*Pol. J. Environ. Stud. Vol. 33, No. 4 (2024), 4561-4571*
DOI: *10.15244/pjoes/176703* ONLINE PUBLICATION DATE: 2024-05-21

*Original Research*

# The Effect of Environmental Regulation and Regional FDI on Firms' Productivity in China: Using a DDD Method

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*Received: 15 August 2023*
*Accepted: 9 December 2023*

## Abstract

This study employs a difference-in-difference-in-difference (DDD) analysis to examine the effects of environmental regulation on firms' total factor productivity (TFP) while accounting for variations in foreign direct investment (FDI) across different cities. Specifically, the study uses China's $SO_2$ emission trading pilot (ETP) as a quasi-experimental setting. This analysis incorporates temporal, provincial pilot policy, and city-specific FDI differences. A placebo test and a parallel trend test are performed. The results show that $SO_2$ ETP policy can considerably enhance a firm's TFP, supporting the Porter hypothesis. It also demonstrates that the positive effect of ETP on TFP will be enhanced in cities with fewer FDI inflows. On average, a 1% increase in local FDI results in a reduction of around 0.05% in the stimulating impact of the SO2 ETP on firm productivity. Heterogeneity analysis shows that private enterprises are more affected than state-owned enterprises.

**Keywords:** environmental regulation, FDI, firm TFP, Porter hypothesis, DDD analysis

## Introduction

There has been a dramatic increase in foreign direct investment (FDI) into China since the reform and opening up because China has selected the trade market for technology solutions to speed up the closure of the technological gap with developed countries [1]. However, investment in polluting sectors has caused serious environmental damage in China [2, 3]. The whole country's environmental awareness is on the rise.

To combat environmental decline, the Chinese government has instituted several environmental regulations (ER) [4, 5]. There is genuine concern about the potential implications of environmental regulations on the competitiveness of enterprises [4, 6]. Do these rules force costs and reduce business outputs? Alternatively, as predicted by the Porter Hypothesis, will these regulations increase productivity? When FDI and ER intersect, the issue becomes more complex [7]. Since productivity is one of the most important criteria that determines the success and competitiveness of economic units [1, 8, 9], the examination of the above inquiries holds significant importance for China and other developing nations that are grappling with the

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simultaneous challenges of economic development and environmental preservation.

According to proponents of neoclassical environmental economics, the objective of environmental legislation is to internalize negative externalities, which results in higher costs for companies and potentially limits their ability to innovate and compete [10, 11]. However, the "Porter Hypothesis" posits that the implementation of a regulatory framework that is both well designed and effectively enforced has the potential to incentivize companies to engage in innovative practices aimed at reducing the costs associated with compliance. In turn, this can lead to an increase in overall productivity [12]. Furthermore, the impact of environmental regulations on firm productivity may vary based on industries and specific policies [13]. The impact of regulatory policies on a firm's productivity is a significant obstacle to policy implementation because of the intricate nature of this relationship. Prior research has explored the impact of ER and FDI on productivity at both industrial and regional levels [4, 7]. However, little attention has been paid to investigating the differential effects of ER on productivity in regions with varying levels of FDI. Additional investigation is required to ascertain the impact of heightened environmental regulatory stringency on the advancement of TFP within cities that exhibit diverse levels of FDI. Moreover, the assessment of the level of ER stringency within the existing body of literature is a challenging task. The measurement remains contentious due to a lack of a standardized model for government action. Several commonly referenced indicators of regulatory intensity include expenses associated with waste reduction [14] and the implementation of environmental taxes [15]. Nevertheless, it is widely acknowledged that these measurements can be subject to substantial simultaneity bias and inaccuracies. Researchers have increasingly utilized quasi-natural experiments to examine the impact of external shocks on environmental regulations [16]. Furthermore, previous studies have investigated the aforementioned concerns across various sectors, provinces, and nations [17, 18]. Nevertheless, it is important to note that the use of aggregated statistics may overlook diversity among companies, and the conclusions drawn from such statistics may be influenced by the aggregation process [19].

