Can environmental regulation achieve win-win growth in environmental and economic performance: evidence from the sugar industry under China's mandatory environmental information disclosure policy

Jingfang Ge:
College of Economics and Management, China Agricultural University, No.17 Tsinghua East Road, Beijing 100083, China
Wiktor L. Adamowicz: https://orcid.org/0000-0002-7634-2985
Department of Resource Economics and Environmental Sociology, University of Alberta, Edmonton, AB, Canada T6G 2H1
Wei Si: http://orcid.org/0000-0002-2270-897X
Corresponding Author
College of Economics and Management, China Agricultural University, No.17 Tsinghua East Road, Beijing 100083, China

Abstract

Environmental information disclosure policies have been used in many jurisdictions yet the impact on the environmental and economic performance of enterprises remains a question. This paper adopts China's mandatory environmental information disclosure (MEID) policy implemented in 2014 as an example to examine the relationship between environmental policy and enterprise performance. We apply a Difference-in-Difference (DID) and Propensity Score Matching (PSM) sampling method to examine the issue, using a panel data set of nearly 90 sugar enterprises in Guangxi in China from 2008 to 2016. Return on sales and pollution emissions are considered as the proxies of economic and environmental performance respectively. We found that the 2014 MEID policy reduces pollution emissions, and no significant effect on return on sales. These effects vary with corporation size and ownership. Production shrinkage appears to be the main reason for the reduction in pollutant emission in terms of the Guangxi sugar industry, rather than technology innovation in the pollution treatment process. We discuss the study's limitations and the policy implications.

Keywords China's mandatory environmental information disclosure, Economic performance, Environmental performance, Environmental regulation, Sugar industry

Introduction

Tietenberg (1998) has called Environmental Information Disclosure (EID) the "third wave" of pollution prevention instruments among which the first and the second waves are command-control regulation and market-based regulation. With increased accessibility and transparency of information, EID has gradually become a common tool of environmental governance around the world. From the single voluntary disclosure for acquiring a company's reputation to a mixture of voluntary and mandatory disclosure required by governmental authorities, countries endeavor to deliver effective pollution information to the public is making significant changes in the government's role in information-based regulation.

This study focuses on China's mandatory information disclosure policy launched by the Ministry of Environmental Protection (MEP) in 2014. Though the two mandatory information disclosure projects, Green-watch and Green-security, have existed for more than a decade in China till now, the level of disclosed information was low and the contents of disclosed information were inconsistent making it hard to compare all companies' reports (Wang et al. 2004; Wang and Bernell 2013). It is just within this context that China's government has launched a stricter and more detailed policy, Measures on Self-monitoring, Surveillance and Information Disclosure in National Key Monitored Enterprises (hereafter, MEID) (Zhang et al. 2016). It has covered all industries and all enterprises with high pollution outputs, while the Green-security project only covers a limited number of highly polluting industries (14) (Wang and Bernell 2013). Also, it stipulates the environmental administrative penalties upon enterprises for violating the articles in policy such as not disclosing information. Zhang et al. (2016) point out that China no longer lacks the law and policy for guaranteeing environmental information disclosure and transparency since launching the MEID policy. However, to the best of our knowledge, there is no empirical research on this MEID policy. Thus this study seeks to evaluate the MEID policy and the underlying impacts on treatment groups.

From the Guangxi Sugar Industrial Statistic Yearbook, we collect a set of sample data of 781 sugar enterprises in Guangxi province which is the biggest sugar producer in China contributing over 60% of total sugar production[1]. This study adopts the Propensity Score Matching (PSM) sampling method and Difference-in-Difference (DID) approach to examine the effect of China's MEID policy on sugar enterprises. This paper mainly focuses on economic performance proxied by return on sales (ROS) and environmental performance measured by the emissions of four types of water pollutants (i.e., wastewater, chemical oxygen demand (COD), biochemical oxygen demand (BOD), and suspended solids (SS)). We also control for a series of variables including individual firm characteristics, production, and energy consumption. Results indicate that China's MEID program has a significantly negative effect on a sugar enterprise's pollution emissions, and no effect on economic performance. The reduction of pollution emission has been increasing year by year. Further analysis shows that production shrinkage is the main reason for pollution reduction rather than technology innovation. This may be why the MEID has no significant effect on economic performance as the Porter hypothesis would suggest. We also explore the enterprise-specific heterogeneity of policy effects.

Some potential contributions are presented as follows. First, to the best of our knowledge, this is the first pilot study to empirically evaluate the 2014 MEID policy. The MEID policy is an improved policy, covering all heavy-polluting enterprises rather than only publicly traded ones treated under the Green-security project (Wang and Bernell 2013). Therefore, the MEID policy divides all enterprises in each industry into treatment and control groups, and we then use the PSM-DID method to evaluate the policy impact within a quasi-experimental framework. Second, this paper uses a set of micro-data of China's sugar enterprises, which could overcome the positive (negative) individual effect being offset by negative (positive) individual effect among a macro-analysis. Dechezleprêtre et al. (2019) suggest that more analysis about the joint effect of policy on environmental and economic performance is needed, and thus to make clear whether a policy is designed for the environment while not at the expense of economic growth. Therefore, this dataset, including both environmental and economic data, makes research about policy impact and heterogeneity analysis possible. Third, technological innovation measured by the emissions intensity of pollution is a mathematical multiplicand of the pollution emissions, which successfully connects environmental performance and innovation. Therefore, this paper also examines the potential mechanism by which the treated enterprise responds to the MEID policy.

The remainder of this paper is organized as follows. Section 2 briefly introduces the background of the MEID policy in China and reviews the relative literature. We describe the data source and method in section 3 and present the empirical results and discussion in section 4. Section 5 summarizes the research conclusions and provides the implications and limitations.

Background

The Evolution of China’s Mandatory Environmental Information Disclosure

In 1979, China enacted a comprehensive Environmental Protection Law (hereafter, EPL), an important milestone in China's evolution of legal governance on environmental protection. This is the first time environmental protection was written into China’s basic law, and the “Right to participate” and the “Right to supervise” of ordinary citizens are mentioned in the law, which ensures civil participation in environmental protection campaigns. Since then, the central government enacted a series of specific laws on pollution prevention and control in terms of air, noise, water, etc. These legal provisions [2] have highlighted that non-governmental organizations (NGO) and citizens have the right to prosecute polluters and claim compensation for damage caused by pollution[3].

In 1998, the “Right to know” appears in the law for the first time. Article 15 in RACPEP reads “A project should solicit public feedback on environmental protection in the environmental impact assessment (EIA) process[4]”(The RACPEP, 1998: article 15, no page numbers). It is the beginning of addressing information asymmetry issues in the environmental protection campaign. In 2008, the central government enacted a succession of specialized laws focusing on information disclosure, one is the Open Government Information Regulations (OGIR) and the other is the Environmental Information Disclosure Measures (EIDM) (Zhang et al. 2016). These laws aim at reducing the information asymmetry between polluters and the public by providing better guidance and legal supports for information disclosure, especially in the environmental area. Greenpeace shows, however, that 2008 EIDM failed to promote the disclosure of an enterprise’s environmental information due to ambiguous statements such as the definition of “major pollutants”, inefficient supervision, weak sanctions, and non-compliance of enterprises (Zhang et al. 2010; Mol et al. 2011; Greenpeace, 2009).

In 2014, the Ministry of Environmental Protection (MEP) carried out a set of laws to push forward the information publication process (Zhang et al. 2016). One is the Measures on Self-monitoring, Surveillance, and Information Disclosure in National Key Monitored Enterprises (MEID), aiming at regulating a polluter’s activity of self-monitoring and information disclosure. The other is the Measures on Pollution Sources Supervisory Monitoring and Surveillance and Information Disclosure in National Key Monitored Enterprises (Trial) (PSSM), aiming at ensuring high-quality and high-quantity disclosed information by regularizing supervision of environmental protection authorities[5]. Compared with the 2008 EIDM, the 2014 MEID is better designed, emphasizing more detail, such as the type of main pollutants, pollution monitoring technology, frequency, and means of disclosure, including a penalty for violating the regulation. The penalties are as follows:

"Being published online; increasing the frequency of the supervisor of authority; suspending the issue of pollutants discharge permits and the approval process of EIA[6]; suspending all funds for environmental protection; financial and insurance services are advised to refuse credit or increase the premium rate; advising to disqualify from government procurement[7]" (MEID, 2014: article 23, page 9).

The "Right to know", the "Right to participate" and the "Right to supervise" are three fundamental rights of an individual citizen to engage themselves in environmental protection initiatives, among which the "Right to know" is a precondition for the other two rights. Therefore, the MEID policy is a crucial program to guarantee citizen engagement in environmental protection by opening information.

The Evolution of the Other Countries' Environmental Information Disclosure

In other countries, EID programs have existed for a few decades. Two main categories of EID program are as follows: a Pollutant Release and Transfer Registry (PRTR), a project where the government authority collects, processes and compiles the disclosed data from polluters and releases to the public (Blackman 2010); and a Performance Evaluation and Ratings Program (PERP), an approach where the government authority rates enterprises according to environmental performance and regulatory compliance, and publishes the rankings online (Dasgupta et al. 2007).

The U.S. TRI is a widely known PRTR pioneer. It goes back to the early 1980s when a series of severe toxic chemical leakages made the U.S. government realize the importance of information disclosure in the decision-making process of government agencies, communities, and others, and subsequently enacted the TRI program in 1987[8]. It requires all TRI-covered enterprises to report their annual TRI-listed toxics emission data to the Environmental Protection Agency (EPA) who publishes the data. The coverage of the TRI policy has increased in terms of the chemicals, chemical categories, industries, and sectors. For instance, the TRI policy covers 770 listed chemicals that are more than double the 328 toxic chemicals in 1987[9]. In addition to the U.S., more than 50 countries, such as Greece, Bulgaria, and others, have established similar TRI programs. Also, some countries have shown deep interest in the PRTR program, including China, Russia, Mongolia, and Vietnam[10].

