mediating mechanism test reveals that environmental information disclosure improves urban green economy efficiency by fostering green innovation and attracting foreign direct investment. Therefore, China should further enhance and refine its environmental information disclosure system, increase policy support for green innovation, actively leverage foreign direct investment to promote green development, strengthen the capacity of local government environmental governance, and ensure the effective implementation of environmental information disclosure policies to advance the development of the green economy.

Keywords

Environmental information disclosure, Green economy efficiency, Green innovation, Foreign direct investment, Difference-in-Differences model

1. Introduction

During the forty years of reform and opening up, China has realized sustained and rapid economic growth, and has maintained a medium-to-high average annual growth rate of over 6 percent since the economy entered the "new normal". However, economic growth has been accompanied by environmental pollution and energy depletion, which have constrained sustainable economic development. In recent years, the average concentration of air pollutants in China has seen "three decreases, two flats and one rise", with ozone concentration fluctuating and rising, and sulfur dioxide concentration basically flat, but the results of the improvement are not solid, and the country is facing the pressure of increasing pollutant emissions. In terms of energy consumption,

China is the world's largest energy consumer, and the total energy consumption is increasing year by year, and fossil energy consumption remains high. The 19th CPC National Congress report clearly put forward to realize green development, green development is the development of maximum economic and social benefits at the cost of minimum resources and environment, China's economic development should be shifted to green development in the future with comprehensive consideration of economic growth, environmental protection, and resource conservation, which will help to better ecological civilization construction [1].

The "14th Five-Year Plan" clearly points out that it is necessary to increase the disclosure of environmental information, strengthen the construction of corporate environmental governance system, improve the public supervision and reporting feedback mechanism, and guide social organizations and the public to participate in environmental governance. Environmental information disclosure is the third means of environmental regulation after the command-and-control and market-oriented environmental regulation, the introduction of public participation in environmental governance to a certain extent to solve the problem of unsatisfactory implementation of formal environmental regulation [2]. As a form of informal environmental regulation, how is the impact on China's green development?

Thanks to the protection of the state at the level of environmental laws, especially the implementation of the “Measures for the publicity of environmental information (for Trial Implementation) in 2008, some civil environmental non-governmental organizations (NGOs) have gradually appeared on the public horizon. The most representative organization is the Institute of Public and Environmental Affairs (IPE), founded in 2006, which, together with the Natural Resources Defense Council (NRDC), developed the Pollution Information Transparency Index (PITI) to evaluate the environmental information of Chinese cities for the first time, and released the first report in 2008, which has been continuing until now, reflecting the active efforts of civil environmental NGOs to participate in environmental governance. This article attempts to answer the following questions through an empirical study of the relationship between environmental information disclosure and green economy efficiency in Chinese cities at the prefecture level and above: First, how does environmental information disclosure affect urban green economy efficiency? Second, through which path is the impact of environmental information disclosure on urban green economy efficiency transmitted?

2. Literature Review

In recent years, many scholars have studied the relationship between environmental regulation and green economy efficiency. The impact of environmental regulation on green economy efficiency is still controversial, and can be mainly divided into three categories based on the conclusions: Firstly, environmental regulation has a promoting effect on green economy efficiency, which follows the Porter hypothesis. Environmental regulation directly promotes the improvement of green economy efficiency [3], or there is a "U-shaped" nonlinear relationship [4], which reflects the promoting effect in the long run; Secondly, environmental regulations hinder the improvement of green economy efficiency [5], which is supported by the "cost increase hypothesis". The revision cost of environmental regulations is relatively high nationwide, making it difficult to effectively improve green economy efficiency; Thirdly, this impact is uncertain and may be related to the selection of different environmental regulatory policies. Heterogeneous environmental regulations have different impacts on green economy efficiency. Heterogeneous environmental regulation produces different outcomes on green economy efficiency, and to further refine the relationship between them, some studies have classified environmental regulatory instruments into three types: administrative, market-oriented, and public participation tools [6, 7]. The limitations of the above studies are that they do not take into account the fact that environmental information disclosure combines the advantages of both public participatory and voluntary environmental regulatory tools [6], and there is a lack of research on how environmental information disclosure affects green economy efficiency.

