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Foreign Direct Investment and Air Pollution: Re-Estimating the "Pollution Haven Hypothesis" in China

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Abstract: This paper focuses on the relationship between foreign direct investment (FDI) and air pollution. Based on the relaxation of China's FDI regulation policy as well as the "China Environmentally Extended Input-Output" database, we utilize a difference-in-differences methodology and investigate the casual effects of FDI liberalization on air pollution intensity. The empirical results demonstrate that FDI reduces the air pollution intensity. However, it is more pronounced in sectors with higher levels of absorption ability and human capital. The reduction in air pollution is mainly driven by technical effects through the enhancement of total factor productivity and technological efficiency. FDI can help achieve the green development goals in developing countries with a more liberalized policy.

Keywords: FDI; liberalization; air pollution intensity; technical effects

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1. Introduction

During the last few decades, foreign direct investment (FDI) has sped up the process of developing countries' integration into the world. As restrictions on FDI have been drastically removed, China, which is the largest developing country, has grown to be the most attractive destination for investment. Since 2004, China has become the second largest FDI recipient around the world and the largest in the developing world. The utilization of FDI increased from USD 10.29 billion in 1990 to USD 179 billion in 2021. FDI brings advanced technologies and contributes to the economic growth of the host developing countries [1,2]. However, the literature on the environmental effects of FDI has failed to uncover conclusive evidence.

With China's remarkable opening up to the world in the last three decades, the air quality has deteriorated. According to "The 2018 World Air Quality Report", nearly two million people die each year in China from diseases caused by air pollution. In 2016, the average annual exposure concentration of PM 2.5 in China was four times higher than the value recommended by the World Health Organization (WHO). Then, should the inflow of FDI be responsible for China's air pollution? In this paper, we will re-estimate this effect by focusing on the case of China and aim to identify the causal effects of FDI on air pollution by taking advantage of the plausibly exogenous relaxation of the FDI regulation policy and the unique database of Chinese Environmentally Extended Input–Output (CEEIO).

Early studies investigate the effects of FDI on the environment through two main potential but conflicting hypotheses. The most popular one is the "Pollution haven hypothesis" [3], which states that multinationals reallocate to countries with looser environmental regulations and increase pollution in the host country. Some empirical studies support this and find a negative impact of FDI on environmental quality (for example, [4–10]). Meanwhile, the other one is the "Pollution Halo Hypothesis", which points out that FDI reduces pollution due to the transfer and spillover of advanced and clean technologies in the host country. Many empirical papers support this hypothesis, such as Antweiler et al. [11], Wang and Jin [12], Liang [13], Eastin and Zenge [14], Kim and Adilov [15], Zugravu-Soilita [16], and Jiang et al. [17]. From the above, it can be seen that the impact of FDI on the environment is still controversial, and a unified conclusion has not yet been reached. This is partly due to the difficulty in addressing the endogeneity problem of FDI and environment. For example, studies about the case of China (such as [6,9,17–20]), generally use province- or city-level data, and the measure of FDI is a performance-based proxy, such as the actual or contract level of FDI. However, the decision taken by foreign multinationals to enter Chinese cities is endogenous, due to the fact that the FDI entry decision can be affected by cities' stringency of environmental regulations, economic development status, geographic location, industrial agglomeration, infrastructure, and other factors [18,21], which partially explains the difficulty to identify the causal environmental effects of FDI and the mixed empirical results.

Our paper takes advantage of the plausibly exogenous FDI policy upon China's World Trade Organization (WTO) accession at the end of 2001. Specifically, the National Development and Reform Commission (NDRC) conducted a significant revision of "the Catalogue for the Guidance of Foreign Investment Industries" (henceforth, the Catalogue) in March 2002, substantially relaxed the restrictions on foreign investment entry, and liberalized more industries for FDI. The 2002 revision was substantial and strictly in line with the commitments that the Chinese central government made during the negotiations with the WTO members before China's WTO accession. Thus, in this 2002 version, the revision of the Catalogue was quite exogenous to China's internal situation. Based on the changes in China's FDI policy, using difference-in-differences (DID) methodology, we are able to compare the air pollution in the treatment group (industries in which FDI entry was encouraged) with that of the control group (industries for which the FDI policy did not change), before and after China's entry into the WTO. When verifying the effectiveness of the FDI policy, we find that the liberalized industries experienced a fast increase in FDI inflow after 2002. We also check the exogenous nature of the FDI policy by investigating the determinants of FDI deregulation and find that the air pollution has muted effects on the FDI policy revision. To check the validity of the DID methodology, we investigated the pre-trend differences between the treatment and control groups and the randomization of time and liberalized industries.

Our paper provides evidence that FDI liberalization reduces the air pollution intensity in China. The results are robust to the alternative measures of air pollution, the multi-stage DID model, and the consideration of confounding policies. FDI improves the air quality in both the manufacturing and service industries and has stronger effects on sectors with higher levels of human capital. To explore the mechanisms of FDI impacts on pollution, we decompose the changes in air pollution intensity into within-industry effects and between-industry effects. The within-industry effects account for about 90% of the reduction in air pollution intensity in the manufacturing industry and dominate the positive impacts on air quality. Moreover, FDI improves air quality by increasing productivity mainly through technological efficiency. Thus, our paper provides evidence supporting the "Pollution halo hypothesis" in China.

This paper contributes to the literature in three aspects. First, based on industry-level pollution data of CEEIO and the plausible exogenous relaxation of the FDI policy upon China's accession to the WTO, we are the first to identify the causal effects of FDI liberalization on pollution. Second, we move the typical decomposition of the effects on total pollution by scale, technology, and composition effects [4,22] and focus on the effects on pollution intensity by decomposing them into within-industry and between-industry effects. We find that the industries in which FDI was encouraged experienced a within-industry pollution intensity reduction effect. This is attributed to the fact that FDI inflows promote technological upgrading and improve resource utilization within the industries. Moreover, the promotion effect of FDI deregulation on TFP has also been verified, and this promotion effect is mainly driven by the technological efficiency change. Therefore, the domination of within-industry effects and the increasing of productivity support the "Pollution Halo Hypothesis" in China. Third, we also contribute to the literature on the effects of FDI on developing countries. A large number of studies have discussed the economic impacts of FDI, such as FDI and economic growth [23], FDI and firms' productivity [24–26], FDI and the labor market [27–29]. Our paper is an extension on the analysis of the relationship between FDI and the environment, with a focus on China's air pollution.

The remainder of the paper is organized as follows: Section 2 presents China's FDI liberalization policy. Section 3 introduces the empirical specification and data. Section 4 analyzes the empirical results, which include baseline results, DID identification checks, robustness checks, and heterogeneous effects. Section 5 discusses the relevant mechanisms, and Section 6 concludes.