The other category, PERP, is popular among some Asian countries often supported by the World Bank (Dasgupta et al. 2007). For example, the Program for Pollution Control Evaluation and Rating (PROPER), a PERP pioneer was enacted in 1995 In Indonesia. They classify the listed enterprises into five categories, colors, gold, green, blue, red, and black, respectively corresponding to the world-class, above-standard, complaint, non-compliant, and least compliant based on their self-reported pollution data (Dasgupta et al. 2007). Following Indonesia, other Asian countries also established similar EID projects, such as India's Green Ratings Project (GRP) in 1997, Philippines' Eco-Watch in 1997, China's GreenWatch in 1999, Vietnam's Environmental Information and Disclosure System (EIDS) in 2001. In recent decades, the rating system has also been introduced into other countries not in Asia, like Ghana (Bedu-Addo et al. 2019), Mexico, Colombia, and Papua New Guinea (Kathuria 2009).

Mandatory Environmental Information Disclosure and enterprise's performance

Using various levels of data, a large amount of literature has explored the effect of the environmental regulation on a treatment group in terms of trade, facility location, profitability, productivity, emissions, and so on (Dechezleprêtre et al. 2019). Most of the papers reviewed in Dechezleprêtre et al. (2019) find that environmental regulation involving command and control and market-based regulations have a significant emission reduction impact. A large number of papers have examined the subsequent economic effect on treated entities, while the impact is still not clear to date. Rubashkina et al. (2015) and Greenstone et al. (2012) find that environmental regulation has a significantly negative effect on an enterprise's productivity. In contrast, Eli and Bui (2001) and Albrizio et al. (2017) conclude that a relatively stringent environmental regulation leads to an increase in productivity growth.

This study focuses on environmental information disclosure (EID), a typical informal regulation that provides pollution information to communities and engages them in environmental protection (Pargal and Wheeler 1996). The literature most related to this paper is about information disclosure. A wide range of research has studied the key role of information disclosure in the process of consumer purchasing, especially the effect of eco-labeling on the environment (D'Souza 2004; Motoshita et al. 2015). However, considerable research has examined the effect of information disclosure on enterprise activity. On the one hand, legitimacy theory has proposed that congruence between the behavior of a legitimated organization and social norms is vital to retain the legitimacy of an organization[11](Suchman, 1995). Thus, a company would like to disclose its environmental information to meet the public's expectation on aspects such as product quality and production environment, to maintain the legitimacy of activity (Gray et al. 1995; Brouhle 2007; Clarkson et al. 2008; Doshi et al. 2013; Grewal et al. 2019). On the other hand, information can reduce information asymmetry among polluters and stakeholders that is a source of market failure, and thus improve allocation efficiency of materials and resources (Brouhle 2007; Ambec et al. 2013; Ahmad et al. 2019; Dechezleprêtre et al. 2019; Ren et al. 2020).

In the environmental area, the growing concerns for information transparency have aroused interest in evaluating various environmental information programs. Voluntary and mandatory EID are two different forms of EID. Many companies, especially the listed companies, make greater use of voluntary disclosure to deliver information favorable to them (Huang and Chen 2015). Research about voluntary EID mainly focuses on the quantity and quality of the disclosed information and its decisive influence factors, for instance, company size, geographical location, economic performance, and others (Liu and Anbumozhi 2009; Meng et al. 2014). Some scholars point out that voluntary EID still faces severe challenges to break down the communication barriers between polluters and the public due to the existence of "greenwashing" activities and low-quality disclosed information (Kim and Lyon 2011; Huang and Chen 2015; Luo et al. 2019).

To date, empirical research on mandatory EID is relatively scarce. Existing research has shown the effectiveness in pollution reduction of mandatory EID (Konar and Cohen 1997; Wang et al. 2004; Bennear and Olmstead 2008; Delmas et al. 2010; Doshi et al. 2013; Ahmad et al. 2019). An opposite opinion from Bui (2005) proposes that the potential driving force of pollution-reduction is strict monitoring rather than the TRI program itself. From an economic perspective, the existing conclusion is ambiguous. Hamilton (1995) shows that enterprises experienced a sharp decline in stock value on the first enactment day of the TRI program. In contrast, Konar and Cohen (1997, 2001) conclude that under the TRI program the enterprises with the most pollution reduction suffer a large stock price decline, but then experience a subsequent lagging increase in market value. Many scholars have explored the effectiveness of mandatory EID (Weil et al. 2006; Delmas et al. 2010; Liu et al. 2010; Matisoff 2013). For instance, the difference in dissemination manner and information type lead to a different amount of pollution information received by the public and different levels of subsequent pressure received by polluters (Weil et al. 2006; Liu et al. 2010). Compared with disclosing information online, disseminating information directly from polluters to consumers or introducing information into the decision-making process could more efficiently transmit information (Delmas et al. 2010; Liu et al. 2010; Matisoff 2013).

Therefore, this study discusses whether and how mandatory environmental information disclosure policy works in China. Compared with existing studies, this study makes a few contributions to the current literature on information disclosure. First, the MEID policy, a trial policy, to the best of our knowledge has not been empirically studied. It is important to China's environmental protection development and also offers an experience for other countries. Second, this study combining environmental and economic performance is a supplement to policy evaluation with a single performance. It gives a comprehensive assessment of information disclosure policy. Third, we adopt quasi-experimental DID and PSM methods to identify the causal relationship between the MEID policy and enterprise performance. This approach helps alleviate potential endogeneity issues in the policy evaluation process. Moreover, a set of enterprise-level data allow us to explore the individual response to policy and its heterogeneity.

Data Collection and Methodology

Data Source

We collect data from the main source, Guangxi Sugar Industrial Statistic Yearbook[12] which is published by Guangxi Sugar Association and Guangxi Sugar Industry Development Office, a government organization. The data is collected from an annual report that is self-reported annually by sugar enterprises and processed by Guangxi Sugar Association, mainly including sugar production, economic and environmental data. We collect a dataset with 781 firms from 2008 to 2016, a set of enterprise-level micro-data for evaluating the effect of the MEID policy on individual enterprises. This dataset is checked by environmental monitoring agencies and environmental protection departments, which should reduce concerns about the accuracy of the data. On the one hand, according to the MEID policy, each national key monitored sugar enterprise[13] should post its self-monitoring data of pollution sources on provincial open information platform within a prescribed time and guarantee its accuracy, which is in line with data in the annual report. On the other hand, according to PSSM policy[14], environmental monitoring agencies should supervise sugar enterprises in their jurisdiction, and report monitoring records to the environmental protection department at least once a quarter.

This paper examines the relationship between the MEID policy and the enterprise's economic and environmental performance. Prior research has used various measures to express performance. Among these, the economic measures include an actual accounting-based measure (e.g., return on sale (ROS), return on equity (ROE), return on assets (ROA)), and stock market-based measure (e.g., Tobin's Q, stock price), and so on (Dechezleprêtre et al. 2019). The environmental measure includes pollution emissions, and environmental certification from a third party or environmental standards, and so on (Dechezleprêtre et al. 2019). Given the purpose of this research and data accessibility, we select return on sale (Ros) and pollution emissions as the core economic and environmental dependent variables. We consider the emissions of four pollutants, wastewater, chemical oxygen demand (COD), biochemical oxygen demand (BOD), and suspended solids (SS), as indicators for environmental performance. They are proxied by Wwt, Codt, Bodt, and Sst. Three types of independent variables are included in the subsequent empirical analysis: enterprises characteristics, age (Age), ownership (Poe), and firm scale (Size); energy consumption of power (Power), coal (Coal), and freshwater (Freshw); other indicators on the production process, the productivity of continuous production (Sr) and recycling rate of wastewater (Reuse). The definition of the above variables is shown in Table 1.

The DID Method Based on PSM Sampling

The DID method is a typical quasi-experimental design widely used in the public policy evaluation field. In general, a DID model requires two groups of the sample either affected or unaffected; and two types of periods, before or after the policy. A DID model is as shown in Eq.(1) where Y_{it} represents an economic dependent variable (i.e., Ros) and an environmental dependent variable (i.e., Wwt, Codt, Bodt, and Sst). The subscript t refers to different years and the i refers to different sugar enterprises; ε_{it} is a random disturbance term; the matrix-vector **Controls** refers to a series of the control variables including Poe, Size, Power, Coal, Freshw, Sr, and Reuse, the definitions of which are shown in Table 1. Of specific interest is the coefficient β_3 of the interaction term Time×Treat, which reflects the real net effect of the MEID policy on both economic and environmental performance. The dummy variable Time equals 1 if a year is in the post-implementation period (i.e., 2014 - 2016), and 0 otherwise. Simultaneously, we define the dummy variable Treat as equal to 1 if an enterprise is in the list of national key monitored sugar enterprises (i.e., regulated group) all the time after MEID policy implementation[15] (i.e., 2014 - 2016), and 0 otherwise.

$$Y_{it} = \beta_0 + \beta_1 \times Time_{it} + \beta_2 \times Treat_{it} + \beta_3 \times Time_{it} \times Treat_{it} + \beta_j \times \mathbf{Controls}_{it} + \varepsilon_{it} \quad (1)$$

Most importantly, there is an underlying common trend assumption that must be examined before conducting any DID model. It is that the trends of the outcomes of the two groups are required to be approximately identical in the absence of the policy treatment. However, in the post-treatment period, the counterfactual outcome of the treatment group is unable to be assessed in the absence of the policy treatment. Thus, the common trend assumption is usually tested by judging whether the outcome trends of the two groups are nearly parallel to each other in the pre-treatment period.

It is not unusual for the common trend assumption to not be met, which would lead to common sample selection bias. The Propensity Score Matching (PSM) sampling method proposed by Heckman et al. (1997, 1998) is a method widely used to reduce selection bias before a DID process. PSM aims to get a pair of matched groups by reducing their difference in the relevant outcomes and other time-invariant characteristics relative to policy selection, and eventually making the probability of the matched pairs being selected the same as each other. Here, the selection probability mentioned is a propensity score obtained from a Logit or Probit model taking the idea of dimension reduction to calculate the probability (Rosenbaum and Rubin 1983) (see Appendix 1).

Results and Analyses

This section presents the empirical results using the PSM-DID method based on the panel data of nearly 90 enterprises from 2008 to 2016. We first adopt the PSM method to do sample matching using the original dataset and obtain a pair of matched groups. Based on the matched dataset, we conduct a series of empirical analyses. More specifically, we first investigate the effects of the MEID policy on both environmental and economic performance; then we explore the influence mechanism; in the end, we discuss the dynamics and heterogeneity of the impact from the MEID policy.