Some scholars believe that the landing point of environmental information disclosure is to improve the level of corporate disclosure and study the impact of environmental information disclosure on the economic and environmental performance of enterprises from the micro level of enterprises. Wang et al. used the data of enterprises in the heavy pollution industry from 2013-2017 to construct an environmental information disclosure index to study the impact of environmental information disclosure quality on enterprise value and found that improving the quality of environmental information disclosure can significantly enhance enterprise value [8]. Meng et al. took the 2011-2015 heavily polluted listed companies as a research sample, took the quality of environmental information disclosure as a moderating variable, and found that there was a significant moderating effect of environmental information disclosure on the relationship between executive characteristics and corporate environmental performance [9]. Such studies do not consider environmental information disclosure as an environmental regulatory tool and focus only on examining the impact of environmental disclosure on corporate economic and environmental performance, respectively, which cannot fully explain the connotation of the green economy. From the perspective of research progress, some scholars are concerned about the role of environmental information disclosure in regional economic development and environmental protection. Qiao et al. used 248 cities at or above the prefecture level from 2005 to 2017 as research samples and concluded that environmental information disclosure significantly inhibits the high-quality development of the urban economy [10]. Li et al.

narrowed down the research sample to cities in the Yangtze River Economic Belt and found that environmental information disclosure is beneficial for improving the level of high-quality economic development [11]. Liu et al. evaluated the policy effect of environmental information disclosure on industrial pollutant reduction using the Difference-in-Differences model (DID) and found that environmental information disclosure has a significant pollution reduction effect [12]. Yan Zhijun et al. studied the relationship between environmental information disclosure and energy efficiency, and the results showed that environmental information disclosure policies have a significant positive impact on improving urban total factor energy efficiency [13]. Pan Xuwen et al. found that environmental information disclosure can lower local governments' economic growth targets, increase environmental protection efforts as an alternative, and promote actual regional economic growth [14]. The limitation of existing research is that existing literature only studies the impact of environmental information disclosure from the aspects of economic development, energy conservation, environmental protection, etc., and has not yet incorporated the evaluation of green economy into a DEA model with multiple input factors and multiple outputs to explore the impact of environmental information disclosure on green economy efficiency.

A small amount of literature has studied the relationship between environmental information disclosure and green economy efficiency. Liu (2021) studied the impact of environmental information disclosure on green development efficiency based on data from 278 cities in China from 2005 to 2017 and found that environmental information disclosure improves green development efficiency by improving urban innovation levels and reducing environmental pollution levels [15]. Lin measured green economy efficiency of 113 cities in China from 2008 to 2018 based on the Malmquist index, which includes unexpected outputs. The Pollution Information Transparency Index (PITI) was used to represent the level of urban environmental information disclosure, and it was found that there is a "U"-shaped nonlinear relationship between environmental information disclosure and urban green economy efficiency [16].

Compared with the existing studies, the possible contributions of this article are as follows: Firstly, with the help of environmental information disclosure, which is an event with the nature of a "quasi-natural experiment", the causal relationship between environmental information disclosure and green economy efficiency is verified by using DID, which can effectively solve the problem of endogeneity brought by PITI and other assessment indexes. Second, the super-efficiency SBM model based on non-expected output is used to select industrial sulfur dioxide, industrial dust, and industrial wastewater as indicators to measure the pollution brought by economic development, and to measure the green economy efficiency of 282 prefectural-level cities and above in China from 2006 to 2021. Thirdly, from the perspective of the green innovation effect and the foreign direct investment effect, it clarifies the path of environmental information disclosure on urban green economy efficiency, which will help to open the "black box" of this kind of environmental regulatory tool for green economic development.