Existing studies have investigated the effect of environmental regulation on productivity, but have reached contradictory conclusions. One plausible explanation for these bifurcations may be attributed to the absence of a comprehensive assessment of environmental regulatory measures. Additionally, it is worth noting that many previous studies have overlooked the implementation context of environmental regulatory policies, where FDI plays a significant role. The goal of this paper is to find a way to measure environmental regulations by using the quasi-experiment method and to look at the conditions under which environmental regulations are put into place. There are studies that use the DID (difference-in-differences) method to measure the effect of ER on TFP, but they rarely look at the effect of FDI. This study also used data from the firm level to address both apparent and undetected heterogeneity.

This study aims to improve the understanding of the relationships among environmental regulation, foreign direct investment, and firm total factor productivity. It utilized China's sulfur dioxide emissions trading pilot scheme as a quasi-natural experiment to control for the degree of regulatory stringency. Furthermore, considering the differences in FDI among cities, we incorporate Foreign Direct Investment (FDI) into our analysis framework and employ a difference- in-difference-in-differences (DDD) methodology to analyze the effects of the SO2 emission trading pilot (ETP) on firm productivity among cities with different levels of FDI. After the robustness test, this study conducted a comprehensive analysis of heterogeneity among different ownership types.

Our contribution to the literature is two-fold. First, this paper evaluates the effect of ER on TFP as well as considering FDI, which provides more in-depth knowledge of the links between ER, FDI, and firm TFP. Second, we concentrated on the influence of environmental regulation on total factor productivity at the company level. Previous studies have employed data from diverse industries, regions, and countries. Such aggregated macro-level data could overlook company variation, resulting in an aggregate bias [19, 20].

The remainder of this paper is organized as follows: Section 2 examines the current literature on the relationship between ER, FDI, and TFP. Section 3 discusses the method used in this study, as well as the data and variables. Section 4 discusses the preliminary results, robustness tests, and heterogeneity analyses. Finally, Section 5 concludes the paper.

## Research Hypothesis

### Environmental Regulation and Total Factor Productivity

Environmental regulation and productivity have a complicated relationship. Neoclassical environmental economists argue that environmental legislation aims to internalize undesirable externalities, inevitably leading to increased company costs and reduced creativity and competitiveness [10]. Empirically, [21] used data from ten polluting German firms between 1975 and 1991 to find that regulation policy has a detrimental influence on productivity. Similar results can also be found in other countries [10, 22]. However, the "Porter Hypothesis" suggests that a well-designed and well-enforced regulatory framework could encourage companies to innovate and reduce compliance costs, thus boosting productivity [12]. Studies have found that environmental policies can promote productivity growth through innovation and improve resource allocation efficiency

[23-26]. The allocation of substantial resources towards innovation might result in an initial spike in costs for a company [27]. However, this adverse impact tends to diminish with time [28] and may even transform into a favorable influence on innovation endeavors, manufacturing technology, and overall productivity [29]. Environmental policies can also positively impact industry productivity by weeding out less productive firms [30].

Such disagreements are not in conflict with one another because there are generally three kinds of environmental regulations: command-and-control regulations [31]; market-based regulations [32]; and those driven by societal involvement [33]. The effect of environmental regulations on firm productivity may differ depending on specific policies [13]. However, the efficiency of command-and-control environmental regulations needs to be improved in many ways, according to several studies that have already been done [34-36]. Recent research has shown that market-based environmental policies have considerable effects on environmental governance [37]. For instance, [38] observed that, compared to the absence of emissions trading, carbon emissions trading lowered global welfare losses by 0.1% to 0.5%. [39] claim that the EU Emissions Trading System increased low-carbon innovation among regulated firms by 10% without displacing other patents. Additionally, a number of studies have demonstrated that market-based environmental regulation can lower the costs of emission reduction [40], increase the effectiveness of resource allocation, encourage enterprises to make green investments [41], and achieve the Porter effect [42]. The results of [43] show that China's carbon market pilot policy increased enterprises' TFP in the pilot areas.

This paper is aimed at exploring the effect of SO2 ETP, a market-based environmental regulation, on firms' TFP. Based on existing studies, the following hypothesis is proposed:

H1: The $SO_2$ ETP, a market-based environmental regulation is positively related to the firm's TFP.

