

Emission Reduction Investment, Technology Choice and Business Environmental Performance: Evidence from China's Foreign Investment Liberalization Reform

Chao Han, Zhen Wang*

Pollution has become an unavoidable concern as China's high-quality development is underway. How to reduce pollution is an imperative issue for China to address. Pollution emissions are closely related to factor inputs, production processes and pollution control measures. Are there other forces to cut emissions besides regulatory control? Taking sulfur dioxide as an example, this paper probes into the potential mechanism through which technical efficiency drives pollution reduction in the context of opening to foreign investment. The results reveal that the openness to foreign investment remarkably lowers pollution emissions of firms, with SOEs, large firms and exporters seeing more pronounced pollution reduction effect after opening to foreign investment, while firms in pollution-intensive industries and less regulated areas are weaker in pollution reduction. A look into firm behavior suggests that the openness to foreign investment reduces pollutant emissions by improving technical efficiency rather than by raising investment in pollution control. The pollution reduction effect resulting from the openness is reflected in the improvement of intra-firm emission reduction capacity instead of inter-firm resource reallocation effect, according to an analysis at the aggregate level. This paper concludes that technical efficiency gains are an important tool to advance pollution reduction, and that China must be more flexible in leveraging the pollution reduction effect of other policies regarding technical efficiency to drive its high-quality development that is green.

Keywords: pollution reduction, openness to foreign investment, firm behavior, technical efficiency

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1. Introduction

Pollution has become an unavoidable concern as China's high-quality development is underway. How to effectively control pollution is an imperative issue for China to address. Conventionally, pollution control targets have been achieved by relying on mandatory regulatory measures that are undeniably significant for pollution reduction (Liu and Chen, 2016) but may have negative effect of distorting market mechanisms or end up with poor results in cutting emissions (Tombe and Winter, 2015; Chen *et al.*, 2018). Are there other paths to lower emissions besides regulatory control? Based on China's practices, the opening up, especially the liberalization of foreign investment, is an essential driver for market-oriented reforms which have transformed so many aspects of economic development and one of the major engines for high-speed development, as well as a national strategy for high-quality development into the future.¹ To attract foreign investment with a better protection of the legitimate rights and interests of overseas investors, China passed the *PRC Foreign Investment Law* on March 15, 2019 to replace the *Law for Sino-Foreign Equity Joint Venture Enterprises*, the *Law for Wholly Foreign Owned Enterprises*, and the *Law for Sino-Foreign Cooperative Joint Venture Enterprises*, raising the laws protecting foreign investment to a higher level. Focusing on the firm behavior in the openness to foreign investment, this paper investigates whether foreign investment facilitates high-quality growth including green development. That is, does the openness of foreign investment bring about pollution reduction effect? And if it is of positive environmental impact, in what way and mechanism does it lower emissions? And how does this differ from the conventional environmental regulation? Despite that the above questions have been covered in part of literature, no robust and reliable answers could be found for them.

A firm's final pollution emissions depend on the generation and treatment of pollutants, where energy efficiency improvement or green technical advances will likely impact pollutant generation by optimizing the stages of production, while the intensified use of pollution control facilities will enable direct treatment of pollutants at the end. Also the overall emission of pollutants is impacted by inter-firm allocation and related to market entry and exit of firms (Grossman and Krueger, 1991; Shapiro and Walker, 2018). The environmental regulation, the most direct response tool to pollution emissions, has been a top choice for governments to control pollution and objectively has played a key part in curbing emissions. Quite a few studies have also noted that environmental regulation deals with pollution mainly by lowering emissions with the use of pollutant treatment facilities, but fundamentally it has not eliminated pollutants

¹ The *Circular on Measures for Active and Effective Use of Foreign Investment in Promoting High-Quality Economic Development* has made it clear "to roll out special administrative measures of foreign investment access (Negative List) for pilot free trade zones and nationwide" for wider openness to the outside world and higher-quality economic development.

but discharged them somewhere else (Greenstone, 2003). Along with curbing emissions, environmental regulation could mount the operating costs of firms and slow down their productivity growth (Gray, 1987; Gray and Shadbegian, 2003). Since environmental regulation might generate some unfair effect upon implementation, such as resource misallocation (Tombe and Winter, 2015) and sometimes serve as a means to seek illicit competitive advantages (Dechezleprêtre and Sato, 2017). The differences in environmental regulation could lead to the transfer of pollutants, firm siting or other behavior across areas, but the overall pollution reduction effect has not been evident (Lipscomb and Mobarak, 2016; Chen *et al.*, 2018). There are also considerable costs associated with the implementation of environmental regulation, including regulatory staffing costs and hidden agent costs, leaving high uncertainties about if environmental regulation would result in positive net benefits (Greenstone and Hanna, 2014).

As the idea of controlling pollution emissions by regulation suffers from the above problems, seeking forces outside the regulatory tool to propel the cut of emissions becomes a critical task for pollution reduction and orderly and sound industrial development. As a matter of reality, be it China and Mexico in developing countries or the United States in developed countries, governments have not only adopted environmental regulation to reduce emissions, but encouraged technical efficiency gains to make pollution reduction (Duflo *et al.*, 2013; Ryan, 2017). For this paper, does the openness to foreign investment that has played a major role in driving marketization in China have a pollution reduction effect? Previous studies pointed to advances in technical efficiency as the mechanism through which openness has impacted emission behavior (Shapiro and Walker, 2018), and some found that trade openness, rather than increased investment in pollution control, has lifted technical efficiency and hence led to the pollution reduction effect (Gutiérrez and Teshima, 2018). The openness to foreign investment has been found to have a significant causality with total factor productivity (TFP) and innovation in studies on technical efficiency, with some arguing that the openness would depress domestic firms' TFP (Lu *et al.*, 2017) and others claiming it would boost innovation capacity (Mao, 2019). While these findings are inconsistent, they provide an empirical basis for further reflection over whether the openness to foreign investment helps with pollution reduction by impacting technical efficiency. However, in practice, the inquiry into the impact of openness on pollution emissions is confronted with some objective challenges, and particularly the lack of core pollution emission indicators makes relevant conclusions unconvincing (Gutiérrez and Teshima, 2018). Previous studies have either used intermediate inputs (Ryan, 2017) or investment in pollution control (Wang, 2002) to measure pollution emissions. Even though the indicators could reflect pollution emissions to some extent, they are not fully equal to pollution emissions. Meanwhile, foreign investment might be strongly related to the industrial development of the host country, and to exclude the impact of industrial characteristics on foreign