Common trend test and PSM matching

We conduct a common trend test before exploring the DID process. We plot lines for the trend of economic and environmental outcomes (see Fig.1) and find that the trend lines of the treatment and control groups are not parallel. Also, the treatment group has higher *Ros* and pollution emissions than the control group. The original dataset has probably not met the common trend assumption, which indicates that the selection into the treatment group is not random and might be strongly associated with enterprise characteristics and factors affecting outcomes. In this case, results derived from a single DID regression are not totally convincing. Therefore, a PSM is adopted for data matching to reduce selection bias.

First, we establish *Logit* regressions to estimate the probability of enterprise being treated each year (see Appendix 1). Table 2 shows the results from the *Logit* regression taking 2008 as an example. Two characteristics have a relatively low correlation with the selection of the treatment object (see Table 2 for the insignificant coefficients of *Poe* and *Age*). In contrast, the other four coefficients are statistically significant at the 1% level. That is to say, sugar enterprises with ex-ante low abatement and production efficiency (i.e., *Reuse* and *Sr*) are more likely to be enrolled in the treatment group of the MEID policy. In other words, the higher *Sr* and *Reuse*, the cleaner sugar enterprises would be, and the lower the probability of being treated would be. The relationship between sugar production and the probability of being selected follows an inverted-U-shaped curve, that is, the enterprises with ex-ante high-volume sugar production are more likely to be treated, but this relationship may reverse as sugar outcomes increase beyond a certain level. The high-volume production sugar enterprises would focus more on their pollution levels and invest more in pollution control, eventually being cleaner and being more likely to be taken off the list of regulated enterprises.

Then, we match each treated firm to an untreated firm whose probability score is similar via three common matching methods (i.e., nearest-neighbor (NN) matching, kernel matching, and radius matching). Hence, we get a pair of groups among which one group is comprised of treated firms and another group comprised of untreated firms. We also do a series of tests for the effectiveness of the PSM, including a covariates' balance test (see Table 3) and a comparison of kernel density before and after matching (see Fig.2). From Table 3, the standardized bias of *Spro*, *Spro*Spro,* and *Sr* among the treatment and control groups decreases dramatically and becomes insignificant. Whereas the standardized bias of *Poe* and *Age* are both insignificant before and after matching, which is in line with the previous results of the *Logit* regressions that these two characteristics are less relevant to the treatment selection of the MEID policy. The coefficient of *Reuse* is not significant in both periods, that is, the differences in *Reuse* among the two groups barely exist in the pre-implementation period and the bias also hasn't widened after matching. Therefore, the PSM indeed appears to reduce the between-group difference in each covariate. A comparison between the left figure and the right one in Fig.2 also shows that the sample distributions of the two policy groups for each propensity score are very similar after matching, which means that the selection into the MEID treatment group approximately is closer to a random selection scenario.

Finally, we obtain a pair of matched sugar enterprises belonging to the treatment and control groups respectively. Table 4 shows the descriptions of the all variables used in this study before and after PSM matching. There are 781 sugar enterprises in our sample before PSM and 692 after matching. In our sample, 33.4% are enrolled in the MEID policy, while this decreases to 29.3% after PSM. The average *Ros* is positive, indicating the whole sugar industry makes a profit from 2008 to 2016 while *Ros* in both treatment and control groups experience a decrease since 2011 and a rebound since 2014 (see the first figure in Fig.1). The other environmental indicators, *Wwt*, *Codt*, *Bodt,* and *Sst*, have been decreasing in the sample period especially since the 2014 MEID policy launched. Compared to the average emission in the whole sample, the amount of pollution emission slightly decreases in the PSM sample, while the emissions intensity changes little. The market share of private-owned sugar enterprises is over 60% that doubles the share of the state-owned ones. Table 4 shows that the size of sugar enterprises is relatively small with an average of 35.6% and a standard deviation of 47.9% that refers to only 35.6% of enterprises own net sales of over 400 million.

Effect of the MEID Policy on Environmental Performance

We assess the effect of the MEID policy on an enterprise's environmental performance. Following Eq.(1), we include four dependent variables, *Wwt*, *Codt*, *Bodt,* and *Sst*. The vector **Controls** includes two enterprise characteristics (i.e., *Poe* and *Size*), three types of energy consumption (i.e., *Power*, *Coal,* and *Freshw*), and the productivity of continuous production (*Sr*). Then we apply DID method to estimate the MEID policy's impact on the above dependent variables (i.e., *Wwt*, *Codt*, *Bodt,* and *Sst*) respectively. Three types of DID models are established for estimation, controlling for the above control variables. The first model M1 follows Eq.(1) to include two dummy variables (i.e., *Treat* and *Time*) and their interaction term (i.e., *Treat*×*Time*). Whereas in the other DID models, M2 and M3, we introduce the enterprise-and year- fixed effect variables, and thus delete *Treat* and *Time* to examine more precise information of variation within various *Treat* and *Time* categories than solely *Treat* and *Time* (Chen et al. 2018). Among these, M2 uses the matched database while M3 uses the original enterprise-level data to do a comparison before and after the PSM.

The estimates are shown in *Table* 5, the coefficients on the interaction term *Treat*×*Time* of four pollutant emissions are all almost significantly negative. The values of these coefficients show that the MEID policy results in a reduction of 0.1288 million tons, 5.9337 tons, 2.8019 tons, and 2.8040 tons of wastewater (*Wwt*), COD (*Codt*), BOD (*Bodt*), and SS (*Sst*) in the sugar treatment group. In other words, the emissions of wastewater (*Wwt*), COD (*Codt*), BOD (*Bodt*), and SS (*Sst*) decrease by 19.80%, 22.13%, 23.54%, and 18.66%[16] due to the mandatory pollution-reducing requirement of the MEID policy. In addition, we found that the magnitude of β_3 in M3 is nearly double that in M2, which illustrates the possibility of selection bias into the treatment group of the MEID policy. A single DID without data-matching via PSM would indeed have overstated the net effect of the MEID policy.

Next, we examine the coefficients on dummy variables, *Treat* and *Time*. The results in *Table* 5 show that all coefficients on *Time* are significantly negative. This means that the sugar control group also experiences a significant decrease in all pollutants, which refers to the so-called time trend of whether an enterprise is regulated by the MEID policy or not. Furthermore, the coefficients on *Treat* for all pollutants are significantly positive, which says that the treatment group releases more pollution emissions than the control group does before the implementation of the MEID policy (*Time*=0). Thus, the sugar enterprises with higher pollution might have a higher probability of being selected into the treatment group.

From the above analysis, the MEID policy has an obvious influence in reducing the pollution emission of the sugar enterprises in Guangxi. To verify the reliability of these estimates on emission-reducing effect, we conduct a series of robustness tests. Two approaches are adopted, the one is the placebo test that is frequently used after a DID regression, and the other is to detect whether the previous conclusion is still valid based on the alternative subsamples. The first model M1 is a placebo regression where the year 2011 is assumed as a pseudo implementation year of the MEID policy replacing the factual adoption year 2014. Thus, the years falling in and after 2011 are labeled as the “post-implementation period”, otherwise they are the pre-implementation period. Then we re-run the benchmark DID model to judge if the impact of the 2014 MEID policy is unique and robust. If the pseudo 2011 MEID policy also shows an emission-reducing effect the same as the 2014 MEID policy, the preliminary abatement effect is likely to be questioned because no MEDI program was implemented in 2011 actually. The second model M2 uses the data from 2011 to 2016 aiming to keep the same sample size in the pre- and post-implementation period. The last model M3 uses the dataset excluding 2014 because an implementation year of a policy is usually a transition period for the treatment enterprises to adapt and do the corresponding adjustments.

Results for the robustness tests are shown in *Table* 6. All coefficients on the interaction term of *Treat* and pseudo year *Time*11 have not passed the significance test, which means the pseudo 2011 MEID policy has no effect on emission reductions further confirming the robustness of the previous conclusion. In the following two regressions using the modified subsample, all coefficients on the interaction terms *Treat**Time* remain significantly negative, which indicates that the emission-reducing impact of the MEID policy exists. Therefore, all the above tests support the robustness and credibility of conclusions derived from the previous PSM-DID regressions.

Effect of the MEID Policy on Economic Performance

This section explores how the MEID policy affects the economic performance of sugar enterprises, which is crucial to comprehensively evaluating the impacts of the MEID policy on both environmental and economic performance. To answer the question, we still use the same PSM-DID model, but we choose Return on sales (*Ros*) to measure sugar enterprise's economic performance as the dependent variable. The control variables include two enterprise characteristics (*Poe* and *Size*), the productivity of continuous production (*Sr*), and the recycling rate of wastewater (*Reuse*). The enterprise and year fixed effects remain controlled in the following regressions. Here, we establish four models, the first and third model, M1 and M3, both control for the above control variables, whereas the others do not include them; the first two models, M1 and M2, use the matched enterprise-level data, whereas the others use the original data without data matching.

Table 7 shows that all the coefficients on *Treat**Time* have not passed the test of significance at the 10% level, which suggests that we cannot reject the null hypothesis that there is no relationship between the MEID policy and economic performance. Thus, this study fails to find evidence to support the strong Porter Hypothesis (Jaffe and Palmer 1997). The MEID policy shows no positive effect, and no adverse effect, on the sugar enterprise's economic performance.

We then use gross profit margin and markup to check the robustness of the estimates on economic performance. Gross profit margin (*Gpm*) is given by the (selling price- production cost)/selling price, and markup (*Mp*) is given by the (selling price- production cost)/production cost. M1 uses data after matching while M2 uses the original data to estimate the effect of the MEID policy on *Gpm* and *Mp*. As shown in *Table* 8, all coefficients on the interaction term Treat*Time are insignificant, indicating that there is no significant relationship between the MEID policy and sugar enterprise's economic performance. We also run a DID regression where the dependent variable is total returns (the numerator of the fraction *Ros*). Results in *Table* 8 show a significant negative effect from the MEID policy, which indicates that the MEID policy might decrease total returns though has no significant impact on *Ros*.