2. FDI Liberalization Policy in China

2.1. FDI Policy and Development in China

In 1978, China initiated the economic policy of opening up to the world, and the inward FDI policy constituted an important component of the policy. The period from 1979 to 1990 was the initial stage of FDI pilot exploration. "Three Laws on Foreign Investment" covering Sino-foreign equity joint ventures, foreign-funded enterprises, and Sino-foreign co-operative joint ventures were successively promulgated and revised, granting preferential policies to foreign-invested firms (FIEs) to promote the inflow of FDI. In 1995, China formally applied to join the World Trade Organization. To accelerate its domestic reform and development, China issued and revised a large number of laws and regulations related to trade and FDI, among which a critical policy was "The Catalogue for the Guidance of Foreign Investment Industries". The Catalogue was first promulgated in 1995, regulating the inflow of FDI into different industries, covering over 300 products and services. With the heightening of China's opening up, the Catalogue was revised every few years. The first major revision was conducted in 1997, but a wide range of restrictions on FDI still existed. After China's accession to the WTO in 2001, to fulfill its commitments to the WTO, the new version of the Catalogue was issued in 2002, introducing substantial FDI liberalization measures for the manufacturing and service sectors. As China relaxed the restrictions on FDI in 2002, China's actual utilization of FDI accelerated from USD 46.88 billion in 2001 to USD 134.97 billion in 2018, as shown in Figure 1.

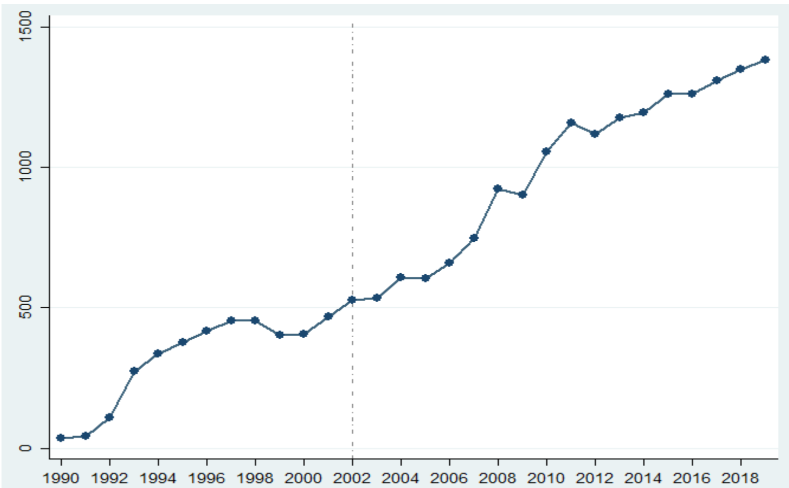

Figure 1. FDI trend in China. Notes: The vertical axis represents China's FDI (realized), and the unit is USD 100 million. The horizontal axis represents the year. The data on foreign direct investment were obtained from the National Bureau of Statistics in China.

2.2. Identification of FDI Policy in China

The Catalogue provides a natural experiment to identify the causal effects of FDI liberalization on air pollution. The Catalogue covers various products and services, which are classified into four categories: encouraged, restricted, prohibited, and permitted. As the first three categories are clearly indicated in the Catalogue, products and services that are not mentioned in the Catalogue are classified as the permitted category. Referring to Lu et al. [26], we focus on the policy changes between 1997 and 2002 to construct our DID model. The main steps of our methods are as follows: First, we match the products and services in the 1997 and 2002 versions of the Catalogue with the four-digit industry codes from Chinese Industry Classification in 2002 (CIC2002). Each four-digit CIC-coded industry may correspond to one or multiple products or services in the Catalogue. Second, by comparing the policy changes between the 1997 and 2002 Catalogues, the four-digit CIC-coded industries were classified into four types. (1) Encouraged industries: Under the condition whereby the four-digit-coded industry corresponded to one product or service, the FDI policy regarding a product or a service of the industry was more liberalized from 1997 to 2002; under the condition whereby the industry corresponded to multiple products or services, the policy regarding all the products or services of the industry became more liberalized, or there was an improvement in FDI regulations for some products or services, while the remaining products or services were not changed. (2) No-change industries: The FDI policy regarding any product or service of a four-digit CIC-coded industry remained unchanged. (3) Mixed industries: The FDI policy regarding some products or services of a four-digit CIC-coded industry was liberalized, while the regulations for others were stricter with respect to FDI inflows. (4) Discouraged industries: These were industries showing completely opposite characteristics compared with the encouraged industries. Third, we define the treatment group and control group. Since the industry classification in the Chinese Environmentally Extended Input–Output (CEEIO) database is roughly consistent with the two-digit CIC industry coding, we aggregate the four-digit CIC-coded industries into two-digit CIC-coded industries and similarly divided them into four types: CIEEO encouraged industries, CIEEO no-change industries, CIEEO mixed industries, and CIEEO discouraged industries. Then, we define the encouraged industries in the CEEIO database as the treatment group, while the no-change industries as the control group. The remaining eight discouraged or mixed industries are excluded from our analyses. Finally, after coordinating the CIC industry coding with CEEIO database, there are 40 industries as the treatment group and 44 industries as the control group.

2.3. The Effectiveness of FDI Policy

Then, we may ask the question of whether the relaxation of FDI policy effectively promotes the inflow of FDI. According to the FDI trend in Figure 1, it could be seen that the actual utilization of FDI in China sharply increased after 2002, and the growth rate was significantly faster than that in the period before 2002. Meanwhile, the FDI Regulatory Restrictiveness Index calculated by the Organization for Economic Co-operation and Development (OECD) showed that China's restrictions on foreign investment were gradually relaxed. The FDI index was 0.625 in 1997, sharply plunged to 0.468 in 2006, and decreased to around 0.43 in 2014. The declining trend of China's FDI Regulatory Restrictiveness Index can be observed in Appendix B Figure A1. In addition, our study also carried out a further analysis based on China's industrial enterprise data from 1998 to 2007. We compare the FDI growth trend of the two groups (the treatment group and the control group) by taking foreign-registered capital as the proxy variable of FDI. As shown in Figure 2, it could be seen that before 2002, there was a similar and slow growth trend of FDI in both groups. However, after 2002, the growth rate of FDI in the treatment group was significantly faster than that in the control group, with a widening gap between these two groups.

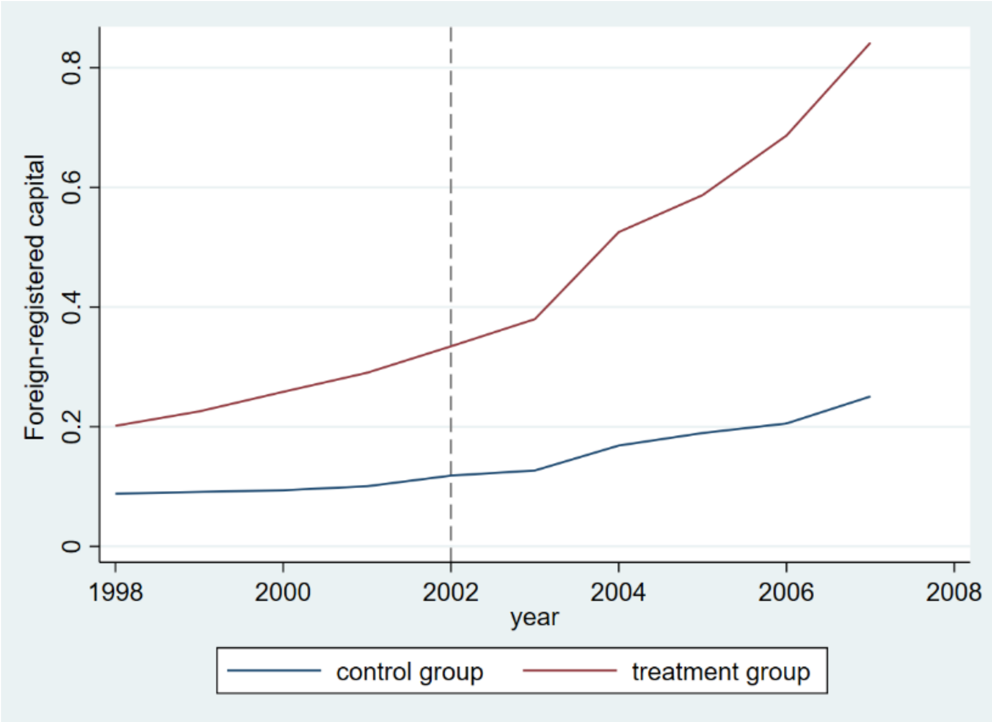

Figure 2. Treatment group and control group performance based on foreign-registered capital. The unit of foreign-registered capital is USD 100 million. Notes: We define encouraged industries based on the Catalogue and the CEEIO database as the treatment group, while no-change industries as the control group.