investment access, most of the existing literature on openness to foreign investment has analyzed using exogenous shocks (Aghion *et al.*, 2009; Lu *et al.*, 2017). This paper investigates whether the openness to foreign investment generates pollution reduction effect as well as the mechanism, based on the exogenous impact of China's substantial liberalization of foreign investment after its accession to the WTO, specifically by a major revision of the *Catalog for the Guidance of Foreign Investment Industries* (hereinafter referred to as "the *Catalog*") in 2002.

The literature directly associated with this paper is a study on the relationship between FDI and environmental performance. Some studies suggest that FDI could ultimately reduce environmental pollution by technical efficiency gains and improved treatment capacity of pollution. The presence of foreign investment may create a significant learning effect as foreign-owned firms possess high levels of technology and treatment capacity of pollution. Zheng *et al.* (2010) also found a significant negative correlation between per capita FDI and the pollution level in Chinese cities based on the Chinese context. Similar findings were obtained based on other national contexts (Eskeland and Harrison, 2003), revealing that domestic firms in developing countries have significantly higher pollution intensity than foreign firms. In contrast, some literature has not found a pollution mitigation effect resulting from foreign investment access (Pargal and Wheeler, 1996). There is also a body of literature holding that foreign investment into developing countries has a pollution haven effect, on the basis that developed countries transfer polluting industries or products to developing countries by investing abroad, exploiting the differences in environmental regulation between their own and host countries (Chung, 2014). The overall evidence supporting the pollution haven effect is limited (Eskeland and Harrison, 2003). Some studies combining the pollution haven effect with technical efficiency advancement effect found that lower environmental regulation, despite of facilitating the attraction of foreign investment, enjoy a large advantage over domestic firms in terms of pollution generation and treatment technology, and the net effect is still noticeable in pollution reduction (Kim and Adilov, 2012). Compared with similar research topics, this paper has innovative contributions as follows. First, it presents empirical evidence that technical efficiency gains drive the pollution reduction. While current studies on the drivers for emission reduction in China have mostly focused on the impact of environmental regulation and directed policy insights to the reform and refinement of regulation, this paper finds that technical efficiency gains resulting from the openness to foreign investment are also an effective force for pollution reduction. Second, it enriches the studies related to the impact of foreign investment access on pollution emissions at the business level. Existing studies have analyzed the relationship between foreign investment access and pollution emissions either at the area level or the industry level. The focus, confined to impact of aggregate factors at the area or industry level, has not been on the business level, so it is unable to answer how micro-firms react to foreign investment access, and

thus to reveal whether the impact of foreign investment access on pollution emissions results from structural factors, size factors or technical efficiency factors.

2. Policy Background and Stylized Fact

The biggest transformation in China's economy and society since 1979 has been the shift from a planned economy to a socialist market economy, and opening up (including trade and investment) has been a crucial driver behind market-oriented reforms. In the investment perspective, the openness of foreign investment was initially for economic promotion, but amidst exerting influence over China's economy, foreign investment access may impact the environmental quality of China. In regulating and guiding foreign investment, the *Catalog* is a fundamental guideline that has played a fundamental role in attracting foreign investment. China developed its first *Catalog* in 1995, and as of 2018 seven adjustments were made to the document. Figure 1 is drawn upon the investment projects explicitly prohibited, restricted and encouraged in the successive *Catalog* documents to visualize the industrial adjustments of restrictions over foreign investment. The biggest change in foreign investment access was made in 2002, with an increase of 25.1% in encouraged industries and a reduction of nearly 62.7% in restricted industries compared to 1997. As the major revision of the *Catalog* in 2002 was intrinsically linked with China's accession to the WTO in the same period and only a slight adjustment to the document was made after that, thus making 2002 the year with the largest adjustment of the *Catalog*. With the above mentioned, this paper draws attention on the impact of 2002 revision in the *Catalog*. To explore the relationship between openness to foreign investment and pollution emissions, we first look into the potential correlation between openness to foreign investment and pollution emissions by the 2002 revision of the *Catalog*.

