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The Impact of SO_2 Emission Trading Policy on Enterprise Performance

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Abstract: We used the latest database of Chinese industrial enterprises to make an empirical test of the relationship between the SO_2 emissions trading pilot (ETP) policy implemented in 2007 and enterprise performance based on a difference-in-difference (DID) method since the ETP policy tends to be a "quasi-natural experiment." The empirical results show that the ETP policy has a significant promotion effect on enterprise performance, which provides evidence supporting the "Porter hypothesis" in China. Heterogeneous regression results show that ETP policies play a vital role in promoting development in heavily polluting industries, state-owned enterprises, and central regions. The test results of the mechanism demonstrate that the ETP policy has two mechanisms to affect enterprise performance: "improving the total factor productivity of the enterprise" and "increasing the extra cost of the enterprise." There are two policy implications of our research: first, government departments should strive to explore and implement relevant market-based environmental regulations and policies; second, government departments should vigorously support small and medium-sized enterprises and backward areas in the west while focusing on heavily polluting industries and making the best use of environmental regulations in pollution control, which are the key points for China to win the defense of the blue sky.

Keywords: ETP policy, enterprise performance, environmental regulation

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Introduction

Since the first Law on the Prevention and Control of Environmental Pollution by Solid Wastes of the People's Republic of China was enacted by China's central government in 1987, the Air Pollution Prevention and Control Action Plan, known as the strictest air control plan in history, was released in 2013. The Central Committee of the Communist Party of China promulgated the Law on the Prevention and Control of Environmental Pollution by Solid Wastes of the People's Republic of China (Revised Edition) again in 2018, which reflects the central government's determination to control air pollution. The 2021 Government Work Report states that we should strengthen pollution prevention and ecological construction, continue to improve environmental quality, in-depth implementation of sustainable development strategies, consolidate the results of the blue sky, blue water, clean soil defense war, and promote the green transformation of production and lifestyle. All of these exemplified the fact that China's central government has attached great importance to protecting and improving the environment, advancing the construction of an ecological civilization, and promoting sustainable economic and social development. As we all know, the development of enterprises is inseparable from the consumption of natural resources. At the same time, it is inevitable to produce pollution of "three industrial wastes," namely wastewater, waste gas, and waste residue. This naturally leads to a question: Can enterprise development coexist with environmental regulations and policies that aim to protect an ecological civilization? The answer to this question is seriously related to whether China's economy can achieve sound and rapid development.

Regarding the relationship between environmental regulation policies and enterprise performance, there are two main types of research literature in the academic field: the first type of literature supports the "inhibition hypothesis" of neoclassical economics (Gray, 1987; Barbera et al., 1990; Gray et al., 2003; Lanoie et al., 2008; Tu et al., 2015; Wang, 2017; Xie, 2017; Li et al., 2019; Zhang et al., 2019), that is, the implementation of environmental regulations adds additional cost burdens to enterprises, leading to a decline in enterprise performance. On the other hand, some literature supports Porter's "promoting hypothesis" view (Montgomery, 1972; Porter et al., 1995; Jaffe et al., 1997; Brannlund et al., 1998; Hamamoto, 2006; Testa et al., 2011; Ambec et al., 2013; Rubashkina et al., 2015; Qi et al., 2018; Ren et al., 2019; Borsatto et al., 2020; Zhang, 2020; Tao,2021). According to the "Porter hypothesis," appropriate environmental regulations can improve the efficiency of enterprise by stimulating corporate innovation to offset or even exceed the additional environmental protection costs, thereby improving enterprise performance. Based on a comprehensive review of the two types of literature, it was difficult for us to judge the relationship between environmental regulation policies and enterprise performance in theory, so we researched an answer from an empirical perspective.

In 2007, China implemented the largest SO_2 emission trading pilot (ETP), an environmental regulation policy in 11 provinces, which is equivalent to a rare "quasi-natural experiment" (Li et al., 2016), which provided a valuable opportunity for us to test the relationship between environmental regulation and enterprise performance. The following figure shows the impact of the ETP policy on SO_2 emissions in experimental areas (11 provinces, represented by the Treated group) and non-experimental areas (other provinces, represented by the Control group). It is noticeable that the average SO_2 emission in the experimental area is significantly higher than that in the non-experimental area, which indicates the accuracy of selecting regions; secondly, after the implementation of the ETP policy in 2007, the average SO_2 emissions of both the experimental group and the non-experimental group have been in a downward trend, and this downward trend began to appear in 2006, which may reflect the expected effect of the ETP policy approaching implementation. Finally, it can be seen that the average SO_2 emissions remained stable in 2009 and 2010 and began to show an increase after 2010. One possible reason may be the side effects of the central government's response to the global economic crisis by stimulating the economy.

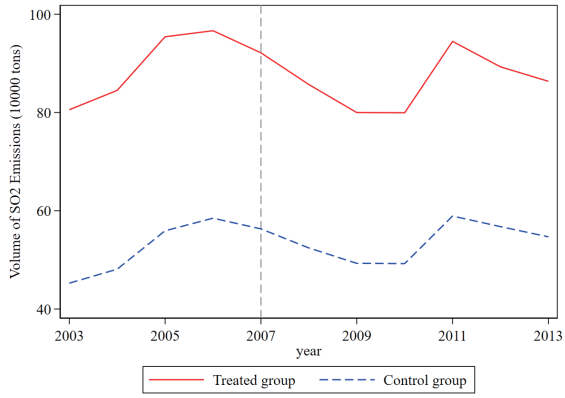

Fig.1 The time trend of SO_2 emission
Note: Data from the China Statistical Yearbook

