Does International Trade Drive Manufacturers to Go Green? Firm-level Evidence from China

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Abstract

This paper delves into the question of whether trading with developed countries that have higher environmental standards and customers with higher environmental awareness exerts spillover effects on firms' environmental performances in China. This study utilized a comprehensive annual environmental survey dataset from 2011 to 2013 and matched it with the customs data. A full discussion will be presented of how firms' exportation influences their efforts toward environmental protection, measured using four different aspects, including four pollution treatment ratios, energy and resource structures, pollution intensities in production, and pollution-control expenditures. A further mechanism discussion is conducted from the perspectives of pollution abatement investments and the convergence between Chinese exporters and their developed trading partner countries regarding environmental standards. This study provides insights into the environmental benefits of trading with developed countries for both China and other developing countries, which are experiencing the quick shift of global manufacturing and the supply chain.

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Highlights

- We find that exportation to developed countries with stricter environmental regulations promotes firms' environmental performance in China
- A wide range of pollution abatement indicators is adopted
- We distinguish different types of exports
- We examine the mechanism from the spillover effects on pollution abatement investments and convergence of environmental standards
- We alleviate the endogenous concerns from both the firm and policy levels

1. Introduction

Global manufacturing and the supply chain connect developed and developing worlds closer through trade, bringing multiplex effects to developing countries that are mainly manufacturers of labor-intensive goods. Developing countries receive valuable capital but face environmental challenges (i.e., the pollution haven hypothesis[1].). China has become the largest exporter in the world[2] and the most important trading partner to both many developed and many developing countries. However, the quick expansion of international trade contributes to the serious environmental problem in China, in which mixed evidence of the pollution haven hypothesis has been found.(Dean et al., 2009; Cai et al., 2016; Yang et al., 2018) On the other hand, the potential benefits of environmental standards at the firm level are less discussed. Even though exportation will inevitably cause more pollution due to the transfer of the labor-intensive production of industrial goods, trading with developed countries with stricter environmental regulations could motivate Chinese exporters to move toward cleaner production.

The background of this hypothesis comprises two parts based on the foundation laid out from the earlier work in the discussion of the relationship between pollution and international trade at the national level. First, the trading partner countries have higher environmental standards for goods, including imports, and second, customers in developed countries have higher environmental awareness(Copeland & Taylor, 1994; Antweiler et al., 2001), which pressures importers, indirectly raising the environmental requirements for Chinese exporters. Thus, this hypothesis indicates an increase in total pollution in developing countries due to the rise in economic production. However, there could be a decrease in pollution concentration because exporters in developing countries face pressure and competition in the market to upgrade to cleaner production, which would benefit the environment in the long term.

Previous literature either looks at the impacts of trade on the environment from a macro view, such as the country or city level(Grossman & Krueger, 1991; Prakash & Potoski, 2006; Frankel & Rose,

[1]The pollution haven hypothesis claims that firms in developed countries with stricter environmental regulations may respond by relocating their production to countries with less stringent ones; See studies by Cole (2004) and Kellenberg (2009)

[2]China's export value reached $\$2,643,377$ in 2019. Source: The World Bank

2005), or does not fully distinguish firms' exportation behaviors(Antweiler et al., 2001; Jiang et al., 2014). Nevertheless, the types of trade and the mechanisms driving exporters in developing countries have not been clearly addressed. This paper fills this gap by examining the relationship between a full range of environmental performance indicators and firms' detailed exportation activities. We consider three aspects with regard to the cleanliness of production by focusing on the pollution abatement efforts of firms at the micro level instead of traditional macro-level pollution indexes. These include two air and two water pollutants' ($SO2$, dust, chemical oxygen demand (COD), and ammoniacal nitrogen) treatment ratios; energy and resource structures that include the types and proportions of energy firms utilize and water recycled during production; and the pollution intensities of the four abovementioned pollutants in production that measure the environmental cost per unit of product. In addition, we look into firms' investments in pollution abatement, from which we intend to decipher whether these investments work as channels in which exportation activities influence firms' decisions on environmental investments that ease the pollution.

Another important subject upon which we build and expand is the measurement of exportation. Based on our hypothesis, we scrutinize the complete exportation information of each firm from the customs data, including exportation destinations, exportation values, and categories of goods. We classify the exports according to whether the destination is a member of the OECD, which is one of the traditional ways to define developed countries (e.g., Mani & Wheeler (1998) and Cole (2004)), and whether the goods are agricultural, industrial, or other types. We consider industrial goods exported to developed countries to have larger impacts on firms' environmental performance. By doing this, we disentangle these exports from other exports that are simple expansions of firms' sales networks.

In order to test the solidity of our hypothesis of the positive impacts of trading with countries enforcing higher environmental standards on firm environmental protection, we test the mechanism from two perspectives. First, we test whether exports to developed countries can promote investment in pollution abatement. This test comes with the reality that the amount of pollution that is produced and the cost of treating one unit of pollution vary dramatically across different industries. In this way, we put forward a conceptual model that consists of the spillover effect from trading with developed countries and eliminate the industrial impacts. Thus, if the Chinese exporters do benefit from this trading in terms of more environmentally friendly production, we should expect a positive spillover effect. Second, under the assumption that developed countries have stricter environmental regulations than developing countries, we investigate whether trading between developed countries and Chinese firms can inspire a convergence of environmental standards. We adopt the Yale Environmental Performance Index (EPI) as a proxy for environmental regulation stringency and construct weighted export values, for which we put more weight on exports to countries with higher scores.

In the next step, we attempt to alleviate the endogenous concern from two viewpoints: firm level and policy level. The discussion above may bring the problem of endogeneity since there may be some micro and macro factors that influence both exportation activities and efforts toward environmental protection. Ergo, it is essential to ensure that those most observable features of firms–such as better corporate performance, which may correlate with exportation–do not enlarge our estimation of the role of exportation activities. Second, we must examine whether there could be export and import policies restraining firms' pollution production and exportation. If policy effects exist at the firm level, this may bias the results since the influence on cleaner production is driven by the policies. In addition, a placebo test that consists of a re-export sample will be conducted to further strengthen our conclusions.

The structure of this article is as follows: The second part reviews the main literature. Part three introduces the data that we use and gives a summary. Part four introduces our baseline model specifications and the corresponding results. The fifth part tests the two mechanisms. In the sixth part, we conduct a series of robustness tests, which include tackling the endogenous concern. The last part concludes the paper.

2. Literature Review

Closely related literature with respect to the specific topic in which firm pollution abatement and exportation activities are inspected at a micro level is limited. However, relevant literature in a broader definition of how international trade between developed and developing countries can promote cleaner production or environmental protection substantially exists. Our hypothesis is supported by theoretical base such as Forslid et al. (2018), who put forward a model that firms involving exportation activities face more competition from outside producers, which leads them to adopt more efficient producing methods and invest more in pollution abatement in developed countries.

Works such as Copeland & Taylor (1994) and Antweiler et al. (2001) construct an open-economy macro model with a micro firm production base. They found that trade between the North (developed countries) and the South (developing countries) can induce a technique that leads to a reduction in pollution during production and shift the composition of national output, which implies a different way than income gains obtained through economic growth. However, an unanswered question is whether, in developing countries, firms with more exports face more pressure from their trading partners regarding environmental concerns compared with their counterparts who focus on the domestic market. Another issue that needs addressing is that environmental protection and pollution control involve a wide range of issues, such as firms with different sizes in different industries produce totally different amounts of different pollutants and require a different amount of investments to treat the same amount of one pollutant. In addition, regional environmental policies based on administrative regions and geography such as drainage basins also influence firms' behaviors(Liu et al., 2017). These industries may require varying amounts of investment in cleaning pollution even though the same amount of the same pollutants are produced. Moreover, these issues cannot be fully incorporated into theoretical models and thus need empirical support.

Positive impacts of international or regional trade on the environment have also been found in a series of empirical studies. Prakash & Potoski (2006) research a wide range of countries to investigate in which conditions trade linkages can encourage national environmental standards measured by ISO 14001 adoption, thereby countering environmental races to the bottom. They find that trade linkages encourage ISO 14001 adoption if a country's major export markets have adopted relevant regulations. Similarly, Frankel & Rose (2005) find that trade tends to reduce concentrations of $SO2$ significantly and of $NO2$ moderately but has little effect on the particulate matter by looking into cross-sectional data of a dozen countries. When looking into specific environmental provisions, Baghdadi et al. (2013) find that Regional Trade Agreements with environmental regulations affect relative and absolute pollution levels by accelerating the trading countries to converge in CO2 emissions and lowering the total emissions by using data from 182 countries over the period 1980 to 2008. On a related note, important and large-scale trade agreements such as NAFTA have been discussed with respect to the pros and cons of the environment. Grossman & Krueger (1991) have a full examination of the impacts of NAFTA. Not only do they find that the trade agreement triggered more American firms to move their production to Mexico, but they also find that this has benefited Mexico to some extent by increasing Mexican specialization in sectors that cause less than average amounts of environmental damage. In a more detailed inspection of specific pollutants, Stern (2007) uncover a trend of convergence led by NAFTA in indicators such as emissions, environmental efficiency, and emissions specific technology among Mexico, the United States, and Canada. From the viewpoint of firms, Jiang et al. (2014) discuss the determinants of pollution levels in the Chinese industrial sector. They find that foreign-owned and domestic public-listed firms, firms in regions with less local protection, firms under better property rights protection, and firms in industries with higher absolute export values have less intense pollutant emissions.

3. Data and Summary Statistics

3.1. Survey and Data Description

The data used come from three sources: the Chinese Industrial Enterprises Pollution Discharge, Treatment and Utilization Survey ($2011 - 2013$), which is maintained by the Ministry of Environmental Protection of China (MEP); the China Industry Business Performance Database, and Chinese customs data. The Ministry of Environmental Protection of China inspects the pollution of industrial firms annually, a process conducted by every local government first and then consolidated by the central bureau. It is compulsory for every firm to report its environmental information as long as it involves industrial production. The main indexes include the annual production and emissions of air pollution such as $SO2$, NO_x, and dust; production and discharge of water pollution such as the COD and ammoniacal nitrogen; the annual investment in different types of pollution control; energy and resource consumption such as the annual usage of coal, fuel, gas, electricity, and water; and the geographic locations of firms, such as drainage basins in which firms are located.

However, the Pollution Survey data contains limited information about corporate structures. Since tremendous variations in pollution production and treatment processes can be seen across different industries and production, taking firm characteristics into account is critical to control for heterogeneities in production modes. The corporate information in the China Industry Business Performance Database includes different types of assets, sale performance, revenue, profit, ownership structures, major products, and industries. The samples in the China Industry Business Performance Database are limited to comparatively large firms with at least 5 million *yuan* assets. Thus, part of the small firm samples in the Pollution Survey cannot be matched with the China Industry Business Performance Database, and we only consider firms that can be matched with enough corporate information.

The customs data consists of all single trade records. Specifically, the major statistics included in a single record are the company name and address, the type of transaction (import/export), the origin or destination, the trade value, and the type of goods. Nevertheless, the coding system in the customs data is different from that in either of the other two datasets. Thus, it is impossible to match these datasets directly using firm codes. However, we present the details of a novel fuzzy matching method that we devise to match these three datasets in Appendix A1.

3.2. Summary Statistics

Firms export to overseas markets, especially those of developed countries with stricter environmental regulations may show different characteristics from those that focus on the domestic market. This study compares the firms with exports to the OECD countries with that export but only to non-OECD countries and non- exporters in several aspects, including their corporate structures and environmental performance. The latter performance includes three parts: pollution production and treatment, energy and resource structures, and pollution control expenditure. In addition, we conduct t-statistics to check the difference between the three groups.

[Insert Table 1]

Table 1 presents the mean values of corporate and environmental performance variables of the full samples, the sample with OECD exports, and the sample which exports but to non-OECD countries and non-exporters. Column 4 (Difference1) is the difference between the sample with OECD exports and the sample that exports but to non-OECD countries. It also gives the t-test significance levels. Column 6 (Difference2) is the difference between the sample with OECD exports and non-exporters with the t-test significance levels.

The average size of OECD exporters is slightly larger than the other groups measured by total assets and employee numbers. However, the full sample and subgroups show the same magnitudes in both indicators. Thus, the scale effects on exportation should be considered to be very limited. Figures 1 and 2 further explain that the relationship between firm scale and exportation activities to OECD countries is limited. We divide the sample into ten groups according to each firm's total assets and employees from small to large. The two figures exhibit the percentages of total exports comprised by agricultural, industrial, and miscellaneous exports to OECD countries in each group. First, this confirms that industrial merchandise accounts for most of the exports, in which the OECD industrial export category alone is over 40%. Second, we notice that the percentages of OECD industrial exports do not fluctuate significantly across different quintile groups. These figures hold steady at a 40% level, whether measured by total asset value or employee number, whereas agricultural products that are exported to OECD countries make up slightly smaller parts of exports in larger firms.