3. Research Hypothesis

3.1 The direct impact

Environmental information disclosure (EN) is a voluntary environmental regulation aimed at enhancing the transparency of regional environmental information, incorporating central government and public supervision into the environmental governance system, and providing stronger supervision over the implementation of local government's green economy development goals and enterprise energy conservation and environmental protection [14, 15]. Specifically, at the public level, environmental information disclosure enables the public to distinguish polluting enterprises from clean enterprises. As the public's environmental awareness gradually increases, more attention is paid to green consumption, which plays a role in guiding enterprises to transform into green and produce green products [17]; Providing an important basis for public supervision of government environmental performance and corporate environmental compliance, reducing the possibility of rent-seeking phenomena such as government enterprise collusion, and improving regional energy performance and pollution reduction performance from the perspective of reducing unnecessary losses [18]. At the government level, the disclosure of environmental information enables the central government to comprehensively evaluate the effectiveness of regional economic growth and ecological protection work when assessing local officials, encouraging local governments to weaken economic goals and pay more attention to the achievement of environmental goals, and promoting the development of green economy [14]. Local government officials will require polluting enterprises within their jurisdiction to adopt long-term mechanisms to control pollution, improve the quality of the ecological environment, attract a large number of high value-added, high-efficiency, and low pollution industrial clusters, and actively guide the transformation and upgrading of the industrial structure to obtain multiple benefits such as economic growth, energy conservation, and pollution reduction [14, 19]. At the corporate level, companies that proactively disclose environmental information can receive policy support, while intentionally concealing high pollution and energy consumption behaviors will face government penalties and negative public evaluations. The combination of environmental information disclosure and government regulatory measures promotes the internalization of negative externalities of pollution behavior. Enterprises need to incorporate environmental factors into their production and operation decisions, weigh the benefits of improving environmental performance

and exiting the market [16, 20]; With the improvement of environmental information transparency, local and foreign enterprises can evaluate whether they have a competitive advantage in clean production, attract more clean production technology enterprises to enter the region, and make backward enterprises in the region exit the market [21]; at the same time, areas without environmental information disclosure tend to adopt "bottom-up competition" to attract high polluting and high energy consuming enterprises to enter, promoting the upgrading of the industrial structure of areas with environmental information disclosure towards low energy consumption and high output. In short, environmental information disclosure reduces information asymmetry among economic entities, guides local governments to set sustainable development goals, increases public demand for green products, and encourages enterprises to prioritize environmental goal achievement, promoting the development of a green economy in areas with environmental information disclosure.

Based on the above analysis, the following hypothesis is proposed:

H1: Environmental information disclosure regions place greater emphasis on economic sustainability, which enhances urban green economy efficiency.

3.2 The mediating effect

3.2.1 Green innovation effect

Green innovation (GINN) refers to technological innovation that saves resources and energy, minimizes ecological negative effects, and is an essential part of green economic development. From an industrial perspective, enterprises are the main body of GINN. Green technology innovation plays a role in promoting the transformation of industries from traditional resource-intensive to knowledge-intensive technologies, reducing the dependence on energy and environmental pollution in the production process of enterprises [15]. From a regional perspective, knowledge spillover promotes the overall improvement of GINN capabilities in the region, enabling more GINN to occur within the region, further enhancing the green production level of enterprises, and improving the GINN within the region. Especially at the urban level, due to the substitution effect of knowledge-intensive technologies, cities have reduced their demand for population, which is the main factor in urban construction. The decrease in construction demand has led to resource waste and a reduction in pollutant emissions during the urbanization process [22]. In short, the improvement of green innovation is a process in which green technology innovation guides the green transformation of enterprises and industrial structures in the region, and promotes the development of the economy towards energy conservation and pollution reduction. Therefore, increased green innovation improves urban green economy efficiency.

Environmental information disclosure may promote the GINN behavior of enterprises from two aspects. On the one hand, the disclosure of environmental information conforms to the characteristics of public participation in environmental regulations, which can enhance the attention of local governments to environmental protection and local governments continuously promote the innovation and development of green technologies through the formulation of various policies. According to the "weak Porter hypothesis", properly designed environmental regulations may promote innovation activities [23], and local government's adoption of pre-incentive and post-penalty measures for GINN by enterprises will have a promoting effect [24]; The Natural-Resource-Based View of the firm points out that when facing government environmental regulation such as collecting sewage fees, enterprises need to consider environmental constraints to build their own competitiveness. They need to weigh the cost of pollution and the cost of adopting GINN. Achieving GINN is more sustainable than reducing production scale, purchasing sewage treatment equipment, and other pollution prevention measures [20, 25]. On the other hand, environmental information disclosure plays a role in alleviating the financing needs of enterprises for GINN. Enterprises in environmental information disclosure areas have the advantage of continuously and stably disclosing information, which helps investors grasp the real performance of the enterprise's environment, avoid sudden exposure to investment risks caused by excessive pollution, and gain more investment attention from stakeholders [26]; Increasing environmental investment by enterprises may lead to a decrease in market competitiveness in the short term, but improving environmental performance is expected to yield more long-term returns [27]; Therefore, enterprises can improve the quality of environmental information disclosure, obtain larger scale, longer term, and lower cost green credit, enjoy local government incentives policies such as tax reductions and environmental subsidies, and alleviate the problem of insufficient funds faced by enterprises in carrying out GINN activities [19]. Based on the above analyses, it can be expected that there is a causal chain between environmental information disclosure, green innovation improvement, and green economy efficiency enhancement. Therefore, hypothesis 2 is proposed:

H2: Environmental information disclosure regions enhance green economy efficiency by improving green innovation.