Currently, there are three important articles closely related to the topic of ETP: the first one belongs to Tu et al. (2015), who explored whether the ETP policy stimulates the "Porter Effect" in China. Their empirical results show that although the emissions trading mechanism has alleviated the pollution to a certain extent, there is a serious shortcoming in this article that cannot be ignored. In the article, the year 2002 was used as the demarcation point of the experimental period. However, it was just in the initial exploration period of the ETP policy, and the central government did not issue a relevant standard policy system at that time, so the trading volume of emission rights in the pilot area was basically zero in 2002 (Li et al., 2016; Ren et al., 2019). Thereby, the empirical results may reflect other policy impacts (Such as the 2007 ETP policy) since its experimental period also includes 2007 to 2012; Second, Qi et al. (2018) used the 2007 ETP policy as a quasi-natural experiment and listed company data to confirm that emissions trading policies have significantly promoted corporate green innovation. The main drawback of this article is that the sample database of listed companies is imperfect because the database ignores many non-listed companies in the industry (annual observation value is 200,000 to 300,000) (Kong et al., 2013). Meanwhile, this article lacks a mechanism test for ETP policies promoting corporate green innovation. In the last one, Ren et al. (2019) also used the 2007 SO_2 emission trading policy as a quasi-natural experiment and found that the emission trading system significantly improved the total factor productivity of listed companies in the pilot area. However, this article also used an imperfect database of listed companies. In addition, it is argued that the sample period should not include 2015 because the ETP policy had by that time spread throughout the country.

Our paper fully draws on the merits of the above studies and has made some improvements.

Specifically, we make the following contributions: First, the latest industrial enterprise data from 2003 to 2013 was used for the first time. Taking 2007 as the cut-off point of the ETP policy period, we conducted a strict normative, empirical test on the ETP policy, which included not only the data of listed companies, but also a large number of non-listed companies, which makes the data more rigorous, comprehensive, and credible. Besides, we included return on assets (ROA) as an agent variable of enterprise performance since it can be divided into "profit margin on sales" and "turnover rate of total assets," which is helpful when analyzing the real source of enterprise performance improvement at a deeper level. Finally, we improved the robustness test conducted by Ren et al. (2019) by using the random sampling method. It not only carries out random sampling for the experimental group to capture the unobservable impact in different areas but also carries out random sampling for the experimental period to capture the unobservable impact at different times.

The structure of this paper is as follows: The first part is a review of the mainstream literature on the current research on environmental regulation and enterprise performance and a brief introduction to China's pilot policy on emissions trading. The second part is the research design, including sample selection, variable measurement, and econometric model setting. The empirical analysis is the third part, including basic regression analysis, robustness analysis, heterogeneity analysis, and mechanism testing. The last is our conclusions and policy recommendations.

Literature Review and Policy Background

Literature Review

On the relationship between environmental regulation and enterprise performance, there is a large debate in the academic community at present, and the views are quite the opposite. Some scholars hold the view that environmental regulation hurts enterprise performance, which is a typical view of neoclassical economics. Gray (1987), after research, believes that environmental regulation will add additional burdens on production costs to enterprises and, therefore, will pose a depressing effect on enterprise performance. Barbera et al. (1990) found that imperative environmental regulations also have a suppressive effect on manufacturing productivity. Furthermore, Gray et al. (2003) pointed out that under the requirements of environmental regulations, enterprises must conduct additional R&D and technological innovations in energy conservation and emission reduction, which in turn, have led to the "crowding-out effect" of productive investment in enterprises. Lanoie et al. (2008), though analyzing data from Quebec, Canada, found that environmental regulation makes companies' performance negative by increasing their extra costs. Tu et al. (2015) tried to explore whether the pilot policy of SO_2 emission trading in China stimulated the Porter effect. However, the empirical results show that observing from both realistic and potential perspectives. The Porter effect has not been verified in China, although to a certain extent, the problem of inefficient allocation of pollution rights has been alleviated. Wang (2017) empirically tested the relationship between environmental regulations and the company's total factor productivity using data from China's industrial enterprises' database and city-level data. The empirical results show that for every 1 percent increase in the intensity of environmental regulation measured by the proportion of industrial pollution control investment, the productivity of enterprises in the current period decreases by about 1 percent. Li et al. (2019) studied the relationship between environmental regulation and green total factor productivity of enterprises based on the Malmquist-Luenberger productivity index method and found that environmental regulation will reduce the the green total factor productivity of enterprises in the short term. Zhang et al. (2019) explored the impact of environmental regulation on the total factor productivity of enterprises in the Yangtze River Economic Belt, and the results showed that environmental regulation induced fluctuations in the total factor productivity of enterprises.