2.4. The Endogeneity of FDI Policy

When using the Catalogue to investigate the effects of FDI on the environment, the potential reverse causal relationship between FDI and the environment should also be considered [5,8,30]. If this issue is ignored, it may lead to a biased estimation. That is, in order to attract more FDI, the Chinese government might liberalize FDI selectively in industries that pollute more. There are several studies confirming that environment regulation stringency is an important factor in the location choice of FDI [31,32]. To further eliminate the possible reverse causal relationship between the FDI policy and environmental performance, we use the probit model to estimate the following equation:

$$FDI\_change_{it} = \alpha_{it} + \beta_1 pollution_{it} + \beta_2 X_{it} + \gamma_i + \delta_t + \varepsilon_{it}$$

where FDI_change_{it} is the dependent variable relating to whether the industry was liberalized in 2002 compared with 1997 based on the Catalogue. Independent variable $pollution_{it}$ is the industry-level total air pollution emissions ($Total\_AP_{it}$), which is constructed based on the CEEIO database (the construction process of $Total\_AP_{it}$ is shown in Appendix A and also mentioned in Section 3.2 under the introduction of the dependent variable). Meanwhile, the independent variable $pollution_{it}$ also includes the industry-level pollutant emissions of the three most important air pollutants, i.e., $Total\_SO_2$, $Total\_NO_X$, and $Total\_PM_{10}$. In addition, we also control industry *size* as measured by the logarithm of industry output. γ_i and δ_t are the industry fixed effect and the year fixed effect, respectively. The regression results are shown in Table 1. None of the pollutant emission coefficients is significant at the 10% confidence level, which means that pollutant emission is not a determinant for the revision of the Catalogue in 2002, thus alleviating the reverse causality between the FDI policy and air pollution.

Table 1. Analysis investigating whether the FDI policy was relative to pollutant emission.

	Post (FDI Policy Change)			
	(1)	**(2)**	**(3)**	**(4)**
Total_AP	0.071			
	−0.116			
$Total\_SO_2$		0.159		
		−0.118		
$Total\_NO_X$			0.142	
			−0.102	
$Total\_PM_{10}$				−0.002
				−0.111
size	−0.035	−0.11	−0.105	0.033
	−0.16	−0.158	−0.149	−0.157
Industry fixed effect	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES
Observations	84	84	84	84

Notes: The outcome is a dummy variable of the policy implementation year of 2002. *Total_AP* is the logarithm of the total pollution emissions calculated in our paper, while $Total\_SO_2$, $Total\_NO_X$, *and* $Total\_PM_{10}$ are the logarithms of industry-level pollutant emissions. Controls included industry-level control variables, industry fixed effects, and year fixed effects. Standard errors in parentheses are clustered at the industry level.

3. Empirical Specification and Data

3.1. The Empirical Specification

We use the difference-in-differences (DID) model to identify the effects of FDI liberalization on China's air pollution. Our main specification is as follows:

$$API_{it} = \alpha_{it} + \beta_1 \times treat_i \times post_t + \beta_2 X_{it} + \gamma_i + \delta_t + \varepsilon_{it} \quad (1)$$

where API_{it} is the air pollution intensity in industry i in year t; $treat_i$ is a dummy variable that equals to 1 if industry i is classified into the treatment group (i.e., industries in which FDI was encouraged) and equals to 0 if industry i belongs to the control group (no-change industries); $post_t$ is also a dummy variable that takes the value of 1 if the year is 2002 and afterward ($t \geq 2002$) and 0 if $t < 2002$. The coefficient of $treat_i \times post_t$ (β_1) is what we are interested in. If β_1 is significantly less than 0, it means that FDI deregulation has a negative impact on air pollution intensity. If β_1 is significantly bigger than 0, it indicates that FDI deregulation stimulates the air pollution intensity. The control variable (X_{it}) is the industry-level output. γ_i is the industry fixed effect used to capture the unobserved industry-level features which may affect our estimations. δ_t is the year fixed effect. ε_{it} is the error term.

3.2. Dependent Variable: Air Pollution Intensity (API)

Advanced countries such as the United States and Japan have set standards for air quality. In China, the "Ambient Air Quality Standard" (henceforth, the Standard) was first published by the Ministry of Ecology and Environment in 1982. The Standard is the environmental quality target set to realize the environmental policy requirements and is also the key reference for evaluating air quality. The Standard specifies the definition and concentration of pollutant items, as well as the classification of functional areas. Referring to the 1996 version of "Ambient Air Quality Standard", we select sulfur dioxide (SO_2), nitrogen oxides (NO_x), and inhalable particles (PM_{10}) as the main components of air pollution. Sulfur dioxide and nitrogen oxides are the main culprits behind acid rain, while inhalable particles are the main culprit aggravating pollution in hazy weather; these three components are the top three air pollutants.

To evaluate industry-level air pollution, we use the entropy weight method to construct an industry-level composite total air pollution emissions (*Total_AP*), taking sulfur dioxide (SO_2), nitrogen oxide (NO_x), and inhalable particles (PM_{10}) as the basic pollutants. The entropy weight method was derived from physics, then introduced by Shennong into Information Theory. The main principle of the entropy weight method is to firstly determine the information entropy according to the degree of the variation in different indicators, then use the information entropy to correct the original simple weights, and finally obtain relative objective weights. The detailed construction process of the total air pollution emissions is shown in Appendix A.

Based on our calculation, Figure 3 shows the time trends of the total air pollution emissions (*Total_AP*) and air pollution intensity (*API*, measured using the total air pollution emissions per unit of output, the same practice can be found in Cai et al. [32] as well as Zhu and Sun [33]). Despite the overall upward trend of the total air pollution emissions, the air pollution intensity significantly decreased from 1992 to 2012. In our study, we use the air pollution intensity (*API*) as the main dependent variable.

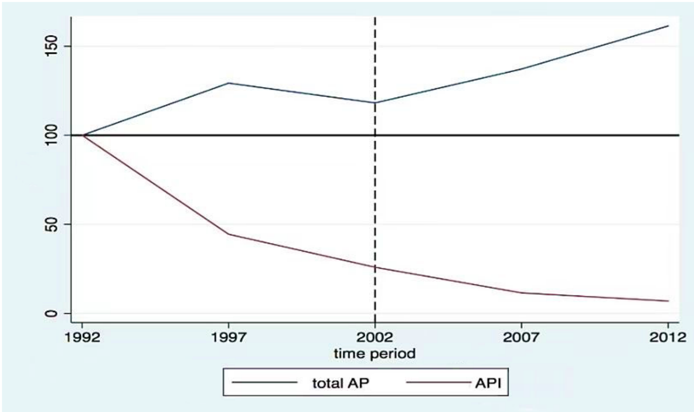

Figure 3. Time trends of the total air pollution emissions (*Total_AP*) and air pollution intensity in 1992–2012. Notes: *API* is the logarithm of total air pollution emissions per unit of output (*Total AP/Output*). Data were obtained from the CEEIO database.