Further Mechanism Analysis

The previous analysis shows that the MEID policy has a significant abatement effect and an insignificant economic effect on sugar enterprises. The well-known Porter Hypothesis has argued that a well-designed environmental regulation could lead to improvement in both environmental and economic performance simultaneously (Porter, M.E. 1991; Porter and van der Linde 1995). They point out that a flexible environmental regulation could stimulate an enterprise's environmental innovation activities, therefore, improving productivity, which in turn might partially or fully offset the increasing compliance cost and lead to an increase in economic performance. Thus, a possible explanation for the limited economic impact is weak and limited technology innovation. Given the core mediator function of technology innovation, this section provides an influence mechanism discussion of how the MEID policy affects the environmental and economic performance of sugar enterprises.

We introduce the emissions intensity of wastewater (*Ww*), COD (*Cod*), BOD (*Bod*), and SS (*Ss*) that refers to the pollution emission per ton of crushed-sugarcane as a set of proxy indicators of the technology innovation level. Also, the emission intensity is a sign of abatement efficiency, that is to say, the more environmental innovation measures a sugar enterprise takes, the higher abatement efficiency would be, and the lower the emission intensity would be. Furthermore, the previous dependent variables *Wwt*, *Codt*, *Bodt,* and *Sst* are the product of the emission intensity (i.e., *Ww*, *Cod*, *Bod*, *Ss*) and the amount of crushed-sugarcane. Therefore, we introduce another dependent variable, the scale of crushed-sugarcane (*Sc*), which makes it possible to investigate whether a decrease in the production scale (*Sc*) or a decrease in the emission intensity (i.e., *Ww*, *Cod*, *Bod*, *Ss*) or both have contributed to the decrease in the pollutant emissions.

First, we investigate the effect of the MEID policy on emissions intensity (i.e., *Ww*, *Cod*, *Bod*, *Ss*). A PSM-DID model is used, where the dependent variable is the emission intensity of wastewater (*Ww*), COD (*Cod*), BOD (*Bod*) and SS (*Ss*), and the independent variables (i.e., *Poe*, *Size*, *Power*, *Coal*, *Freshw*, *Sr*) are the same as those used in the previous models of evaluation on environmental performance. The two fixed effects from enterprise- and year- level are also included in regressions. Second, we investigate the effect of the MEID policy on the scale of crushed-sugarcane (*Sc*) using the same PSM-DID model where *Sc* is the dependent variable. The independent variables only include *Poe* and *Size*, because *Sc* represents the total amount of raw material (i.e., sugarcane) available for each enterprise, therefore having an extremely low correlation with the energy consumption and productivity in the production process. We still control for the enterprise and year-fixed effects.

Table 10 presents all the regression estimates. The estimate on *Treat**Time* shown in the first column shows that the scale of the crushed-sugarcane (*Sc*) has been decreasing starting from the launch of the MEID policy. Compared with the average *Sc* in the treatment group in the pre-implementation period, *Sc* experiences a significant decrease of 9.02% subsequent to the MEID policy. However, the MEID policy has not shown any obvious stimulus to the emission intensity of sugar enterprises. Thus, this study has not found evidence that the MEID policy facilitates accelerated innovation activity within the sugar enterprises in our sample period in Guangxi.

To sum up, the MEID policy has a significantly negative effect on the production scale of sugar enterprises, while its innovation effect is not significant. Hence, this study concludes that shrinkage in production scale is the main reason for the emission reductions of sugar enterprises, rather than innovation in pollution treatment technology. Furthermore, the MEID policy is still in its infancy, and the influence of such projects on pollution reduction might suffer from a time-lag effect (Zhang et al. 2017). Thus, the motivation for sugar enterprises to reduce pollution emission has remained relatively low, limited, and insignificant, which appears to be why the MEID policy has no statistically significant effect on economic performance as argued by the Porter Hypothesis. Additionally, Ramanathan et al. (2010) has argued that environmental regulation might damage an enterprise's innovation activities in the short run, but could promote technology innovation in the longer term. Therefore, more microdata is required to investigate the MEID policy's impacts in the short and long term.

Conclusions and Implications

This study explores the effect of China's information-based environmental regulation on sugar enterprises. The MEID policy is China's first policy covering most industries, especially the highly-polluting food industry like the sugar industry, and most pollutants. Based on a micro dataset of sugar enterprises, we use a PSM-DID empirical method to reduce estimation bias in the policy evaluation process. This study shows the impact of information disclosure in a developing country taking the example of China's MEID policy.

Our estimation shows that the MEID policy has a significant environmental effect on the treatment group. More specially, the emissions of wastewater (*Wwt*), COD (*Codt*), BOD (*Bodt*), and SS (*Sst*) decrease by 19.80%, 22.13%, 23.54%, and 18.66% subsequent to the MEID policy respectively. Previous studies have verified a similar emission-reduction effect of information disclosure using various data from different countries. Hsu et al.(2020) use China's environmental complaints data and find that complaints and reports from the public result in a 36.3%-38.9% reduction in COD emission 5-6 months after receiving complaints. Garcia et al. (2007) find that Indonesia's information disclosure, the PROPER policy, results in a total 32% reduction in COD and BOD. The sizes of our estimated emission reductions are between the two reductions in the above studies, which supports the reliability of our estimates and the success of information disclosure in China. We test the dynamics and heterogeneity of the impact and influence mechanism. Production shrinkage appears to be the main reason for the reduction in pollutant emission in terms of the Guangxi sugar industry, rather than technology innovation in the pollution treatment process. All the emissions experience accelerating reduction after policy implementation, except for a decrease in wastewater (i.e., *Wwt*) in the first year. The larger enterprises reduce more pollution than the smaller ones, and the SOEs perform better in wastewater-reduction (i.e., *Wwt*).

Our results also show that the MEID policy has no significant economic effect on the treatment group. But the MEID policy causes a significant decrease in total returns perhaps because of the decrease in demand for raw materials after the MEID policy. The Strong Porter hypothesis has proposed the vital role of innovation in spurring the increase in economic performance (Porter and van der Linde 1995; Jaffe and Palmer 1997). Our estimation shows that the MEID policy has no significant effect on technology innovation, hence we infer that insufficient innovation is likely to be the reason for the nonexistence of the Strong Porter hypothesis. Existing studies have offered some possible reasons. First, innovation usually experiences a time-lag process (Zhang et al. 2017), and the "Porter innovation offsets" would appear in the long-term (Ramanathan et al. 2010). Second, a nationwide industrial regulation such as the MEID policy would force enterprises to allocate more funds into pollution treatment than in production operation compared to a regional regulation, which might result in economic damage and a decrease in productivity (Jiang et al. 2018). Third, many scholars have emphasized the decisive role of the disclosure manner and type of information, and suggest that more accurate and transparent information helps to make the best of the EID policy to result in pollution reduction (Weil et al. 2006; Delmas et al. 2010; Liu et al. 2010; Matisoff 2013). There are still some ambiguities in provisions of information such as the definition of the disclosure manner [17], though the MEID policy is stricter than the prior policy. Lastly, a stricter environmental regulation could trigger more innovation activities than in a loose institutional environment (Lounsbury and Crumley 2007; Kneller and Manderson 2012; Jiang et al. 2018). Currently, the government at all levels in China may be more concerned with economy growth, thus leading to a relatively loose institutional environment and weak enforcement (Kuo et al. 2012; Zhang et al. 2016).

While providing an evaluation of information disclosure from the perspective of China, this study has some limitations, and extensions are essential for further research. First, this study is limited due to the data limitation that the sample only covers the sugar industry in Guangxi, and we only access to data to 2016. Thus, we should be very cautious about generalizing the results to other industries in China or other countries. More data about all industries within a longer period are needed for further research. Second, this study doesn't consider entry and exit. Although this might result in estimation bias, it appears that this limitation may not have much effect on the magnitude of estimates (Shapiro and Walker 2018).

To sum up the above, the MEID policy achieves its goal in pollution-reduction, with no significant economic effect. Thus, some implications are drawn from the results. First, mandatory information disclosure is an important tool of environmental governance, thus, the government should support the MEID policy and enhance enterprise emission monitoring to better involve the public in environmental protection. Second, pollution emission reduction at a cost of output may not be sustainable, therefore governments could devote more effort to improving innovation levels in the process of emission reduction in the future. For instance, extending a special subsidy for innovation, and providing strong financial and political support for cooperation in technology research and innovation between different organizations such as university, high-technology company, and government may improve the outcomes from emissions reduction approaches. Third, the government could support larger scale firms in the sector to take advantage of the potential environmental benefits of scale advantages of larger enterprises.

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[1] China's total sugar production is 10.6 million tons during 2018/19 market year (i.e. China's sugar market year is from October 1 to September 30). Cane sugar is a dominating sugar type and contributes 87.26% of total sugar production, and the other type is beet sugar whose production is 1.35 million tons (Source: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Sugar%20Annual_Beijing_China%20-%20Peoples%20Republic%20of_5-3-2019.pdf, accessed on 30 March, 2020, in Chinese). Guangxi's sugar enterprises mainly produce cane sugar.

[2] The provisions of law are translated into English by the authors of this study.
Environmental Protection Law of the People's Republic of China 1989 is available via http://english.mofcom.gov.cn/aarticle/lawsdata/chineselaw/200211/20021100050466.html, accessed on 30 May, 2021 (in Chinese).
The 1st Draft Environmental Protection Law revision is available via http://www.npc.gov.cn/wxzl/gongbao/2000-12/10/content_5004381.htm, accessed on 30 May, 2021 (in Chinese).

[3] For example, Dalian environmental protection volunteers association of Liaoning province prosecutes Dalian RiQian company who secretly dumps raw hazardous wastewater, and receives 7.22 million Yuan in compensation (http://www.gov.cn/xinwen/2015-12/30/content_5029607.htm, accessed on 28 May, 2021, in Chinese).
A citizen tips the Henan environmental protection bureau off about a stone factory, and receives 50 thousand yuan (http://www.hnr.cn/news/snxw/201808/t20180808_3127087.html, accessed on 28 May, 2021, in Chinese).

[4] Article 15 in the Regulations on the Administration of Construction Project Environmental Protection (RACPEP). For a full law, see http://www.mohurd.gov.cn/fgjs/xzfg/200611/t20061101_158949.html, accessed on 8 June, 2021 (in Chinese). It was translated from the original by the authors.

[5] The MEID and PSSM can be downloaded from the link below: http://www.gov.cn/gongbao/content/2013/content_2496407.htm, accessed on 8 June, 2021 (in Chinese).

[6] An enterprise cannot launch a project until it passes the EIA.