## FDI and TFP

Learning from advanced foreign experience can help enterprises in developing countries improve their technology and productivity. Along with funds, FDI also provides management expertise and technology, giving home nations more potential for successful technology spillovers and collaborative green research and development. In these ways, FDI can make innovative technology more accessible [44-47], boost productivity via imitation, staff mobility, upstream and downstream cooperation with neighborhood firms, and exports [48]. On the other hand, constrained by the disparity in technology and absorptive capacity as well as the potential cost of technological innovation [49], domestic companies are likely to be trapped in a low-tech lock-in dilemma. FDI may make domestic enterprises inert in the development of environmentally advanced technology, which would impair their capacity for both independent innovation and identifying advanced green technology [50]. Moreover, FDI may reduce local businesses' input variety and host countries' productivity if multinational companies utilize fewer resources in host nations than their indigenous counterparts do [51]. Therefore, it is unclear how FDI would affect the technology of domestic enterprises.

In the context of environmental protection, the presence of FDI can potentially yield positive outcomes. This is based on foreign-owned companies assuming social responsibility for environmental preservation. In such cases, FDI can facilitate the introduction of green management principles and pollution control technologies to both upstream and downstream sectors of the domestic industry. Consequently, this can foster the enhancement of local industrial structures and promote environmentally friendly production practices. Additionally, it can contribute to the efficacy of environmental regulation measures. However, considering the theory of pollution heaven, several studies point out that developed countries tend to transfer some declining industries and polluting technologies to developing countries through FDI in order to cope with the increasing factors and environmental costs. Countries with loose environmental restrictions are more likely to attract foreign direct investment [52, 53]. It will be detrimental to the industrial upgrading of local economies and may impede the effectiveness of environmental regulation if the transfer of these industries and technologies increases the pollution intensity of the host country's industries.

Based on the above analysis, this paper believes that in regions receiving different amounts of FDI, the effect of environmental regulation on firm TFP is different. However, whether this kind of influence is positive or negative is uncertain, so the following hypothesis is proposed:

H2a: The $SO_2$ ETP policy contributes more to the TFP of enterprises in cities with more FDI.

H2b: The $SO_2$ ETP policy contributed more to the TFP of enterprises in cities with less FDI.

# Material and Methods

## Model Specification

This study examines the effect of environmental regulations on firms' TFP and further checks whether this effect shows differences across regions with different FDI. In econometrics, researchers employ the DID and DDD approaches to calculate the effects of external events, such as natural catastrophes, financial crises, and policy applications [54]. DID aims to examine the differences between the control and treatment groups before and after a policy is adopted. Therefore, we can calculate the effects of a policy. The

DID approach offers several advantages. For example, it can eliminate endogenous issues to a large extent [31]. This study utilizes DID and DDD analyses to isolate the causal effects related to China's sulfur dioxide emissions trading pilot implemented on a large scale in 2007.

The $SO_2$ ETP program covers 11 pilot provinces: Jiangsu, Hunan, Zhejiang, Mongolia, Hebei, Hubei, Shanxi, Henan, Shaanxi, Tianjin, and Chongqing. The policy mainly targets sulfur dioxide emitters, so this study selects sulfur dioxide emission-intensive enterprises listed in the Chinese stock market as a research sample to compare the changes in these firms' TFP in the trial and non-pilot areas before and after the pilot. We consider $SO_2$ emission-intensive firms in pilot areas as the treatment group and the other $SO_2$ emission-intensive firms operating elsewhere as the control group. As per the rules of DID analysis, we set the model as Equation (1). *Treat* is a dummy variable that denotes the firm's pilot status; that is, $Treat_i$ is equal to one if company *i* is in the treatment group, and $Treat_i$ is equal to zero if firm *i* is in the control group. Variable is a dummy variable differentiating pre-polit and post-pilot periods, $Post_t$ is equal to one if $t \geq 2008$, and $Post_i$ is equal to zero otherwise.

$$TFP_{it} = \alpha + \beta Treat_i \times Post_t + \gamma X_{it} + u_t + \theta_j + \delta_k + \varepsilon_{ijkt} \quad (1)$$

In Equation (1), $TFP_{it}$ indicates TFP measured by the Olley and Pakes (OP) method [55]. The coefficient for the interaction term $Treat_i \times Post_t$ denotes the average treatment effect of the ETP on firm productivity. $X_{it}$ is a vector of control variables, including firm ownership (SOE), age (AGE), firm size (SIZE), return on assets (ROA), regional command and control environmental regulation (CAC), regional economic development (ED), and regional industrial structure (IS). $u_t$, $\theta_j$, $\delta_k$ are variables that control the fixed effect of year, industry, and province, respectively. $\varepsilon_{ijkt}$ is the error term.