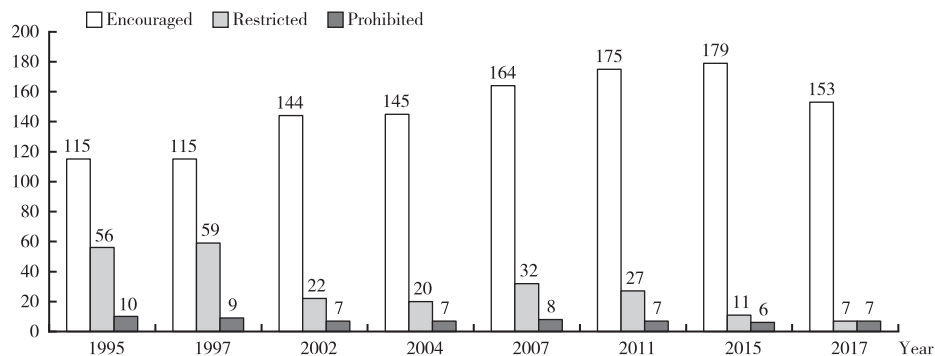
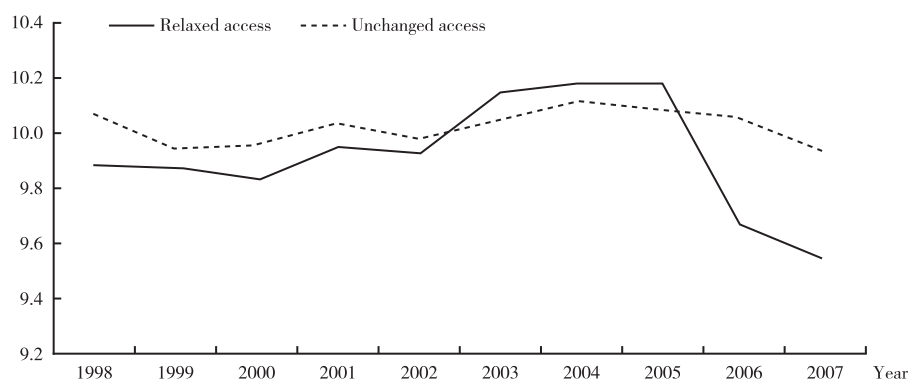
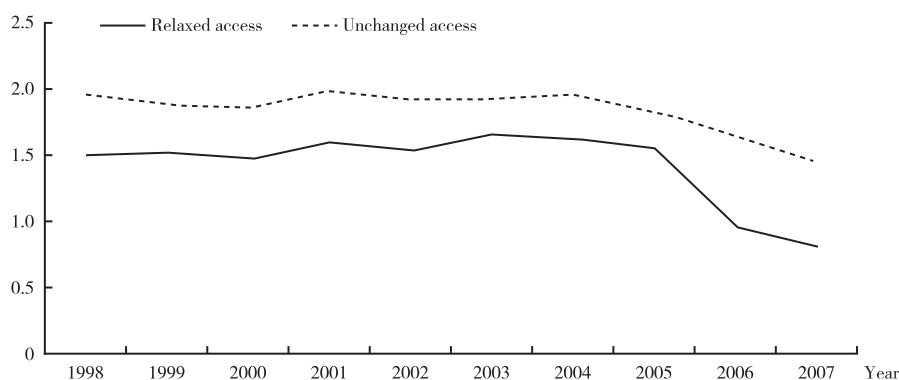


Figure 1. The Number of Encouraged, Restricted and Prohibited Industries

Figure 2. Openness to Foreign Investment and SO₂ EmissionsFigure 3. Openness to Foreign Investment and SO₂ Emission Intensity

By the 2002 revision of the *Catalog*, the sample firms are divided into two groups, one with relaxed foreign investment access and the other with unchanged access, as a basis for plotting the trend of SO₂ emissions (in logarithmic form) (see Figure 2). The comparison shows that overall, the growth rate of SO₂ emissions in industries with relaxed access slowed down notably after 2003 and was much slower than in industries with unchanged access. It seems to suggest that the openness to foreign investment can actually enhance the environmental performance of firms. The period from 2003 to 2004 in Figure 2 had seen more emissions in industries opening up to foreign investment, which was associated with the trend before the openness. Observed from the trend before openness, the pollution emissions of industries opening up to foreign investment exhibited a more pronounced phase of enhancement, and the growth rate after 2003 had clearly started to be curtailed and become gradually slower than the industries with unchanged access. A comparison of the two reveals that the openness to foreign investment presents signs of curbing emissions. Besides, the size of firms is not accounted for in Figure 2. To exclude the influence of size, there also plots the trend of SO₂ emission intensity (in logarithmic form) of the two groups (see Figure 3). The emission intensity of firms in industries with

relaxed access had been lower than that of firms in industries with unchanged access in the period from 1998 to 2007, and there was a clear drop in the former in 2003 following the enhancement in the latter. The comparison between Figure 3 and Figure 2 reveals that the illustrative graph of the difference in emissions between the two groups after excluding the factor of firm size further suggests that the openness to foreign investment may create a pollution reduction effect. While the above findings are schematic, it already shows some signs of correlation between openness to foreign investment and pollution emissions, but of course no definite answer is available before a scientific analysis. It essentially is an empirical matter and one of the main ideas here.

3. Empirical Strategy and Data Description

The first *Catalog*, marking the formal administration and guidance for foreign investment, was developed and implemented in 1995. As noted above, it had received as many as seven revisions as of 2018, with the largest-range adjustment in 2002, which is taken as the basis for identifying the openness to foreign investment in this paper. Foreign investment projects are specifically classified into the encouraged, restricted, prohibited and permitted entries (those not listed in the *Catalog* are permitted investment projects) in the *Catalog* developed by China. To finally be able to analyze the differences of openness to foreign investment in various firms, we need to match product items in the *Catalog* to the four-digit codes classifying industries and sectors of the national economy. Since the entries of the *Catalog* are approximated at the product level, precise mapping requires base identification at the product level. The identification is based on the idea and steps as follows: firstly, the product terms in 1997 and 2002 are assigned to eight-digit codes, referring to the *Catalog of Products Classified for Statistical Purposes*; next, by the rules in Table 1, the product items in 2002 are categorized into three specific cases relative to the adjustments in 1997, namely, products with increased, unchanged and reduced incentives, respectively. According to product-level incentives, the reform of restrictions over foreign investment access at the industry level (mainly industry) is then distinguished: (1) industries with relaxed access, where the investment incentive is increased for all products, or where the level of incentive remains the same for some products and is increased for others; (2) industries with unchanged access, where the investment incentive remains unchanged for all products. For clearer results, other types of industries, including those with declining foreign investment access, are excluded, and only industries with relaxed access (94 four-digit industries) and industries with unchanged access (324 four-digit industries) are adopted for analysis.¹

¹ Borrowing from Copeland and Taylor's (2004) classification of polluting and clean industries, no endogenous pollution differences between these two types of industries are found, i.e., there is no direct correlation between the openness to foreign investment in an industry and its polluting attribute.