The opposite view is that environmental regulation can promote enterprise performance. Montgomery (1972) proved theoretically that environmental regulation could effectively reduce the cost of reducing pollution. Porter et al. (1995) proposed the famous "Porter hypothesis," which predicts that under certain conditions, environmental regulation can offset the cost of production brought by environmental regulation through innovation incentives and improving the production efficiency of enterprises so as to improve the performance of enterprises. Environmental regulation and enterprise performance can coexist completely. Jaffe et al. (1997) believe that environmental regulation policy can internalize the negative environmental externalities in the process of pollution discharge into the production costs of enterprises and then force enterprises to carry out reform and technological innovation, to achieve the improvement of performance. Besides, Brannlund et al. (1998) believed that the trading mechanism of emission rights had realized the growth of corporate profits in the paper industry in Sweden. Hamamoto (2006) studied the data of the Japanese manufacturing sector and found that environmental regulations have improved the productivity of enterprises by improving their R&D and innovation. Testa et al. (2011) also supported the view with empirical research of the EU construction companies. Ambec et al. (2013) found that environmental regulation is consistent with the growing trend of enterprise innovation. Li et al. (2013) found that the air pollution control method played a significant role in promoting the total factor productivity of industrial enterprises by using the DID method. Jefferson et al. (2013) studied the related policies of acid rain and SO_2 emission in 1998 and found that environmental regulatory policies promoted profits for enterprises in heavily polluted areas of China. Qi et al. (2018) used data from listed companies with the SO_2 emission trading policy of 2007 as a quasi-natural experiment to confirm that the emission trading policy significantly promoted corporate green innovation. Ren et al. (2019) also used the 2007 SO_2 emission trading policy as a quasi-natural experiment and found that the emission trading system significantly improved the total factor productivity of listed companies in the pilot regions. Borsatto et al. (2020) combed through 96 academic papers published in databases such as Web of Science over the last ten years and found that most of the relevant literature identified environmental regulations as one of the main factors that motivate firms to engage in green innovation. Zhang (2020) found that the stronger the dynamic innovation capacity to a certain extent, the better the promotion of corporate financial performance, and the environmental regulation policy is significantly and positively related to the firm's performance; that is, the environmental regulation can significantly improve the financial performance of the firm. Tao (2021) found that the environmental target responsibility system can lead to an increase in the number of green innovations, and the establishment of an innovation review system can maximize the quality of corporate innovation, stimulate a high level of corporate innovation, and ultimately improve corporate performance.

In addition, some scholars have found that the relationship between the two is non-linear. For example, Wang et al. (2014) empirically tested the impact of environmental regulation on the total factor productivity of enterprises using data from Chinese industrial enterprises and found that there is an inverse N-type relationship between environmental regulation and enterprise total factor productivity. Xing (2020) analyzed the relationship between environmental regulation and enterprise profitability in Guangdong province and found that the relationship between environmental regulation and enterprise profitability is complicated by the dual effect of "innovation compensation" and "compliance cost" on performance improvement, which is not a simple linear relationship, but an inverted U-shaped relationship.

Policy Background

China's extensive economic growth has created many environmental problems, so how to effectively deal with environmental issues and achieve sustainable economic development is an urgent challenge for China to tackle. The ETP policy of China was first implemented in the field of water pollution. It was not until the mid-1990s that the former Ministry of Environmental Protection decided to conduct pilots for air pollution trading in 6 cities, including Baotou and Guiyang (Li et al., 2016). In 2000, the central government began to explore market-based environmental regulations (Ren et al., 2019). In March 2002, in order to explore the trading mechanism of SO_2 pollution rights, the former Ministry of Environmental Protection took the lead in four provinces; Shandong, Shanxi, Jiangsu, and Henan, and three cities; Shanghai, Tianjin, and Liuzhou, and later joined the Huaneng Group to launch the SO_2 ETP policy, which was also called the "4 + 3 + 1" trading pilot policy. Since this policy did not have a strictly regulated trading system nor an emission trading center or trading market, the emission trading volume in many places after the implementation of the policy was zero (Li et al., 2016; Ren et al., 2019), and the "Porter effect" was not detected (Tu et al., 2015; Qi et al., 2018).

In 2007, the central government officially launched the SO_2 pollution rights trading policy. The Ministry of Finance of the People's Republic of China, the former Ministry of Environmental Protection and the National Development and Reform Commission approved eleven provincial-level regions as pilot areas: Jiangsu, Tianjin, Zhejiang, Hebei, Shanxi, Chongqing, Hubei, Shaanxi, Inner Mongolia, Hunan, and Henan, involving multiple industries such as glass, chemical, mining, and cement. The implementation of the emission trading policy was coordinated and realized under the guidance of the central top-level design, local government supervision, and market mechanism. During this period, the standardization process of emission rights was significantly accelerated

(Li et al., 2016). At the same time, various regions formulated a series of relevant implementation policies, resulting in an increase in the volume of emission trading year by year. Then in 2008, the first municipal-level emission right reserve and trading center was established and listed in Zhejiang province, and the corresponding offices and relevant supporting system measures were also introduced one by one. Until 2014, the general office of the State Council issued guidance on further promoting the pilot work of paid use and trading of emission rights, which marked the formal and comprehensive spread of the SO_2 pollution rights trading policy.

Empirical Design

Sample Selection

We selected the micro-data of manufacturing enterprises from 2003 to 2013 for our research, with data mainly coming from the database of Chinese industrial enterprises. The specific selection processes were as follows: Referring to the processing method of Cai & Liu (2009), the first step was to eliminate missing observations of key indicators (such as government subsidies, total profit, income tax expenses, number of employees, total industrial output value, sales income, etc.); the second step was to eliminate observations that did not meet the “above-scale” standard, which means the total industrial output value was less than RMB10 million. Sales were less than RMB10 million, or the number of employees was less than 30; the third step was to exclude some observations that did not meet accounting principles. In the end, we obtained sample data of manufacturing enterprises for a total of nine years, from 2003 to 2013 (data missing in 2009 and 2010), covering 31 manufacturing double-digit industries, which better reflected the overall situation of the entire manufacturing industry.