[7] Article 23 in the 2014 MEID policy issued by MEP that is the predecessor of Ministry of ecology and environment (MEE). For a full law, see http://www.mee.gov.cn/gkml/hbb/bwj/201308/t20130801_256772.htm. accessed on 01 Sep 2020 (in Chinese). It was translated from the original by the authors.
In general, the sanction published online is mostly penalty and companies' pollution information. For example, some companies that don't monitor pollutants or disclosure the monitoring information are informed that they will face a high penalty of up to 29 thousand. (http://sx.people.com.cn/n2/2016/0419/c189132-28173371.html. Cited 25 November 2020, in Chinese)

[8] Source: Environmental Protection Agency. "Why was the TRI Program created?" https://www.epa.gov/toxics-release-inventory-tri-program/what-toxics-release-inventory#What%20is%20the%20Toxics%20Release%20Inventory? accessed on 8 June, 2021.

[9] Data source:
https://www.epa.gov/toxics-release-inventory-tri-program/tri-listed-chemicals.
https://www.washingtonpost.com/archive/lifestyle/wellness/1989/06/27/how-epas-new-toxics-list-can-help-trace-nearby-hazards/e786dc8a-10e9-444f-84ff-d93114c73d85/ , accessed on 8 June, 2021.

[10] Source: Environmental Protection Agency. https://www.epa.gov/toxics-release-inventory-tri-program/tri-around-world, accessed on 8 June, 2021 (in Chinese)

[11] Suchman defines legitimacy as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995: page 574).

[12] This yearbook is released by Guangxi Sugar Association and Guangxi Sugar Industry Development Office. But it is not public since it involves enterprises' financial information. We can provide a copy of anonymized data with the above organizations' permission for replication .

[13] The list of national key monitored sugar enterprises comes from the list of national key monitored wastewater enterprises annually published by Ministry of Ecology and Environment (MEE). The national ley monitored enterprises is a group of the union of firms whose COD and ammonia nitrogen productions respectively account for 50% of total productions of sugar industry, and firms whose COD and ammonia nitrogen emissions respectively account for 65% of total emissions of sugar industry. This list dynamically updates once a year on the basis of the pollution data of enterprises in the last two years.
(i.e., 2012 and 2014 lists can be accessed via following links:
http://www.mee.gov.cn/gkml/hbb/bgt/201207/t20120710_233240.htm, in Chinese
http://www.mee.gov.cn/gkml/hbb/bgt/201312/t20131231_265877.htm, in Chinese)

[14] PSSM policy refers to Measures on Pollution Sources Supervisory Monitoring and Surveillance and Information Disclosure in National Key Monitored Enterprises (Trial) that is a policy released at the same time as the MEID policy. http://www.mee.gov.cn/gkml/hbb/bwj/201308/t20130801_256772.htm. Cited 01 September 2020 (in Chinese). It was translated from the original by the authors.

[15] The list of national key monitored sugar enterprises (i.e., regulated enterprises) is slightly adjusted every year after implementation, thus we define the enterprises being in the list all the time as treatment group.

[16] The 19.80% for wastewater (*Wwt*) equals -12.8842/65.0714, where -12.8842 is the coefficient of interaction term in column M2 in *Table* 5, and 65.0714 is the average emission of wastewater of treatment group before the implementation of the MEID policy. The change ratios for COD (*Codt*), BOD (*Bodt*) and SS (*Sst*) are 2.13%= 5.9337/ 26.8140, 23.54%=2.8019/11.9012, and 18.66%=2.8040/15.0292 respectively, the same as wastewater (*Wwt*).

[17] The disclosure manner is expressed in sentence "any manner easily delivered to the public is available, for instance, website, newspaper, radio or television and so on". (MEID policy, Article 19: page 8). http://www.mee.gov.cn/gkml/hbb/bwj/201308/t20130801_256772.htm. Cited 01 September 2020 (in Chinese). It was translated from the original by the authors.

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Tables

Table 1 The list of dependent and independent variables in this paper

Variables	Definitions and calculations	Unit
Dependent variables		
Ros	Return on sales (economic performance) calculated as the ratio of operating profit (i.e., earnings before income and tax) to net sales	-
Ww	The wastewater emission per sugarcane crushed	ton per ton cane
Cod/Bod/Ss	The cod/bod/ss emission per sugarcane crushed	Kg per ton cane
Sc	The total amount of sugarcane crushed	10 000 tons
Wwt	The emission of wastewater per year (environmental performance) calculated as the product of *Sc* and *Ww*.	10 000 tons
Codt/Bodt/Sst	The emission of pollutants cod/bod/ss per year (environmental performance) calculated as the product of *Sc* and *Cod/Bod/Ss*.	ton
Independent variables		
Age	*Age* is defined by the difference between an enterprise's present year and establishment year.	Year
Poe	Ownership, a dummy variable, equals 1 if it is a private-owned enterprise, and 0 otherwise.	-
Size	Size, a dummy variable, equals 1 if the enterprise's net sales are beyond 400 million, and 0 otherwise.	-
Spro	The total amount of sugar output	10 000 tons
Reuse	The recycling rate of wastewater	%
Sr	The probability of keeping production line in ceaseless normal operation	%
Power	Power consumption per sugarcane crushed	KW□h per ton cane
Coal	Coal consumption per sugarcane crushed	Ton per 100 tons cane
Freshw	Freshwater Consumption per sugarcane crushed	Ton per ton cane

The table shows the definition of all used variables. All data come from the Guangxi Sugar Industrial Statistics Yearbook.

Table 5

Regression results for the effect of the MEID policy on emissions of wastewater (*Wwt*), COD (*Codt*), BOD (*Bodt*), and SS (*Sst*)

Independent variables	*Wwt*			*Codt*			*Bodt*			*Sst*		
	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Treat	19.1712***			5.5498**			4.2493***			3.4812**		
	(3.5909)			(2.7060)			(1.4504)			(1.4798)		
Time	-8.3188***			-6.0207***			-2.3769***			-4.2921***		
	(2.0806)			(1.1148)			(0.6024)			(0.8906)		
Treat*Time	**-14.8782*** **	**-12.8842***	**-22.7521***	**-5.8244***	**-5.9337***	**-11.7699***	**-3.9542***	**-2.8019***	**-3.8837***	**-2.9076***	**-2.8040†**	**-4.5146***
	(4.3037)	(5.3557)	(9.4107)	(2.5560)	(3.0658)	(4.7499)	(1.6118)	(1.2678)	(1.9049)	(1.5181)	(1.7212)	(1.7179)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	No	Firm, year	Firm, year	No	Firm, year	Firm, year	No	Firm, year	Firm, year	No	Firm, year	Firm, year
N observations	692	692	781	692	692	781	692	692	781	692	692	781
N clusters	-	88	90	-	88	90	-	88	90	-	88	90
R-squared	0.4826	0.3096	0.3217	0.2594	0.2462	0.2290	0.2006	0.2102	0.1952	0.2087	0.1443	0.1360
F-test	49.5450	9.6435	8.3901	22.0938	11.5993	10.4509	34.1230	8.2494	6.6116	17.4376	6.7991	6.7115
(*p*-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

M1 and M2 use the matched data after PSM (N=692); M3 uses original unmatched data (N=781) to make a comparison with M1 and M2.

The superscripts †, *, **, *** indicate significance at the 15%, 10%, 5%, and 1% levels (two-tailed), respectively.

Robust standard errors clustered by the enterprise are reported in parentheses.

Table 7 Regression results for the effect of the MEID policy on enterprise's Return on Sales (*Ros*)

Independent variables	M1	M2	M3	M4
Treat* Time	**0.0003**	**-0.0015**	**0.0308**	**0.0313**
	(0.0358)	(0.0376)	(0.0280)	(0.0291)
Controls	Yes	No	Yes	No
Fixed effects	Firm, year	Firm, year	Firm, year	Firm, year
N observations	692	692	781	781
N clusters	88	88	90	90
R-squared	0.4619	0.4572	0.4581	0.4555
F-test	55.7369	81.4875	60.1616	83.7288
(*p*-value)	0.0000	0.0000	0.0000	0.0000

M1 and M2 use the data after matching (N=692); M3 and M4 use the original data (N=781).
The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively.
Robust standard errors clustered by the enterprise are reported in parentheses.

Table 10 Effect mechanism analysis via regressions of the dependent variables production scale (*Sc*), the emission intensity of wastewater (*Ww*), COD (*Cod*), BOD (*Bod*), and SS (*Ss*) on the MEID policy respectively

Independent variables	*Sc*	*Ww*	*Cod*	*Bod*	*Ss*
Treat* Time	**-8.2539****	**0.0090**	**0.0025**	**-0.0007**	**0.0005**
	(3.6648)	(0.0685)	(0.0057)	(0.0028)	(0.0024)
Controls	Yes	Yes	Yes	Yes	Yes
Fixed effects	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year
N observations	692	692	692	692	692
N clusters	88	88	88	88	88
R-squared	0.4887	0.3777	0.2470	0.1761	0.2018
F-test	34.0921	6.3036	5.7937	3.7802	6.5778
(*p*-value)	0.0000	0.0000	0.0000	0.0000	0.0000

The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively.
Robust standard errors clustered by the enterprise are reported in parentheses.

Appendix

PSM Sampling

Here, we present the PSM modeling process. Firstly, a *Logit* model is established to calculate the propensity score of each enterprise. The propensity score is a conditional probability of being a regulated enterprise, thus we choose a series of the observed covariates that might affect enterprise whether to be regulated by the MEID policy as the control variables in the *Logit* regression. Three sets of control variables are considered: a. characteristics of the enterprise, *Age* and *Poe*; b. the sugar production of enterprise and its square, *Spro* and *Spro*× *Spro*; c. the indicators of the production process, *Sr* and *Reuse*. As shown in Eq.(2), the subscript *i* refers to the various sugar enterprises; $p(\mathbf{X}_i)$ is the propensity score of enterprise *i* being regulated; dummy variable *D* equals 1 if the enterprise *i* is regulated by the MEID policy (i.e., national key monitored sugar enterprises), otherwise 0; the vector $\mathbf{X}_i$ represents the above covariates.

$$p(\mathbf{X}_{it}) = pr(D = 1|\mathbf{X}_{it}) = \frac{\exp(\lambda \mathbf{X}_{it})}{1 + \exp(\lambda \mathbf{X}_{it})} \tag{2}$$

Secondly, we use the PSM matching method to match each regulated enterprise to one or more unregulated ones with the statistically identical propensity score. To avoid that a regulated enterprise in the year *i* is matched to an unregulated enterprise in other years excepting *i*, we conduct PSM matching for each year to find a match among the control group for the treatment group in the same year. Besides, given the statement that the covariates should be time-invariant or fixed before the enterprise being treated by the policy (Caliendo and Kopeinig 2008), thus we replace the actual $\mathbf{X}_i$ between 2014 and 2016 with the mean $\mathbf{X}_i$ from 2011 to 2013, and the $\mathbf{X}_i$ between 2008 and 2013 remains its actual value.