Table 1. Identification Rules for Product-Level Access Restrictions

1997	2002			
	Prohibited	Restricted	Permitted	Encouraged
Prohibited	Unchanged	Increased	Increased	Increased
Restricted	Reduced	Unchanged	Increased	Increased
Permitted	Reduced	Reduced	Unchanged	Increased
Encouraged	Reduced	Reduced	Reduced	Unchanged

Source: Author's compilation.

To investigate the impact of openness to foreign investment on firms' pollution emissions, the baseline model is constructed as follows (1):

$$SO_2_emission_{fit} = \alpha + \beta open_{it} + \rho X_{it} + \delta N_{fi} + \lambda_t + \mu_f + \varepsilon_{it} \quad (1)$$

where the explanatory variable $SO_2_emission_{fit}$ denotes the SO_2 emissions (in logarithmic form) of firm f in industry i in year t . $open$ is the policy variable for openness to foreign investment and the core explanatory variable of interest here, depicted in the context of the 2002 revision of the *Catalog*. Make $open_{it} = en_ind_i \times post_t$, where the dummy en_ind denotes the industries with relaxed access ($en_ind_i = 1$) and industries with unchanged access ($en_ind = 0$); $post$ denotes the time dummy and takes the value of 1 for years after 2002, and otherwise the value of 0. λ_t denotes the time fixed effects, μ_f denotes the firm fixed effects, and ε_{it} is the random error term. Additionally, to minimize the potential impact of endogenous selection within industry while maximizing the estimation consistency, there add characteristics variables on the industry-level, including the number of firms within industry (num_firm), the age of firms within industry (age_firm), the density of new products within industry ($new_product_density$), and the export density within industry ($export_density$). To control for other factors influencing firm emissions, the regression model includes firm control variables: firm size $\ln V$, number of employees $\ln L$, asset size $\ln K$, and firm age $\ln P$. Finally, to mitigate the impact of inter-sample correlation, this paper clusters standard errors to the year-four-digit industry level in the baseline model. The descriptive statistics of primary variables are presented in Table 2.

Table 2. Descriptive Statistics of Primary Variables

Variable	Sample size	Mean	Standard error	Minima	Maxima
$SO_2_emission$	226057	9.996	2.033	0	13.24

Variable	Sample size	Mean	Standard error	Minima	Maxima
<i>open</i>	292756	0.138	0.344	0	1
<i>post</i>	292756	0.586	0.493	0	1
<i>en_ind</i>	292756	0.243	0.429	0	1
<i>num_firm</i>	292756	574.5	890.6	1	3531
<i>age_firm</i>	292756	18.55	14.63	0	988
<i>new_product_density</i>	292753	0.452	9.422	0	2395
<i>export_density</i>	292753	1.002	4.237	0	609.9
$\ln V$	288436	8.240	1.860	-2.430	17.88
$\ln L$	292756	5.589	1.181	2.079	12.18
$\ln K$	291873	9.592	1.765	-0.157	18.35
$\ln P$	292756	2.410	0.976	0	7.602

Source: Author's calculation.

The business-level data used in this paper are from the Chinese Industrial Enterprise Database and the Chinese Enterprise Pollution Emission Database,¹ and the data on the openness to foreign investment are constructed by collating the *Catalog* documents. The China Industrial Enterprise Database features comprehensive, detailed basic information on firms and their financial operations, from which detailed information is available on variables such as gross industrial output, number of employees, net fixed assets and export delivery value. The Chinese Enterprise Pollution Emission Database contains detailed information on the environmental performance of firms, including information on the generation, treatment and discharge of major pollutants, as well as information on the use of pollution control facilities and energy inputs. This paper merges and matches the Chinese Industrial Enterprise Database with the Chinese Enterprise Pollution Emission Database from 1998 to 2007 based on information of firm codes, names and addresses. Finally, the combined data set is used to find the environmental effect resulting from the openness to foreign investment in a comprehensive manner.

4. Regression Results and Analysis

4.1. Baseline Regression Results

The estimated results of the baseline model (1) are shown in Table 3, and from

¹ The reliability of this database has been adequately described in several existing studies and will not be repeated here. Please see Zhang *et al.* (2018).

columns (1) to (3), it is observed that whether or not the model contains firm or industry characteristic variables does not interfere with the basic conclusions. A more robust conclusion is presented in column (4), where the estimated coefficient of *open* is significantly negative, indicating that the openness to foreign investment significantly lowers SO₂ emissions from firms, all else equal, and that FDI significantly alleviates the environmental pollution in the host country. As the baseline results show that the openness indeed significantly boosts environmental performance, China needs to further relax market access in industrial investment and pursue high-quality development that is environmentally friendly by actively bringing in foreign investment.