We construct a DDD model to check the effect of the $SO_2$ ETP on the TFP of firms in different cities that receive varying amounts of FDI. We combine three categories of variation: time (before and after the pilot's implementation), province (whether a province is a pilot or not), and FDI variation across cities. Following existing studies [56], Equation (2) structures the model.

$$TFP_{it} = \alpha + \beta Treat_i \times Post_t \times FDI_{ct} + \gamma X_{it} + u_t + \theta_j + \delta_k + \varepsilon_{ijkt} \quad (2)$$

where $TDI_{ct}$ is the FDI in city *c* in year *t*.

## Variables and Data

In this study, firm-level TFP is the dependent variable, which is calculated using the OP method [55]. This method is widely used in empirical studies on firm productivity and has been shown to produce reliable estimates [57].

The primary independent variable is *Treat×Post*, which equals one when firms are located in the pilot province during the policy implementation. In the DDD model, we incorporate regional FDI to examine whether the effect of ETP on firm productivity varies across regions with different levels of FDI. We measure FDI by the amount of FDI received in each city in year *t* with a natural logarithm form. Control variables include (1) firm ownership donated by SOE. It equals one if the firm has investment from the government and zero otherwise. (2) Firm age, donated by AGE, measured as the current year minus the year when the firm started, plus one. (3) ROA, measured using the company's return on assets. (4) Firm size, denoted by SIZE, is measured by the number of employees in natural logarithm form. (5) Regional command and control environmental regulations, donated by CAC and measured by the number of local environmental regulations. (6) Regional economic development, denoted as ED, is measured by regional GDP per capita. (7) Regional industrial structures donated by IS. We calculate this as a percentage of the tertiary sector's added value to regional GDP.

This paper used data from the China Stock Market and Accounting Research Database (CSMAR). We can identify whether a company produces a high level of sulfur dioxide emissions by examining the information disclosed in its corporate social responsibility and annual reports. After excluding firms' missing important variables and those receiving special treatment from the Stock Exchange, we were left with 270 $SO_2$ emission-intensive enterprises. 110 were in the pilot region, whereas 160 were in the non-pilot region. We took data at the regional level fromthe China City Statistical Yearbook. Table 1 presents the descriptive statistics for the main variables. The FDI among cities is 11.145 on average, with a standard deviation of 1.82. In addition, state-owned companies comprise 60.4% of the sample, reflecting that they are the major $SO_2$ emission firms.

Table 2 lists the correlation matrices. We found no fair values that exceeded the crucial value of 0.80, implying that this study had no multicollinearity issues.

Table 1. Descriptive Statistics.

| Variables | Mean | SD | Min | Max |
|---|---|---|---|---|
| FDI | 11.145 | 1.820 | 3.091 | 14.557 |
| SOE | 0.604 | 0.489 | 0.000 | 1.000 |
| ROA | 4.990 | 22.188 | -197.460 | 226.520 |
| SIZE | 8.085 | 1.241 | 3.555 | 11.297 |
| AGE | 15.626 | 6.416 | 3.000 | 73.000 |
| CAC | 2.167 | 2.620 | 0.000 | 23.000 |
| ED | 10.614 | 0.702 | 8.120 | 13.056 |
| IS | 3.748 | 0.277 | 2.609 | 4.378 |

Table 2. Correlation Analysis.

| | TFP | FDI | SOE | ROA | SIZE | AGE | CAC | ED |
|---|---|---|---|---|---|---|---|---|
| TFP | 1 | | | | | | | |
| FDI | 0.2331* | 1 | | | | | | |
| SOE | -0.0388 | -0.1307* | 1 | | | | | |
| ROA | 0.3562* | 0.0139 | -0.0348 | 1 | | | | |
| SIZE | 0.0400 | -0.0337 | 0.1531* | 0.0535* | 1 | | | |
| AGE | 0.0409 | 0.1216* | -0.0207 | -0.0565* | 0.0918* | 1 | | |
| CAC | -0.0526* | -0.0197 | 0.0407 | -0.0014 | -0.0064 | 0.0060 | 1 | |
| ED | 0.2484* | 0.7272* | -0.1204* | 0.0097 | 0.0944* | 0.2926* | -0.0619* | 1 |
| IS | 0.1986* | 0.5527* | -0.0996* | 0.0019 | -0.0505* | 0.0634* | -0.0888* | 0.4404* |

Additionally, we examined the variance inflation factors (VIF) and found that the largest VIF value was less than 10, confirming no multicollinearity issues.