3.3. Data

The data of the main explanatory variable is constructed based on the Catalogue. By comparing the 2002 version with the 1997 version, we can construct two groups: encouraged industries as the treatment group and no-change industries as the control group.

The air pollution data and industry-level output data were derived from the CEEIO database, which was developed by Liang et al. [34]. The database spans across a wide time period, including the years of 1992, 1997, 2002, 2007, and 2012. Not only the CEEIO database includes basic input–output tables, but also the environmental satellite provides information on 256 types of resources and 30 kinds of pollutants. In this paper, we choose sulfur dioxide (SO_2), nitrogen oxides (NOx), and inhalable particles (PM_{10}) as the basic pollutants to evaluate the air pollution intensity (*API*).

The summary statistics for the key variables are shown in Table 2.

Table 2. Summary statistics.

Variable	N	Mean	Std. Dev.	Min	Max
API	374	205,281.7	693,850.1	378.0101	7,104,457
SO_2	398	205,351.3	914,117.4	307	1.15×10^7
NO_x	396	164,316.9	876,262.6	216.4681	1.02×10^7
PM_{10}	376	221,265.4	546,767.9	311.7129	3,966,227
$output$	400	5.61×10^7	1.17×10^8	114,817.2	1.39×10^9
$Treat \times post$	419	0.2887828	0.4314416	0	1

Notes: *API* and output were obtained based on CEEIO data for 1992, 1997, 2002, 2007, and 2012. The construction of the treatment group is based on the 2002 and 1997 Catalogues.

4. Main Results

4.1. Baseline Results

We use Equation (1) to estimate the effect of FDI liberalization on air pollution intensity. We present our baseline results in Table 3. From columns (1) to (3), we gradually control the industry fixed effect, the year fixed effect, and industry-level output as a measure of industry size. We find a consistently and significantly negative effect of FDI liberalization on air pollution, which means that FDI reduces the air pollution intensity in China. We take Table 3 column (3) as our baseline results. The results reported in column (3) suggest that the air pollution intensity in the industries in which FDI was encouraged (the treatment group) has reduced by about 49.9% compared with the industries for which the FDI policy did not change (the control group). Thus, FDI liberalization leads to a reduction in the industry-level air pollution intensity. Our results coincide with the findings of Liang et al. [13], Bao et al. [18], and Jiang et al. [17], which found that FDI contributed to the reduction in pollution emissions as well as the reduction in pollution emission intensity in China. The potential reason is that the continuous inflow of FDI brings capital and advanced clean technology into the host country, which leads to technological diffusion and transmission through training, competition, and imitation [25,34–36]. Consequently, this technological spillover effect leads domestic firms in the host country to learn about and use environmentally friendly technologies, thus reducing the pollutant emissions generated for each unit of output [37,38].

Table 3. Baseline results.

Variables	***API***		
	(1)	**(2)**	**(3)**
Treat × *Post*	−0.915 ***	−0.550 **	−0.499 **
	(−5.457)	(−2.213)	(−2.264)
Size			0.687 ***
			(5.666)
Industry fixed effect	YES	YES	YES
Year fixed effect	NO	YES	YES
Observations	398	398	398
R square	0.135	0.237	0.318

Notes: The outcome is the air pollution intensity. *API* is the logarithm of the total air pollution emissions per unit of output (*Total AP/Output*). *Treat* is a dummy variable that equals to 1 if the industry belongs to the treatment group, 0 otherwise. *Post* is a dummy variable, where $Post = 1$ if $t \geq 2002$ and 0 if $t < 2002$. We control for industry-level output, the industry fixed effect, and the year fixed effect. Standard errors in parentheses are clustered at the industry level. *** $p < 0.01$, ** $p < 0.05$.

4.2. DID Identification Checks

4.2.1. Parallel-Trend Test

The baseline empirical specification of our paper is based on the DID methodology. As the underlying hypothesis of the DID model is that the control treatment group had a similar trend prior to policy implementation in 2002, we construct year dummy variables (*year*1992, *year*1997, *year*2007, *year*2012) and have them interact with the treatment indicator, $treat_i$, to investigate the validity of the parallel-trend hypothesis. The estimation specification is as follows:

$$\begin{aligned} API_{it} = \beta_1 year1992_t \times treat_i + \beta_2 year1997_t \times treat_i + \beta_4 year2007_t \times treat_i \\ + \beta_5 year2012_t \times treat_i + X_{it} + \gamma_i + \delta_t + \varepsilon_{it} \end{aligned} \quad (2)$$

The results are shown in Table 4 column (1) and Figure 4. Table 4 column (1) shows the comparison of the variations in the *API* between the treatment group and the control group in the years during the 1992–2012 period. We can find that there were no differences in air pollution intensity changes between the treatment group and the control group before the policy was implemented in 2002, which alleviates the concern that the treatment and control groups are incomparable, and satisfies the parallel-trend hypothesis. On the other hand, after the 2002 policy implementation, the coefficients of yearly interaction (i.e., *Treat* × *2007* and *Treat* × *2012*) were significantly negative, which is consistent with the baseline results.

Table 4. DID identification tests.

Variables	Parallel-Trend Test	Placebo Test	
		Sample Selection Randomization	Timing Randomization
	(1)	(2)	(3)
Treat_random × *Post*		−0.260 (−1.197)	
Treat × *Post1997*			−0.311 (0.228)
Treat × *1992*	−0.242 (−1.038)		
Treat × *1997*	−0.169 (−0.690)		
Treat × *2007*	−0.693 ** (−2.381)		
Treat × *2012*	−0.821 ** (−2.516)		
Controls	YES	YES	YES
Industry fixed effect	YES	YES	YES
Year fixed effect	YES	YES	YES
Observations	399	399	374
R-squared	0.729	0.717	0.763

Notes: The outcome is the *API*, which is the logarithm of total air pollution emissions per unit of output (*Total AP/Output*). Treat is a dummy variable that equals to 1 if the industry belongs to the treatment group, 0 otherwise. *Post* is a dummy variable, where *Post* = 1 if $t \geq 2002$ and 0 if $t < 2002$. We control for industry-level output, the industry fixed effect, and the year fixed effect. Standard errors in parentheses are clustered at the industry level. ** $p < 0.05$.

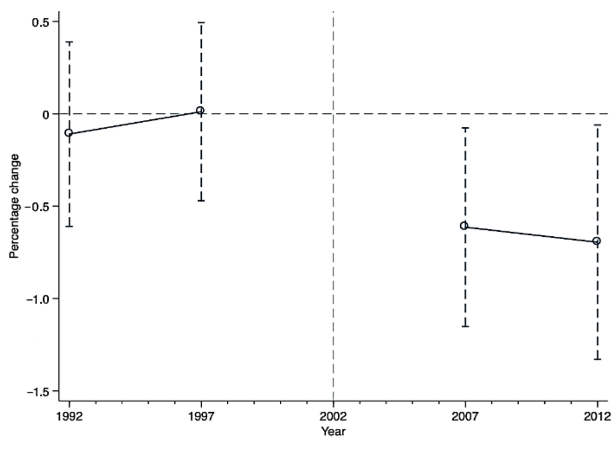

Figure 4. The effect of FDI liberalization on air pollution intensity. Notes: The vertical axis indicates the percentage change in *API*, while the horizontal axis represents the year. The solid line represents the time trend of the difference in air pollution intensity between the treatment and control groups. The dashed lines represent the 95% confidence interval of the estimation. *API* is the industry-level air pollution intensity and was constructed based on the CEEIO database.