[Insert Figures 1 and 2]

Regarding profit rate, which is measured by dividing sale profits by total sales and has a mean of 9.88%, samples with OECD exports have a minor advantage over samples with only non-OECD exports. In addition, non-exporters perform slightly better in profit rate but not at a statistically significant level. Among all firms, 9.29% of them are state-owned. The ratios of SOEs among three subgroups show no significant difference where the non-exporter group is roughly 3.5% higher than exporters. Overall, even though the mean values reflect part of the characteristics of the groups with different exportation activities, no major gaps are found.

Nonetheless, pollution production and control variables show more variation among the three subgroups, especially between exporters and non-exporters. First, samples with OECD exports produce much less $SO2$. However, the overall $SO2$ treatment ratio is low compared with that of other pollution treatments, and the $SO2$ treatment ratio among the full sample is 9.30%. Considering the fact that around 90% of $SO2$ emission comes directly from coal combustion (Xu et al., 2000; Chen & Xu, 2010), the $SO2$ reduction process is more likely to be conducted in coal quality improvement, resulting in reduced $SO2$ production instead of an augmented treatment ratio (van der A et al., 2017; Chen & Xu, 2010). However, different results can be seen in dust production and treatment. Moreover, the Pollution Survey does not distinguish different sizes of particulates in the dust. Since coarse particle dust costs much less than fine particle dust, the treatment ratio of dust is as high as 73.15% in the full sample. Samples with OECD exports not only produce less dust than the other two groups on average but also contain a 3% higher dust treatment ratio. As for water pollution production, the sample with OECD exports has very limited advantages in both COD and ammoniacal nitrogen. That is because it is harder to adopt a cleaner production mode by changing water resources since the pollution is produced during the production from other sources (Yu et al., 2013). Nevertheless, the sample with OECD exports is significantly higher in the COD pollution treatment ratio compared with the sample that exports to only non-OECD countries and non-exporters with 1.4% and 7.1% margins. In addition, the sample with OECD exports is 3.1% statistically higher than non-exporters in the ammoniacal treatment ratio.

The third section in Table 1 presents differences in energy and resource structures. Chinese industrial firms heavily rely on fossil fuels, which account for over 90% of the country's total energy consumption, of which coal makes up roughly 80% (Ji & Zhang, 2019). Among the four energy sources, the sample with OECD exports tends to use less coal compared with the other two subgroups at a statistically significant level. Beyond this, fuel oil, gas, and electricity comprise higher ratios in energy consumption. Since coal is considered to be the most polluting energy source(Xu et al., 2000), the sample with OECD exports shows the advantage in this aspect, which is 25.6% lower than the sample that exports to only non-OECD countries. In addition, it is 4 times lower than non-exporters, whereas limited gaps can be seen in the other three types of energy resources. Another way to measure the cleanliness of production is from the sulfur and dust ratios in coal. Even though coal is highly polluting, it is possible to significantly mitigate air pollution by reducing the sulfur and dust ratios. Furthermore, the sample with OECD exports behaves better in coal cleanness with respect to these two indicators. The sulfur ratio in coal for the sample with OECD exports is 0.07% and 0.1% lower than that of the other two subgroups at a 0.92% level. The group with OECD exports also sees a lower dust ratio in coal, which is 20.27% and 1.1% lower than that of non-exporters. Moreover, the sample with OECD exports uses less than half of the industrial water used by non-exporters. In addition, its reclaimed water ratio is 0.86% higher than that of the sample which exports to only non-OECD countries. The survey provides further information on pollution abatement expenditure on desulfurization, dust collection, and wastewater processing. Since the desulfurization and dust collection expenditures are regarded as post-production endeavors, the sample with OECD exports shows lower mean values. However, we cannot directly derive a conclusion because the sample with OECD exports also produces less pollution, but wastewater processing expenditure is used to produce reclaimed water. The group with OECD exports is significantly higher in this measure than non-exporters even though the former uses less industrial water on average.

4. Empirical Specifications and Baseline Results

This section discusses the impacts of trade on environmental protection with empirical specifications and presents the baseline results. We consider the environmental protection of firms from three perspectives: pollution treatment, the cleanliness of the energy and resource structures, and pollution intensities in production. This part attempts to uncover the primary relationship between firms' efforts toward environmental protection and their exportation activities. At the same time, it considers the heterogeneities in several aspects, including corporate structures, industrial characteristics, and geographic features. Furthermore, this study disentangles the impacts of the exportation activities to OECD countries on environmental protection from correlations between corporate characteristics and exportation activities. To accomplish this, we adopt the Propensity Score Matching (PSM) method to construct a subsample in which exporters are paired with opposites that share similar features. Lastly, since our hypothesis claims that exportation to developed countries encourages firms to adopt cleaner production due to the stricter environmental regulations in the destinations and fierce competition in the market, exportation to other developing countries should not have such impacts and be regarded as expansions of firms' sales networks. Nevertheless, the complex part of disentangling the two types of exportation is that firms which export to developed countries have low costs to expand sale networks to developing countries and not vice versa. We provide the test of the relationship between pollution treatment and non-OECD exports while further considering the ratios of that type fo exports to the total values in Appendix A.2.

4.1. Baseline Model Specifications

4.1.1. Baseline Specifications Regarding Air and Water Pollution Treatment

First, we test whether the exportation to the OECD countries encourages the firms to make more efforts toward pollution control by directly examining the relationships between OECD export values[3] and pollution treatment ratios. We study two air pollutants, $SO2$ and dust emission, and two water pollutants, COD and ammoniacal nitrogen. The economic specification for air pollution abatement exists as follows:

$$\text{Pollution control}^{p}_{i,j,k,t} = \alpha^{p} + \boldsymbol{\beta}^{p}_{1}\,\text{OECD export}_{i,j,k,t} + \boldsymbol{\beta}^{p}_{2}\mathbf{X}_{i,j,k,t} + \eta_j + \mu_k + \tau_t + \varepsilon_{i,j,k,t} \tag{1}$$

where Pollution $\text{control}^{p}_{i,j,k,t}$ stands for the treatment ratio of pollutant P (2 air pollutants and 2 water pollutants) for firm i in industry k in province j at time t. OECD $\text{export}_{i,j,k,t}$ is a 2×1 vector, which consists of the values of agricultural and industrial exports for firm i at time t and $\boldsymbol{\beta}_1$ is 2×1 coefficient vector. In addition, $\mathbf{X}_{i,j,k,t}$ comprises a string of firm characteristics used as control variables for the heterogeneities of corporate structures measured with the corresponding coefficient vector $\boldsymbol{\beta}_2$. Moreover, η_j, μ_k, τ_t control provincial, industrial, and time-fixed effects, respectively. We do not set the control variables at the individual level because the time span for the survey data is limited to 3 years, during which we would not expect to see much variation at the individual level. In addition, when testing the water pollution treatment, since firms aiming to derive freshwater from and discharge processed wastewater into rivers or lakes, the heterogeneities might not be set at the

[3] We measure the export value in a form of logarithm. Considering the fact that there are firms that do no export or export to only non-OECD countries, and that the trading values are usually large enough if there are any, the form is $log(\text{OECD export} + 1)_{i,t}$ for either agricultural or industrial products for firm i at time t.

provincial level. Since a river or lake, which the survey defines as the drainage basin in which a firm is located, can cover more than one province, there can be joint environmental policies from the provinces involved (e.g. The Water Management Policies in the Taihu Lake Basin joint by Shanghai, Jiangsu, Zhejiang and An'hui that began in 2007). Thus, in the water pollution control test, we also introduce the fixed effects of geography. This specification appears below:

$$\text{Water pollution control}^{p}_{i,j,b,k,t} = \alpha^{p} + \boldsymbol{\beta}^{p}_{1}\ \text{OECD export}_{i,j,b,k,t} + \boldsymbol{\beta}^{p}_{2}\mathbf{X}_{i,j,b,k,t} + \eta_j + \xi_b + \mu_k + \tau_t + \varepsilon_{i,j,b,k,t} \tag{2}$$

where Water pollution control$^{p}_{i,j,b,k,t}$ presents the treatment ratio of pollutant P (2 water pollutants) for firm i in industry k in province j located in drainage basin b at time t. The drainage basin fixed effects help to control the heterogeneities from multiregional environmental policies. Possible risks include the agglomeration of a certain industry along one river or around one lake due to some specific features attractive to that industry, such as a fast water flow rate. However, in our data, we do not observe a strong collinearity between these two variables.

4.1.2. Baseline Specifications Regarding Energy or Resource Structures

The next step delves into the relationship between energy or resource structures and exportation to OECD countries. Considering that coal is the major energy source and highly polluting (Xu et al., 2000; Chen & Xu, 2010), we construct three ratios by dividing fuel oil, gas, and electricity by coal consumption. Beyond this, we consider the sulfur and dust ratios in coal, which reflect how clean the energy is that a firm uses. In addition to energy usage, we consider how efficiently a firm reclaims used water by constructing the ratio of reclaimed water to the total industrial water usage. The specifications for energy and resource structure tests are as follow:

$$\text{Energy/Resource structures}^{e}_{i,j,k,t} = \alpha^{e} + \boldsymbol{\beta}^{e}_{1}\ \text{OECD export}_{i,j,k,t} + \boldsymbol{\beta}^{e}_{2}\mathbf{X}_{i,j,k,t} + \eta_j + \mu_k + \tau_t + \varepsilon_{i,j,k,t} \tag{3}$$

where Energy/Resource structures$^{e}_{i,j,k,t}$ stands for the three energy ratios, reclaimed water ratio, or sulfur or dust ratio in coal, which is indicated by the superscript e for firm i in industry k in province j at time t. Considering that any test related to water usage or processing might involve multiregional water protection policies, in discussing the reclaimed water ratio in industrial water usage, we also include the drainage basin fixed effects.

$$\text{Reclaimed water ratio}_{i,j,b,k,t} = \alpha^W + \boldsymbol{\beta}_1^W \text{ OECD export}_{i,j,b,k,t} + \boldsymbol{\beta}_2^W \mathbf{X}_{i,j,b,k,t} + \eta_j + \xi_b + \mu_k + \tau_t + \varepsilon_{i,j,b,k,t} \tag{4}$$

4.1.3. Baseline Specifications Regarding Pollution Intensities

This section further discusses whether exportation to OECD countries is connected to lower pollution intensities during production. Compared with the previous tests, which focus on pollution control post-production or reduce the pollution from the source, we focus more on whether the technologies that firms adopt in production are less polluting. Even though energy sources may also play a role in reducing pollution intensities during production since cleaner sources lead to less pollution, this test reveals whether the exportation to OECD improves the production efficiency measured by the environmental costs. This study analyzes the two air pollutants and two water pollutants in the same way as was done earlier. The pollution intensity index is constructed as shown here:

$$\text{Pollution intensity}^p_{i,j,k,t} = \frac{\text{Pollution produced}^p_{i,j,k,t}}{\text{Production value}_{i,j,k,t}}$$

where the pollution intensity of pollutant p is the fraction of the correspondent pollution p produced divided by the production value of firm i at time t. A lower ratio (intensity) means a firm can produce more efficiently with less pollution. The detailed model specifications regarding the relationship between pollution p intensity and exportation to OECD countries are as follows, with drainage basin fixed effects controlled for the water pollution intensities.

$$\text{Pollution intensity}^p_{i,j,k,t} = \alpha^p + \boldsymbol{\beta}_1^p \text{ OECD export}_{i,j,k,t} + \boldsymbol{\beta}_2^p \mathbf{X}_{i,j,k,t} + \eta_j + \mu_k + \tau_t + \varepsilon_{i,j,k,t} \tag{5}$$

$$\text{Pollution intensity}^p_{i,j,b,k,t} = \alpha^p + \boldsymbol{\beta}_1^p \text{ OECD export}_{i,j,b,k,t} + \boldsymbol{\beta}_2^p \mathbf{X}_{i,j,b,k,t} + \eta_j + \xi_b + \mu_k + \tau_t + \varepsilon_{i,j,b,k,t} \tag{6}$$

4.2. Baseline Results on Environmental Protection and OECD Exportation

4.2.1. Post-production Pollution Treatment

This section presents the empirical results following the specifications in Section 3.1.1. In addition, to rule out the concern that endogenous problems may occur if some corporate characteristics are related to firms' exportation activities, we adopt the Propensity Score Matching (PSM) method. Using this, we select a battery of corporate factors, including the industry, employee number, and sale performance to narrow down the sample to matched firms with similar characteristics. Table 2 shows the test results regarding air pollution treatment, where the first two columns are the full sample and the next two columns are the PSM sample. After the matching process, the sample sizes are pared by $40 - 50\%$. The odd-numbered columns present the effects on $SO2$ treatment ratio, and the even-numbered ones are for the dust.