3.2.2 Foreign direct investment effect

Related studies suggest that foreign direct investment (FDI) inflows have the effect of promoting regional capital stock accumulation, increasing employment, and technological progress, and have a positive impact on both economic efficiency and environmental efficiency. Green economy efficiency is the result of considering the combined effects of both factors [28]. When FDI reaches a certain scale, industrial agglomeration significantly has a positive impact on the regional economy and environment

[29]; Furthermore, scholars believe that the role of FDI in green economy efficiency is achieved through economies of scale, technological effects, and structural effects [30, 31]. The scale effect increases the industrial scale, forms broader industrial connections, improves energy utilization efficiency, and brings economic growth, but also causes pollution problems to a certain extent; Due to technological effects, the technology spillover generated by FDI brings advanced clean technologies and management systems to local enterprises, which helps to improve environmental pollution problems; At the same time, FDI can promote industrial structure upgrading in the short term, while the long-term effect depends on the type of FDI. With the optimization of the regional foreign direct investment structure, the structural effect promotes the development of a green economy [32-34]. In short, FDI can promote the upgrading of regional industrial structure and industrial agglomeration, and enhance green economy efficiency.

There is currently no consensus on the impact of environmental information disclosure on FDI. Some studies indirectly support the "pollution paradise hypothesis", which suggests that areas with environmental information disclosure will reduce FDI inflows, while this is not the case in other studies. This is due to the government's investment strategy, which causes FDI to shift from areas with environmental information disclosure to non-public areas [35]. However, from a long-term perspective, regions with open environmental information can attract more FDI. Multinational enterprises need to consider environmental factors when investing, and FDI focuses more on the market capacity, related industries, and institutional environment of the region. The disclosure of environmental information reduces the cost of multinational corporations collecting environmental information, improves the transparency and reliability of environmental information, provides a high-quality investment environment, and promotes the formation of long-term cooperative relationships between multinational corporations and local enterprises in green production [21]. At the same time, the entry of FDI also needs to consider the market environment. The increase in demand for green products in regions with open environmental information may encourage market-seeking FDI inflows [33]. Based on the above analysis, it can be expected that the causal chain of environmental information disclosure, increased foreign direct investment, and improved green economy efficiency exists. Therefore, hypothesis 3 is proposed:

H3: Environmental information disclosure can enhance urban green economy efficiency by attracting foreign direct investment.

4. Research Design

4.1 Sample selection and data sources

The research sample of this article is 282 prefecture-level cities and above in China from 2006 to 2021. The following screening methods were applied to the sample: (1) excluding observation samples with missing data or key urban statistical data are excluded, as the lack of key data cannot complete empirical research. (2) conducting a 1% truncation process on all continuous variables in order to eliminate the influence of extreme values on the regression results.

The list of pilot cities for environmental information disclosure comes from the annual PITI index report released by the Institute of Public and Environmental Affairs (IPE) and the Natural Resources Defense Council (NRDC), while the rest of the data comes from the China Urban Statistical Yearbook and CEIC Data.

4.2 Variable measurement

4.2.1 Dependent variable

The dependent variable of this article is green economy efficiency (GEE), which refers to Lin Boqiang's framework for assessing environmental technology in each city as a decision-making unit [1], and refers to Li Jianglong's use of the super-efficient DEA model for the calculation and its input-output weights vector weights setting [36]. The data used to calculate this indicator are capital, labor, energy, GDP, industrial wastewater, industrial sulfur dioxide, and industrial smoke and dust. The capital stock data are calculated using the perpetual inventory method, and the raw data required are fixed asset investment in cities at all levels and above, from the CEIC China Economic Database; the capital stock data for each city in the base period (2000) are estimated by Ke [37]; and the depreciation rate of the capital stock is considered to be the same for each city in the same province, which is also from Ke [37].