Furthermore, we present the effects of the policy across the years in Figure 4. As shown in Figure 4, the coefficients of the interaction terms were not significantly different from zero before policy implementation, which means that there were no significant differences in *API* changes between the treatment and control groups before the policy was implemented.

On the contrary, after 2002, these two groups showed significant differences. The treatment group exhibits a gradual decline in *API* compared with the control group. This indicates that FDI liberalization has a negative impact on *API*, which also means a positive effect on air quality.

4.2.2. Placebo Tests

The DID methodology based on the revision of the Catalogue requires the randomness of the FDI policy, including the selection of the treatment group and the control group, as well as the timing of policy implementation. Therefore, we conducted placebo tests to investigate whether the FDI deregulation policy is correlated with other omitted variables. The core idea underlying the placebo tests was to construct a pseudo treatment group or a pseudo policy time point, and then use Equation (1) to re-estimate the baseline DID model. If the coefficient of the pseudo policy variable turns out to be significant, it means that the former estimation might be biased and influenced by other policies or other unobserved factors.

Firstly, the changes in the Catalogue in 2002 were substantial and random, since they were strictly in accordance with China's WTO commitment. Therefore, the deregulation of FDI inflows in several industries was exogenous to China's internal situation [26]. Notably, it is hard for multinational companies to interfere with China's "opening-up" policy, as they can hardly affect the central government's decision on when and which industry to open up. We then conducted a placebo test using the random sampling method to regroup the treatment and control groups (the same practice can be found in Cai et al. [32]; Li et al. [39]). Figure 5 presents the kernel density distribution of the coefficients of $treat \times post$ after 500 simulated DID regressions; the mean of the coefficients is near zero, indicating that randomly sampled groups have no effects on *API*. Meanwhile, as shown in Table 4 Column (2), the coefficient of $Treat_{random} \times Post$ is not significant either, which provides additional evidence to support the randomness of the industry selection.

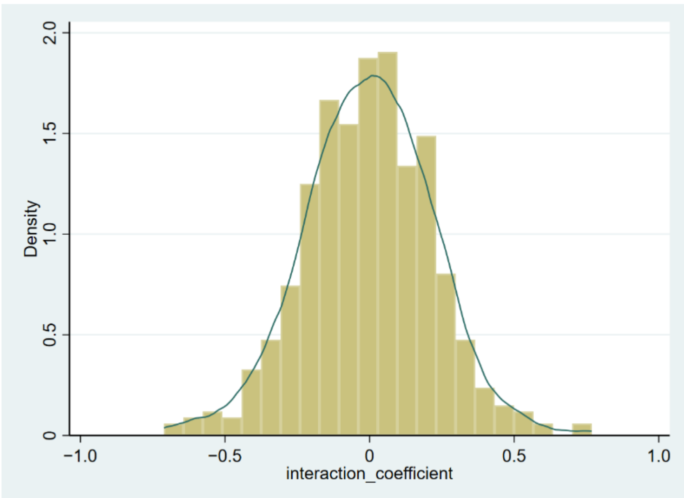

Figure 5. Placebo test. Notes: The density distribution diagram of the coefficient of $treat \times post$ after 500 simulated DID regressions.

Secondly, the timing of FDI liberation is exogenous. As mentioned above, the implementation of the revised Catalogue in 2002 was to fulfill China's WTO accession commitments. However, China's accession to the WTO was itself marked by uncertainty [26,40,41], as it lasted 15 years, with several rounds of negotiations with the existing WTO members. Therefore, there was also great uncertainty about the FDI policy timing. We also followed the approach used by Topalova [42] to bring forward China's deregulation of the FDI policy to 1997 and conduct a pseudo DID regression analysis. Since 1997 is not the actual policy implementation year, we assume that the coefficient of $treat_i \times post_t$ in Equation (1) not to be significant. The regression results are shown in Table 4 Column (3). The estimated coefficient of the pseudo year is not significant, which also provides evidence to support the randomness of policy timing.

4.3. Robustness Checks

4.3.1. Alternative Measures for Air Pollution Intensity

As discussed above, the dependent variable is the air pollution intensity. We also construct alternative indexes to measure the air pollution intensity by decomposing *API* into the original air pollutants, SO_2, NO_x, and PM_{10}. Then, we explore the effects of FDI liberalization on the emission intensity of SO_2, NO_x, and PM_{10}. The results are shown in Table 5 columns (1) to (3). Thus, after policy implementation in 2002, the average emission intensities (measured by dividing by output) of SO_2, NO_x, and PM_{10} in the treatment group decreased by approximately 61.6%, 49.9%, and 43.3%, respectively.

Table 5. Robustness check: alternative measures of air pollution.

Variables	**Decomposition of *API***			**Alternative Index**
	SO_2	NO_x	PM_{10}	CO_2
	(1)	**(2)**	**(3)**	**(4)**
Treat × *Post*	−0.616 **	−0.499 **	−0.433 *	−0.236 *
	(−2.312)	(−2.438)	(−1.871)	(−1.838)
size	YES	YES	YES	YES
Industry fixed effect	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES
Observations	398	396	376	397
R-squared	0.652	0.829	0.796	0.869

Notes: The outcome is the air pollution intensity. Columns (1) to (3) show the decomposition of the *API* in our baseline regression. Column (1): SO_2 is calculated based on SO_2 emission per unit of output. Column (2): NO_x is calculated based on NO_x per unit of output. Column (3): PM_{10} is calculated based on PM_{10} per unit of output. Column (4) is the alternative definition of air pollution based on the unit emission of CO_2. All the outcome variables were taken in the logarithmic form. *Treat* is a dummy variable that equals to 1 if the industry belongs to the treatment group, 0 otherwise. *Post* is a dummy variable, where $Post = 1$ if $t \geq 2002$ and 0 if $t < 2002$. We control the industry size as well as the industry fixed effect and the year fixed effect. Standard errors in parentheses are clustered at the industry level. ** $p < 0.05$, * $p < 0.1$.

In addition, China became the country with the largest carbon emission in 2017 (Jun et al., 2018). The excessive emission of carbon dioxide (CO_2) can enhance the greenhouse effect, which also raises concern around the world (Cole et al. [43]). Thus, we use CO_2 emission intensity as another measure of air pollution (Zhu and Sun [33]). The results are shown in Table 5 column (4); we find similar and consistent results indicating that FDI liberalization reduces CO_2 emission intensity in the industries in which FDI was encouraged (the treatment group) by approximately 23.6%.