[Insert Table 2]

First, the industrial exports to OECD countries show statistical significance for both $SO2$ and dust treatment ratios in either full or PSM samples, whereas agricultural OECD exports show no significance. In addition, the full and PSM sample group shows the estimation results of industrial OECD exports at the same scale with the same value as in $SO2$ treatment test. The positive coefficients indicate that a 1% increase in the industrial OECD exports leads to 0.1% and 0.2% increases in $SO2$ and dust treatment ratios. However, considering the industrial average treatment ratios of $SO2$ and dust are 9.3% and 73.15%, even though the scales of the $SO2$ and dust treatment ratios are at the same level, the effects on $SO2$ treatment ratio are greater. Moreover, the scientific background that indicates that most of $SO2$ emission is directly from coal combustion(Xu et al., 2000; Chen & Xu, 2010) also shows substantial improvement from $SO2$ treatment.

Table 3 presents the results of water pollution treatment testing. Similarly, we construct a PSM sample group according to the standards above, leading to a $30 - 40\%$ deduction in the size. The first four columns show the results of the full sample, and the next four columns are those from the PSM sample. The first and second columns in each group (all/PSM sample) are the estimations without drainage basin fixed effects controlled, whereas the third and fourth columns in each group have these effects controlled.

[Insert Table 3]

The industrial OECD exports show consistently significant positivity across all groups for both COD and ammoniacal nitrogen treatment ratios. However, agricultural OECD exports show positive signs only when we do not have drainage basin fixed effects controlled and use the full sample. Thereafter, we will not focus on agricultural OECD exports since they carry less weight in the total exports and have less industrial production activities involved. Notably, the coefficients of the industrial OECD exports in both COD and ammoniacal nitrogen estimations show almost the same value except in the PSM group with no drainage basin fixed effects controlled for the impact on ammoniacal nitrogen, which is 0.3%. In general, the results demonstrate that a 1% increase in the industrial OECD exports can promote treatment ratios at least 0.2% higher for COD and ammoniacal nitrogen.

4.2.2. Energy and Resource Structures

We present the outcomes of energy and resource structure analyses in Table 4. The first three columns are three ratios that indicate the energy structure of a firm. The fourth and fifth columns test the relationship between industrial OECD exports and reclaimed water ratio in industrial water usage without and with the drainage basin fixed effects controlled. The last two columns show the resulting sulfur and dust ratios in coal.

[Insert Table 4]

A higher ratio in one of the three indicators means a company uses more modern energy sources. Adoption of a different energy structure implies that a firm also must update its production mode. Considering that China is the world's largest coal producer and consumer(Lin & Liu, 2010), changing its energy structure would be costly. The results in the columns show no significant impact from industrial OECD exports on the energy structures. Unlike previous results on pollution treatment, the energy structures may involve an investment in the long term, focusing on the production of pollution rather than post-production treatment. Since coal consumption is closely associated with the emission of $SO2$, NO_x and dust and is a major cause of haze(Chen & Xu, 2010; Fujii et al., 2013; van der A et al., 2017), reducing the negative impacts would require the country to either adopt cleaner coal or treat the emission after production. However, no evidence in our analysis implies the first channel is the major one that firms adopt. Since there is no indicator that reflects the sources of water pollution, this study focuses on only the ratio of the reclaimed water in the total industrial water usage. That is, a higher ratio indicates a higher utilization rate of wastewater. The results show a significant positive correlation between industrial OECD exports and reclaimed water ratio when we control the drainage basin fixed effects. On the other hand, no significant difference can be seen when the fixed effects are not controlled. This impact is comparatively small; a 1% increase in industrial OECD exports leads to 0.1% higher in the ratio of reclaimed water. However, this shows the need to control the drainage basin fixed effects when analyzing water pollution and treatment because the features of the drainage basin in which a firm is located heavily influence decisions on and costs of its water pollution treatment. Lastly, we delve into the impacts on the sulfur and dust ratios in coal considering the same reasons as previously stated regarding the essential role of coal in energy consumption. We find that a 1% industrial OECD export increase is associated with a 0.2% reduction in a sulfur ratio in coal. Although the average sulfur ratio stays at the 1% level, the magnitude of the effect is considerable. In addition, this is consistent with the fact that coal burning is the main source of $SO2$ emissions. Thus, reducing the coal sulfur ratio is one of the most direct – though very limited – methods to reduce the total $SO2$ released into the air(van der A et al., 2017). Nevertheless, similar results do not arise from the coal dust ratio. On one hand, dust makes up a much higher ratio in coal, which is 22.2% on average. Second, a larger proportion of dust emission is formed during the production than during coal burning when compared with $SO2$ and NOx(Fujii et al., 2013). Combined with the previous results, this shows that the reduction of $SO2$ by firms with industrial exports to OECD countries reduces $SO2$ emissions through two channels: enhancing treatment after production and adopting cleaner coal sources. However, these firms mostly rely on post-production treatment to lessen the dust pollution.

A noticeable feature in the pollution treatment and cleanliness of energy is that state-owned enterprises (SOEs) perform better than other forms, even when the sample is selected through matching. For instance, SOEs have $SO2$ treatment ratios 4.9%, 4.8%, 3.4%, 5.7%, 1.9% higher than collective, private, Hong Kong, Macau or Taiwan-owned (HKMT), foreign-owned, and other-forms companies, respectively. Furthermore, SOEs are 3.1% and 4.5% higher than collective and private companies in their dust treatment ratios. SOEs have 4.3%, 4.5%, 2.6%, and 1.6% higher advantages in COD treatment ratios than collective, private, HKMT, and foreign-owned firms. Lastly, the treatment ratio in the ammoniacal nitrogen of SOEs is 2.6% and 2.1% higher than those of private and foreign-owned firms. In addition, further discussion with regard to SOE perform is provided in Appendix A4.

4.2.3. Pollution Intensity

Another aspect regarding the environmental protection of firms involves the pollution intensities from production. Even though firms can choose to mitigate pollution after production or choose cleaner energy, they usually choose short-term solutions instead of long-term efficiency improvements in environmental performance, which is reflected in their production modes. If a firm can produce the same value with less pollution, it can save on expenditures on pollution treatment. However, this would require a large-scale update to its production system and depends on the characteristics of pollutants. On this subject, Table 5 presents the results of pollution intensity tests. The dependent variables are the emission intensities of $SO2$, dust, COD, and ammoniacal nitrogen. First, firm characteristics are not strongly associated with pollution intensities, for which firm size and age are both statistically insignificant. However, for exportation activities, the test outcomes show that the industrial OECD exports have significantly positive effects on reducing air pollution intensities (i.e., $SO2$ and dust), whereas they have no influence on water pollution. Specifically, a 1% increase in the industrial OECD exports leads to 1.2 and 4.2 tons/million *yuan* reductions of $SO2$ and dust pollution intensities.

[Insert Table 5]

The tests make certain suggestions regarding 4 pollutants in 3 dimensions. These include treatment after pollution produced, cleanliness of energy resources, and reducing pollution intensities during the production. OECD exporters show advantages in all 3 aspects in reducing $SO2$ emission, but the effects to mitigate dust pollution from OECD exporters are mainly reflected in post-production treatment and more efficient production methods, which expel less dust during production. In addition more efforts arise from OECD exporters in water pollution treatment, whereas less investment has been seen in efficiently reducing water pollution during industrial production. Furthermore, OECD exporters reclaim more wastewater, which is reused in industrial water usage.

5.Mechanism Analysis

In this section, we further delve into the causal relationship between exportation activities and environmental protection efforts. The baseline estimation provides a preliminary view of this correlation, whereas the channels of how exports to developed countries influence firms' efforts toward environmental protection require further discussion. We explore this mechanism from two perspectives. First, we consider the spillover effects from environmental protection in developed countries on investment in pollution treatment. Second, we consider the convergence of environmental regulations in the firms that export to developed countries and those of the export destinations.

5.1. Conceptual Model of the Environmental Protection Investment

We construct a conceptual model illustrating the spillover effects of environmental protection in developed countries resulting from the comprehensive pollution treatment information available in the survey. The main pollution treatment investments considered in our analysis include the desulfurization, dust collection, and wastewater treatment expenditures. The latter includes fees on reclamation, processing before discharging, and sewage treatment plants. The primary assumption is that the exportation activities to developed countries, where the environmental regulations are stricter, work as a channel for the environmental protection spillover effects on firms' environmental protection investments. This hypothesis is based on empirical observations in works such as Prakash & Potoski (2006) and Baghdadi et al. (2013), as well as the theory by Forslid et al. (2018). In addition, there is tremendous variation across different industries, in which treating the same amount of pollution requires totally different amounts of investment. Figure 3 shows three different pollution treatment efficiencies, measured by the amounts of pollutants treated with one unit of investment in 37 main industries. They include desulfurization, dust treatment, and wastewater treatment efficiencies.

[Insert Figures 3]

The treatment efficiencies show large variations across different industries even for the same type of pollutant. Industries such as steel, non-ferrous metal, and transportation equipment require large investments in all desulfurization, dust, and wastewater treatment. The medical industry requires high investment in wastewater treatment but is more efficient in sulfide and dust treatment. On the other hand, the chemical fiber industry sees high costs in desulfurization but more efficiency in wastewater treatment. Thus, we construct the model of investment in environmental protection that consists of two parts. The first part comes as a fixed amount that depends on which industry contains the firm. The second part implies that the investment is a fraction of the total production value, where OECD exporters see spillovers. This specification is illustrated below:

$$
\begin{aligned}
I_{i,k,t}^{P} &= M_k^P + r_{i,k,t} \cdot y_{i,k,t} && (7)\\
&= M_k^P + (c_k^P + o_{i,k,t}^P) \cdot y_{i,k,t} && (8)\\
&= M_k^P + (c_k^P + z_k^P \cdot \frac{OECD_{i,k,t}}{y_{i,k,t}}) \cdot y_{i,k,t} && (9)
\end{aligned}
$$

where $I_{i,k,t}^{P}$ stands for the investment in pollutant P control of firm i in industry in year t, and M_k^P is a fixed amount investment if the firm is in industry k. This can be industrial-level investment, such as specific pieces of equipment for industry i. $y_{i,k,t}$ is the total production value of firm i, whereas $r_{i,k,t} \cdot y_{i,k,t}$ is the portion firm i invests in pollutant P treatment as a part of the total production. The coefficient $r_{i,k,t}$ depends on the types of firms and whether they export to developed countries. We assume that there is a constant coefficient c_k^P for every firm in industry k, which can be interpreted as a compulsory portion of the production value that is a minimum requirement of the government on pollution control. In this way, $c_k^P \cdot y_{i,k,t}$ is the part of production value of firm i that does not export to developed countries. Meanwhile, for those exporting to developed countries, there is a spillover of $o_{i,k,t}^P$ regarding the portion of production value, and the spillover portion $o_{i,k,t}^P$ is motivated by the value of OECD exports, which can be written as $\frac{OECD_{i,k,t}}{y_{i,k,t}}$ in an explicit form with the coefficient z_k^P.

The estimation of this model is consequently reduced to two coefficients, c^P and o^P, which correspond to mandatory-level environmental protection investment requirements and spillover effects from trading with developed countries. Nevertheless, the constant industrial level investment M_k^P data is hard to directly obtain, which makes the estimation of the initial model difficult. Thus, we make the first-order difference with respect to time assuming that the constant industrial-level investment does not vary with time. Table 6 presents the coefficient estimation of the model, where Δ Production value is the estimation of c^P and Δ OECD export value is for o^P. The estimation of c_k^P and z_k^P is in an industrial mean.

$$\Delta I_{i,k,t}^P = c_k^P \cdot \Delta y_{i,k,t} + z_k^P \cdot \Delta OECD_{i,k,t} \tag{10}$$

[Insert Table 6]

The results show statistical significance in both Δ Production value and Δ OECD export value in all 3 pollution treatment investments, confirming the solidarity of the conceptual model. Table 7 summarizes the estimation results and explains their magnitude in industrial and sample means.

[Insert Table 7]

The constant coefficients c_k of the industrial mean for desulfurization, dust collection, and wastewater treatment are 7.5%, 5.1%, and 4.8%, respectively. This demonstrates those fractions of production values are invested to satisfy the most basic average environmental requirements. The spillover coefficients for desulfurization, dust collection, and wastewater treatment are 2.4%, 0.4%, and 0.6%. Together with the sample mean of $\frac{OECD_{i,k,t}}{y_{i,k,t}}$ for OECD exporters, the sample means of the investments on desulfurization, dust collection, and wastewater treatment of OECD exporters are 8.2%, 5.2%, and 5.0%. These are 0.7%, 0.1%, and 0.2% higher than those of firms that do not export to developed countries. A larger gap can be seen in desulfurization, which is consistent with the previous analysis and the matter of the fact of $SO2$ pollution.