Table 3. Basic Results

Variable	(1)	(2)	(3)	(4)
	<i>SO₂_emission</i>	<i>SO₂_emission</i>	<i>SO₂_emission</i>	<i>SO₂_emission</i>
<i>open</i>	-0.0487** (0.0222)	-0.0531*** (0.0198)	-0.0586*** (0.0221)	-0.0628*** (0.0196)
<i>num_firm</i>		0.0002*** (2.27e-05)		0.0002*** (2.35e-05)
<i>age_firm</i>		-0.0006* (0.0004)		-0.0008** (0.0004)
<i>new_product_density</i>		-0.0002 (0.0005)		-0.0004 (0.0005)
<i>export_density</i>		0.0001 (0.0021)		0.0010 (0.0021)
<i>lnV</i>			0.1060*** (0.0036)	0.1061*** (0.0036)
<i>lnL</i>			0.1968*** (0.0097)	0.1962*** (0.0097)
<i>lnK</i>			0.0536*** (0.0067)	0.0535*** (0.0066)
<i>lnP</i>			0.0375*** (0.0073)	0.0391*** (0.0072)
Control for firm	Yes	Yes	Yes	Yes
Control for year	Yes	Yes	Yes	Yes
Observations	200,326	200,324	197,260	197,260
R ²	0.8312	0.8315	0.8352	0.8355

Note: ***, **, and * mean significant at the 1%, 5%, and 10% levels, respectively; values in the brackets are clustered standard errors on the industry-year level. The regression results control for both industry and firm characteristic variables, and for firm fixed effects as well as year fixed effects. The same is set hereinafter.

4.2. Parallel Trends Test and Dynamic Effect

The baseline model is an estimation based on the difference-in-difference (DID) technique. The robustness and reliability of its conclusions are premised on the parallel trend assumption, i.e., the group with relaxed access maintains the same trend as that with unchanged access in the face of openness policy impact. The core explanatory variables are reconstructed based on this. In detail, the time dummy of each year is used to interact with the industrial policy dummy *en_ind*, and the starting time of the study, 1998, is set as the base year. Figure 4 is drawn according to the regression estimation results, and it displays the dynamics of the openness of foreign investment impacting the pollution emissions of firms more clearly. As can be found in Figure 4, the impact coefficient of inter-group differences of the two types of industries on SO₂ emissions before the revision of the *Catalog* is not significant, so it satisfies the parallel trend. As the reform of foreign investment policies has progressed after the revision of the *Catalog*, the difference between the two enhances in significance, and the coefficient of the group with relaxed access generally is smaller relative to the group with unchanged access.

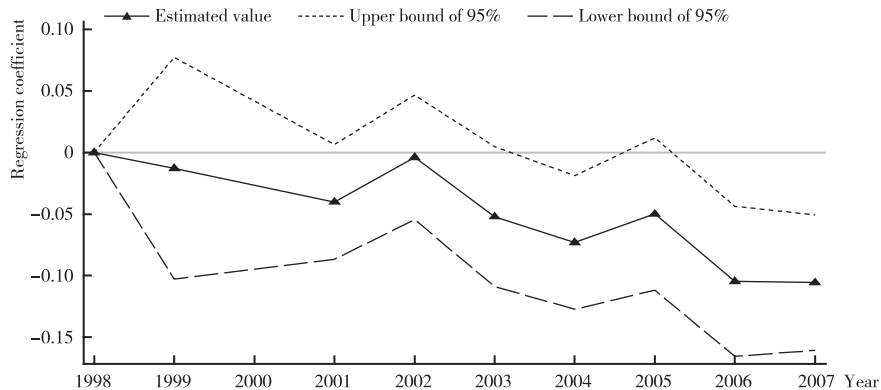


Figure 4. Parallel Trend Test Diagram

4.3. Robustness Test

For the robustness of the conclusions, the tests are performed from the following aspects. First, to exclude the impact of tariff changes, the 2001 import tariff is multiplied with year dummy and controlled to eliminate the impact on openness to foreign investment by the ex ante level of product trade openness. Second, the joint province-year fixed effects and the joint double-digit industry-year fixed effects are added to the control variables for ruling out impacts of area factors, such as economic fluctuations and industry-level macro shocks. Third, considering the potential impact of foreign investment access, openness policies are taken as an instrumental variable for the share of foreign investment, based on which the changes in pollution emissions

as a result of changes in the share of foreign investment caused by the openness to foreign investment are analyzed. Fourth, to avoid the interference of random factors, the policy time is advanced to 1999, 2000 and 2001, and in addition, pollution emission indicators are replaced with chemical oxygen demand, ammoniacal nitrogen and industrial wastewater for test. The basic results have shown no fundamental changes in the above tests and prove good robustness.

5. Mechanism Test and Heterogeneity Analysis

5.1. Mechanism Test

5.1.1. Intrinsic Mechanism: Increased Investment in Pollution Control or Technical Efficiency Gains

When it comes to practices, firms normally use two ways for pollution control, namely end-of-pipe treatment by increasing investment in pollution control or front-end control by gaining technical efficiency. But exactly which way of pollution reduction needs to be discovered. The SO_2 generation and SO_2 removal rate (removal divided by generation) indicators are used to initially determine whether the pollution reduction effect is a result of technical efficiency gains or increased investment in pollution control. With an insight into the indicators, SO_2 generation embraces the influence of technical efficiency, i.e., firms use technical upgrading for the mitigation of pollutant generation to eventually reduce pollutant emissions; and SO_2 removal rate represents the end-of-pipe treatment behavior, i.e., firms directly treat pollutants with facilities to achieve rapid emission reduction. On this basis, columns (1) and (2) in Table 4 show the regression of the openness to foreign investment on SO_2 generation $SO_2_production$ and SO_2 removal rate $r_treatment$, respectively. The results show that the coefficient of $SO_2_production$ is significantly negative and that of $r_treatment$ is negative but fails the significance test. Based on the analytical facts as well as estimation results, this paper holds that in the context of opening to foreign investment, firms reduce their emissions by improving technical efficiency instead of increasing investment in pollution control. To further rule out the possibility of firms reducing pollution emissions by increasing investment in pollution control, we construct the indicator $abatement_intensity$ to measure the investment in pollution control of firms, and defines $abatement_intensity = \ln (facilit_num / y_sale)$, where $facilit_num$ denotes the number of desulfurization facilities and y_sale denotes the industrial sales output (the definition is the same hereinafter). Then the openness to foreign investment is regressed on the investment in pollution control indicator $abatement_intensity$, and the results are shown in column (3). The regression coefficient of $open$ fails the significance test, again confirming that firms have not lowered pollution emissions by increasing investment in pollution control.