Finally, we get a pair of matched groups with statistically similar $\mathbf{X}_i$.

The Dynamic Impact of the MEID Policy

Common trend assumption is a necessary precondition to conduct a DID model. Except for the descriptive figure of common trend (Fig.1), we also do an ex-post evaluation of common trend using a dynamic model. Hence, we introduce a group of interaction terms that are the product of Treat and corresponding year dummy variables (i.e., Treat*Time_{2011}, Treat*Time_{2012}, Treat*Time$_{2013}$, Treat*Time$_{2014}$, Treat*Time$_{2015}$ and Treat*Time$_{2016}$) to replace the previous term Treat*Time. Among these time dummy variables, Time$_{2011}$ of value 1 refers to the years in and before 2011, whereas the other time dummy variables of value 1 correspond to the years in subscript, respectively. We set 2011 as the base year, thus Treat*Time$_{2011}$ should be omitted from regression to avoid the multicollinearity of the dummy variable trap. The dynamic model is as follows:

$$Y_{it} = \beta_0 + \sum \alpha_j (Year_{it} \times Treat_{it}) + \beta_j(\mathbf{Controls}_{it}) + \mu_i + \nu_t + \varepsilon_{it} \quad (3)$$

where the subscript t refers to time variables; the subscript i refers to various sugar enterprises; the dependent variable Y_{it} refers to economic (i.e., Ros) or environmental performance (i.e., Wwt, Codt, Bodt, and Sst); the matrix-vector **Controls** is the same as the previous. Besides, the μ represent enterprise-level fixed effects; the ν represents year-level fixed effects; the ε represents the stochastic disturbance term. A group of αs, our most concerned coefficients, represent the changes in the value of the dependent variable relative to that in the base year after MEID policy. To save space, we only present the common trend figure of Ros and Wwt (see Fig.3), and the estimates of the other three pollutant emissions are shown in Table 9.

Fig.3 shows that there is no statistically significant difference in Ros and Wwt between the pre-implementation years and base year, which confirms the common trend before DID model setting. Regarding post-implementation years, Fig.3a shows Ros hasn't statistically changed compared with the base year, which indicates that the MEID policy hasn't significantly affected Ros. Whereas all confidence intervals of Wwt are statistically away from the 0-level line in Fig.3b, which indicates that the MEID policy has a significant negative impact on Wwt. Besides, Table 9 presents the dynamic trend of Codt, Bodt, and Sst. The insignificance of estimates on Treat*Time$_i$ ($i<2014$) indicates that the common trend is tested true. And the treated sugar enterprises experience a significant decrease in Codt, Bodt, and Sst after the MEID policy. These results also confirm the previous results that the MEID policy has a significant impact on pollution emission while no impact on Ros.

Specially, we also conclude the dynamic change trend of the impact from the MEID policy. Wwt experiences a significant decrease starting from 2014, Codt and Bodt experience a significant decrease starting from 2015, and Sst begins to decrease in 2016 that is the third implementation year. The MEID policy has different abatement effects on four pollutant emissions' reduction, almost all of which change from less to more, and from insignificant to significant over time.

Enterprise Heterogeneity in the Impacts of the MEID Policy

The previous analysis shows that the MEID policy has a significant environmental effect and an insignificant economic effect on sugar enterprises. This section explores the different responses to the MEID policy across sugar enterprises with different individual characteristics. We choose enterprise size and ownership, and divide the whole sample into two ownership subsamples: the private-owned enterprises (POEs) and the state-owned enterprises (SOEs); or two size subsamples: the larger and the smaller groups. Some researchers suggest that the larger enterprises' greater visibility in their local communities makes them more sensitive to the public pressure resulted from information disclosure, and makes them under even greater social attention and scrutiny, thereby triggers improved responsiveness towards pollution and more abatement effort (Liu and Anbumozhi 2009; López-Gamero et al. 2010; Doshi et al. 2013). Regarding ownership, on the one hand, the SOEs are more willing to disclose more environmental information and invest more in environmental protection for a better political reputation and a greener image, eventually achieving executives' promotion. On the other hand, compared to the POEs, the investment of the SOEs in environmental protection is less efficient due to the existence of agency problems and the heavy burden of social responsibility required by local government (Kuo et al. 2012; Cheng et al. 2017; Chen et al. 2018). Therefore, heterogeneous responses of enterprises to environmental regulation might lead to various net effects from the policy. The core issue concerned in this section is whether the effect of the MEID policy on sugar enterprises' performance varies across size and ownership.

Two types of models are constructed for heterogeneity analysis. The first model is a Difference in Difference in Difference (DDD) model based on PSM. The DDD model is an advanced DID model through adding a dummy variable (either Size or Soe) and corresponding interaction terms of the new dummy variable and three DID dummy terms (i.e., $Treat$, $Time$, and $Time \times Treat$). Hence, we get the PSM-DDD regression model shown in Eq.(4). The second model is a PSM-DID model same as the previous models. We apply to two size categories separately: the larger (Size=1) and the smaller (Size=0) groups; and also apply to two ownership categories separately: POEs (Poe=1) and SOEs (Poe=0).

$$Y_{it} = \beta_0 + \beta_1(Time_{it}) + \beta_2(Treat_{it}) + \beta_3(D_{it}) + \beta_4(Time_{it} \times Treat_{it}) + \beta_5(Time_{it} \times D_{it}) + \beta_6(Treat_{it} \times D_{it}) + \beta_7(Time_{it} \times Treat_{it} \times D_{it}) + \beta_j(Controls_{it}) + \varepsilon_{it} \quad (4)$$

Where dependent variable *Y* refers to sugar enterprises' economic performance (i.e., *Ros*) or environmental performance (i.e., *Wwt*, *Codt*, *Bodt,* and *Sst*); the dummy variable *D* refers to category dummy variable (i.e., either *Size* or *Soe*); the control variables refer to *Size*, *Poe*, *Reuse,* and *Sr* for the economic dependent variable, and *Size*, *Poe*, *Power*, *Coal*, *Freshw,* and *Sr* for environmental dependent variables. Here are brief explanations for heterogeneity coefficients, taking an example of *Poe*. The coefficient β_4 captures the net effect of the MEID policy on the SOEs (*Poe*=0), and the sum of β_4 and β_7 (i.e., $\beta_{4+}\beta_7$) captures the net effect of the MEID policy on the POEs (*Poe*=1). Thus, the coefficient β_7 on $Time \times Treat \times Poe$ reflects the change in the dependent variable among the sugar POEs relative to the sugar SOEs after the MEID policy, and it is what we are most concerned with. Besides, coefficients on other interaction terms like β_5 and β_6 are of no real significance.

We still control for the enterprise and year fixed effect to capture more specific individual information, thus omitting four terms, $Time_{it}$, $Treat_{it}$, $Time_{it}\times D_{it}$ and $Treat_{it}\times D_{it}$ to avoid multicollinearity. *Table* 11 presents all estimates of the heterogeneity effect of the MEID policy on economic performance (i.e., *Ros*). All coefficients on $Time \times Treat \times Poe$ and $Time \times Treat \times Size$ in M1 are insignificant. We could only infer that the larger and the SOEs are more likely to get a promotion of return driven by the MEID policy. Also, all coefficients on $Treat*Time$ in M2 and M3 are insignificant, while only the coefficient for the smaller enterprises is negative though insignificant as well. That reflects that the MEID policy might have a potentially damaging effect on the profitability of the smaller group.

Table 12 presents the estimates of the heterogeneity effect of the MEID policy on environmental performance, including Panel A of size heterogeneity and Panel B of ownership heterogeneity. The DDD estimates on *Treat**Time**Size* in the M1s indicate that the larger enterprises reduce more pollution after the MEID policy than the smaller ones. Especially in the early-stage start-up period of the policy, the relatively low marginal cost of pollution treatment gives the larger sugar enterprises a significant advantage of technology innovation over the smaller ones under the pressure from complying with regulation. And the more the enterprises reduce the pollution emissions, the greener image and more community support they will get.

Regarding the ownership heterogeneity in Panel B, the POEs and the SOEs both derive a significant reduction in *Wwt* from the MEID policy, but apparently, the effect on the SOEs is stronger than the POEs. As for other pollutants, the MEID policy seems likely to produce a more powerful abatement effect on the POEs than the SOEs, though almost estimates are insignificant. Furthermore, it is interesting that the effort devoted by the SOEs in reducing wastewater seems to be much more effective than the POEs, while the POEs perform better in dealing with the emission-reducing issue of other pollutants. A possible reason is that wastewater is easier to be seen through our eyes or be observed through other senses, while the other pollutants are hard to be observed by community residents through any senses. Therefore, the SOEs tend to bolster their green image by reducing the emission of a pollutant that is visible to community members, hence the MEID policy seems to have a much greater effect on the POEs than the SOEs.

To sum up, the MEID policy might boost the more rapid economic growth of the larger and the SOEs than the other enterprises. Furthermore, it should be noted that the MEID policy also has a trend of slowing the economic growth in smaller enterprises. As for environmental performance, the larger enterprises reduce much more pollution than the smaller ones, and the POEs do better than the SOEs in emission-reducing of pollutants except for wastewater.