5.2. Convergence in Environmental Regulation Standards

Statistical significance in the relationship between OECD exports and environmental protection efforts is seen in the previous discussion. Nonetheless, this study does not further distinguish the destinations of exports. Since the hypothesis is that those firms trade (export) to developed countries, where the environmental regulations are stricter, these firms face pressures from their trading partners regarding environmental concerns during production. Specifically, firms in countries with stricter regulations tend to have higher environmental awareness. The country level convergence has been seen in works such as Prakash & Potoski (2006), where ISO 14001 adoption is used as the indicator. Thus, it is necessary to further test different pressure levels from trading with developed countries with different environmental regulation stringencies at the individual level. However, environmental regulation is a very broad definition that includes many aspects and is especially influenced by the geographic features that a country possesses. In addition, it is more difficult to use similar indicators at the country or city levels. Thus, we use a well-recognized environmental index named the Yale Environmental Performance Index (EPI) to proxy the stringency of environmental regulations of a country and construct a weighted OECD export value. As in 2013, the Chinese performance index ranked 118th with a score of 43 (range: $0 - 100$), whereas the average OECD score is 59.37. This construction appears below:

$$\text{Weighted OECD export value}^{z}_{i,j,k,t} = \sum_{c=1}^{C} EPI_{c,t} \cdot \text{OECD export value}^{z}_{i,j,k,t} \tag{11}$$

The value of the EPI is rescaled from 0 to 1, where $EPI_{c,t}$ indicates the stringency of environmental protection in country c at time t. By timing the export value of either agricultural or industrial goods, indexed by z in the formula, we put more weight on the destinations with stricter environmental protections. Specifically, the more goods a firm exports to countries with stricter environmental regulations, the more the firm is impacted to make efforts during production. In the next step, we replace the OECD export value in previous regression models with the weighted values.

[Insert Table 8]

Table 8 presents the weighted export value results. The coefficient estimation of industrial OECD exports shows consistent results with the previous unweighted tests, where the scales of coefficient and standard error values are the same as before, both of which are statistically significant and positive. The results reveal that trading partner countries with higher environmental standards and carrying more weight on one unit of exports have greater impacts on firms' pollution control behaviors. This also indicates that the convergence between them is faster. However, since the weighted values are always smaller than the unweighted ones, we cannot directly compare these magnitudes. The test outcomes confirm the hypothesis of more significant effects from countries with higher environmental standards. In addition, they indirectly reveal the trend that the firms in China that export to those countries gradually converge with their trading partners' standards during production.

6. Robustness Tests

In this section, we conduct a battery of robustness tests to solidify our conclusions. These include a different measurement of exportation activities and three attempts to disentangle the effects of exportation activities from other endogeneities from three different perspectives. The endogenous concerns can be from both firm and policy levels. For instance, we might doubt whether there are corporate characteristics observable to buyers that influence both the exportation activities and environmental performance. In addition, from the policy level, there may be policies that specifically target high polluting industries regarding exportation.

6.1. Measurement of Exportation Activities

We use the exact export values to OECD countries to measure a firm's exportation activities in previous tests. By using that measurement, we fully consider the scale effects, in which the more a firm exports to developed countries, the larger impacts the exportation will have on a firm's environmental protection performance. The hidden assumption is that the exports to other developing countries do not have significant effects on firms' awareness of the environment. However, we do not isolate the effects of how the proportions of OECD exports accounting for the total business of a firm impact their environmental protection efforts. Specifically, aside from the values of a firm's exports to developed countries, we raise another hypothesis that the more OECD trades account for a firm's total business, the more will the firm must devote to environmental protection. Furthermore, we replace the OECD export values with the ratios of OECD exports to the total exports in previous regression models regarding the pollution treatment of $SO2$, dust, COD, and ammoniacal nitrogen.

[Insert Table 9]

Table 9 shows the test results with the OECD export ratios as the main explanatory and different pollution treatment ratios as the dependent variables. We also set the drainage basin fixed effects to be controlled for when discussing the water pollution. The estimation of industrial OECD export ratios exhibits statistical significance and positivity in all four pollution treatments. In addition, we found that adding the drainage basin fixed effects drives down the estimation values on the water pollution treatments, indicating that lacking the consideration of those effects could lead to an upward bias of the effects of OECD export ratios. A 1% increase in the ratio of industrial OECD exports leads to a

0.8%, 3.2%, 2.5%, 1.6% growth in $SO2$, dust, COD, and ammoniacal nitrogen treatments when the drainage basin fixed effects are controlled for water pollution analysis. Since the industrial OECD export ratio fluctuates at the 40% level (see Figure 1 and 2), the impacts of trade are considerable. Beyond this, the test results indicate that without considering the scale effects of exports, the impacts of trading with developed countries still occur. Even though we must acknowledge that both indicators have their own pros and cons in reflecting the activity of a firm trading with developed countries, clear evidence connects environmental protection efforts and trade with developed countries from two perspectives.

6.2. Heterogeneities of the Corporate Performance

Another endogenous concern comes from the causal relationship between exportation activities and environmental protection efforts. Even though significant positivity has been found between the exportation activities and pollution control, a further discussion into causality is needed. This is because the positive relationship can be either triggered by exportation to developed countries or by a selection process through which firms with superior qualities are chosen by trading partners from developed countries. First, we assume that a firm's corporate structures and characteristics are the only features that outsiders can observe through disclosures such as accounting statements, which means information and observation of a firm's social ethics are limited to the public.

We consider two major indicators that reflect a firm's abilities: profitability and management efficiency, which are measured as the ratios of the total profit to the total revenue and the sale costs to the management costs, respectively. High values in these two ratios indicate that a firm has higher profitability and more efficient management. Specifically, the endogeneity could come from a firm selection involving as these characteristics. Firms with higher profitability and management efficiency ratios are more desirable for trading partners since they are labeled as good firms (Lee & Habte-Giorgis, 2004). However, these two aspects are not the full image of a firm, and a more efficient firm does not necessarily put more effort into environmental protection even though higher productivity leads to less pollution during production. Considering that these two indicators reflect different features, we also construct an interaction term with them. Table 10 presents these results with the full and PSM samples in Panels A and B, respectively.

[Insert Table 10]

The dependent variables are the treatment ratios of four pollutants, for which drainage basin fixed effects for water pollution. The main explanatory variables include the exports to OECD countries and the corporate performance indicators. Thus, if there exists a strong relationship between the industrial exports to OECD countries and corporate performance, the exclusion of the corporate performance indicators could lead to biased results of estimation. Nevertheless, the outcomes in both Panels A and B show either insignificant or negative coefficient estimation in the corporate performance indicators and the interaction terms. The results imply that profitability and efficiency in company management do not increase efforts toward pollution abatement. Considering the assumption that the corporate performance indicators are the features outsiders observe and the factors on which they base trade decisions, we eliminate the endogenous concern that raises regarding firm characteristics.

6.3. Tests on the Policy Endogeneities

In addition to the endogenous concern from the firm level, the trade policy at the national level could also drive endogeneity regarding the impacts of the industrial exports to developed countries. For instance, if there were relevant trade policies that hit the polluting firms exporting to developed countries, this would drive down the pollution levels in firms that trade with developed countries and bias our estimation. Therefore, we must remember that most of the policies are set at the industrial level instead of targeting a few specific firms. The most direct method that the government can use to control trade activities is through import and export taxes. China has long been conducting positive exportation policies, including very low or zero export taxes on most types of goods. In addition, the Chinese government encourages exportation through a series of value-added tax (VAT) rebate policies. These rebates largely depend on the types of goods that a firm exports. Evidence shows that VAT rebates have been widely used by the government to target pollution-intensive industries, for which firms exporting more polluting types of goods receive fewer rebates (Eisenbarth, 2017). However, this discussion does not distinguish the heterogeneities among firms in the same industries, especially regarding the trading activity with developed countries. In this section, we illustrate the role of VAT rebate, which is measured as the ratio of the total rebated value to the total production value of a firm. A higher ratio means a firm gets more compensation from the government. We construct an interaction term of the export values and VAT rebate rates[4] to reflect the mutual effects from the exportation and government regulations. Following Eisenbarth (2017), we construct another interaction term of the VAT rebate rates and pollution intensities of $SO2$, COD, and ammoniacal nitrogen at the industrial levels. These interaction terms reflect the government's pollution control of polluting industries that export through VAT rebates. We consider the treatment ratios of four pollutants as the measurements of pollution abatement efforts, and Table 11 shows these test results.

[Insert Table 11]

First, the test of whether the government takes advantage of the VAT rebate policies based on the polluting level of each industry fails to convey statistically significant results at the individual level for all four pollutants. This is the case even though significantly positive effects have been seen in previous literature at the industrial level (Eisenbarth, 2017). Next, we look at the interaction effects of exportation to developed countries and the VAT rebate policies, for which a significantly positive result could indicate that large OECD exporters who also get more rebates are at an advantage for controlling pollutions. This may make it difficult to distinguish whether the policies show an endogenous role in promoting exportation if the VAT rebate variable also shows a significantly positive sign. Nonetheless, the single VAT rebate variable and the interaction term both show nonsignificant results or results significantly close to zero. The latter should not be the result of the scale since we already timed the VAT rebate rate values with 1000. In other words, the relationship between VAT rebate and pollution abatement is more random at the individual level than at the industrial level. The results also confirm the VAT rebate policies target more polluting industries instead of individual firms according to their exportation activities.

[4]The scale of the VAT rebate rate is 0.1%, considering values of VAT rebate rates are small.

6.4. Tests on Re-export

One of the main explanations of the mechanism on how trading with developed countries promotes firms' efforts toward pollution abatement is the pressure from trading partners who face customers with higher environmental awareness. To further test our hypothesis, we consider a subgroup of exports: re-exports, which are goods being exported to China to be processed and then re-exported to their countries of origin. Our customs data allows us to differentiate whether exports are re-exported. A few features can be found in this type of export, which are closely correlated with China's production and trading modes. First, most re-export trades happen between China and Japan, South Korea, or Taiwan. Second, these exports are mostly industrial goods. Due to comparative advantages in labor costs, China has been the intermediary for assembly for these goods. Consequently, companies in China are not the final producers and do not directly trade with the OECD buyers. Therefore, if our hypothesis holds, we would expect the re-exports to have no higher positive or non-significant effects on pollution abatement effort. We limit the sample in the test to only exporters, no matter the destinations. This helps to identify the effects of re-exports among all exports without the comparison of non-exporters, and we do not further classify the destinations of the re-exports. The test results are presented in Table 12, where the dependent variables are the treatment ratios of four pollutants.

[Insert Table 12]

For the treatment ratios of dust and ammoniacal nitrogen, the industrial re-exports do not exhibit any significant impacts on them. The industrial OECD exports, however, show similar effects on $SO2$ and COD treatment ratios to those of the total industrial OECD exports. We must remember that Japan and South Korea, even as two large re-exporting destinations, are also members of the OECD. In addition, the re-export values could be correlated with the total export values for some of the firms. Thus, in general, the impacts of the industrial re-exports are on a smaller scale than the overall industrial exports that mostly consist of final products to developed countries while positive influence can still be observed.

7. Conclusion

This paper fills the gap that exists in the literature in terms of the impacts of international and regional trade on the environment in developing countries from the perspective of the effort that is made by exporters in developing countries toward environmental protection. To begin, we adopt a comprehensive Chinese annual nationwide firm environmental performance survey dataset from 2011 to 2013. From there, we delve into the environmental performance of Chinese firms from four different aspects, including air and water pollution ($SO2$, dust, COD, and ammoniacal nitrogen) treatment ratios; energy and resource structures; pollution intensity and production; and pollution control expenditures. To measure the trade activities of firms in China, we take advantage of the Chinese customs data, collecting full information from every single transaction that a firm reports to customs. Based on this exportation data, we distinguish firms by whether, how much, and in what categories of goods they export to developed countries (i.e., measured by whether they are OECD members). We propose the hypothesis that firms that export more to developed countries tend to face pressure to establish cleaner production due to higher environmental awareness among their customers, which passes pressure to the companies that trade with developing countries.

We consider the heterogeneities that exist across different industries, provinces, and geographic features, in addition to corporate structures, which help to disentangle the role of exportations to developed countries. The results show that exports of industrial goods to developed countries are significantly positively correlated with higher treatment ratios in all four pollutants. A 1% increase in the industrial OECD exports is associated with at least a 1%, 1%, 2%, and 2% increase in $SO2$, dust, COD, and ammoniacal nitrogen treatment. Nonetheless, no exportation activities change the energy structures of the firms in China, although OECD exporters do tend to recycle more industrial water and consume coal with less sulfide. During production, OECD exporters exhibit more cleanliness in air pollution emission but no statistical difference in water pollution. Furthermore, a 1% increase in the industrial OECD exports drives down the $SO2$ and dust pollution density by 0.012 and 0.042 tons/10 million *yuan*.

We examine the mechanism from two perspectives: the investment in pollution abatement and the convergence of environmental protection stringency between the exporters in China and their developed trading partner countries. After controlling for the industrial heterogeneities, the investments in desulfurization, dust collection, and wastewater treatment of the OECD exporters are 9.33%, 1.96%, and 4.17% higher than those that do not export to OECD countries at the sample mean. In addition, there exists convergence between OECD exporters and trading partner countries that have higher environmental standards, as measured by the Yale Environmental Performance Index (EPI). Through these two findings, we indirectly prove that firms exporting to developed countries do face higher pressure to establish environmental protections.