4.2.2 Independent variable

The main independent variable in this article is environmental information disclosure (EN), which is a variable constructed from the cross-multiplication term of Treat and Post, where Treat = 1 if it is a city in the list and 0 otherwise, and Post = 1 if the year of observation is in 2008 and later, and 0 otherwise. The main independent variables are based on the PITI, jointly developed by two independent research institutions: The Institute of Public and Environmental Affairs (IPE) and the Natural Resources Defense Council (NRDC). The IPE and NRDC have evaluated 113 cities their pollutant emission regulatory information transparency situation since 2008 and published a PITI report, which was China's first civil government environmental information transparency evaluation report. PITI information disclosure can be viewed as a quasi-natural experiment, with 113 cities as a treatment group, and the cities uncovered in the PITI list as a control group.

4.2.3 Intermediate variables

(1) Green innovation (GINN)—in this study, the total number of green invention and green utility model patents filed in the city year plus 1 to take the logarithm represents the level of green innovation.

(2) Foreign direct investment (FDI)—measured using the amount of foreign direct investment actually used by the city in the year.

4.2.4 Control variables

The control variables for this article are Regional economic development (PGDP), Industrial structure (PSI), Fiscal regulation (GOV), and Urbanization (UR). The specific measurement method is shown in Table 3.

4.3 Model settings

$$GEE_{it} = \beta_0 + \beta_1 EN_{it} + \beta_2 Treat_{it} + \beta_3 Post_{it} + \beta_4 Control_{it} + \delta_t + \mu_i + \varepsilon_{it} \quad (1)$$

$$GINN_{it} = \beta_0 + \beta_1 EN_{it} + \beta_2 Treat_{it} + \beta_3 Post_{it} + \beta_4 Control_{it} + \delta_t + \mu_i + \varepsilon_{it} \quad (2)$$

$$FDI_{it} = \beta_0 + \beta_1 EN_{it} + \beta_2 Treat_{it} + \beta_3 Post_{it} + \beta_4 Control_{it} + \delta_t + \mu_i + \varepsilon_{it} \quad (3)$$

Among them, $Control_{it}$ are various control variables, δ_t are time fixed effects, μ_i are city fixed effects, and, $\varepsilon_{it}$are random disturbance terms.

5. Empirical Analysis

5.1 Descriptive statistics

Table 1 presents the descriptive statistical results. The median of GEE is 0.297, slightly lower than the mean of 0.322, indicating a slightly skewed data distribution, but overall showing a certain normal distribution trend. Since there is a large gap between the maximum value of 1.007 and the mean value of 0.322, and the standard deviation is 0.126, it indicates that there are large differences in GEE. Further analysis shows that the top 5 cities with the average GEE for all observed years in the sample are Maoming, Shenzhen, Ordos, Sanya, and Changde. The bottom 5 cities are Guiyang, Xining, Yinchuan, Shizuishan, and Wuzhong. The number of observation values with an EN value of 1 is 1593, which means that the proportion of observation values in pilot cities and time periods is 38.45%.

Table 1. Descriptive Statistics

Variable	Obs.	Mean	Std.	Min	Median	Max
GEE	4143	0.322	0.126	0.141	0.297	1.007
EN	4143	0.385	0.487	0.000	0.000	1.000
Treat	4143	0.435	0.496	0.000	0.000	1.000
Post	4143	0.887	0.317	0.000	1.000	1.000
GINN	4143	4.032	1.761	0.693	3.970	8.371
FDI	4143	54.893	112.237	0.038	13.949	707.407
PGDP	4143	10.528	0.686	8.865	10.549	12.008
PSI	4143	0.471	0.103	0.195	0.474	0.727
GOV	4143	0.175	0.078	0.064	0.156	0.455
UR	4143	0.416	0.183	0.134	0.376	0.995

5.2 Correlation analysis

Table 2 shows the results of the correlation test. The correlation coefficient between the vast majority of variables does not exceed 0.5, indicating that there is no issue of multicollinearity between variables in regression analysis. The correlation coefficient between EN and GEE is significantly positive at the 1% statistical level, which preliminarily supports the research hypothesis of this article. The significance level of most variables in the overall correlation analysis results is 1%, indicating good correlation analysis results.

5.3 Benchmark regression analysis

Columns (1) and (2) in Table 4 report the results of the benchmark regression. The regression coefficient of EN in column (1) is 0.026, which is significantly positive at the 1% statistical level, indicating a significant positive causal relationship between EN and GEE. This suggests that environmental information disclosure is beneficial for significantly improving urban green economy efficiency, which is supported by H1. In column (2) on the basis of column (1), control variables are introduced, and the regression coefficient of EN is 0.024. Although the coefficient has decreased slightly, it is still significant, and the conclusion remains unchanged.