Variable Measurement

In related literature, there are many indicators for measuring enterprise performance. These indicators usually include Tobin’s Q (Zhao et al., 2015), total ROA (Zhou et al., 2015), and return on net assets (ROE) (Peng et al., 2015). We believe that Tobin’s Q method is only suitable for listed companies. On the other hand, the database of Chinese industrial enterprises lacks some specific data needed in this method. At the same time, considering the advantages of ROA that indicators can be further decomposed, it will help us analyze the true source of enterprise performance improvement at a deeper level. In contrast, ROE focuses more on the leverage of enterprises. To avoid a possible error in the research results caused by the different emphasis on ROE, we finally decided to use the ROA as the primary measure of enterprise performance.

$$ROA = \frac{\text{Net profit}}{\text{Total assets}} = \frac{\text{Net proft}}{\text{Sales}} \times \frac{\text{Sales}}{\text{Total assets}}$$

According to the DuPont analysis formula, an enterprise’s ROA is composed of two parts, which are the profit margin on sales and the turnover rate of total assets. The product competitiveness and operation efficiency of an enterprise can be properly displayed by the above two indicators. Meanwhile, on the premise that the total assets of an enterprise remain relatively stable, the turnover rate of total assets can also represent the expansion of the sales scale of an enterprise, which can help us to understand the Internal influence approach of the ETP policy on enterprise performance from a deeper level. Therefore, in the basic regression analysis, both indicators will be included in the measurement of enterprise performance. In addition, to control the influence of financial subsidies on the net profit of enterprises, we deducted the financial subsidies from the net profit in advance when calculating the above indicators by referring to the practice of Zhao et al. (2015). According to Aghion et al. (2015) and Wang et al. (2014), "tax benefits" is an important explanatory variable that affects enterprise performance. The tax benefits obtained by a company are equal to "total profit * corporate income tax rate-the actual enterprise payable income tax." Regarding the establishment of the corporate income tax rate, we have sorted out the Detailed Rules for Implementation of the Income Tax Law for Enterprises with Foreign Investment Enterprises and Foreign Enterprises, "Notice on Tax Preferential Policies for the Development of the Western Regions," and the "Enterprise Income Tax Law of the People's Republic of China (Amended in 2018)." Among these and other relevant tax policy documents, it was found that the setting principles are as follows: The income tax rate of western development enterprises and high-tech enterprises is set at 15 percent; the income tax rate of foreign-funded enterprises and enterprises in the special economic zone is set at 15 percent before 2008, and then gradually increased to 25 percent within five years according to the tax law setting rules. Excluding other small corporate income tax rates that cannot be judged, the remaining corporate income tax rates were uniformly set to 33 percent before 2008 and 25 percent after 2008, according to tax law requirements. Although the intensity of fiscal subsidies and income tax preferences are not the focus of this article. To control the impact of the two, we added two variables, lag periods for fiscal and tax intensity. In addition to the above variables, we also referred to the control variables commonly used in related research, such as corporate growth capacity, asset guarantee value, corporate age, main business profitability, and main business growth rate (Hong et al., 2006; Chen et al., 2012; Zhao et al., 2015; Liu, 2016), to control the regression equation. The setting method of all basic variables in this article is shown in Table 3 below:

Table 1 Main variables and measurement

Variable	Meaning	Measurements
ROA	Enterprise performance	(Total profits-income tax-subsidies)/total assets
Treat	Dummy variable	In the pilot area, make it 1, or 0
Post	Dummy variable	After 2007, make it 1, or 0
Sub	Fiscal subsidies	Measurement 1: log (1+fiscal subsidies) Measurement 2: fiscal subsidies/total assets
Comp	Competition	Measurement 1: 1- Herfindahl index of sales Measurement 2: 1- Average industry profit margin
Tax	Income tax preferences	log (1+ Nominal tax-Actual tax)
NPR	Corporate growth capacity	(Net profit t-Net profit t-1)/Net profit t-1

Variable	Meaning	Measurements
Tar	Asset guarantee value	(Stock+fixed assets)/total assets
Age	Corporate age	ln (2013-Establishment year +1)
Prof	Main business profitability	(Main business income-Main business cost)/Main business income
Growth	Main business growth rate	Main business income t-Main business income t-1)/Main business income t-1

Model Setting

To examine the impact of the ETP policy on enterprise performance, we refer to the practices of Zhou et al. (2018), Zheng et al. (2018) and Ren et al. (2019) to construct the following two-way fixed effect model:

$$ROA_{it} = \beta_0 + \beta_1 Post_t * Treat_i + \beta_2 Post_t + \beta_3 Treat_i + \beta_4 Z_{it} + u_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In the equation above, the subscript t represents time, and i represents the enterprise. This regression adopts clustering robust standard error, clustering to industry level. The coefficient of the core explanatory variable *Post* * *Treat* in the equation was the focus of our attention, and Z was the control variable, including the strength of financial subsidy (Sub), the strength of tax benefits (Tax), the growth ability of the company (NPR), the asset guarantee value (Tar), the age of the company (Age), the main business profit margin (Prof) and main business growth rate (Growth), The calculation of specific variables is shown in table 1. In addition, u_i represents the individual effect of the enterprise, λ_t represents the fixed effect of time, and ε_{it} is the error term.

Empirical Analysis

Basic Regression Analysis

The results of basic regression analysis show that the ETP policy has a significant promotion effect on enterprise performance, providing evidence for the "Porter hypothesis," which means that the promotion effect of the ETP policy on enterprise performance is greater than the inhibitory effect. The following are the specific analysis: Column (1) is the regression result of ordinary ordinary least square(OLS) without any control variables. We found that the emission trading policy Treat # Post has no significant impact on enterprise performance after the reform, maybe because we did not control the impact of other variables, leading to an inaccurate estimation; Then, in column (2), when we introduce all the control variables without controlling overtime fixed effects and individual fixed effects to capture the uncertain impact of a specific year and a specific individual, a significant negative impact of Treat # Post on enterprise performance shows up; while in column (3), the time-fixed and individual fixed effect are added to the control variables on the basis of column (2), that is, a two-way fixed-effect model is used to capture the uncertain impact of a specific year and the individual enterprise's heterogeneity difference respectively, then the result of Treat # Post is significantly positive; Column (4) is based on the two-way fixed model with the robust standard error clustering to the industry to capture the correlation and heteroscedasticity of individual error terms in the industry. As a result, the coefficient of Treat # Post is 0.00666, and it is significantly positive at the level of 5 percent, which fully indicates that emissions trading policies have a significant promotion effect on enterprise performance. To further investigate the internal source of enterprise performance change, we decomposed enterprise performance into sales profit rate and total asset turnover rate, and then regress them respectively. The results are shown in columns (5) and (6). It is obvious that Treat # Post has a significant promoting effect on sales profit rate with a coefficient of 0.00304, which is significant at the level of 1 percent, but has no significant effect on the total asset turnover rate. This shows that the improvement of enterprise performance is more from the growth of the sales profit rate.