We further solidify our conclusion by conducting a series of robustness tests. We first replace the OECD export value variables with the ratios of different goods exported to the OECD countries to the total exports by conducting tests for which we exclude scale effects. This study aims to solve the endogenous concern from two perspectives: firm and policy levels. We prove that better corporate performance, such as higher profitability and management efficiencywhich are commonly observable and conventionally recognized as indicators for better firmscannot explain better performance in environmental protection. In addition, we verify that an industrial-level Value-Added Tax (VAT), which can be used as a policy tool to curb industries with high pollution, cannot explain the pollution abatement performance at the firm level. Lastly, we use re-exportation activities as a comparison to further solidify our hypothesis of environmental pressure from developed trading partner countries.

Our paper has broad policy implications on environmental issues in both China and other developing countries. We prove the positive environmental impacts that exist in the trading between developed and developing countries, in which the former present higher environmental standards and have higher environmental awareness customers. Being open to the capital from and trades with developed countries motivates firms in China to put more effort into pollution abatement. The conclusions from our paper encourage firms to engage more with developed countries that have higher environmental standards, during which competition and pressure can benefit the environment in the long term and help to upgrade environmental performance during production instead of simply increasing production quantity and entering markets with equivalent or lower environmental thresholds.

Furthermore, our findings and conclusions are not limited to China but also apply to other developing countries, especially the southeastern Asian region, which has been more frequently engaging in the global production chain. The case of China provides an example for other countries that are or wish to be involved in the global production chain transfers in environmental protection and pollution abatement.

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Appendix

A.1. Data matching

The details of matching three datasets: (1) the Chinese Industrial Enterprises Pollution Discharge, Treatment and Utilization Survey (available between $2011 - 2013$), (2) the China Industry Business Performance Database (available between $1998 - 2013$), and (3) the Chinese customs data (available all years) are as follows.

The firm code assignment system of (1) the Chinese Industrial Enterprises Pollution Discharge, Treatment and Utilization Survey, and (2) the China Industry Business Performance Database are exactly the same. The main firm codes in both datasets consist of 9 digits and followed by 2 digits which stand for subsidiaries (00 if it is the parent company). They both survey industrial firms. However, (2) the China Industry Business Performance Database only includes firms whose asset scales are larger or equal to 5 million *yuan* while (1) the Chinese Industrial Enterprises Pollution Discharge, Treatment and Utilization Survey provides the information of firms in all scale ranges as long as their business involves any industrial production. Theoretically, both datasets separate the parent company and the subsidiaries and survey them individually. Nevertheless, we observed that (2) the China Industry Business Performance Database includes a very limited number of subsidiaries, presumably because subsidiaries tend to be small in scales. Thus, we choose to drop subsidiaries in both datasets. Initially, there are $182,330$ firms in total in (1) the Chinese Industrial Enterprises Pollution Discharge, Treatment and Utilization Survey. Since we would need corporate information as control variables and for matching, we drop those appear in (1) the Chinese Industrial Enterprises Pollution Discharge, Treatment and Utilization Survey but not show in (2) the China Industry Business Performance Database. After matching these two datasets, there are $66,086$ firms with full corporate and environmental performance information from 2011 to 2013.

(3) the Chinese customs data is made of single pieces of transactions that firms reported to the customs. The major information in a transaction includes the firm name, codes (10 digits), address, the transaction type (i.e. exportation or importation), the good type, destination/original country, and traction value. In total, there are 98 different types of goods. We further reduce these 98 types into 3 major categories: agriculture, industrial, and others. Next, we sum up all the values of one

category of goods that a firm export(import) to(from) a country in a year. In our baseline estimations, we divide the countries into two groups: OECD and non-OECD. Thus we sum up the values of a firm export(import) to(from) OECD and non-OECD countries in one year. Consequently, the new customs data shows the value of one category of goods that a firm export(import) to(from) OECD and non-OECD countries in one year.

In the next step, we match the merged firm dataset with the Chinese customs data. However, the code system used by (1) the Chinese Industrial Enterprises Pollution Discharge, Treatment and Utilization Survey, and (2) the China Industry Business Performance Database is totally different from (3) the Chinese customs data. There is no way to connect the firms in the two datasets by their codes. The only way to connect the firms is by matching the Chinese names. Nonetheless, the name of a firm can appear slightly different in the two datasets (e.g. Jiangsu Province Suzhou City AAA Company v.s. Jiangsu Suzhou AAA Trade Company). Hence, we adopted the fuzzy matching method. In order to match as accurately as possible, the following criteria are applied:

(1.) We segregate the name of a company into several parts [5]. We notice the name structure of firm names is always in the form as: Address + Firm name (Core part) + Company form (e.g. Jiangsu Province Suzhou City AAA Company v.s. Jiangsu Suzhou AAA Trade Company). The variation of firm names mainly appears in the Address and Company form parts. Thus, after the segmentation, we put extra weight on the core part (e.g. AAA) since we must keep the core parts consistent in the two datasets.

(2.) The address codes in (1) the Chinese Industrial Enterprises Pollution Discharge, Treatment and Utilization Survey, and (2) the China Industry Business Performance Database stand exactly for where the companies are located. However, we found that the address codes in (3) the Chinese customs data do not necessarily present the locations of the companies (i.e. the addresses of the customs where they report to). Thus, we cannot constraint the matching of firms within the same cities but have to expand to the same provinces.

(3.) In this step, we have to find the corresponding firm names from the customs data for the firms in the merged firm dataset. First, we limit the firm name selection from the customs data to those in

[5] The module we use is Jieba Chinese Text Segmentation System based on Java^{TM}. We enhanced the lexicon by importing the Chinese Geography Dictionary and Business and Economics Dictionary.

the same provinces. Then we calculate the matching scores of different firms from the customs data where we put extra weight on the core part. We set thresholds for the matching scores[6], so that if there is no name in the customs data exceeds the threshold, we regard there are no exportation and importation activities of that firm. Lastly, we pick the name with the highest score as the matched.

(4.) While most of the firms, if they appear in both datasets, turn to have exactly the same names, there are $4,817$ firms appear differently. In order to guarantee accuracy, in the last step, we manually checked if the algorithm worked efficiently. It turned out that there were less than 10 samples mistakenly matched. Lastly, since (2) the China Industry Business Performance Database provides the total values of exports of firms, we drop the observations whose the total values of exports from (2) the China Industry Business Performance Database are not in the same scales as the total values from (3) the Chinese customs data after matching. The results show that $51,861$ of firms did not have any exportation activities during the period.

A.2. Winsorization of the dust data

Not only is there a higher ratio of dust produced during production compared with $SO2$, we can also see a much larger scale in produced dust (Table 1). After initial winsorization, we found not like other types of pollution, the distributions of dust produced and treatment show higher skewness. Figure A1 shows a high right skewness of dust production. 25% of the samples are below 7.5 tons while the 95^{th} percentile is $17,900$ tons. Furthermore, when we divide the whole sample into three quantiles according to the dust production (bottom 10%, 20% to 90% and top 10%), we found that 38.7% of the samples in the bottom 10% group do not treat the dust emission at all while over 85% of the samples in the top 10% group have a dust treatment ratio larger than 90%. This is potential because the dust collection technology is much more complex and costly such as that the process requires more advanced machines. Thus, firms with small dust emissions would be reluctant to purchase high-cost machines while as long as a firm is equipped, the marginal cost is comparatively low.

[6]If there are 2 segments in the firm's name, we require a 100% match. If there are 2 segments in the firm's name, we require the scores to be at least 3. If there are more than 2 segments in the firm's name, we require the scores at least be $length * 2 - 3$

[Insert Figure A1]

Table A1 shows the baseline regression results with different quantile groups including the full sample, the bottom 10%, middle 80% and top 10% regarding the dust treatment. The specifications are the same as the baseline regressions in Table 2. The middle 80% is the sample we use in Table 2. The full sample shows the same estimation value regarding industrial OECD exports as the 80% group while less significant. The bottom 10% and top 10% show different estimation results. However, these results are less interesting to us since the extremely low treatment ratio in the bottom 10% group and high treatment ratio in the top 10% group. Practically, a 90% treatment ratio is much higher than the industrial average and totally meets the environmental protection requirements.

[Insert Table A1]

A.3. Non-OECD exportation placebo tests

Even though the major focus of the discussions is the impacts from OECD exports, it is still necessary to examine whether non-OECD exports might have similar results. Since the assumption is the spillover effects of the stricter environmental regulations in the developed countries (i.e. OECD countries), if exports to non-OECD countries also show the same trend, we might have to reconsider the mechanism. In this part, we conduct a placebo test for non-OECD exports. Considering that a firm exports more to OECD countries also tend to have some exports to non-OECD countries may cause multicollinearity (i.e. insignificance in OECD and non-OECD exports and failed F-tests), we mainly focus on discussing non-OECD exporting effects in the models.

[Insert Table A2]

Firstly, we can notice that except $SO2$ treatment, non-OECD exports show no significance regarding the impacts on pollution treatment when measured in exact value. Due to the concern that there might be a positive correlation between OECD and non-OECD exports, which could lead to the significant positive effects of non-OECD exports resulting from the correlation with OECD exports. Thus, we further consider the ratio of non-OECD to OECD exports and construct an interaction term of the ratio and the exact value. Thus, a higher interaction value indicates non-OECD countries alone account for large exporting values, which helps us to disentangle the influence of OECD exports. The results show that a high non-OECD to OECD ratio has significantly negative effects on treatment for $SO2$ pollution and two water pollutants. Nevertheless, the interaction terms for pollution treatment are mostly insignificant except $SO2$, which is statistically negative. This confirms that non-OECD exports alone are not related to sparking efforts to combat pollution and even have negative effects on $SO2$ treatment.

A.4. State-owned Enterprises Robustness Tests

Previous tests reveal the advantages of state-owned enterprises in pollution abatement in almost all aspects. Even though we had firm characteristics, including firm sizes, controlled and matched–meaning the advantages are not from the scale effects–the gaps between SOEs and other types of ownerships are still considerable. However, low efficiency in management and business operation has been widely observed in many SOEs in China (Bai et al., 2006; Dollar & Wei, 2007). In addition, SOEs are also frequently used as tools to achieve political and economic goals for both state and local governments, such as economic growth and employment rates (Bai et al., 2006). These overly set goals may lead to SOEs' participating in fraudulent reporting, especially in economic performance(Hou & Moore, 2010). Consequently, the better environmental performance of SOEs may be from the over-reporting of their environmental performance. Since it is hard to directly test whether a firm has fraudulent behaviors, we choose to test by contradiction by posing the hypothesis that SOEs did make fraudulent reports in their environmental performance.

Following the conclusions in Bai et al. (2006) that the government utilizes SOEs to achieve political and economic goals, we take advantage of the only large-scale nationwide pollution control policy in China before the Twelfth Five-Year Plan on Environmental Protection in 2012. This is named the

Two Control Zone policy (TCZ)[7]. In the next step, we test how the implementation of the TCZ would impact the cost-to-revenue ratio of SOEs. That is, if the hypothesis is true that SOEs are used to achieve environmental goals, and they falsely over-report their environmental performance–which is measured by the treatment ratios of two air and two water pollutants–we should see a statistically significant, negative or nonsignificant impact from pollution treatments on the cost-to-revenue ratio. This also requires the assumption that SOEs accurately disclose their financial information so that the cost-to-revenue ratio is not biased.

[Insert Table A3]

Table A3 presents the results of the tests by contradiction. The main explanatory variable is an interaction term of pollutant treatment ratio and the TCZ policy dummy variable, indicating the pollution abatement efforts of SOEs in the TCZ region. The dependent variable is the cost-to-revenue ratio, which reflects the cost that corresponds to a firm's revenue. Similarly, we have the drainage basin fixed effects controlled for the water pollution treatment discussion. The test results show significant positive coefficients of the interaction terms for all pollutants when the drainage basin fixed effects are not controlled for the pollution treatment. In addition, they are significantly positive for ammoniacal nitrogen treatment when the drainage basin fixed effects are controlled. This occurs because the treatment of pollution does increase the cost of the SOEs. Thus, we cannot conclude that fraud exists in SOEs' environmental performance reporting. Nonetheless, we must keep in mind that we also cannot directly conclude the accuracy of the reporting either due to the nature of contradictory tests where more than one factor defines a precise environmental report.