Table 2. Correlation Analysis

	GEE	EN	GINN	FDI	PGDP	PSI	GOV	UR
GEE	1.000							
EN	0.202***	1.000						
GINN	0.377***	0.418***	1.000					
FDI	0.264***	0.377***	0.483***	1.000				
PGDP	0.414***	0.479***	0.352***	0.460***	1.000			
PSI	-0.159***	0.065***	-0.127***	-0.083***	0.109***	1.000		
GOV	-0.139***	-0.284***	-0.222***	-0.179***	-0.268***	-0.457***	1.000	
UR	0.190***	0.404***	0.489***	0.450***	0.436***	-0.054***	-0.230***	1.000

Notes: P-value < 0.01 marked as * * *; P-value < 0.05 marked as * *; P-value < 0.1 marked as *.

5.4 Robustness test

5.4.1 Replace variables

In benchmark regression, the super-efficient SBM model is used to measure GEE, while in column (3), the super-efficient CCR model is used to measure it. The results show that the regression coefficient of EN is still significantly positive, and the conclusion is robust.

Table 3. Variables

Variable type	Variable	Variable symbol	Variable Declaration
Dependent variable	Green economy efficiency	GEE	Measured using both super-efficient SBM and super-efficient CCR models
Independent variable	Environmental information disclosure	EN	The cross-multiplication term of Treat and Post constructs a DID variable
	Pilot cities	Treat	Assign a value of 1 if it is a city in the PITI list, otherwise 0
	Pilot time	Post	Assign a value of 1 if the year of observation is 2008 or later, and 0 otherwise
Mediator	Green innovation	GINN	Total number of green invention and green utility model patents filed in the city year plus 1 to take the logarithm
	Foreign direct investment	FDI	Amount of foreign capital actually utilized in the year (billions of yuan)
Control variables	Regional economic development	PGDP	Logarithmic regional GDP per capita
	Industrial structure	PSI	Regional secondary GDP/Gross Regional Product
	Fiscal regulation	GOV	Regional general public budget expenditures/ Regional GDP
	Urbanization	UR	Regional non-agricultural population/Regional household population at the end of the year

5.4.2 PSM-DID

To achieve a randomized equilibrium treatment for confounding factors in nonrandomized studies and reduce selection bias, this study used propensity score matching (PSM-DID) for robustness testing, with covariates as all control variables mentioned above. Using the Logit model for regression, and based on the obtained conditional probabilities, further sample matching was

performed through kernel matching. There was a significant difference between the pre-treatment group and the control group before matching (unmatched p>chi2=0.000), while there was no significant difference between the post-treatment group and the control group after matching (matched p>chi2=0.536). This indicates that after matching, the treatment group and the control group have heterogeneity in the six characteristics of covariates. The figure shows the distribution of % bias values of covariates before and after matching. It can be seen that the % bias values of all covariates are less than 10%, and they are significantly smaller than the% bias values before and after matching.

The conclusion drawn from the P values before and after kernel density matching is consistent with the above. The regression results based on the matched samples are shown in column (9) of Table 4, and the regression coefficient of EN is still significantly positive, indicating a robust conclusion.

5.4.3 Parallel trend test

The premise for the validity of the model conclusion is that the model passes the parallel trend test, that is, there is no significant difference in GEE between the experimental group and the control group before policy implementation. Prior to policy implementation, the confidence intervals of the core explanatory variables all contained 0 and were not significant, indicating that the Pilot cities and other cities had consistent trends in GEE changes before policy implementation. After three years of policy implementation, there was a significant difference in GEE between the experimental group and the control group, indicating that the environmental information disclosure can effectively improve urban green economy efficiency, and the model satisfies the parallel trend assumption. The result is shown in Figure 1.

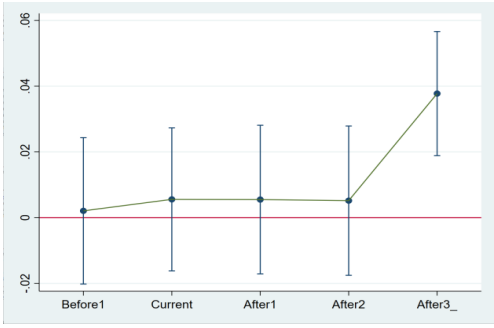

Figure 1. Parallel Trend Test.