4 Figures and Tables

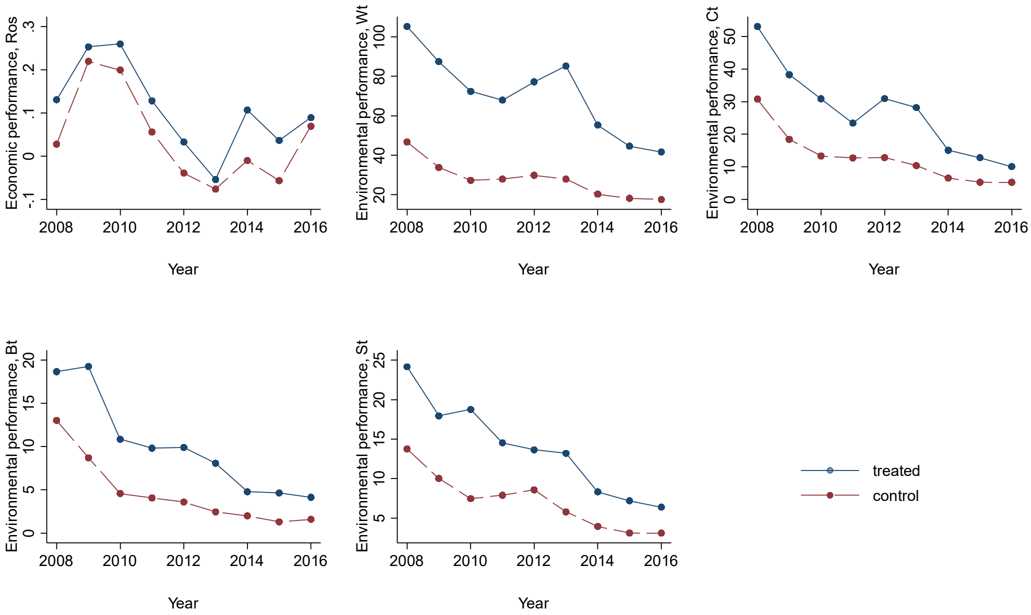

Fig.1 The trend of economic and environmental output

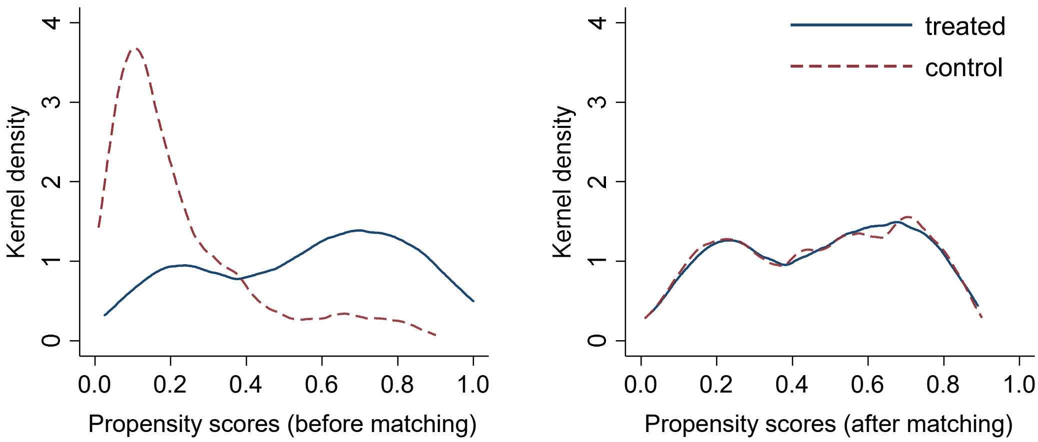

Fig. 2 The kernel density of sugar enterprise's propensity score

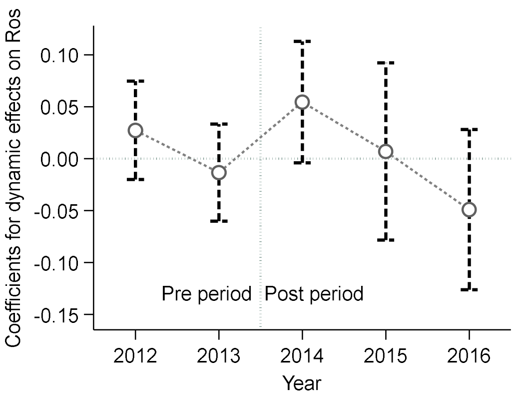

Fig. 3a common trend of *Ros*

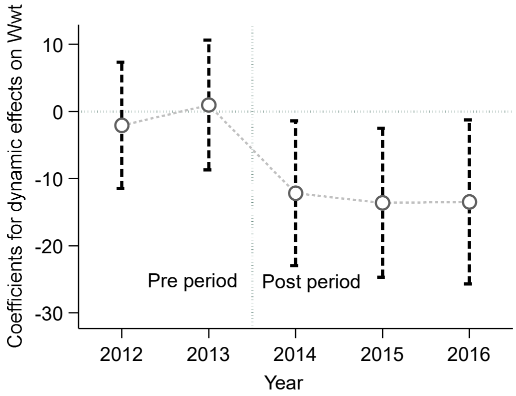

Fig. 3b common trend of *Wwt*

Fig. 3 The common trend test for dependent variables *Ros* and *Wwt*. *Notes*: the vertical line aims to distinguish the pre-implementation period (before 2014) and the post-implementation period (2014 and after).

Table 2 *Logit* regression on the treatment decision (2008)

Independent variables	Coefficients	Standard error
Poe	0.761	0.844
Age	-0.001	0.041
Spro	0.670***	0.186
Spro×Spro	-0.015***	0.005
Sr	-0.303***	0.144
Reuse	-0.050***	0.029

All estimated coefficients come from the *Logit* regression using one-year data. Here, we show the estimates of 2008 as an example.

The dependent variable, a dummy variable, refers to whether to be treated by the MEID policy after controlling for the bias from these independent variables.

The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively.

Table 3 Covariates' balance test of PSM

Covariates	Matching status	2008		2009		2010		2011		2012		2013		2014		2015		2016	
		Standardized bias (%)	t-value	Standardized bias (%)	t-value	Standardized bias (%)	t-value	Standardized bias (%)	t-value	Standardized bias (%)	t-value	Standardized bias (%)	t-value	Standardized bias (%)	t-value	Standardized bias (%)	t-value	Standardized bias (%)	t-value
Poe	Unmatched	-33.70	-1.46	-15.20	-0.66	-14.40	-0.64	-14.40	-0.64	-20.40	-0.92	-20.40	-0.92	-27.10	-1.23	-4.80	-0.21	-1.20	-0.05
	Matched	25.90	0.76	42.90	1.39	5.90	0.20	-2.10	-0.07	27.90	0.92	-21.20	-0.66	8.80	0.30	-23.10	-0.76	-4.30	-0.14
Age	Unmatched	14.00	0.58	10.00	0.42	4.00	0.17	4.00	0.17	1.60	0.07	1.60	0.07	1.60	0.07	-2.70	-0.12	-2.70	-0.12
	Matched	37.10	1.15	-3.90	-0.15	1.00	0.04	11.70	0.44	19.00	0.72	18.40	0.65	25.20	1.03	13.90	0.51	12.20	0.46
Spro	Unmatched	129.60	5.88***	120.10	5.66***	100.10	4.87***	95.60	4.63***	106.50	5.13***	109.90	5.29***	105.00	5.09***	100.10	4.72***	98.60	4.66***
	Matched	9.30	0.28	13.80	0.44	-11.00	-0.38	6.80	0.20	-2.40	-0.08	-4.90	-0.16	18.60	0.62	23.10	0.81	10.00	0.35
*Spro*Spro*	Unmatched	94.10	4.62***	89.70	4.52***	82.00	4.19***	76.60	3.91***	91.50	4.64***	91.40	4.68***	87.40	4.48***	84.60	4.18***	84.10	4.16***
	Matched	7.80	0.26	26.30	0.83	-15.80	-0.67	15.40	0.45	-5.80	-0.21	-11.90	-0.45	14.10	0.50	15.60	0.66	2.80	0.11
Sr	Unmatched	-26.70	-1.22	-28.40	-1.26	-19.60	-0.88	-46.90	-2.36**	-33.80	-1.66*	-49.00	-2.62***	-47.90	-2.50**	-49.90	-2.53**	-50.90	-2.58**
	Matched	-36.10	-1.17	38.00	1.29	17.20	0.46	-6.90	-0.33	12.10	0.54	-7.00	-0.55	16.50	0.87	10.40	0.51	10.40	0.53
Reuse	Unmatched	-7.70	-0.31	-4.20	-0.18	-22.60	-1.05	-28.60	-1.38	-17.10	-0.82	-2.00	-0.09	-16.50	-0.80	-24.10	-1.15	-23.40	-1.12
	Matched	78.50	1.52	-17.70	-0.82	-18.00	-0.71	-11.00	-0.47	-0.60	-0.02	-15.60	-0.53	19.60	0.71	33.60	1.46	9.50	0.37
Joint test		N	LR χ^2	N	LR χ^2	N	LR χ^2	N	LR χ^2	N	LR χ^2	N	LR χ^2	N	LR χ^2	N	LR χ^2	N	LR χ^2
	Unmatched	9	38.30***	3	30.07***	3	23.65***	6	28.62***	16	27.94***	13	35.72***	24	31.38***	8	29.69***	7	29.42***
	Matched	74	6.97	81	4.73	84	2.43	81	1.43	74	2.58	77	3.08	66	2.63	77	3.18	78	1.56

The absolute standardized difference in percent is represented by the ratio of the mean difference and the average standard deviation.
The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% significance levels, respectively.