Table 4. Increased Investment in Pollution Control or Technical Efficiency Gains?

Variable	(1)	(2)	(3)
	<i>SO₂_production</i>	<i>r_treatment</i>	<i>abatement_intensity</i>
<i>open</i>	-0.0604*** (0.0191)	-0.0208 (0.0164)	0.0026 (0.0221)
Observations	197397	53131	25133
R ²	0.8509	0.6495	0.9296

5.1.2. Some Evidence of Technical Efficiency Gains: Energy Use Efficiency, New Product Output and Green Patents

While it is found that firms have not cut pollution emissions by increasing investment in pollution control and the effect of technical efficiency gains is revealed by the SO₂ generation, more direct evidences are required to prove that technical efficiency gains are the mechanism through which firms enhance their environmental performance. Now energy use efficiency, new product output, and innovation patents will be used for the following explanation.

Energy use efficiency is chosen as a proxy variable for the technical efficiency of firms and it consists of water use efficiency *water_efficiency* and fuel use efficiency *fuel_efficiency*, defined as $water_efficiency = \ln(water_consump/y_sale)$, $fuel_efficiency = \ln(oil_consump/y_sale)$, where *water_consump* denotes total industrial water use and *oil_consump* denotes fuel oil consumption. Directly regressing the openness to foreign investment *open* on the two energy use efficiencies, respectively, the estimated results are shown in column (1) and (2) of Panel A in Table 5. The coefficients of *open* are all significantly negative. It suggests that the openness to foreign investment effectively elevates the energy use efficiency of firms, which, theoretically, is generally a result of improved technical efficiency of production. Next, the new product output *new_product* is applied to roughly measure the technical level of firms. The results of regressing *open* on new product output *new_product* are shown in column (3) of Panel A. The coefficient of *open* is significantly positive, implying that the openness to foreign investment drives firms to upgrade their technology. Moreover, the number of invention patents *patent_num* and the quality of invention patents *patent_quality* are used to measure the technical efficiency of firms, while green patents relating to pollution reduction are considered more directly.¹ Directly regressing *open* on the

¹ Based on the China National Intellectual Property Administration(CNIPA) database, this paper refers to the patent quality construction idea of Aghion *et al.* (2019) to calculate the patent quality indicators at the business level and draws on Chen *et al.* (2018) to additionally identify green patent information with environment-related terms.

above patent indicators, respectively, and the estimation results in Panel B of Table 5 indicate that the openness to foreign investment boosts the clean technical efficiency of firms significantly. Whether it is probed with energy use efficiency, new product output or innovation patents, the conclusion is consistently robust in that the openness to foreign investment indeed significantly reduces pollution emissions of firms by gaining technical efficiency.

Table 5. Technical Efficiency Gains Contribute to Pollution Reduction?

A. Indirect evidence of emission reduction resulting from technical efficiency gains: energy use efficiency and new product output			
Variable	(1)	(2)	(3)
	<i>water_efficiency</i>	<i>fuel_efficiency</i>	<i>new_product</i>
<i>open</i>	-0.0329* (0.0180)	-0.0531* (0.0321)	0.0668*** (0.0215)
Observations	239030	26903	224158
R ²	0.8708	0.9048	0.7958
B. Direct evidence of clean technology upgrading: innovation patents			
Variable	(4)	(5)	(6)
	<i>patent_num</i>	<i>patent_quality</i>	<i>greenpatent</i>
<i>open</i>	0.0446 (0.0476)	0.0026*** (0.0009)	0.0704* (0.0424)
Observations	199224	199224	8982
R ²	0.4848	0.3470	0.7331

5.1.3. Exclusion of Potential Interferences: Pollution Transfer, Production and Emission Reductions, and “Fake” Pollution Reduction Effect

Whilst this paper finds and concludes that the mechanism by which the openness to foreign investment impacts emission reduction lies in technical efficiency gains, there are still possibilities that could challenge the conclusion.

First, will the openness to foreign investment lead to pollution transfer? The massive foreign investment into industries with relaxed access may raise the productivity of firms significantly. In such case, firms in industries with unchanged access could have an incentive to enter industries opening to foreign investment for economic interests. It will definitely produce the pollution transfer effect if this industry transfer occurs. Apparently, if the openness to foreign investment does lead to a transfer phenomenon, it will impact the number of firms within industry and the industrial output. Based on

the above facts, regression tests are performed on the number of firms (in logarithmic form) *firm_num*, gross industrial output (in logarithmic form) *g_value*, and industrial value added (in logarithmic form) *a_value* at the four-digit industry level in the year of aggregation to investigate whether there is pollution transfer. The regression results are shown in columns (1) to (3) of Panel A in Table 6. Compared with industries opening up, the number of firms in unopen industries is actually larger, showing no big transfer to the former. The estimation results of the other two output indicators are not significant, which to some extent means that the openness to foreign investment has not caused pollution transfer.

Second, do firms reduce emissions by cutting down production under the openness to foreign investment? To eliminate the possibility of firms reducing emissions by adjusting their way of production, we regress the openness of foreign investment on the logarithmic form of industrial output *output*, and the estimation results in column (4) of Panel A show the regression coefficient is insignificant. This reveals that firms impacted by the openness will not adjust their production scale, and this indirectly rules out the possibility of reducing production and emissions.