5.4.4 Placebo test

To eliminate the interference of other unobservable factors in the evaluation of the effectiveness of environmental information disclosure, this article adopts a placebo test of randomized policy shocks to verify whether environmental information disclosure will have an impact on the green economy efficiency of pilot cities. The specific idea is to randomly select the same number of virtual experimental groups based on the actual number of pilot cities in each year, and use the remaining cities as virtual control groups for 1000 simulation estimates. The graph depicts the probability distribution of the estimated coefficients of the fictitious treatment group for pilot cities under 1000 random samples. Among them, the vertical dashed line represents the policy effect of environmental information disclosure policy on the real experimental group, which is 0.024, and the black solid line represents the kernel density curve of the impact coefficient of environmental information disclosure policy on the fictional experimental group. It can be seen that most of the fictional experimental groups are concentrated in positions close to 0 and basically follow a normal distribution, with significant differences in the coefficient of influence from the baseline regression. It can be ruled out that other unobservable factors may interfere with the conclusion, indicating that the conclusion of benchmark regression is effective. The result is shown in Figure 2.

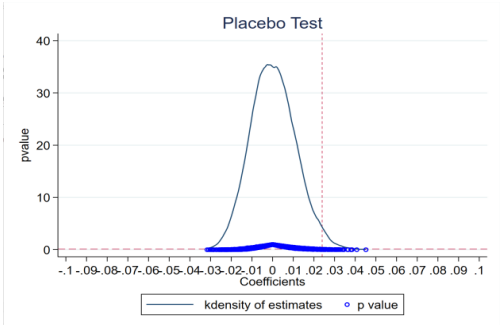

Figure 2. Placebo Test.

5.4.5 Exclude the impact of other policies

To exclude the impact of other policies on GEE in the observed years, this article selects four policies, namely "Smart City", "Broadband China", "Low Carbon City", and "Innovative City", for robustness testing. The regression results of introducing other policies are reported in columns (4) to (8) of Table 4. The results show that after introducing other policies, the regression coefficient of EN is still significantly positive.

Table 4. Benchmark Regression and Robustness Test

	Benchmark Regression		Robustness Test						
			Replacement of the dependence variables	Exclusion of other policy implications					PSM-DID
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	GEE	GEE	GEE	GEE	GEE	GEE	GEE	GEE	GEE
EN	0.026***	0.024***	0.027***	0.024***	0.026***	0.024***	0.020**	0.020**	0.022**
	(0.008)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Smart City				-0.003				-0.004	
				(0.009)				(0.009)	
Broadband China					0.009			0.008	
					(0.010)			(0.009)	
Low Carbon City						-0.007		-0.008	
						(0.008)		(0.008)	
Innovative City							0.014	0.014	
							(0.009)	(0.008)	
Control Variables	N	Y	Y	Y	Y	Y	Y	Y	Y
City Fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year Fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y
Unmatched (p>chi2)									0.000***
Matched (p>chi2)									0.536
N	4143	4143	4143	4143	4143	4143	4143	4143	4016
Adj.R^2	0.669	0.674	0.735	0.674	0.674	0.674	0.675	0.675	0.668

Notes: P-value < 0.01, marked as * * *; P-value < 0.05, mark * *; P-value < 0.1, mark *.

5.5 Mediation effect

Due to the serious endogeneity and low statistical testing efficiency of the traditional three-step testing mechanism, this article adopts the causal inference method proposed by Jiang (2022) for mechanism testing analysis [38]. This section demonstrates the correctness of the mechanism path through which environmental information disclosure ultimately affects urban green economy efficiency through the effects of green innovation and foreign direct investment.