Table 2 Baseline results

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ROA	ROA	ROA	ROA	Sales profit rate	Total asset turnover rate
Treat#Post	0.113	-0.0118***	0.00666***	0.00666**	0.00304***	-0.705
	(0.108)	(0.00193)	(0.00192)	(0.00317)	(0.000570)	(0.685)
Treat	-0.126	0.0202***	0.000936	0.000936	-0.00421***	0.674
	(0.0810)	(0.00150)	(0.00387)	(0.00678)	(0.000796)	(0.594)
Post	-0.0757	0.0395***	0.0795***	0.0668***	-0.00490***	1.347***
	(0.0651)	(0.00134)	(0.00244)	(0.00688)	(0.00129)	(0.363)
Constant	0.254***	0.138***	0.0449***	0.0449***	0.0285***	3.536***
	(0.0512)	(0.00961)	(0.0171)	(0.0118)	(0.00431)	(1.133)
Controls	N	Y	Y	Y	Y	Y
Year FE	N	N	Y	Y	Y	Y
Firm FE	N	N	Y	Y	Y	Y
Clustered	N	N	N	Y	Y	Y
Observations	959,677	440,675	440,675	440,675	440,675	440,675
R-squared	0.000	0.119	0.077	0.077	0.235	0.000

Note: *, ** and *** represents the significance level at 10%, 5% and 1% respectively. The standard errors are reported in parentheses and clustered at the industry level.

Parallel Trend and Dynamic Effect Test

Consistency of double-difference or multiple-difference estimators requires the assumption of parallel trends (Fu et al., 2015). As we all know, the premise of using the DID method is that the experimental group and the non-experimental group must meet the parallel trend hypothesis. On the assumption of a parallel trend, many scholars use the drawing observation method to identify it, which is intuitive but not rigorous. In this part, with reference to the practices of Kong et al. (2015), Zheng et al. (2018), Ren et al. (2019), the "event study approach" was used to test the balance trend.

This method is different from the DID method, which can only identify the average effect before and after the ETP policy period and can also observe the dynamic effect brought by the ETP policy in each year. Assuming the ETP policy reform takes place in each year of the sample period, the following measurement equation was constructed:

$$ROA_{it} = \beta_0 + \beta_t \sum_{t=2003}^{2013} Post_t * Treat_i + \beta_2 Z_{it} + u_i + \lambda_t + \varepsilon_{it} \quad (2)$$

The meaning here is different from equation (1). Specifically, when t = 2003, *Post*2003 = 1, and other years are replaced by 0, then every year, the situation is analogous in this way. Representing the effect of the ETP policy every year is the coefficient we care about, with the explanation of other variables unchanged. The regression results are shown in Table 3 below. No significant differences in enterprise performance are shown in 2004, 2005, and 2006. This means that there was no significant difference between the experimental group and the non-experimental group before the ETP policy reform, which indicates that this empirical analysis meets the assumption of parallel trends. Meanwhile, the ETP policy has significantly promoted enterprise performance since 2007. Then the promotion effect weakened in 2008 and disappeared in 2011, indicating that although the emission trading policy has a significant impact on enterprise performance, the impact decreases with time.

Table 3 Dynamic results

	Year 2004	Year 2005	Year 2006	Year 2007	Year 2008	Year 2013
Coefficient	0.00173	-0.000191	0.00176	0.00741**	0.00947***	0.00602**
Standard error	(0.00334)	(0.00347)	(0.00349)	(0.00324)	(0.00314)	(0.00218)

Note: *, ** and *** represents the significance level at 10%, 5% and 1% respectively. The standard errors are reported in parentheses and clustered at the industry level. Because of collinearity and missing values, the coefficients of the year 2003, 2011, and 2012 are missing. The database of manufacturing enterprises does not include the year 2008 and 2009, then we also do not report the results.

Figure 2 shows the dynamic change of β_t and its 90 percent confidence interval. From the figure, it is noticeable that the dynamic regression coefficient was not significantly different from 0 in 2006 and before at 90 percent confidence interval, while the data were significantly different from zero in 2007 and 2008 until the policy effect disappeared in 2013.