## Empirical Results and Discussion

### Preliminary Results

Table 3 shows the results based on DID analysis. Column (1) utilizes control variables at the firm level. We apply firm- and city-level control variables in column (2). It denotes that *Treat×Post* has a significantly positive coefficient under both settings, implying that the $SO_2$ ETP positively contributes to the improvement of TFP; that is, total factor productivity has increased in pilot zones compared to that before the ETP. These results support Hypothesis 1. This finding provides evidence that the implementation of market-based environmental regulations grants enterprises more flexibility in allocating resources and enables them to effectively use market mechanisms to address the demands of emission reduction.

This study conducted a DDD analysis to ascertain whether the effect of ETP on a firm's TFP shows heterogeneity across regions with different FDI. The findings are shown in Table 4. This analysis considered the control variables included in the basic model and the interaction terms of *Treat*, *Post* and *FDI*. To save space, we only present the coefficients of *Treat×Post×FDI* and relevant interaction terms. The coefficients of *Treat×Post×FDI* are significant and negative in all the models. This finding suggests that the pilot program on $SO_2$ emission trading had a greater impact on the development of TFP in cities with lower levels of FDI, supporting Hypothesis 2b.

Table 3. Estimation Results of DID Analysis.

| | (1) | (2) |
|---|---|---|
| | TFP | TFP |
| | 0.2955*** | 0.2801*** |
| | (0.0518) | (0.0527) |
| SOE | 0.0856 | 0.0898* |
| | (0.0618) | (0.0613) |
| AGE | -0.0045 | -0.0038 |
| | (0.0051) | (0.0050) |
| ROA | 0.0109*** | 0.0109*** |
| | (0.0006) | (0.0006) |
| SIZE | -0.0882*** | -0.0893*** |
| | (0.0180) | (0.0179) |
| CAC | | -0.0050 |
| | | (0.0056) |
| ED | | 0.1844*** |
| | | (0.0569) |
| IS | | 0.0552 |
| | | (0.1241) |
| _cons | 4.3392*** | 2.4023*** |
| | (0.2713) | (0.7158) |
| Year fixed effect | Yes | Yes |
| Province fixed effect | Yes | Yes |
| Industry fixed effect | Yes | Yes |
| N | 3240 | 3240 |
| $R^2$ | 0.5211 | 0.5445 |
| *Wald Chi²* | 772.39*** | 790.99*** |

Standard errors are shown in parentheses. *** indicates significance at 1%, ** indicates significance at 5%, * indicates significance at 10%.

Table 4. Estimation Results of DDD Results.

| | TFP | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| $Treat_i \times Post_t \times FDI_{ct}$ | -0.0611** | -0.0511* | -0.0543** |
| | (0.0325) | (0.0312) | (0.0312) |
| $Treat_i \times Post_t$ | 0.9126*** | 0.8039*** | 0.8263*** |
| | (0.3639) | (0.3481) | (0.3487) |
| $Treat_i \times FDI_{ct}$ | 0.0883*** | 0.0759*** | 0.0775*** |
| | (0.0373) | (0.0342) | (0.0342) |
| $Post_t \times FDI_{ct}$ | 0.0203 | 0.0136 | 0.0187 |
| | (0.0177) | (0.0170) | (0.0174) |
| Firm-level control variables | No | Yes | Yes |
| City-level control variables | No | No | Yes |
| Year-fixed effect | Yes | Yes | Yes |
| Province-fixed effect | Yes | Yes | Yes |
| Industry-fixed effect | Yes | Yes | Yes |
| N | 3240 | 3240 | 3240 |
| $R^2$ | 0.4389 | 0.5290 | 0.5397 |
| *Wald Chi²* | 332.15*** | 790.34*** | 798.46*** |

Standard errors are shown in parentheses. *** indicates significance at 1%, ** indicates significance at 5%, * indicates significance at 10%.

## Robustness Tests

### *Alternative Measurements of the Dependent Variable*

In this section, we adopt an alternative measurement of TFP proposed by [58]. Table 5 displays the research findings. We confirmed the robustness of the regression results reported above by the negative significant coefficient of *Treat×Post×FDI* and the positive and significant coefficient of *Treat×Post*.