Table 4 Descriptive statistics of enterprise-level variables

Variables	Whole sample						PSM sample					
	N	Mean	SD	Min	Med	Max	N	Mean	SD	Min	Med	Max
Treat	781	0.334	0.472	0.000	0.000	1.000	692	0.293	0.456	0.000	0.000	1.000
Ros	781	0.064	0.182	-0.925	0.084	0.514	692	0.067	0.181	-0.925	0.083	0.514
Wwt	781	41.927	53.406	0.235	25.989	561.897	692	36.249	37.112	0.235	25.082	431.967
Codt	781	17.398	26.740	0.122	9.619	349.687	692	15.461	21.964	0.122	9.143	349.687
Bodt	781	6.315	12.356	0.015	2.240	164.559	692	5.955	11.544	0.015	2.223	164.559
Sst	781	9.253	13.693	0.031	5.005	164.559	692	8.662	12.555	0.031	4.895	164.559
Ww	781	0.650	0.468	0.010	0.560	4.470	692	0.636	0.440	0.010	0.550	4.470
Cod	781	0.032	0.043	0.000	0.020	0.550	692	0.032	0.044	0.000	0.020	0.550
Bod	781	0.012	0.025	0.000	0.005	0.350	692	0.012	0.024	0.000	0.005	0.350
Ss	781	0.017	0.019	0.000	0.010	0.200	692	0.017	0.019	0.000	0.010	0.200
Poe	781	0.620	0.486	0.000	1.000	1.000	692	0.632	0.483	0.000	1.000	1.000
Size	781	0.356	0.479	0.000	0.000	1.000	692	0.321	0.467	0.000	0.000	1.000
Age	781	13.676	8.653	2.000	12.000	66.000	692	13.434	8.347	2.000	12.000	66.000
Spro	781	7.701	6.182	0.146	5.679	34.512	692	7.047	5.383	0.146	5.486	32.908
Sr	781	98.517	1.992	81.730	99.100	100.000	692	98.618	1.731	81.730	99.100	100.000
Reuse	781	94.916	6.001	48.160	96.500	100.000	692	95.085	5.748	48.160	96.515	100.000
Power	781	34.215	10.358	22.970	33.740	296.950	692	34.249	10.900	22.970	33.760	296.950
Coal	781	4.809	0.801	1.960	4.720	14.780	692	4.827	0.826	1.960	4.735	14.780
Freshw	781	0.572	0.544	0.010	0.410	5.770	692	0.563	0.523	0.010	0.410	5.770

This statistics information includes the number of firm-years observations (N), mean, standard deviation (SD), minimum (Min), median (Med), maximum (Max) of all variables used in this paper.
This table presents the summary statistic of original and matched data used in the subsequent empirical analysis.

Table 6 Robustness check results of the effect of the MEID policy on emissions of wastewater (*Wwt*), COD (*Codt*), BOD (*Bodt*), and SS (*Sst*)

Independent variables	*Wwt*			*Codt*			*Bodt*			*Sst*		
	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
*Treat*Time*$_{11}$	-7.7294			-6.0717			-2.3667			-1.7132		
	(5.8264)			(4.7789)			(2.3217)			(2.5208)		
Treat*Time		**-11.7550****	**-13.2120****		**-3.5640**	**-8.2713*****		**-2.2342*****	**-3.0746****		**-3.0187***	**-3.5113***
		(4.5881)	(5.8757)		(2.2468)	(3.1192)		(0.8005)	(1.2478)		(1.5469)	(1.8136)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year
N observations	471	453	626	471	453	626	471	453	626	471	453	626
N clusters	88	86	88	88	86	88	88	86	88	88	86	88
R-squared	0.2099	0.3771	0.3075	0.1820	0.3180	0.2452	0.1661	0.2822	0.2030	0.0760	0.1590	0.1431
F-test	3.9762	11.6334	6.8422	3.4099	10.6363	9.3194	3.9755	6.7880	9.0414	2.1281	10.3184	6.8032
(*p*-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

M1 refers to DID regression adopting 2011 as a pseudo implementation year. M2 refers to DID regression using the data from 2011 to 2016. M3 refers to DID regression using the data excluding data in 2014.
The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively.
Robust standard errors clustered by the enterprise are reported in parentheses.

Table 8 Robustness check results of the effect of the MEID policy on *Ros*

Independent variables	Gpm_psm	Gpm	Mp_psm	Mp	Return_psm	Return
	M1	M2	M1	M2	M1	M2
Treat*Time	0.0111	0.0228	-0.0016	0.0075	-1,525.7550*	-1,377.1318
	(0.0273)	(0.0225)	(0.0219)	(0.0183)	(820.4945)	(869.5947)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year
N observations	692	781	692	781	692	781
N clusters	88	90	88	90	88	90
R-squared	0.4627	0.4727	0.5657	0.5756	0.4795	0.4370
F-test	55.7989	60.7904	59.2234	64.7165	13.9007	10.9245
(*p*-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively.
Robust standard errors clustered by the enterprise are reported in parentheses.

Table 9 Regression results for dynamic effects on emissions of COD (*Codt*), BOD (*Bodt*), and SS (*Sst*)

Independent variables	*Codt*	*Bodt*	*Sst*
$Treat*Time_{2012}$	-2.0593	-0.4392	-3.0118
	(5.1001)	(2.0200)	(4.0017)
$Treat*Time_{2013}$	-2.0656	-0.5509	0.2713
	(4.3299)	(1.8244)	(3.0283)
$Treat*Time_{2014}$	**-2.3576**	**-1.9488**	**-2.0232**
	(4.3839)	(2.0116)	(2.5667)
$Treat*Time_{2015}$	**-8.3800***	**-2.9826***	**-3.5195**
	(4.3055)	(1.7533)	(2.3769)
$Treat*Time_{2016}$	**-8.9339****	**-3.9136****	**-4.2952***
	(4.2375)	(1.7956)	(2.2867)
Controls	Yes	Yes	Yes
Fixed effects	Firm, year	Firm, year	Firm, year
N observations	692	692	692
N clusters	88	88	88
R-squared	0.2483	0.2109	0.1464
F-test	9.3281	6.8358	5.4760
(*p*-value)	0.0000	0.0000	0.0000

$Treat*Time_{2011}$ is dropped as a base interaction variable covering the data in and before 2011.
The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively.
Robust standard errors clustered by the enterprise are reported in parentheses.

Table 11 Regression results for heterogeneity of effects across size and ownership on Return on Sales (*Ros*)

Independent variables	Size			Ownership		
	M1 Whole sample	M2 The larger group	M3 The smaller group	M1 Whole sample	M2 The POE group	M3 The SOE group
*Treat*Time*	-0.0343	**0.0038**	**-0.0412**	0.0026	**0.0199**	**0.0488**
	(0.0534)	(0.0213)	(0.0554)	(0.0571)	(0.0335)	(0.0473)
Size	0.0016			0.0141	0.0041	0.0659*
	(0.0246)			(0.0241)	(0.0297)	(0.0372)
Poe	0.0305	-0.0172	0.0495	0.0386		
	(0.0367)	(0.0202)	(0.0463)	(0.0371)		
Treat*Time*Size	**0.0780**					
	(0.0500)					
Treat*Time*Poe				**-0.0043**		
				(0.0548)		
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year
N observations	692	222	470	692	437	255
N clusters	88	44	70	88	62	45
R-squared	0.4665	0.7276	0.4561	0.4620	0.5327	0.4576
F-test	52.2424	54.0694	39.9917	59.7392	55.8767	36.4066
(*p*-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

M1 adopts the DDD model using the full-size sample after matching (N=692); M2 and M3 both use DID model, where the number of the larger and smaller observations is 222 and 470 respectively, and the number of the private-owned enterprises (POEs) and non-private-owned enterprises (SOEs) is 437 and 255 respectively.

The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively. Robust standard errors clustered by the enterprise are reported in parentheses.

Table 12 Panel A. Regression results for size heterogeneity of effects on emissions of wastewater (*Wwt*), COD (*Codt*), BOD (*Bodt*), and SS (*Sst*)

Independent variables	*Wwt*			*Codt*			*Bodt*			*Sst*		
	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
*Treat*Time*	-1.6454	-15.8205	1.9962	-1.0786	-1.4380	-2.0615	-1.5768	0.6877	-2.2685	-0.6644	0.1074	-1.1508
	(4.0977)	(10.2929)	(2.5481)	(2.9284)	(8.2821)	(2.7781)	(1.3712)	(4.0458)	(1.4386)	(1.5188)	(5.1383)	(1.4567)
Size	11.2185***			5.1099**			2.2007**			0.3327		
	(3.2344)			(2.1502)			(0.9367)			(1.7953)		
Treat*Time*Size	**-25.5871*****			**-11.0534*****			**-2.7891***			**-4.8712***		
	(7.4024)			(4.0962)			(1.6598)			(2.9174)		
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year
N observations	692	222	470	692	222	470	692	222	470	692	222	470
N clusters	88	44	70	88	44	70	88	44	70	88	44	70
R-squared	0.3298	0.5674	0.3466	0.2517	0.4462	0.3274	0.2117	0.3453	0.2560	0.1476	0.3102	0.1392
F-test	10.5988	88.8555	9.9535	12.9716	87.3915	7.8414	7.8669	8.7818	3.9170	7.2139	3.5251	10.3198
(*p*-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

M1 adopts the DDD model using the full-size sample after matching (N=692); M2 and M3 adopt DID method and use the sub-sample of larger enterprises (N=222) and smaller enterprises (N=470) respectively.
The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively.
Robust standard errors clustered by the enterprise are reported in parentheses.

Table 12 Panel B. Regression results for ownership heterogeneity of effects on emissions of wastewater (*Wwt*), COD (*Codt*), BOD (*Bodt*), and SS (*Sst*)

Independent variables	*Wwt*			*Codt*			*Bodt*			*Sst*		
	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
*Treat*Time*	-15.6869**	-12.1999*	-20.7601**	-6.1864	-5.5223	-6.0816	-2.8763**	-3.0945*	-1.7338	-1.0706	-5.1987**	0.8943
	(6.9237)	(7.1580)	(8.2749)	(4.0085)	(3.8961)	(4.8731)	(1.4343)	(1.6765)	(2.2926)	(1.8479)	(2.5108)	(2.5038)
Poe	-0.6441			7.0182			-0.2594			1.5999		
	(4.8879)			(4.8180)			(1.7315)			(2.1938)		
Treat*Time*Poe	**5.2841**			**0.4764**			**0.1403**			**-3.2682**		
	(9.2642)			(4.9985)			(1.7887)			(2.8044)		
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year	Firm, year
N observations	692	437	255	692	437	255	692	437	255	692	437	255
N clusters	88	62	45	88	62	45	88	62	45	88	62	45
R-squared	0.3105	0.2610	0.4399	0.2463	0.2161	0.2812	0.2102	0.1976	0.2585	0.1458	0.1764	0.1001
F-test	9.2803	4.8618	9.5042	11.0146	5.7609	25.1615	8.0822	4.3962	11.8825	6.5739	4.6541	6.8431
(*p*-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

M1 adopts the DDD model using the full-size sample after matching (N=692); M2 and M3 adopt DID method and use the sub-sample of private-owned enterprises (POEs, N=437) and non-private-owned enterprises (SOEs, N=255) respectively.

The superscripts *, **, *** indicate significance at the 10%, 5%, and 1% levels (two-tailed), respectively.

Robust standard errors clustered by the enterprise are reported in parentheses.