4.3.2. Alternative Measures to FDI Policy

Our baseline results are mainly based on the change in the FDI policy in 2002. However, the Catalogue was revised three other times after 2002, which may have interfered with the robustness of the empirical results. By comparing the 2002 version with the following revisions in 2004, 2007, and 2011, we find that the 2004 and 2011 versions of the Catalogue did not significantly change in terms of the CIC four-digit codes [26]. The only major change happened in the 2007 version of the Catalogue. However, we find that these changes are mostly caused by a more detailed division of the industries, and we can also find that there is no substantial FDI liberalization according to the FDI Regulatory Restrictiveness Index constructed by the OECD. Regarding the OECD's FDI Regulatory Restrictiveness Index, it is observed that this index unexpectedly dropped when China revised its Catalogue in 2002, while there is a small range of fluctuation in the index before and after 2002, which indicates that other versions of the Catalogue had a lower degree of FDI liberalization. For robustness checks, we also consider FDI policy changes based on the 2002 and 2007 versions of the Catalogue and conducts the multi-stage-DID model. As is shown in column (1) of Table 6, we find a consistent, negative and significant effect of FDI liberalization on air pollution intensity, which further verifies the robustness of our baseline findings.

Table 6. Robustness check: multi-stage DID and SOE reform.

	API	*API*
	Multi-Stage DID	**SOE Reform**
	(1)	**(2)**
Treat × *Post*		−1.479 ***
		(−5.432)
Multi-DID	−0.335 *	
	(−1.802)	
SOE × t		YES
Controls	YES	YES
Industry fixed effect	YES	YES
Year fixed effect	YES	YES
Observations	415	240
R-squared	0.739	0.696

Notes: The outcome is the *API*, which is the logarithm of total air pollution emissions per unit of output (*Total AP/Output*). Treat is a dummy variable that equals to 1 if the industry belongs to the treatment group and 0 otherwise. *Post* is a dummy variable, where *Post* = 1 if $t \geq 2002$ and 0 if $t < 2002$. Column (1) shows results based on the multi-DID model. Column (2): We take the SOE reform into account, and SOE × *t* is the interaction item of the industry-level state-owned capital share in 2001 and year dummies after 2002. We control for industry-level output, the industry fixed effect, and the year fixed effect. Standard errors in parentheses are clustered at the industry level. *** $p < 0.01$, * $p < 0.1$.

4.3.3. Confounding Policy of State-Owned Enterprise (SOE) Reform

Ownership is the basic attribute of enterprises, and there are significant differences in the ability to minimize emissions and their intensity of different ownerships [18]. During the time period from 1992 to 2012, China was also engaged into another highly important reform, the state-owned enterprise (SOE) reform, with the aims of fostering economic development, enhancing the degree of marketization and stimulating the vitality of state-owned enterprises [26,40]. Therefore, following the method by Lu et al. [26], we included the interaction item of the industry-level SOE capital share in 2001 and year dummies after 2002 into our baseline model (i.e., Equation (1)) to control the impact of the SOE reform. The results are shown in Table 6 columns (2). Our main findings are consistent with our baseline results indicating that FDI reduces the air pollution intensity.

4.4. Heterogeneous Effects

As explained in the above sections, we find that FDI liberalization reduces the air pollution intensity in China. Then, is there any heterogeneous effect of FDI on air pollution intensity? In this section, we explore the heterogeneous effects of different industries or human capital levels.

4.4.1. Heterogeneous Effects by Industry

The weak tradable characteristics of services induced service multinationals to enter China, mainly through the commercial presence and FDI entry [44]. In China, the FDI liberalization policy gradually shifted from the manufacturing industry to the service industry. According to World Investment Report 2012, published by the United Nations Organization for Trade and Development (UNCTAD) for the first time since 2001, the service industry attracted more FDI than the manufacturing industry. Therefore, we divided the sample into manufacturing and service industries and explored the heterogeneous effect of FDI on the air pollution intensity. The results are shown in columns (1) and (2) of Table 7. The coefficients of the interaction terms are significantly negative, which suggests that FDI liberalization reduces the air pollution intensity in both the manufacturing and service industries.

Table 7. Heterogeneous analysis.

Variables	Manufacturing	Services	Human Capital
	(1)	**(2)**	**(3)**
Treat × *Post*	−0.279 *	−0.739 **	−0.4026 **
	(0.165)	(−2.551)	(−2.4496)
Treat × *Post* × *Labor*			−0.6621 *
			(−1.9114)
Controls	YES	YES	YES
Industry fixed effect	YES	YES	YES
Year fixed effect	YES	YES	YES
Observations	247	133	399
R-squared	0.876	0.687	0.8609

Notes: The outcome is the *API*, which is the logarithm of total air pollution emissions per unit of output (*Total AP/Output*). *Treat* is a dummy variable that equals to 1 if the industry belongs to the treatment group, 0 otherwise. *Post* is a dummy variable, where *Post* = 1 if $t \geq 2002$ and 0 if $t < 2002$. Columns (1) and (2) report the heterogeneous analysis results based on the different industries, including the manufacturing and service industries, respectively. Column (3) reports the heterogeneous analysis results based on the human capital. Variable "*Labor*" is a dummy variable that equals to 1 if the industry is defined as human-capital-intensive industry and 0 otherwise. We control for industry-level output, the industry fixed effect, and the year fixed effect. Standard errors in parentheses are clustered at the industry level. ** $p < 0.05$, * $p < 0.1$.

4.4.2. Heterogeneous Effects by Human Capital Level

Although FDI brings capital and advanced technology to the host country, it is also necessary to investigate the host country's absorption ability of the FDI spillover effect, and human capital is an influential factor that cannot be ignored. Zugravu-Soilita [16] and Lan [19] find that FDI can help to reduce pollution in regions with abundant human capital. Therefore, we test the heterogeneous effects according to different levels of human capital intensity. We measure the human capital intensity using the sum of fixed assets and salary per output, and we construct a new dummy variable that equals to 1 if the industry is a human-capital-intensive industry, with human capital intensity being larger than the mean, and 0 otherwise. As shown in column (3) in Table 7, the coefficient of *Treat* × *Post* × *Labor* is significantly negative, which shows that FDI liberalization has a more significant effect on reducing air pollution intensity in human-capital-intensive industries. Therefore, by increasing human capital investment, China could improve air quality in a more liberalized FDI environment.

5. The Discussion on the Mechanisms

5.1. Decomposition of Within- and Between-Industry Effects

The traditional theory and methodology reported in Grossman and Krueger [22] and Copeland and Taylor [4] decompose the changes in pollution into three channels: scale effects, composition effects, and technical effects. In our analysis, we focus on the technical effects, which are more relevant to the emission intensity in each industry. FDI can improve the air pollution intensity through two channels: within-industry or between-industry effects. On the one hand, by introducing advanced emission reduction technologies into the host country, FDI improves the utilization of resources within the industry and reduces the emission of pollutants, thus improving the air environment. On the other hand, the industry structure also changes as the output from the pollution-intensive industries shrinks and the output from the clean industries expands. This between-industry effect also improves the air quality. Thus, following the method proposed by Choi and Yi [45], we decompose the changes in pollution intensity (pollution/output) into within-industry and between-industry effects. The specific formula is as follows:

$$\Delta\frac{pollution}{output}=\frac{pollution_t}{output_t}-\frac{pollution_{t-1}}{output_{t-1}}=\sum_{i\in I}\frac{pollution_{it}}{output_{it}}\omega_{it}-\sum_{i\in I}\frac{pollution_{it-1}}{output_{it-1}}\omega_{it-1} \quad (3)$$

$$\Delta\frac{pollution}{output}=\sum_{i\in I}\left[0.5\Delta\frac{pollution_{it}}{output_{it}}(\omega_{it}+\omega_{it-1})+0.5\Delta\omega_{it}\left(\frac{pollution_{it}}{output_{it}}+\frac{pollution_{it-1}}{output_{it-1}}\right)\right] \quad (4)$$

where *Pollution (output)* is the economy's total pollution (output); $Pollution_{it}$ is the air pollution (including *API*, as well as its components, SO_2, NO_x, and PM_{10}) in industry i in year t; and ω_{it} refers to the output ratio of industry i in year t. The first part of the right-hand side of Equation (4) represents the within-industry effects, and the second part represents the between-industry effects.