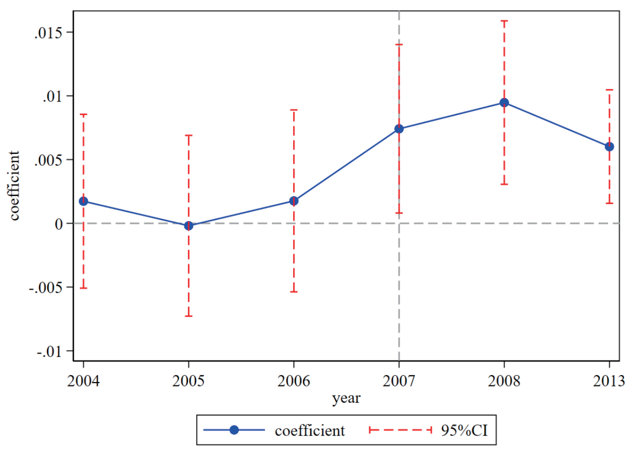

Fig.2 The dynamic effect of the ETP policy on enterprise performance

Robustness Analysis

Placebo Test (a): Referring to the random sampling method used by Zhou et al. (2018) and Ren et al. (2019), our procedure further improves this method and then uses it for a placebo test. Specifically, to start with, 200 random samples were taken from 31 provincial-level administrative units in China. 11 provinces were randomly selected as the experimental group and the remaining 20 provinces as the non-experimental group. The biggest advantage of this is that it cannot only control the observable influencing factors but also capture some influencing factors that are difficult to observe with the change of the region, "such as other industrial policy adjustments of local governments in different regions"(Zhou et al., 2018). Second, the reference method only randomly samples the experimental group, and based on this, 200 random samplings were simultaneously performed for the policy period in this article. Specifically, the first and last two years of the sample period were eliminated, and then a year was randomly selected from 2004 to 2012 as the implementation year of the policy. This year and the following years were designated as the experimental period, and the former as the non-experimental period. The main advantage of this method is that it can eliminate the unobservable shocks that occur in the period, such as the "4 + 3 + 1" ETP policy started from 2002 while superimposed in the same period, and the pollution charge collection policy issued by the State Council in 2003. Third, after 200 random samplings, we could get 200 experimental periods and experimental groups, and then substitute them into equation (1) for regression, respectively, getting 200 regression coefficients and T values of Treat#Post. The last step was to draw the kernel density plots of coefficients and *t* values, as shown in Figures 3 and 4.

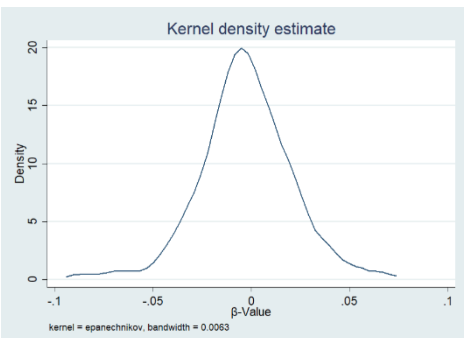

Fig.3 the density of coefficients

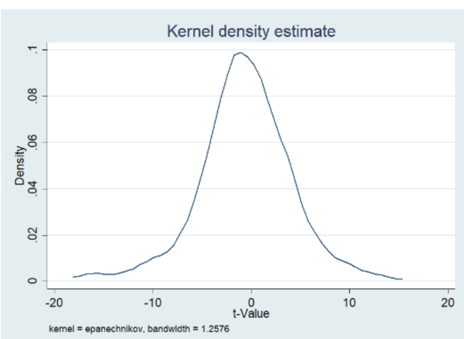

Fig.4 the density of *t* values

It is obvious from Figure 4 that most of the coefficients are distributed around the value of 0, which indicates that the impact of the ETP policy is small. Similarly, in Figure 5 the t value is also mainly distributed around the value of 0, which indicates that the impact of the ETP policy is basically not significant. Combining the results of the two graphs, the impact of ETP policies on enterprise performance is unlikely to be driven by the impact of unobservable shocks in different regions and years.

Placebo Test (b): Referring to the practice of Lu & Yu (2015), we took the sample period from 2003 to 2006 before the ETP policy actually occurred, and assumed that the ETP policy occurred in 2004 and 2005, respectively. Then in 2004 (2005) and after, the *POST* value is 1, otherwise it is 0. The target coefficients we expected were not significant. Otherwise, there may have been other unobservable factors affecting the previous results. The test results are shown in Table 4. Column (1) is the regression result of assuming policy reform occurred in 2004.

Obviously, the coefficient of the interaction term is not significant, indicating that the ETP policy had no impact on enterprise performance. Meanwhile, column (2) assumes that the policy reform that occurred in 2005 shows the same result. Taking the two results together, it is confirmed there was no significant difference between the treatment group and the experimental group before the ETP policy reform was actually implemented, which also supports the parallel trend assumption of the two from another aspect.

Replace Explanatory Variables: For "industry competition variable," "industry average profit rate" takes the place as a different measurement method; the results are shown in column (3) of Table 4. The average impact of the ETP policy on corporate performance is 0.00665, significant at the level of 5 percent, indicating that the ETP policy still has a significant impact on enterprise performance, and the results remain robust. Similarly, using the second algorithm of "financial subsidy intensity" by "subsidy amount / total assets," we found the coefficient was 0.0067, significant at 5 percent. Consistent results suggest that the conclusions are robust. Limited by the length of this article, results are not reported here.

Using D-K Standard Error: Clustering standard error is used in the article, only considering heteroscedasticity and autocorrelation problems of the error term. The error term of the measurement equation may have three major problems of autocorrelation, heteroscedasticity, and cross-section correlation, leading to invalid results. To solve this problem, we used the Driscoll-Kraay (DK) standard error to test, since the DK standard error can deal with the three major problems described above at the same time. The regression results are shown in column (4). With significant results at the level of 1 percent, the ETP policy still has a significant and robust effect on promoting corporate performance.

Using Instrumental Variables: Considering that industry competition Comp1 and corporate performance ROA may have a two-way causal relationship because high-performance companies have stronger market competitiveness, which in turn can further intensify market competition, which could lead to the invalidation of the estimation results of our analysis, we dealt with possible endogenous problems in Comp1 by using the lagging phase 1 and lagging phase 2 of Comp1 as the instrumental variables for regression. Meanwhile, considering the possible heteroscedasticity and autocorrelation of the error term, we further used the Gaussian Mixed Model (GMM) instrumental variable method for regression. The β_1 is 0.0104, shown in column (5), significantly positive at the level of 5 percent, which indicates that the results remain robust after considering endogenous issues. In addition, three major tests on the validity of the instrumental variables were performed: the test results rejected the unidentifiable test null hypothesis (KP statistic is 1795.264), indicating that the instrumental variables meet the rank condition; the test results rejected the weakly recognized test null hypothesis (F statistics is 2411.412), indicating that the instrumental variables have a strong correlation; the test results were also subjected to an over-identification test (Hasen's statistic is 0.164), indicating that the instrumental variables are all exogenous. The above three tests fully show that the instrumental variables selected for our analysis were effective.