Third, is there a “fake” pollution reduction effect? The baseline conclusion suggests that the openness to foreign investment has significant pollution reduction effect. As the regression model is based on the difference-in-difference (DID) technique, there could be a situation where the environmental performance of firms in industries with relaxed access remains unchanged while the pollution emissions of firms in industries with unchanged access worsen to confuse the conclusion. To rule out the potential “fake” pollution reduction effect, the markup *markup* and productivity¹ *tfp* that can measure a firm’s competitiveness are selected for validation. As a matter of fact, compared to firms in industries with relaxed access, firms in industries with unchanged access are in a relatively closed market environment, suffering from lack of competition, management failures and structural rigidities that depress business competitiveness, which could make firms’ environmental performance worse. For firms in industries with relaxed access and firms in industries with unchanged access, respectively, the time dummy *post* is regressed on *markup* and *tfp* in separate samples, and the estimation results are shown in columns (5) to (8) of Panel B in Table. The coefficient of *post* is significantly positive for both samples, pointing to an enhancement in the competitiveness of firms within the two types of industries over time, and it is considered that their environmental performance will increase as well. More directly, the above subsample regression is repeated and the time dummy *post* is regressed on *SO₂_emission*. The results in columns (9) to (10) of Panel B show that the coefficient of *post* is significantly negative for both samples, indicating an improvement in the

¹ The markup is calculated referring to the idea of De Loecker and Warzynski (2012), and TFP is measured based on semiparametric estimation methods (referred to as OP methods).

environmental performance of the two types of industries, and it directly rules out the interference of “fake” pollution reduction effect on the conclusion.

Table 6. Exclusion of Potential Interferences

A. Exclusion of pollution transfer and production & emission reductions						
Variable	(1)	(2)	(3)	(4)		
	<i>firmnum</i>	<i>g_value</i>	<i>a_value</i>	<i>output</i>		
<i>open</i>	−0.0899*** (0.0324)	−0.0745 (0.0680)	−0.0278 (0.0572)	0.0144 (0.0144)		
Control for industrial characteristics	Yes	Yes	Yes	Yes		
Control for firm characteristics	No	No	No	Yes		
Control for firm	No	No	No	Yes		
Control for industry	Yes	Yes	Yes	No		
Control for year	Yes	Yes	Yes	Yes		
Observations	4178	4178	4167	254370		
R ²	0.8994	0.8142	0.8459	0.8238		
B. Exclusion of “fake” pollution reduction effect						
Variable	(5)	(6)	(7)	(8)	(9)	(10)
	<i>markup</i>	<i>markup</i>	<i>tfp</i>	<i>tfp</i>	<i>SO₂_emission</i>	<i>SO₂_emission</i>
<i>post</i>	0.6949*** (0.1110)	0.8943*** (0.1041)	0.5076*** (0.0088)	0.4909*** (0.0048)	−0.0906*** (0.0166)	−0.0358*** (0.0099)
Control for industrial characteristics	No	No	No	No	No	No
Control for firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Control for firm	Yes	Yes	Yes	Yes	Yes	Yes
Control for industry	No	No	No	No	No	No
Control for year	No	No	No	No	No	No
Observations	43,464	135,145	25,042	83,250	46,318	146,424
R ²	0.4863	0.2367	0.9654	0.9582	0.8777	0.8265

Note: Values in the brackets of Panel A are clustered standard errors at the industry-year level and values in the brackets of Panel B are clustered standard errors at the business level.

5.1.4. Technical Efficiency Gains or Resource Reallocation Effect: A Further Analysis Based on the Aggregate Level

In fact, since the econometric model controls for firm fixed effects, the conclusion confirmed previously that the openness to foreign investment has an emission reduction effect applies for incumbent firms, which will not only obscure the potential inter-firm mechanism of impact and fail to capture the environmental impact resulting from the openness at the aggregate level. In view of this, based on the Chinese Enterprise Pollution Emission Database (without matching the Chinese Industrial Enterprise Database), SO₂ emissions of firms are aggregated to the year-city-double-digit industry level, as defined as follows:

$$EMISSION_G = \sum (firm_share \times SO_2_emission) \quad (2)$$

where *firm_share* denotes the share of firm output within the aggregation. This paper probes into the impact of intra- and inter-firm effects resulting from the openness to foreign investment on aggregate SO₂ emissions, drawing on the productivity decomposition approach of Melitz and Polanec (2015). That is, the changes in aggregate SO₂ emissions are decomposed into four parts: first, it is the firm's own growth effect, which represents the decrease in aggregate SO₂ emissions caused by changes in an incumbent firm's emissions while its market share remains unchanged; second, it is the firm market share effect, which represents the reduction in aggregate SO₂ emissions caused by changes in an incumbent firm's market share as its SO₂ emissions stay unchanged; third, it is the entry effect, namely the reduction in aggregate SO₂ emissions due to the entry of firms; and fourth, it is the exit effect, namely the reduction in aggregate SO₂ emissions resulting from the exit of firms. It is expressed by the following equation.

$$\begin{aligned} \Delta EMISSION_G &= (\phi_{S2} - \phi_{S1}) + S_{E2}(\phi_{E2} - \phi_{S2}) + S_{X1}(\phi_{S1} - \phi_{X1}) \\ &= \Delta \bar{q}_S + \Delta cov_S + S_{E2}(\phi_{E2} - \phi_{S2}) + S_{X1}(\phi_{S1} - \phi_{X1}) \end{aligned} \quad (3)$$

where *S* denotes the incumbent firm, *E* denotes the entrant firm, *X* denotes the exiting firm, and ϕ_r denotes the aggregate SO₂ emissions from firms in group *r*. Observing the differences in each decomposition term's impact, it enables to identify intra- and inter-firm mechanisms through which the openness to foreign investment impacts the aggregate SO₂ emissions. This is done by replacing explanatory variables with the aggregate SO₂ emissions *EMISSION_G*, the incumbent firm arithmetic mean *EMISSION_S_aveg*, the OP covariance *cov_S*, the entrant firm effect *entan_eff* and the exiting firm effect *exit_eff* for regression estimation, and selecting to control for cities, two-digit industries, and year fixed effects. The estimated results are shown in Table 7.