[7]the Two Control Zone policy mostly focused on the control of $SO2$ and NOx. The policy divided Chinese cities into two groups: one is subject to the regulation, and the other is not. The policy was first launched in 1998 and had been implemented until a series of stricter air and water pollution control methods were introduced in the Twelfth Five-Year Plan on Environmental Protection

Figure 1: The export ratios of different goods to OECDs in different quantiles (total asset)

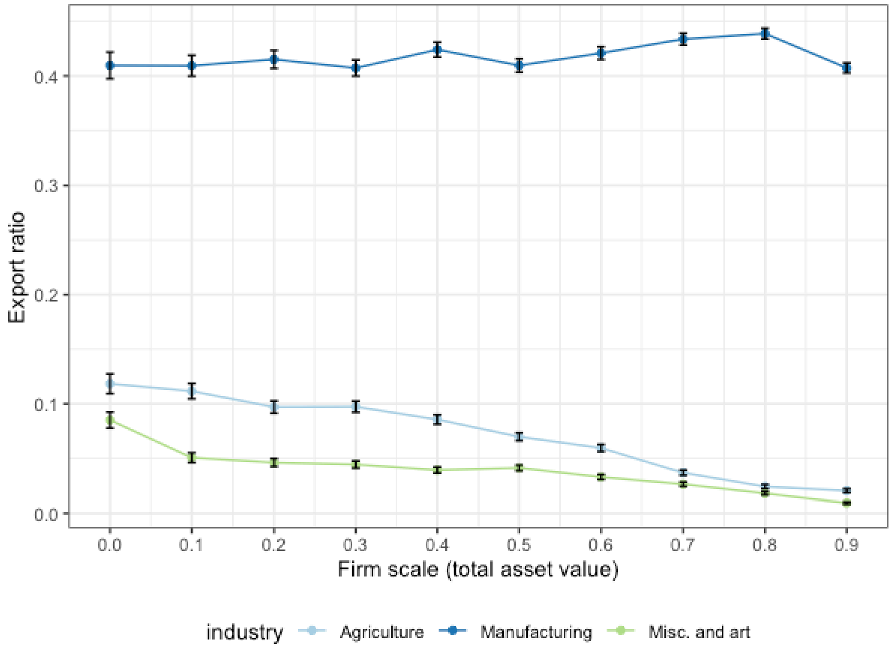

Figure 2: The export ratios of different goods to OECDs in different quantiles (employee number)

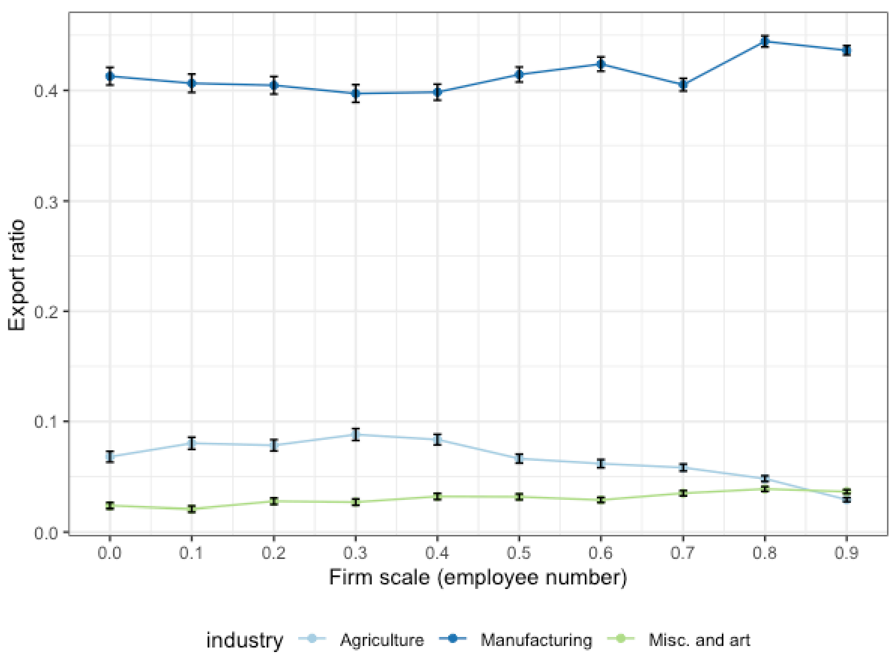

Figure 3: Pollution treatment efficiencies across industries

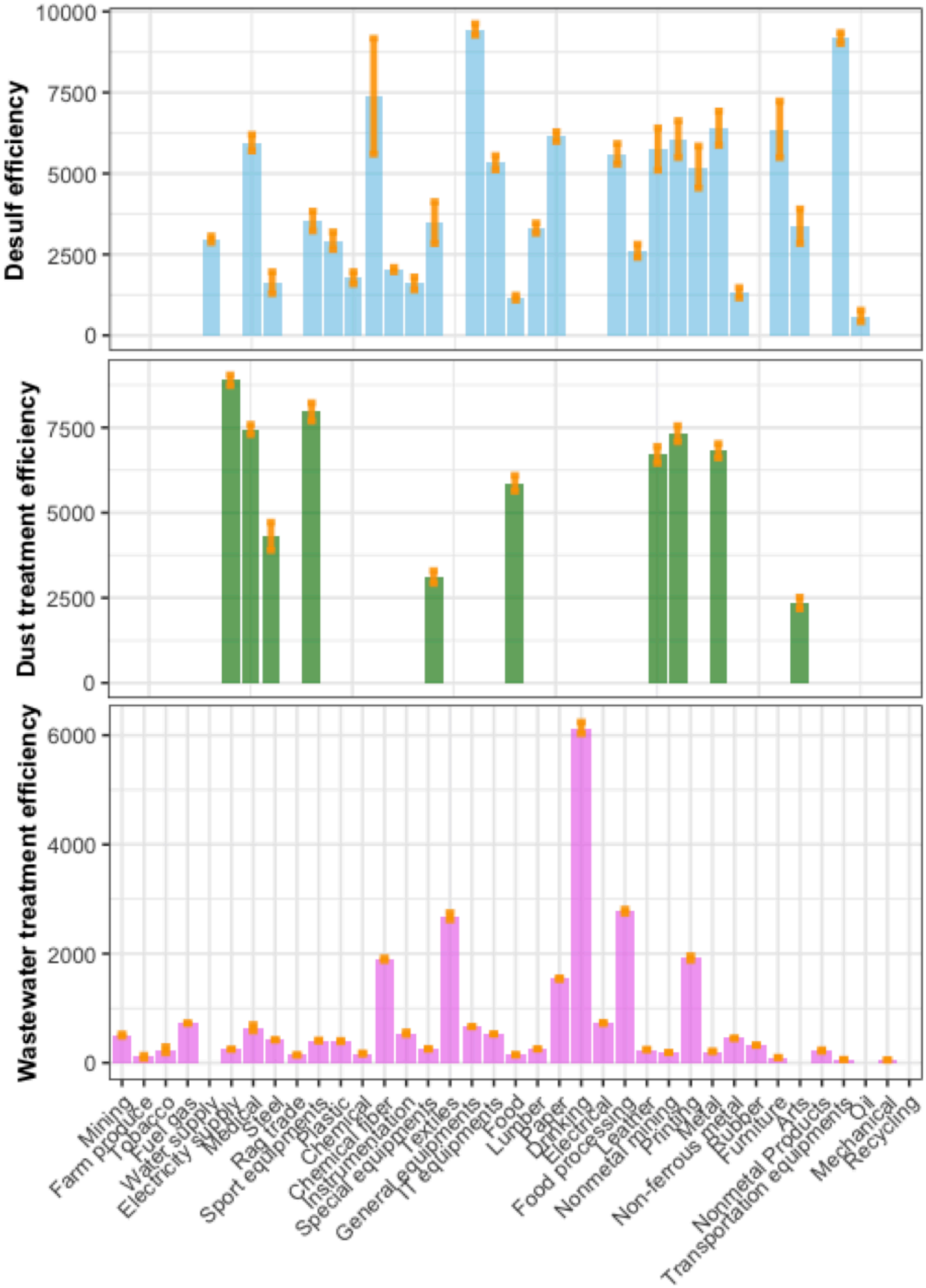

Table 1: Summary statistics

	Full samples	Samples with OECD exports	Samples with only non-OECD exports	Difference1	Non-exporter	Difference2
Corporate characteristics						
Total assets (K *yuan*)	376791	572696.1	441072.6	131623.5***	322049.8	250646.3***
Employee number	507	790	640	150***	425.7754	364.2246***
Profitability (sale profit/sales)	0.09879	0.04164	0.03377	0.00787***	0.1169	-0.07526
SOE ratio	0.09289	0.06241	0.06599	-0.00358	0.1022	-0.03979
Pollution and treatment						
SO2 produced (ton)	761.7	176.5707	258.4399	-81.8692*	908.7501	-732.1794***
SO2 treatment ratio	0.09301	0.09183	0.08876	0.00307	0.09342	-0.00159
Dust produced (ton)	16673	1249.827	5643.702	-4393.875***	19564.306	-18314.479***
Dust treatment ratio	0.7315	0.7554	0.7259	0.0295***	0.7274	0.028***
COD produced (ton)	368.8	611.7208	367.4415	244.2793	296.2719	315.4489
COD treatment ratio	0.4974	0.5500	0.5362	0.0138**	0.4791	0.0709***
Ammoniacal nitrogen produced (ton)	21.71	18.26014	16.87673	1.38341	23.2280	-4.96786*
Ammoniacal nitrogen treatment ratio	0.3009	0.3219	0.3266	-0.0047	0.2914	0.0305***
Energy and resource structures						
Coal consumption (ton)	65857	14604.98	19639.01	-5034.03**	76831.02	-62226.04***
Fuel consumption (ton)	1312	910.8893	843.4589	67.4304	1474.8709	-563.9816
Gas consumption (10K m^3)	1332	1350.1815	742.7957	607.3858	1357.333	-7.1515
Electricity Usage (10K KW/h)	8639	2347.500	3828.851	-1481.351	10516.26	-8168.76*
Industrial water usage (ton)	3403527	1833992	1484852	349140	3910411	-2076419***
Reclaimed water usage ratio	0.2751	0.1993	0.1907	0.0086**	0.2993	-0.1***
Coal sulfur ratio (%)	1.002	0.9163	0.9869	-0.0706***	1.0177	-0.1014***
Coal dust ratio (%)	21.19	20.2689	20.5159	-0.24714	21.3697	-1.1008***
Pollution control expenditure						
Desulf expenditure (K *yuan*)	319.8	65.33045	67.36698	-2.03653	389.4197	-324.0892***
Dust collect expenditure (K *yuan*)	114.2	57.4626	81.0821	-23.6195	127.4617	-69.9991***
Wastewater processing expenditure (K *yuan*)	98.18	112.5815	111.8451	0.7364	92.94156	19.6399**
Number of firms	66086	14034	3299		51861	

Note: Difference1 stands for the difference between the samples with OECD exports and the samples with exports but only to non-OECD countries. Difference2 stands for the difference between the samples with OECD exports and non-exporters. The significance levels of t-tests are presented.

* significant at the 10% level

** significant at the 5% level

*** significant at the 1% level

Table 2: Baseline regression results: air pollution treatment

Panel A: Air pollution				
	All samples		PSM matching	
Dependent variable: treatment ratio	SO2	Dust	SO2	Dust
OECD export				
Agricultural	0.0001	0.001	0.00003	0.0003
	(0.0005)	(0.001)	(0.001)	(0.001)
Industrial	0.001***	0.001***	0.001***	0.002***
	(0.0002)	(0.0003)	(0.0002)	(0.0003)
Firm size	0.017***	0.020***	0.017***	0.022***
	(0.001)	(0.002)	(0.001)	(0.002)
Years since operation	-0.054***	-0.056***	-0.056***	-0.052***
	(0.006)	(0.009)	(0.007)	(0.012)
Years since operation^2	0.011***	0.012***	0.012***	0.011***
	(0.001)	(0.002)	(0.002)	(0.003)
Ownership				
Collective	-0.058***	-0.039***	-0.049***	-0.031**
	(0.007)	(0.011)	(0.009)	(0.014)
Private	-0.064***	-0.057***	-0.048***	-0.045***
	(0.004)	(0.007)	(0.006)	(0.009)
HK, MO, and TW	-0.046***	-0.034***	-0.034***	-0.016
	(0.006)	(0.009)	(0.007)	(0.011)
Foreign	-0.060***	-0.008	-0.057***	0.001
	(0.006)	(0.009)	(0.007)	(0.011)
Others	-0.038***	-0.017*	-0.019**	-0.002
	(0.006)	(0.010)	(0.008)	(0.012)
Industry fixed effects	X	X	X	X
Time fixed effects	X	X	X	X
Province fixed effects	X	X	X	X
Observations	105,780	70,881	60,381	35,345
R^2	0.184	0.155	0.098	0.107

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. Columns 3-4 in the results present the tests with PSM samples. The matching variables are firm-level corporate factors, including the industry, employee number, and sale performance. The matching method is the nearest neighbor matching.