In Table 8, column (1) shows that compared with 1992, the air pollution intensity declined in 2012, both for the *API* and its components, SO_2, NO_x, and PM_{10}. As shown in column (2) and column (3), we find that this result is mainly driven by the within-industry effects. For the full sample, the within-industry effects contributed to more than 100% of the pollution intensity reduction, while the between-industry effects contributed to −9.51% of the reduction in air pollution intensity. Similar results are shown in Table 8 Panel B, for the manufacturing industry, where the within-industry effects dominated the decline in air pollution intensity and contributed to an intensity decrease of more than 90%.

Table 8. Within-industry and between-industry effects.

	Total Effects (1)	**Contribution of Within-Industry Effects (2)**	**Contribution of Between-Industry Effects (3)**
Panel a: full sample range from 1992 to 2012			
API	−0.015988	110.50%	−9.51%
SO_2	−0.017111	117.03%	−14.55%
NO_x	−0.009762	118.44%	−15.57%
PM_{10}	−0.021745	101.66%	−1.63%
Panel b: manufacturing industry			
API	−0.006481	91.66%	9.10%
SO_2	−0.006304	95.18%	5.06%
NO_x	−0.003646	90.15%	10.93%
PM_{10}	−0.009805	90.13%	10.95%

Notes: *API* is the logarithm of total air pollution emissions per unit of output (*Total AP/Output*). SO_2 is the air pollution calculated based on SO_2 per unit of output in logarithmic form. NO_x is the air pollution calculated based on NO_x per unit of output in logarithmic form. PM_{10} is the air pollution calculated based on PM_{10} per unit of output in logarithmic form.

From the above, it is clear that FDI deregulation may contribute to the reduction in air pollution intensity through resource allocation effects (i.e., within-industry effects) and structural adjustment effects (i.e., between-industry effects). Furthermore, we construct a DID model to examine the relationship between FDI deregulation and these two effects using the following estimation:

$$\begin{aligned}within\_effect_{it}&=\alpha_{it}+\beta_1\times treat_i\times post_t+\beta_2X_{it}+\gamma_i+\delta_t+\varepsilon_{it}\\between\_effect_{it}&=\alpha_{it}+\beta_1\times treat_i\times post_t+\beta_2X_{it}+\gamma_i+\delta_t+\varepsilon_{it}\end{aligned} \quad (5)$$

The results are shown in Table 9. Firstly, in general, the conclusion that FDI reduces air pollutant emissions mainly through within-industry effects has been verified again. Secondly, column (1) shows the effects of FDI deregulation on within-industry resource allocation. The results show that compared with no-change industries, industries in which FDI was encouraged experienced a within-industry air pollution intensity reduction. In other words, as FDI enters the host country, it promotes technological upgrading and improves resource utilization within the industries through the technological spillover effect or competition effect, thus reducing the emission of pollutants and improving the air quality. Thirdly, as shown in column (3), the pollution reduction effect on the between-industry structural change is not significant. Thus, the relaxation of FDI entry does not show a pronounced effect on the change in the output structure, and the result is similar with Martin [46], which found that the reduction in greenhouse gas emissions in India was mainly due to within-industry productivity improvements rather than between-industry output structural adjustments. This finding also holds for the three main components of air pollution (SO_2, NO_x, and PM_{10}). The results are consistent with the relevant literature that the environmental improvement of FDI is mostly driven by technical effects rather than the composition effects (Levison [47], Levison [48], Shapiro and Walker [49], Brunel [50]). Thus, our results provide direct and effective evidences against the "Pollution Haven Hypothesis" and support the "Pollution Halo Hypothesis".

Table 9. Mechanism analysis results: within-industry and between-industry effects.

Variables	Within-Industry Effects	Between-Industry Effects
	(1)	(2)
$Treat \times Post\ (API)$	−0.514 ***	0.095
	(−2.653)	(0.870)
$Treat \times Post\ (SO_2)$	−0.651 ***	0.190
	(−2.634)	(1.425)
$Treat \times Post\ (NO_x)$	−0.565 ***	0.113
	(−2.715)	(1.266)
$Treat \times Post\ (PM_{10})$	−0.405 **	0.021
	(−2.365)	(0.179)
Observations	292	292

Notes: The outcome is the *API*, which can be divided into two parts. Treat is a dummy variable that equals to 1 if the industry belongs to the treatment group and 0 otherwise. *Post* is a dummy variable, where *Post* = 1 if $t \geq 2002$ and 0 if $t < 2002$. Column (1) shows the within-industry effects. Column (2) shows the between-industry effects. We control for the industry fixed effect and the year fixed effect. Standard errors in parentheses are clustered at the industry level. *** $p < 0.01$, ** $p < 0.05$.

5.2. Channel of Productivity

In the above analysis, we find that FDI liberalization improves air quality mainly through reducing the air pollution intensity within the industries. Then, we would like to investigate the technological improvement effects of FDI deregulation. The estimation specification is as follows:

$$TFP_{it} = \alpha_{it} + \beta_1 \times treat_i \times post_t + \beta_2 X_{it} + \gamma_i + \delta_t + \varepsilon_{it} \tag{6}$$

Based on the data envelopment analysis (DEA) framework, we use the DEA-Malmquist index [51,52] to measure the changes in total factor productivity (TFP). The DEA-Malmquist index method is independent of specific production functions. It does not need parameter estimation [53], which can effectively avoid the calculation bias caused by inaccurate model setting and parameter estimation. In addition, the DEA-Malmquist index can further decompose TFP changes into technological efficiency changes, changes in returns to scale, and technological progress. The specific index is constructed as follows:

$$M = (x_{t+1}, y_{t+1}, x_t, y_t) = [\frac{D_0^t(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)} \times \frac{D_0^{t+1}(x_{t+1}, y_t)}{D_0^t(x_t, y_t)}]^{1/2} \tag{7}$$

where D_0^{t+1} and D_0^t are the distance functions of year $t+1$ and year t, respectively, referring to the technical level in the t period, and x and y represent input and output, respectively. If the result is greater than 1, the total factor productivity (TFP) improved, and if it is less than 1, the TFP decreased. Furthermore, Formula (7) can be decomposed as follows:

$$M = (x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{D_v^{t+1}(x_{t+1}, y_{t+1})}{D_v^t(x_t, y_t)}\right] \times \left[\frac{D_v^t(x_t, y_t)}{D_c^t(x_t, y_t)} / \frac{D_v^{t+1}(x_{t+1}, y_{t+1})}{D_c^{t+1}(x_{t+1}, y_{t+1})}\right] \times \left[\frac{D_c^t(x_{t+1}, y_{t+1})}{D_c^{t+1}(x_{t+1}, y_{t+1})} \times \frac{D_c^t(x_t, y_t)}{D_c^{t+1}(x_t, y_t)}\right]^{1/2} \tag{8}$$

where the first part on the right-hand side of Equation (8) represents the technological efficiency change (*Pe*); the second part is the change in returns to scale (*Se*); and the third part is technological progress (*Tech*).