### *Parallel Trend Test*

The implementation of a DID methodology should possess the capability to verify the parallel trend hypothesis. If satisfaction is not met, there is a possibility of an erroneous evaluation of the policy's impact. Based on the parallel trend assumption, it may be inferred that prior to the implementation of the emission trading pilot, the treatment and control groups had similar trends in TFP. The average productivity levels of the companies in the pilot region and non-pilot region are computed and compared. The data indicates that the sample firms' productivity trends in pilot and non-pilot regions were comparable before the policy's introduction; the parallel trend condition is met. The sample is further partitioned into two cohorts depending on the average regional FDI amount. One cohort comprises enterprises situated in cities with greater FDI levels, while the other cohort comprises firms situated in cities with lower FDI levels. Two trend charts were generated to depict the temporal evolution of company productivity visually. According to the findings shown in Fig. 1, it can be seen that the parallel trend condition is still met in both groups. The increasing trend of firm TFP is more pronounced in areas with lower FDI as compared to regions with greater FDI. This finding further reinforces the results of our study.

### *Placebo Test*

In order to exclude the potential influence of confounding factors on the observed disparity in TFP between the pilot and non-pilot cohorts, a placebo test was performed. This test included the creation of fake treatment and control groups. Specifically, a selection of 11 provinces was made at random from a pool of 31 provinces. These chosen provinces were designated as fake pilot provinces, while the other provinces were categorized as false non-pilot provinces. Accordingly, we create a false dummy variable $treat_i$, where *treat* is equal to one if the firms are in false pilot regions and zero otherwise. This random data-generation method was repeated 500 times to estimate the baseline model. The kernel density of 500 estimates the coefficient

Table 5. Robustness Check Using Alternative TFP Measurement.

| | TFP(LP) | TFP(LP) |
|---|---|---|
| $Treat_i \times Post_t$ | 0.2962*** | 0.8704*** |
| | (0.0525) | (0.3480) |
| $Treat_i \times Post_t \times FDI_{ct}$ | | -0.0569** |
| | | (0.0311) |
| Firm-level control variables | Yes | Yes |
| City-level control variables | Yes | Yes |
| Year-fixed effect | Yes | Yes |
| Province-fixed effect | Yes | Yes |
| Industry-fixed effect | Yes | Yes |
| N | 3240 | 3240 |
| $R^2$ | 0.6170 | 0.6119 |
| *Wald Chi*$^2$ | 1026.65*** | 1034.91*** |

LP stands for Linear Programming. Standard errors in parentheses $^{*}$ $p<0.15$, $^{**}$ $p<0.1$, $^{***}$ $p<0.05$

of *treat×time* is presented in Fig. 1. The distribution is centered around zero, and the p-values of these estimates are greater than 0.1, which suggests that adopting the fake treatment group has no impact on firms' TFP. The true model's estimated coefficient is depicted by a vertical line, which is an outlier in the distribution. The results confirm that ETP influences firm productivity.

### *Pre-Existing Time Trends*

The predictions can be skewed when considering time trends. To address this issue, we substitute the variable Post in Equation (2) with year dummies for 2005-2015, with 2004 being the base year, and construct the interaction terms *Treat*, *year*, and *FDI*. The results are presented in Table 6. Column 1 shows the findings for TFP measured according to[55], and Column 2 depicts the results for TFP calculated based on [58]. To save space, we only present the coefficients of *Treat×Post×FDI*. The coefficients of the triple interaction items between 2005-2007 are insignificant, whereas those of the items after the pilot implementation are