Table 3: Baseline regression results: water pollution treatment

Panel B: Water pollution	All samples				PSM matching			
Dependent variable: treatment ratio	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen
OECD export								
Agricultural	0.003***	0.002***	0.001	-0.0005	0.001	0.001	-0.001	-0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Industrial	0.002***	0.002***	0.002***	0.002***	0.002***	0.003***	0.002***	0.002***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Firm size	0.028***	0.024***	0.026***	0.022***	0.028***	0.022***	0.026***	0.020***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Years since operation	-0.038***	-0.020**	-0.044***	-0.025***	-0.036***	-0.006	-0.047***	-0.015
	(0.008)	(0.009)	(0.008)	(0.009)	(0.010)	(0.011)	(0.010)	(0.011)
Years since operation^2	0.006***	0.002	0.007***	0.003	0.007***	0.0001	0.009***	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Ownership								
Collective	-0.059***	-0.040***	-0.057***	-0.039***	-0.045***	-0.019	-0.043***	-0.015
	(0.010)	(0.011)	(0.010)	(0.012)	(0.012)	(0.013)	(0.012)	(0.014)
Private	-0.060***	-0.046***	-0.056***	-0.041***	-0.052***	-0.034***	-0.045***	-0.026***
	(0.006)	(0.007)	(0.006)	(0.007)	(0.007)	(0.008)	(0.007)	(0.008)
HK, MO, and TW	-0.005	-0.001	-0.029***	-0.017**	-0.004	0.005	-0.026***	-0.012
	(0.008)	(0.009)	(0.008)	(0.009)	(0.009)	(0.010)	(0.009)	(0.010)
Foreign	0.015**	-0.001	-0.007	-0.019**	0.009	-0.001	-0.016*	-0.021**
	(0.007)	(0.008)	(0.007)	(0.008)	(0.008)	(0.009)	(0.009)	(0.010)
Others	-0.025***	-0.005	-0.028***	-0.007	-0.018*	0.006	-0.016	0.009
	(0.009)	(0.010)	(0.009)	(0.010)	(0.010)	(0.011)	(0.011)	(0.012)
Industry fixed effects	X	X	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X	X	X
Drainage basin fixed effects			X	X			X	X
Observations	124,332	87,008	117,401	81,076	80,832	61,567	75,367	56,826
R^2	0.138	0.099	0.165	0.130	0.154	0.099	0.186	0.137

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. Columns 5-8 in the results present the tests with PSM samples. The matching variables are firm-level corporate factors, including the industry, employee number, and sale performance. The matching method is the nearest neighbor matching. Columns 3-4 and 7-8 are the tests with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment.

Table 4: Baseline regression results: energy structures

Panel C: Energy structures							
Dependent variable:	Fuel oil to coal ratio	Gas to coal ratio	Electricity to coal ratio	Reclaimed water ratio	Reclaimed water ratio	Coal sulfur ratio	Coal dust ratio
OECD export							
Agricultural	-3.510	10.388	-5.593	-0.002***	-0.002***	-0.0004	0.011
	(2.428)	(11.874)	(5.165)	(0.0004)	(0.0005)	(0.001)	(0.018)
Industrial	5.051	-1.825	81.541	0.0004	0.001***	-0.002***	-0.0003
	(3.879)	(10.632)	(59.324)	(0.0002)	(0.0002)	(0.001)	(0.007)
Firm size	15.671	140.213	-9.139	0.026***	0.026***	-0.029***	-0.122***
	(30.003)	(90.666)	(89.787)	(0.001)	(0.001)	(0.004)	(0.041)
Years since operation	0.966	-73.627	-364.243	-0.046***	-0.047***	0.064***	0.121
	(58.256)	(323.253)	(280.902)	(0.006)	(0.006)	(0.016)	(0.201)
Years since operation^2	-5.990	-39.183	29.806	0.011***	0.011***	-0.012***	-0.017
	(9.366)	(63.463)	(59.312)	(0.001)	(0.001)	(0.003)	(0.043)
Ownership							
Collective	-109.498*	-424.587**	-282.706**	-0.070***	-0.070***	0.047*	0.069
	(57.367)	(206.430)	(126.304)	(0.008)	(0.008)	(0.025)	(0.239)
Private	-116.381*	-243.209	-304.592***	-0.070***	-0.072***	0.061***	0.053
	(64.307)	(274.526)	(114.240)	(0.005)	(0.005)	(0.014)	(0.162)
HK, MO, and TW	1.571	-381.227	1,676.080	-0.076***	-0.080***	0.006	-0.183
	(97.260)	(248.726)	(1,963.958)	(0.006)	(0.007)	(0.017)	(0.223)
Foreign	56.919	-225.090	109.822	-0.085***	-0.086***	-0.039**	-0.069
	(109.177)	(243.760)	(346.241)	(0.006)	(0.007)	(0.017)	(0.227)
Others	-129.291**	-344.835	-131.684	-0.039***	-0.041***	0.085**	-0.104
	(61.023)	(257.866)	(206.947)	(0.007)	(0.007)	(0.036)	(0.227)
Industry fixed effects	X	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X	X
Drainage basin fixed effects					X		
Observations	13,588	13,372	89,337	148,174	140,356	81,246	53,180
R^2	0.011	0.003	0.002	0.248	0.254	0.202	0.283

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The units for coal, fuel, gas, and electricity consumption are ton, ton, 10K/m^3, and 10K KW/h. The coal sulfur and dust ratios are in a unit of $\%$. Columns 5 is the test with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment.

Table 5: Baseline regression results: effects on the pollution intensities

Pollution by unit						
Dependent variable: pollution intensity	SO2	Dust	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen
OECD export						
Agricultural	-0.003	-0.026	4.776	0.256	6.46	0.358
	(0.008)	(0.024)	(4.845)	(0.256)	(6.529)	(0.357)
Industrial	-0.012*	-0.042***	0.178	0.001	0.198	0.002
	(0.007)	(0.006)	(0.150)	(0.003)	(0.162)	(0.004)
Firm size	-0.021	-0.007	-1.399	-0.048	-1.733	-0.078
	(0.107)	(0.602)	(0.887)	(0.047)	(1.174)	(0.077)
Years since operation	-0.405	-0.026	1.144	-0.06	0.554	-0.08
	(0.274)	(0.272)	(1.302)	(0.040)	(1.427)	(0.071)
Years since operation^2	0.085	-0.026	-0.411	0.004	-0.355	0.006
	(0.068)	(0.119)	(0.356)	(0.013)	(0.339)	(0.015)
Ownership						
Collective	-0.650	2.630	-0.705	-0.039	-0.792	-0.047
	(0.781)	(2.189)	(0.582)	(0.045)	(0.846)	(0.068)
Private	0.008	4.523	1.649	0.106	0.999	0.05
	(1.282)	(4.054)	(1.739)	(0.133)	(1.268)	(0.088)
HK, MO, and TW	-0.289	3.033	-0.990*	0.005	-1.884*	-0.058
	(0.869)	(2.787)	(0.546)	(0.047)	(1.009)	(0.054)
Foreign	-0.057	3.059	-3.583	-0.13	-4.931	-0.227
	(0.908)	(2.726)	(2.442)	(0.098)	(3.501)	(0.196)
Others	-0.332	3.641	-1.855	-0.08	-1.949	-0.105
	(0.896)	(2.978)	(1.530)	(0.085)	(1.706)	(0.122)
Industry fixed effects	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X
Drainage basin fixed effects					X	X
Observations	105,433	70,660	126,084	87,427	119,046	81,487
R^2	0.006	0.053	0.001	0.001	0.002	0.003

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The units for $SO2$, dust, COD and ammoniacal nitrogen pollution intensities are all tons/10 million *yuan*. Columns 5-6 are the test with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment.

Table 6: Estimation of the conceptual model of the spillover effects on pollution abatement investments

Mechanism: spillover model			
Dependent variable:	Δ Desulf expenditure	Δ Dust collect expenditure	Δ Wastewater treatment expenditure
Δ OECD export			
Agricultural	0.006	-0.001	0.008**
	(0.009)	(0.003)	(0.004)
Industrial	0.024**	0.004*	0.006*
	(0.010)	(0.002)	(0.003)
Δ Production	0.075***	0.051***	0.048***
	(0.017)	(0.006)	(0.008)
Observations	8,506	45,135	54,593

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The units for pollution abatement expenditures are K yuan.

Table 7: Summary of the coefficients of firms' pollution abatement investments

	c_k (industry mean)	z_k (industry mean)	$c_k + o_k$ (sample mean)
Pollution treatment type			
Desulfurization	0.075	0.024	0.082
Dust collection	0.051	0.004	0.052
Wastewater treatment	0.048	0.006	0.050

Table 8: The mechanism of the convergence of environment protection stringency

Mechanism: convergence						
Dependent variable: treatment ratio	SO2	Dust	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen
Weighted OECD export						
Agricultural	-0.00003	0.001	0.001	0.0004	-0.001	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Industrial	0.001***	0.001***	0.002***	0.002***	0.002***	0.002***
	(0.0003)	(0.0004)	(0.0003)	(0.0004)	(0.0003)	(0.0004)
Firm size	0.019***	0.017***	0.024***	0.020***	0.022***	0.018***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Years since operation	-0.051***	-0.058***	-0.022**	-0.001	-0.030***	-0.010
	(0.007)	(0.011)	(0.010)	(0.012)	(0.010)	(0.012)
Years since operation^2	0.010***	0.012***	0.002	-0.002	0.004*	-0.0003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Ownership						
Collective	-0.061***	-0.021*	-0.049***	-0.040***	-0.050***	-0.039***
	(0.008)	(0.012)	(0.011)	(0.012)	(0.011)	(0.013)
Private	-0.064***	-0.045***	-0.054***	-0.041***	-0.051***	-0.035***
	(0.005)	(0.008)	(0.006)	(0.007)	(0.006)	(0.007)
HK, MO, and TW	-0.046***	-0.026**	-0.012	-0.003	-0.033***	-0.018*
	(0.007)	(0.010)	(0.008)	(0.009)	(0.008)	(0.010)
Foreign	-0.066***	-0.003	0.006	-0.003	-0.016**	-0.020**
	(0.006)	(0.010)	(0.008)	(0.009)	(0.008)	(0.009)
Others	-0.037***	-0.017	-0.026***	-0.003	-0.031***	-0.006
	(0.007)	(0.011)	(0.010)	(0.011)	(0.010)	(0.011)
Industry fixed effects	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X
Drainage basin fixed effects					X	X
Observations	71,130	47,731	85,243	60,326	80,180	55,990
R^2	0.208	0.153	0.133	0.102	0.159	0.136

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The weighted OECD export values are constructed according to the 2012 Yale Environmental Performance Index (EPI). Columns 5-6 are the tests with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment.

Table 9: Baseline regression results: exports measured by ratio

By ratio						
Dependent variable: treatment ratio	SO2	Dust	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen
OECD export ratio						
Agricultural	-0.009	0.014	0.033***	0.022*	0.005	-0.011
	(0.008)	(0.013)	(0.012)	(0.013)	(0.014)	(0.015)
Industrial	0.008*	0.032***	0.030***	0.025***	0.025***	0.016**
	(0.004)	(0.007)	(0.006)	(0.006)	(0.006)	(0.007)
Firm size	0.018***	0.021***	0.029***	0.026***	0.028***	0.023***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Years since operation	-0.054***	-0.056***	-0.037***	-0.018**	-0.043***	-0.024**
	(0.006)	(0.009)	(0.008)	(0.009)	(0.008)	(0.009)
Years since operation^2	0.010***	0.012***	0.005***	0.002	0.007***	0.003
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Ownership						
Collective	-0.058***	-0.040***	-0.059***	-0.041***	-0.058***	-0.039***
	(0.007)	(0.011)	(0.010)	(0.011)	(0.010)	(0.012)
Private	-0.064***	-0.057***	-0.060***	-0.046***	-0.056***	-0.041***
	(0.004)	(0.007)	(0.006)	(0.007)	(0.006)	(0.007)
HK, MO, and TW	-0.044***	-0.034***	-0.002	0.004	-0.026***	-0.014
	(0.006)	(0.009)	(0.007)	(0.009)	(0.008)	(0.009)
Foreign	-0.058***	-0.007	0.020***	0.005	-0.002	-0.013
	(0.006)	(0.009)	(0.007)	(0.008)	(0.007)	(0.008)
Others	-0.038***	-0.017*	-0.025***	-0.004	-0.027***	-0.006
	(0.006)	(0.010)	(0.009)	(0.010)	(0.009)	(0.010)
Industry fixed effects	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X
Drainage basin fixed effects					X	X
Observations	105,780	70,881	124,332	87,008	117,401	81,076
R^2	0.183	0.156	0.137	0.098	0.165	0.130

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. Columns 5-6 are the tests with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment.