Then, we calculate the industry-level TFP from 1992 to 2012 using the input–output table from the CEEIO database. The regression results based on Equation (6) are shown in Table 10. The significant effect of FDI on *API* was verified as mentioned above. As shown in column (1), we can find that FDI liberalization significantly increases TFP at the 1% significance level. Further analysis results, shown in columns (2) to (4), shows that the TFP promotion effect is mainly driven by the technological efficiency changes (*Pe*), but not the scale return and technology progress. Though the literature has concluded with the importance of technical effect (Bao et al. [18], Levison [47], Levison [48], Shapiro and Walker [49], Brunel [50]), our paper is the first to find that the technical efficiency mainly drives the effects of FDI liberalization on pollution.

Table 10. TFP regression results.

Variables	*TFP*	*Pe*	*Se*	*Tech*
	(1)	**(2)**	**(3)**	**(4)**
Treat × *Post*	0.565 ***	0.635 ***	0.060	−0.023
	(3.258)	(3.094)	(0.416)	(−1.147)
Controls	YES	YES	YES	YES
Industry fixed effect	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES
Observations	385	385	385	385
R-squared	0.829	0.839	0.783	0.951

Notes: Column (1): TFP is the total factor productivity in logarithmic form calculated using the DEA-Malmquist method. Columns (2) to (4) show the decomposition of TFP, representing technological efficiency changes, changes in returns to scale, and technological progress, respectively. Treat is a dummy variable that equals to 1 if the industry belongs to the treatment group and 0 otherwise. *Post* is a dummy variable, where *Post* = 1 if $t \geq 2002$ and 0 if $t < 2002$. We control for the industry fixed effect and the year fixed effect. Standard errors in parentheses are clustered at the industry level. *** $p < 0.01$.

6. Conclusions

Increasing concerns about the impacts of FDI on the host country's environment, along with the enriched literature on the technological transfer and spillover effects of FDI on developing countries, have led researchers to re-investigate whether FDI is a "Pollution Havens" or a "Pollution Halo" for developing host countries. In this paper, we take China as a case study, and estimate the causal effects of FDI on air pollution. This paper presents the empirical analysis by utilizing the relaxation of the FDI regulation policy upon China's accession to the WTO using the DID methodology, via which we linked industry-level FDI regulation with the air pollution intensity to shed light on the impact of China's FDI liberalization on air pollution.

We find that FDI liberalization significantly decreases air pollution intensity; evidence of this effect exists in both the manufacturing and service industries, and the effect is more pronounced in sectors with higher levels of human capital. The potential endogeneity issues and the validity of the DID settings have also been well addressed and examined. We also carry out a series of robustness checks, such as considering alternative measures of air pollution, introducing alternative measures of the FDI policy and controlling for other confounding policies, as evidence to support the robustness of our main findings.

Moreover, we also explore the channels through which FDI affects China's air pollution. Firstly, by decomposing the changes in air pollution intensity into within-industry effects and between-industry effects, we find that the FDI-liberalization-based reduction in air pollution intensity is mostly driven by technological improvement within the industries. Secondly, FDI liberalization significantly increased TFP, and this promotion effect is mainly driven by technological efficiency changes rather than changes in returns to scale or technological progress. Such effects provide direct and clear evidence supporting the "Pollution Halo hypothesis".

Therefore, the relaxation of China's FDI policies can help promote more environmentally friendly technologies, reduce air pollution intensity, and achieve the goal of green development. Thus, the developing countries could serve FDI deregulation policy as a driver for promoting environmentally sustainable development (Burlea et al. [54]). In our paper, we find that the mitigating effect of FDI on air pollution intensity is more pronounced in the services industry and in sectors with higher human capital. Thus, the FDI liberalization policy should also combine with human capital development and technology development to enhance the absorptive capacity of FDI spillover effects. Moreover, technological improvement within each industry dominates the reduction in pollution intensity according to our results. Thus, the more disaggregated data, such as the firm-level environmental data, as suggested by Cherniwchan [55] and Cui et al. [56], should be utilized to analyze the transmission mechanisms of FDI impacts on the environment.

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Appendix A. Construction of the Industry-Level Total Air Pollution Emissions

The construction process of the industry-level total air pollution emissions (*Total_AP*) is shown below.

The first step is to standardize the air pollutant data: $r_{ij} = [x_{ij} - min(x_{ij})]/[max(x_{ij}) - min(x_{ij})]$, where x_{ij} represents the value of pollutant j in industry i.

The second step is to coordinate the translation of standardized data: $r_{ij}{}^{*} = r_{ij} + 1$.

The third step is to calculate the initial weight of the j pollutant of the i industry: $p_{ij} = r_{ij}{}^{*} / \sum_{i=1}^{m} r_{ij}{}^{*}$.

The fourth step is to calculate the entropy value of the j pollutant: $e_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij}$, where $k = 1/\ln m$; and the entropy weight of the j pollutant (according to our calculation, the entropy weight of sulfur dioxide was 26.62%; the entropy weight of nitrogen oxides was 26.02%; and the entropy weight of inhalable particles was 47.36%) also needs to be calculated: $w_j = (1 - e_j) / \sum_{j=1}^{n} (1 - e_j)$.

Finally, it is hypothesized that the impact of air pollutants on the environment is the same, so the entropy weight is the final comprehensive weight. Thus, *Total_AP* is calculated as follows: $Total\_AP_i = \sum_{j=1}^{m} x_{ij}{}^{*}w_j$.

Appendix B. Temporal Trend of the FDI Regulatory Restrictiveness Index in China

In 1997, the OECD developed the FDI Regulatory Restrictiveness Index to measure the degree of FDI policy liberalization in 22 sectors in OECD and non-OECD countries. The value range of this index is 0–1. The higher the score is, the more restrictive it is. "Fully open" is assigned 0, and "completely closed" is assigned 1.

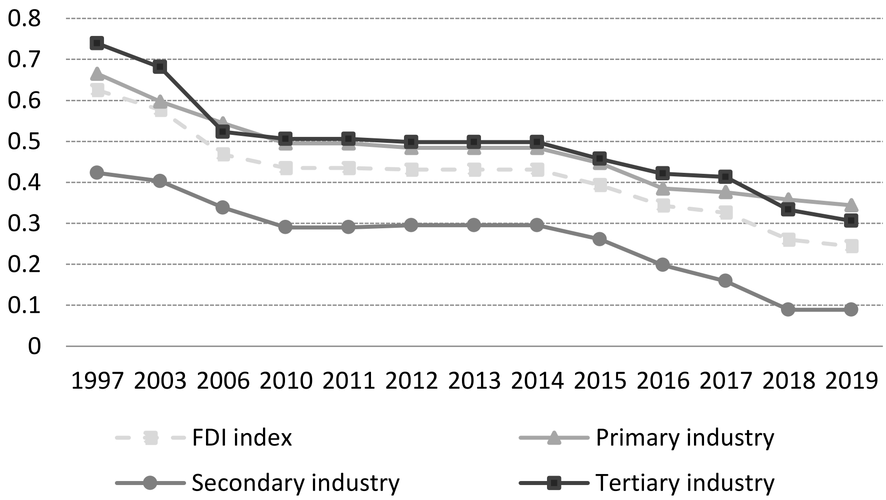

Figure A1. Temporal trend of the FDI Regulatory Restrictiveness Index in China. Notes: The data were obtained from the OCED database.

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