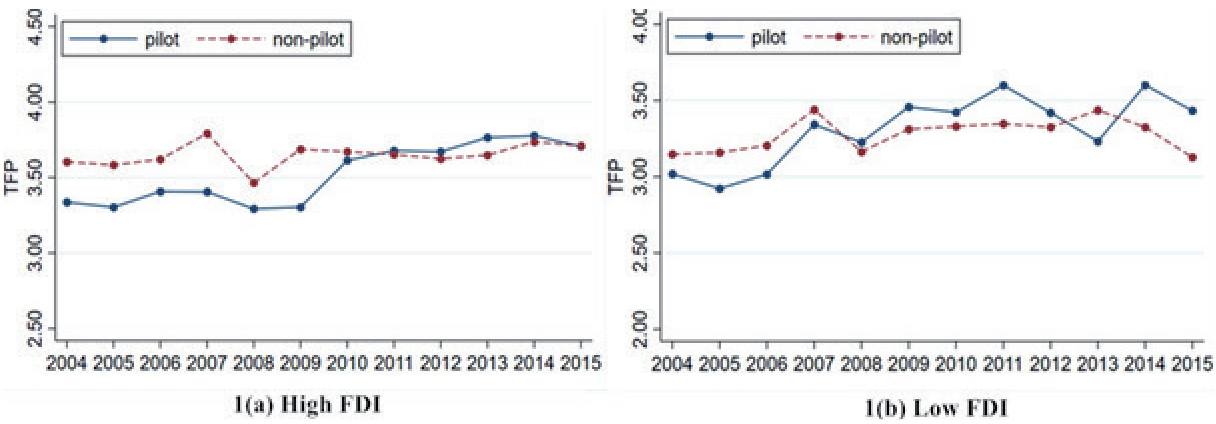


Fig. 1. Parallel trend test.

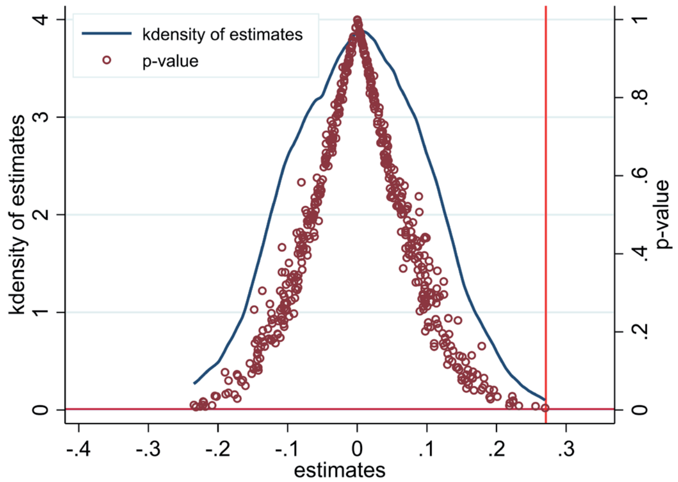


Fig. 2. Placebo test.

Table 6. Pre-existing time trends.

| | (1) | (2) |
|---|---|---|
| | TFP (OP) | TFP (LP) |
| $Treat_i \times Year2005dummy \times FDI_{ct}$ | -0.0077 | -0.0075 |
| | (0.0114) | (0.0114) |
| $Treat_i \times Year2006dummy \times FDI_{ct}$ | -0.0037 | -0.0030 |
| | (0.0114) | (0.0113) |
| $Treat_i \times Year2007dummy \times FDI_{ct}$ | -0.0094 | -0.0081 |
| | (0.0114) | (0.0114) |
| $Treat_i \times Year2008dummy \times FDI_{ct}$ | -0.0489*** | -0.0562*** |
| | (0.0213) | (0.0212) |
| $Treat_i \times Year2009dummy \times FDI_{ct}$ | -0.0587*** | -0.0663*** |
| | (0.0213) | (0.0212) |
| $Treat_i \times Year2010dummy \times FDI_{ct}$ | -0.0403** | -0.0479*** |
| | (0.0212) | (0.0211) |
| $Treat_i \times Year2011dummy \times FDI_{ct}$ | -0.0353** | -0.0422*** |
| | (0.0211) | (0.0210) |
| $Treat_i \times Year2012dummy \times FDI_{ct}$ | -0.0375** | -0.0443*** |
| | (0.0210) | (0.0209) |
| $Treat_i \times Year2013dummy \times FDI_{ct}$ | -0.0353** | -0.0419*** |
| | (0.0209) | (0.0209) |
| $Treat_i \times Year2014dummy \times FDI_{ct}$ | -0.0388** | -0.0458*** |
| | (0.0209) | (0.0208) |
| $Treat_i \times Year2015dummy \times FDI_{ct}$ | -0.0298 | -0.0375** |
| | (0.0210) | (0.0209) |
| Firm-level control variables | Yes | Yes |
| City-level control variables | Yes | Yes |
| Year-fixed effect | Yes | Yes |
| Province-fixed effect | Yes | Yes |
| Industry-fixed effect | Yes | Yes |
| N | 3240 | 3240 |
| $R^2$ | 0.5415 | 0.6131 |
| Wald Chi$^2$ | 805.86*** | 1041.16*** |

Standard errors in parentheses* $p<0.15$, ** $p<0.1$, *** $p<0.05$

significant, indicating that the results obtained above are robust.