The results in column (1) indicate that the openness to foreign investment significantly reduces SO₂ emissions at the aggregate level and are consistent with the micro-firm-level estimates; The coefficient of *open* in column (2) is significantly negative, meaning that the reduction in SO₂ emissions results from the improvement of emission reduction capacity; The coefficient of *open* in column (3) is insignificant, indicating that the openness to foreign investment does not play its role in pollution reduction by inter-firm resource reallocation, i.e., resources do not flow from heavy-polluting firms to less-polluting ones. As the coefficients of *open* in columns (4) and (5) are both insignificant, it indicates that the openness to foreign investment has no significant impact on the entry and exit effects of SO₂ emissions of firms. On account of the above results, it is the effect of intra-firm technical efficiency gains that serves as a major mechanism for the openness to foreign investment impacting the reduction of aggregate SO₂ emissions.

Table 7. Impact of Openness to Foreign investment on SO₂ Emissions at the Aggregate Level

Variable	(1)	(2)	(3)	(4)	(5)
	<i>EMISSION_G</i>	<i>EMISSION_S_aveg</i>	<i>cov_S</i>	<i>entan_effit</i>	<i>exit_effit</i>
<i>open</i>	-0.1597*** (0.0376)	-0.1492*** (0.0320)	0.0069 (0.0109)	0.0005 (0.0331)	-0.0161 (0.0348)
Control for year	Yes	Yes	Yes	Yes	Yes
Control for city	Yes	Yes	Yes	Yes	Yes
Control for industry	Yes	Yes	Yes	Yes	Yes
Observations	46703	35411	46703	13462	13363
R ²	0.2723	0.3606	0.0761	0.0418	0.0426

Note: Values in the brackets are the clustered standard errors of two-digit industries at the year level.

5.2. Heterogeneity Analysis¹

We develop a heterogeneity analysis from the following dimensions to deeply investigate the impact of openness policies on the emission reduction of firms. First, by distinguishing SOEs from non-SOEs by registration type, the differential effects of openness policies on pollution emissions from firms of different ownership are examined, and the openness to foreign investment is found to cut pollution emissions from SOEs significantly more than from non-SOEs. Second, by classifying polluting and clean industries by the mean SO₂ emissions from firms at the industry level, it finds that the effect of emission reduction of firms in polluting industries, which results from openness,

¹ Limited by page space, the regression results are not reported here and are retained for availability.

is not significant. Third, to see whether the effect of openness on emission reduction differs across areas under different regulation, with areas in two control zones defined as the areas under strong regulation pressure, it is found that the effect of openness on emission reduction is more significant in the two control zones under strong regulation pressure.

6. Conclusion & Insight

Pollution has become an unavoidable concern as China's high-quality development is underway. How to effectively control the pollution is an imperative issue for China to address. Conventional pollution control, be it the "Two Control Zones" policy, the binding targets set by the Eleventh Five-Year Plan, or the "coal to gas" retrofitting for optimizing the energy mix, seeks to achieve pollution control targets by regulation. However, as quite a few studies have noted, regulation might interfere with the market order, or even affect the fair play to cause resource misallocation. As the net effect on economic growth has not yet been clearly established, seeking forces outside the regulatory tool to lower emissions is probably a breakthrough for pollution control and high-quality development that is green in China. With an investigation into the effect of openness policies for foreign investment on pollution reduction and the intrinsic mechanism, this paper would like to contribute some ideas of environmental pollution control besides regulation in China.

We find that the openness to foreign investment can significantly reduce pollution emissions of firms, relying on the *Catalog* revised in 2002 and the sample from matching the Chinese Industrial Enterprise Database and the Chinese Enterprise Pollution Emission Database, and by identifying industries with relaxed foreign investment access and industries with unchanged access. It reveals the openness to foreign investment remarkably reduces the pollutant emissions of firms, with SOEs, large firms and exporters seeing more pronounced effect of pollution reduction after opening up, while firms in pollution-intensive industries and less regulated areas are weaker in pollution reduction. By observing the firm behavior impacted by openness, we also find that the pollution reduction effect is achieved by technical efficiency gains instead of increased investment in pollution control. The analysis at the aggregate level reveals that the pollution reduction effect resulting from the openness to foreign investment is reflected mainly in intra-firm improvement of emission reduction capacity rather than inter-firm resource reallocation.

Based on the above findings, we hold that sustainable openness and the use of relevant policies for improving technical efficiency are important paths towards pollution reduction and high-quality development that is green. For this stage of development, compared to domestic capital, foreign investment is greener and cleaner in emissions and production techniques. To exert the positive role of foreign investment in reducing emissions, the government should relax more restrictions on foreign investment access, introduce the negative list management, and continue working for investment liberalization and facilitation. Product trade openness is not

a major part of research here, only as a by-product. That said, this paper believes that tariff cuts help attract more high-quality products to make domestic products cleaner, which may eventually contribute to emission reduction targets by technical efficiency gains as well. Also, the government should adopt an integrated way of thinking in developing policies instead of a “one-size-fits-all” governance approach that is rough and cannot rely entirely on regulatory measures. Meanwhile, more attention should be paid to the policies that improve technical efficiency to reduce emissions. It is a favorable way to achieve high-quality development that is green. With these measures for effective control over environmental pollution, China will eventually embark on a high-quality development journey that is green.

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