Time Trend Effect: Under normal circumstances, there is a tendency for enterprise performance to change over time, which could easily confuse our estimates. To capture the possible trend effect of time, based on the measurement equation (1), we introduced the time trend term to capture the time effect, with results shown in column (6). The β_1 is 0.00666, significantly positive at the level of 5 percent, indicating that the ETP policy still has a significant and robust impact on enterprise performance. In addition, we also introduced the "Provincial Time Trend" and "Industry Time Trend" to capture the province fixed effects and industry fixed effects that change with time trends. The results remained stable but are not reported here because of the limited length of the article.

Table 4 Robustness results

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ROA	ROA	ROA	ROA	ROA	ROA
Treat#Post2004	0.0727					
	(0.0460)					
Treat#Post2005		0.000299				
		(0.00216)				
Treat#Post			0.00665**	0.00666***	0.0104**	0.00666**
			(0.00317)	(0.00232)	(0.00455)	(0.00317)
Constant	-0.0215	-0.0214	0.0390	0	0	0.0272**
	(0.0576)	(0.0578)	(0.0582)	(0)	(0)	(0.0121)
Controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Clustered	Y	Y	Y	Y	Y	Y
Observations	168,877	168,877	440,675	440,675	102467	440,675
R-squared	0.062	0.062	0.076	0.077	0.0729	211,854

Note: *, ** and *** represents the significance level at 10%, 5% and 1% respectively. The standard errors are reported in parentheses and clustered at the industry level.

Heterogeneity Analysis

The heterogeneity of the impact from three different perspectives: industry pollution attributes, ownership attributes, and regional attributes are discussed in this section. Referring to the practice of Fan et al. (2019), the measurement equation was set as follows:

$$ROA_{it} = \beta_0 + \beta_1 Post_t * Treat_i * M + \beta_2 Post_t * M + \beta_3 Treat_i * M + \beta_4 Treat_i * Post_t + \beta_5 Z_{it} + u_i + \lambda_t + \varepsilon_{it} \quad (3)$$

When the industry belongs to a heavy pollution industry, it was assigned as 1, otherwise 0; when the ownership is a state-owned enterprise, it was assigned as 1, otherwise 0; when the region is in the East, it was assigned as 3; when the region is in the middle, it was assigned as 2; when the region is in the west, it is assigned as 1. Among them, the interaction term $Post_t * Treat_i * M$ is the core variable we care about. The essence of this method is the Chow test, which is more standard and accurate than group regression. The specific regression results are shown in Table 5 below:

Column (1) is the regression result of the pollution heterogeneity of the industry. It is not difficult to find that the coefficient of the interaction term is 0.0108, significant at the level of 10 percent, which shows that compared with the industries with light pollution, the ETP policy has a stronger effect on promoting corporate performance in heavily polluting industries. The regression results are also consistent with our intuition since additional environmental costs force highly polluting enterprises to carry out green innovation, which has improved production efficiency and performance. Therefore, we can also conclude that the significant promotion effect of ETP policies on enterprise performance mainly come from heavily polluting industries.

Column (2) is the regression result of enterprise ownership heterogeneity. The interaction term coefficient is 0.00902, significant at the level of 5 percent, which shows that compared to non-state-owned enterprises, the emission trading policy has a greater effect on the performance of enterprises directly controlled by the state. One of the possible explanations is that these enterprises will respond more actively to the ETP policy reforms. At the same time, due to the strong financial resources of state-owned enterprises, they can invest a large number of funds for R&D and innovation in a short period of time, so the effect of policies on state-owned enterprises is more significant.

Column (3) shows the result of regression by different regions. It is not difficult to find that as the region advances from the west to the east, the inhibitory effect of the ETP policy on enterprise performance becomes stronger. The analysis was based on the assumption that there is a linear relationship between the ETP policy and regional heterogeneity, which may be unreasonable. Therefore, to further test the average impact of policy reforms on each region, we also conducted a sub-sample regression of the eastern, central, and western regions. The results show that emissions trading policies have a significant promotion effect on the central region and a significant inhibitory effect on the western and eastern regions. This result is considered to be in line with reality because the pilot areas of the ETP policy reform are mainly concentrated in the central and eastern regions, while the eastern region is located in a coastal zone with a relatively developed economy and relatively intensive production. Because polluting companies have gradually migrated to the central and western regions, the ETP policy has limited incentives in the eastern region, and additional environmental protection costs may not be conducive to the performance improvement of the enterprises in the eastern region. On the other hand, the western region is lacking in funds and technology, which leads to difficulty in offsetting the environmental protection costs created by the ETP policy through technological innovation, resulting in easily causing a decline in performance. In contrast, the central region has more technological and financial advantages. By increasing the investment in research and development of new technology, these enterprises can effectively improve the production mode and enhance the efficiency of enterprises to offset the additional environmental costs, and then promote the improvement of enterprise performance. At last, we can conclude that from the perspective of regional heterogeneity, enterprises in the central regions play a leading role in promoting the performance of enterprises.