### Heterogeneity Analysis

Enterprises with diverse ownership structures are different in administration, business culture, and financial restrictions [1, 59]. According to descriptive statistics, state-owned companies comprise 60.4% of the sample. In this section, we implement a heterogeneous effects analysis on various ownership groups. Table 7 presents the estimated results. It demonstrates that the coefficients of *Treat×Post* and *Treat×Post×FDI*. for non-SOE are significant while those for SOE are insignificant, indicating that ETP has a significantly positive impact on non-SOEs' TFP. For enterprises located in cities with higher FDI, the positive effect of ETP on non-SOEs' TFP is much weaker. However, SOE samples do not corroborate these findings. Consequently, we can draw the conclusion that there are differences between SOEs and non-SOEs in the effect of the emission trading pilot policy on TFP.

Table 7. Results of Heterogeneous Effects on Different Ownership.

| | SOE | Non-SOE |
|---|---|---|
| $Treat_i \times Post_t$ | 0.3478 | 1.6634*** |
| | (0.4252) | (0.6134) |
| $Treat_i \times Post_t \times FDI_{ct}$ | -0.0026 | -0.1369*** |
| | (0.0389) | (0.0533) |
| Firm-level control variables | Yes | Yes |
| City-level control variables | Yes | Yes |
| Year fixed effect | Yes | Yes |
| Province fixed effect | Yes | Yes |
| Industry fixed effect | Yes | Yes |
| N | 1956 | 1284 |
| R$^2$ | 0.5572 | 0.7975 |
| Wald Chi$^2$ | 512.83*** | 467.04*** |

Standard errors in parentheses * $p<0.15$, ** $p<0.1$, *** $p<0.05$

## Conclusions

This study uses the DDD method to investigate the extent to which environmental regulations affect a firm's productivity in regions receiving different amounts of FDI. To explore this effect, we take China's sulfur dioxide emissions trading pilot as a quasi-natural experiment. The analysis results indicate that this market-based regulation policy can considerably enhance a company's total factor productivity. This result supports the Porter hypothesis. Furthermore, in cities with higher FDI inflows, the regulatory policy's effect of enhancing company TFP tends to get weaker. Heterogeneous effect analysis further shows that the emissions trading pilot significantly impacts non-SOEs' TFP, and for enterprises located in cities with higher FDI, the positive effect of ETP on non-SOEs' TFP is smaller.

This research integrates regional FDI into the existing body of work on the relationship between ER and company productivity, thus enhancing our understanding of the interconnections among ER, FDI, and TFP. The findings of the study serve as a reminder that FDI has the potential to diminish the impact of environmental regulations on company productivity due to the possibility of creating a low-tech lock-in conundrum. FDI has the potential to hinder the progress of domestic firms in the field of environmentally advanced technology, limiting their ability to independently innovate and recognize cutting-edge green technology. Furthermore, a significant portion of the capital inflows facilitated by FDI are is allocated towards businesses that have a detrimental impact on the environment. A, as the Pollution Heaven Hypothesis suggests, such investments may exacerbate the challenges associated with implementing effective environmental regulations. Additionally, our focus was directed toward examining the impact of ER on total TFP at the firm level. This approach allows us to mitigate any potential bias that may arise from using macro-level data pertaining to industries, regions, and nations.

The policy implications are as follows:. Governments should encourage market-based environmental regulation to obtain athe productivity- enhancing effect. To fully exploit this positive effect, regional FDI should be considered when implementing these policies. Specifically, the government may consider actively promoting this type of market-based environmental regulation strategy in regions with less FDI inflow. Considering that many state-owned companies are major SO2 emission resources, the government should take into account the characteristics of the competition and governance structure of state-owned enterprises, and formulate targeted policies to fully mobilize the positive role of state-owned enterprises in environmental protection and economic growth.

The enhancement of green TFP serves as a more accurate indicator of the balance between economic advancement and environmental preservation [24]. However, due to constraints in the available data, this study does not include a measurement of green TFP. Consequently, additional investigation is needed to delve into this topic in future research endeavors.

## Acknowledgments

This work was supported by INHA UNIVERSITY Research Grant.

## Conflict of Interest

The authors declare no conflict of interest.

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