5.5.1 Green innovation effect

The results in column (1) of Table 5 show that the regression coefficient of EN is 0.105 and significant at the 10% level, indicating that environmental information disclosure is beneficial for improving the green innovation of the region. Furthermore, according to the theory of endogenous growth, technological innovation is the endogenous driving force for economic growth. The improvement of green innovation means that more environmental protection technologies can be applied, thereby promoting

resource conservation and environmental protection, reducing pollution emissions in the production process, improving resource utilization efficiency, and improving the greening level and operational quality of the entire economic system. The improvement of green innovation helps optimize industrial structure, promote the transformation of traditional industries towards green and low-carbon, cultivate and develop emerging industries such as energy conservation, environmental protection, and clean production, and ultimately promote the improvement of urban green economy efficiency. The impact of green technology innovation on economic efficiency is mainly reflected in improving resource utilization efficiency and labor production efficiency, expanding production scale, and reducing production costs. Wang pointed out that when a company's own green technology innovation capability is improved, it means that the company can identify, update, and integrate technology resources related to green production in a more timely and efficient manner, and can establish more stable research and development cooperation relationships to enhance the trust between partners, thereby achieving a balance between economic growth and environmental protection while also achieving effective connection, thereby improving green economy efficiency [39]. In summary, environmental information disclosure improves urban green economy efficiency by enhancing green innovation performance, and the green innovation effect exists, which confirms H2.

5.5.2 Foreign direct investment effect

Similarly, the results in column (2) indicate that environmental information disclosure is beneficial in promoting the actual amount of foreign direct investment used in the region that year. Furthermore, in terms of promoting the efficiency of the green economy through foreign direct investment, firstly, the inflow of foreign capital helps optimize the regional industrial structure, drive the flow of resources to high-tech, high-value-added, and low-pollution industrial sectors, promote the green transformation of traditional industries, cultivate and develop green industries such as energy conservation and environmental protection, and thus enhance the green level of industrial structure. Furthermore, foreign-funded enterprises usually have a strong sense of social responsibility and place greater emphasis on environmental protection and sustainable development. The green measures adopted in their production and operation can promote local enterprises to strengthen environmental management, improve resource utilization efficiency, reduce pollution emissions, and promote green economic development. Finally, the inflow of foreign capital can broaden the investment and financing channels in the region, provide financial support for green technology research and development, green infrastructure construction, etc., alleviate the funding bottleneck of green development, and lay the foundation for improving urban green economy efficiency. Therefore, the disclosure of environmental information can improve the urban green economy efficiency by promoting the actual use of foreign direct investment in the current year, and the effect of foreign direct investment attraction exists, which confirms H3.

Table 5. Mediation Effect Test

	(1)	(2)
	GINN	FDI
EN	0.105*	34.683***
	(0.058)	(8.431)
Control Variables	Y	Y
City Fixed	Y	Y
Year Fixed	Y	Y
N	4143	4143
Adj.R^2	0.948	0.843

Notes: P-value < 0.01, marked as * * *; P-value < 0.05, mark * *; P-value < 0.1, mark *.

6. Conclusion and Implications

This article uses DID to discuss the impact of environmental information disclosure on urban green economy efficiency. The research shows that: (1) Environmental information disclosure can significantly improve urban green economy efficiency of pilot areas, and this conclusion has passed a series of robustness tests. (2) Environmental information disclosure mainly affects urban green economy efficiency through the effects of green innovation and foreign direct investment.

Based on the above conclusions, this article proposes the following suggestions: Firstly, the environmental information disclosure system should be further improved and perfected. Specifically, expanding the breadth and depth of environmental information disclosure, and improving the accuracy, timeliness, and accessibility of information. At the same time, strengthen the

construction of environmental information disclosure platforms to promote public participation and social supervision, thereby creating a social atmosphere conducive to green development. Secondly, increase policy support for green innovation. Improve the green technology innovation system, strengthen the collaborative innovation mechanism between industry, academia, research, and application, and encourage enterprises to increase their investment in green research and development through financial and tax incentives. At the same time, promoting the promotion and application of advanced and applicable environmental protection technologies, improving green innovation performance, and providing technical support for enhancing urban green economy efficiency. Thirdly, actively utilizing foreign direct investment to promote green development. Improve the policy system for promoting and protecting foreign direct investment, and guide foreign direct investment towards green industries. Encourage foreign-funded enterprises to adopt advanced environmental protection technologies and management models, leverage the technology spillover and demonstration effects of foreign direct investment, drive local enterprises to strengthen environmental management, and improve resource utilization efficiency. Fourth, strengthen the construction of local government environmental governance capacity. Improve the performance evaluation and assessment system for ecological civilization, and establish a green development-oriented cadre appointment and assessment mechanism. Strengthen the environmental protection responsibility of local governments, ensure effective implementation of environmental information disclosure policies, and promote high-quality development of green economy.

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