Table 5 Heterogeneous results

	(1)	(2)	(3)
	Pollution	Ownership	Region
VARIABLES	ROA	ROA	ROA
Treat#Post#pollution	0.0108* (0.00575)		
Treat#Post#soe		0.00902** (0.00372)	
Treat#Post#region			-0.0242*** (0.00566)
Constant	0.0436*** (0.0122)	0.0454*** (0.0125)	0.0375** (0.0175)
Controls	Y	Y	Y
Year FE	Y	Y	Y
Firm FE	Y	Y	Y
Clustered	Y	Y	Y
Observations	440,675	440,675	403,905
R-squared	0.077	0.077	0.079

Note: *, ** and *** represents the significance level at 10%, 5% and 1% respectively. The standard errors are reported in parentheses and clustered at the industry level.

Mechanism Analysis

According to the previous review, there are two main internal mechanisms of the effect of ETP policies on corporate performance: the first is the productivity mechanism. The ETP policy urged companies to increase research and development efforts to improve corporate productivity, thereby making up for the additional environmental protection costs that the companies have added. Eventually, these actions led to the promotion of corporate performance. The second is the pollution cost mechanism. The implementation of the ETP policy has caused enterprises to increase their pollution costs, forcing them to transfer some resources to pollution control, which in turn has reduced their performance. Regarding the second mechanism, there is no relevant pollution data in the database of Chinese industrial enterprises, and the existing data cannot be used for measurement. So, referring to the practice of Fang et al. (2013), we only tested the first mechanism to disprove the second mechanism.

For the measurement of corporate productivity, mainstream literature tends to use TFP (Wang et al., 2014; Ren et al., 2019). However, TFP has two algorithms: the OP method and the LP method. The OP method can better deal with the problem of simultaneity deviation and selectivity deviation by using the current investment of the company as the proxy variable of unobservable productivity, but it can also cause the loss of many samples, while the LP method can better solve the problem of missing samples by using intermediate input instead of investment. To ensure robust results, we used both the OP and LP methods to measure corporate productivity. For the selection of the mechanism test method, we used the "sequential test method" or "casual steps" proposed by Baron & Kenny (1986) in three steps.

The specific results are shown in Table 6: Column (1) is the basic regression result with a significant promotion effect on enterprise performance, same as above. Column (2) is the regression result of the TFP calculated by the OP method as the explanatory variable. It can be seen that the coefficient of the ETP policy is 0.0155, significant at the level of 10 percent, which indicates that the ETP policy has a significant promotion effect on the enterprise's total factor productivity. Column (3) is the regression result of the TFP calculated by the OP method, in which the coefficient is 0.0554, significant at the level of 1 percent. Combined with the results of column (2), the productivity mechanism is fully confirmed. Further observe that the coefficient of Treat # Post is 0.0095, significant at the level of 5 percent, which is only slightly improved compared to column (1), indicating that the productivity mechanism is a mechanism of the ETP policy affecting corporate performance, rather than the main mechanism, which means that there are other mechanism effects, so the second pollution cost mechanism mentioned above is confirmed. The regression results obtained by calculating the TFP using the LP method shown in columns (4) and (5) are very robust.

Table 6 Mechanism results

	(1)	(2)	(3)	(4)	(5)
VARIABLES	ROA	OP_TFP	ROA	LP_TFP	ROA
Treat#Post	0.00666**	0.0155*	0.00950**	0.0167*	0.00959**
	(0.00317)	(0.00830)	(0.00381)	(0.00887)	(0.00383)
OP_TFP			0.0554*** (0.00312)		
LP_TFP					0.0468*** (0.00266)
Constant	0.0449*** (0.0118)	2.176*** (0.130)	-0.168*** (0.0439)	2.315*** (0.141)	-0.159*** (0.0435)
Controls	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y
Clustered	Y	Y	Y	Y	Y
Observations	440,675	261,671	255,987	261,671	255,987
R-squared	0.077	0.109	0.083	0.145	0.078

Note: *, ** and *** represents the significance level at 10%, 5% and 1% respectively. The standard errors are reported in parentheses and clustered at the industry level.

Conclusions and Policy Implication

Based on the existing related literature research, we used the latest database of Chinese industrial enterprises from 2003 to 2013 and the two-way fixed-effect regression model based on the DID method to conduct a strict and standardized empirical test on the relationship between the SO_2 ETP policy and corporate performance with the help of the "quasi-natural experiment" in 2007. The results of the basic regression and robustness tests show that the ETP policy has a significant promotion effect on corporate performance, providing Chinese evidence for the "Porter hypothesis." Heterogeneous regression results show that the SO_2 ETP policy has a more significant promotion effect in heavily polluting industries, state-owned enterprises, and central regions, while in lightly polluting industries, non-state-owned enterprises, and eastern and western regions, there is no significant or even negative impact. The results of the mechanism test show that the ETP policy promotes the improvement of corporate performance through the mechanism of "increasing the total factor productivity of the enterprise," and also implies the existence of a reverse mechanism of "increasing the additional environmental protection costs of the enterprise."

The policy implications of this article focus on two points. First, given that the SO_2 ETP policy conforms with the "Porter hypothesis," central and local government departments of China should strive to explore and implement relevant market-based environmental regulatory policies, so that the market can give full play to the role of resource allocation, promoting corporate R&D innovation capabilities and awareness of energy conservation and emission reduction, to achieve better, faster, and higher-quality economic development. Second, government departments should improve relevant policy supporting measures and market supervision to support enterprises at different levels. For small and medium-sized enterprises and backward areas in the west, we must vigorously support them to promote their R&D and innovation to improve production efficiency. For heavily polluting industries, which are in the worst-hit areas of sewage, we must focus on strengthening supervision and ensuring strict implementation of environmental regulations and policies. At the same time, we can also make use of incentives to achieve a reborn industry as soon as possible, which is the key point to China's victory in defense of the blue sky.

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