Table 10: Robustness tests with corporate performance controlled

Dependent variable: treatment ratio	SO2	Dust	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen
Panel A: full sample						
OECD export						
Agricultural	0.0003	0.001	0.003^{***}	0.002^{**}	0.001	-0.001
	(0.0005)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Industrial	0.001^{***}	0.001^{***}	0.002^{***}	0.002^{***}	0.002^{***}	0.002^{***}
	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Profitability*Management efficiency	-0.001	-0.004	-0.003	0.0002	-0.004^{**}	0.001
	(0.001)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
Profitability	-0.0001^{***}	0.0002	-0.0001	0.0001	-0.0001	0.00001
	(0.00003)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Management efficiency	-0.0001	0.00004	0.0001	-0.001^{**}	0.0002	-0.001^{**}
	(0.0001)	(0.0001)	(0.0003)	(0.0004)	(0.0003)	(0.0004)
Panel B: PSM sample						
OECD export						
Agricultural	0.0001	0.0003	0.001	0.0005	-0.001	-0.001^{*}
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Industrial	0.001^{***}	0.002^{***}	0.002^{***}	0.003^{***}	0.002^{***}	0.002^{***}
	(0.0002)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Profitability*Management efficiency	0.001	-0.004	-0.006	-0.004	-0.006	-0.004
	(0.002)	(0.008)	(0.004)	(0.007)	(0.004)	(0.007)
Profitability	-0.012	-0.030^{*}	-0.019^{*}	-0.025^{*}	-0.014	-0.014
	(0.008)	(0.018)	(0.011)	(0.013)	(0.011)	(0.013)
Management efficiency	-0.001	0.00003	0.0002	-0.001	0.0003	-0.001
	(0.0004)	(0.001)	(0.0003)	(0.001)	(0.0003)	(0.001)
Corporate structures	X	X	X	X	X	X
Ownership structures	X	X	X	X	X	X
Industry fixed effects	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X
Drainage basin fixed effects					X	X

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. Panel B in the results present the tests with PSM samples. The matching variables are firm-level corporate factors, including the industry, employee number, and sale performance. The matching method is the nearest neighbor matching. Columns 5-6 are the tests with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment. Corporate structure variables include firm size, years since the operation, and their squares.

Table 11: VAT rebate robustness tests

VAT rebate Dependent variable: treatment ratio	SO2	Dust	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen
OECD export * VAT rebate						
Agricultural * VAT rebate	-0.0001**	0.0002**	0.0001	0.0001	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Industrial * VAT rebate	0.00000*	0.00000	-0.00000***	-0.00000	-0.00000**	-0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Industry pol. int. * VAT rebate						
SO2 pol. int. * VAT rebate	-0.00000					
	(0.00000)					
Dust pol. int. * VAT rebate		-0.00000				
		(0.00000)				
COD pol. int. * VAT rebate			-0.00000		-0.00000	
			(0.00000)		(0.00000)	
Ammoniacal nitrogen pol. int. * VAT rebate				0.00000		-0.00000
				(0.00000)		(0.00000)
OECD export						
Agricultural	0.001	0.00004	0.001	-0.0001	-0.001	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Industrial	0.001***	0.001***	0.002***	0.002***	0.002***	0.002***
	(0.0002)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0004)
VAT rebate	-0.00000***	-0.00002	0.00000***	0.00000	0.00000	0.00000
	(0.00000)	(0.00002)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Industry pol. int.						
SO2 pol. int.	0.00001					
	(0.00001)					
Dust pol. int.		-0.00000				
		(0.00000)				
COD pol. int.			-0.00003**		-0.00003**	
			(0.00001)		(0.00001)	
Ammoniacal nitrogen pol. int.				-0.001		-0.0004
				(0.001)		(0.001)
Corporate structures	X	X	X	X	X	X
Ownership structures	X	X	X	X	X	X
Industry fixed effects	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X
Drainage basin fixed effects					X	X
Observations	67,066	45,404	81,513	58,241	76,623	54,046
R^2	0.165	0.144	0.132	0.102	0.159	0.136

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The VAT rebate rates are calculated according to the rebates firms received in that year divided by its total production values. Columns 5-6 are the tests with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment. Corporate structure variables include firm size, years since the operation, and their squares.

Table 12: Robustness test on re-export and pollution treatment

Re-export						
Dependent variable: treatment ratio	SO2	Dust	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen
OECD export						
Agricultural	-0.002**	0.003***	0.003***	0.002*	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Industrial	0.001**	0.001	0.002***	0.001	0.002***	0.0003
	(0.0004)	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.001)
Firm size	0.017***	0.020***	0.028***	0.019***	0.025***	0.016***
	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Years since operation	-0.069***	-0.022	0.012	0.045**	0.007	0.042**
	(0.016)	(0.024)	(0.017)	(0.020)	(0.018)	(0.020)
Years since operation^2	0.015***	0.005	-0.002	-0.009**	-0.0003	-0.008*
	(0.003)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Ownership						
Collective	-0.058***	-0.021	0.001	0.018	-0.004	0.027
	(0.017)	(0.022)	(0.020)	(0.023)	(0.021)	(0.024)
Private	-0.049***	-0.063***	-0.014	-0.006	-0.005	0.007
	(0.011)	(0.015)	(0.011)	(0.013)	(0.012)	(0.014)
HK, MO, and TW	-0.030**	-0.032*	0.020	0.024*	0.004	0.015
	(0.013)	(0.017)	(0.013)	(0.014)	(0.013)	(0.015)
Foreign	-0.054***	-0.012	0.027**	0.017	0.004	0.002
	(0.012)	(0.017)	(0.012)	(0.014)	(0.013)	(0.014)
Others	-0.007	-0.026	0.009	0.046**	0.007	0.049**
	(0.017)	(0.019)	(0.016)	(0.018)	(0.017)	(0.019)
Industry fixed effects	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X
Drainage basin fixed effects					X	X
Observations	21,042	13,981	32,932	26,537	29,566	23,563
R^2	0.103	0.116	0.143	0.089	0.179	0.128

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. Re-export goods are defined according to the Chinese customs HS codes. Columns 5-6 are the tests with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment.

Figure A1: The distribution of dust production among firms

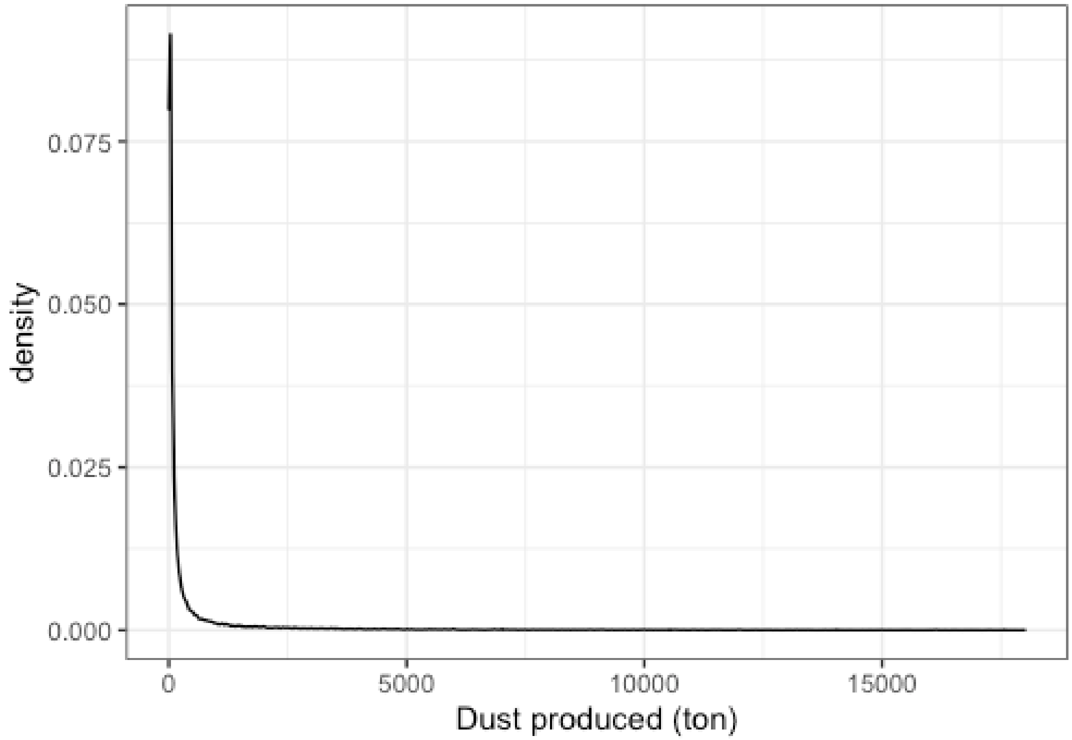

Table A1: OECD exports and dust treatment in different quantiles

Dust pollution samples				
Dependent variable:	Dust treatment ratio			
	Full samples	Bottom 10%	Middle 80%	Top 10%
OECD export				
Agricultural	0.001*	0.002	0.001	0.002**
	(0.001)	(0.003)	(0.001)	(0.001)
Industrial	0.001*	0.002	0.001***	-0.002***
	(0.0003)	(0.001)	(0.0003)	(0.001)
Firm size	0.025***	0.008	0.020***	0.002
	(0.002)	(0.007)	(0.002)	(0.002)
Years since operation	-0.057***	-0.008	-0.056***	0.016
	(0.008)	(0.031)	(0.009)	(0.012)
Years since operation^2	0.013***	-0.002	0.012***	-0.001
	(0.002)	(0.007)	(0.002)	(0.002)
Ownership				
Collective	-0.043***	0.055	-0.039***	-0.009
	(0.010)	(0.038)	(0.011)	(0.008)
Private	-0.071***	0.004	-0.057***	-0.022***
	(0.006)	(0.028)	(0.007)	(0.005)
HK, MO, and TW	-0.046***	0.011	-0.034***	-0.013
	(0.008)	(0.037)	(0.009)	(0.009)
Foreign	-0.024***	-0.010	-0.008	-0.020
	(0.009)	(0.037)	(0.009)	(0.013)
Others	-0.025***	0.034	-0.017*	-0.023**
	(0.009)	(0.038)	(0.010)	(0.011)
Industry fixed effects	X	X	X	X
Time fixed effects	X	X	X	X
Province fixed effects	X	X	X	X
Observations	88,320	8,607	70,881	8,832
R^2	0.148	0.202	0.155	0.191

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The quantiles of dust emissions are defined according to firms' annual dust emission amount.

Table A2: Placebo tests regarding non-OECD exports

Non-OECD exports						
Dependent variable: treatment ratio	SO2	Dust	COD	Ammoniacal nitrogen	COD	Ammoniacal nitrogen
Non-OECD export*Non-OECD/OECD ratio						
Agricultural*Non-OECD/OECD ratio	0.369**	-0.022	-0.812***	-0.788***	-0.725***	-0.495*
	(0.146)	(0.251)	(0.218)	(0.249)	(0.243)	(0.286)
Industrial*Non-OECD/OECD ratio	-0.742**	-0.011	-0.267	-0.191	-0.202	-0.115
	(0.350)	(0.290)	(0.234)	(0.244)	(0.255)	(0.248)
Non-OECD export						
Agricultural	-0.371**	0.019	0.825***	0.796***	0.737***	0.501*
	(0.147)	(0.255)	(0.220)	(0.252)	(0.245)	(0.288)
Industrial	0.749**	0.011	0.274	0.199	0.209	0.123
	(0.350)	(0.290)	(0.235)	(0.244)	(0.255)	(0.248)
Agricultural non-OECD/OECD ratio	0.039	0.030	-0.152***	-0.088	-0.139**	-0.062
	(0.039)	(0.067)	(0.054)	(0.056)	(0.062)	(0.066)
Industrial non-OECD/OECD ratio	-0.070***	0.001	-0.075***	-0.080***	-0.074***	-0.075***
	(0.015)	(0.024)	(0.017)	(0.020)	(0.018)	(0.021)
Firm size	0.014***	0.021***	0.025***	0.015***	0.022***	0.011***
	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Years since operation	-0.070***	-0.021	0.012	0.044**	0.007	0.040**
	(0.016)	(0.024)	(0.017)	(0.019)	(0.018)	(0.020)
Years since operation^2	0.015***	0.005	-0.002	-0.009**	-0.0002	-0.008*
	(0.003)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Ownership						
Collective	-0.055***	-0.021	0.002	0.019	-0.003	0.028
	(0.017)	(0.022)	(0.020)	(0.023)	(0.021)	(0.024)
Private	-0.046***	-0.064***	-0.012	-0.004	-0.002	0.010
	(0.011)	(0.015)	(0.011)	(0.013)	(0.012)	(0.014)
HK, MO, and TW	-0.029**	-0.032*	0.024*	0.025*	0.006	0.016
	(0.013)	(0.017)	(0.013)	(0.014)	(0.013)	(0.015)
Foreign	-0.053***	-0.010	0.030**	0.018	0.006	0.002
	(0.012)	(0.017)	(0.012)	(0.014)	(0.012)	(0.014)
Others	-0.006	-0.026	0.011	0.047***	0.009	0.050***
	(0.017)	(0.019)	(0.016)	(0.018)	(0.017)	(0.019)
Industry fixed effects	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X
Drainage basin fixed effects					X	X
Observations	21,042	13,981	32,932	26,537	29,566	23,563
R^2	0.107	0.116	0.145	0.092	0.180	0.131

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. Columns 5-6 are the tests with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment.

Table A3: State-Owned Enterprises pollution treatment and cost robustness tests

SOE cost and pollution						
Dependent variable:	Cost / Revenue					
Pollution treatment ratio * TCZ						
SO2 treatment ratio * TCZ	0.047*					
	(0.026)					
dust treatment ratio * TCZ		0.073**				
		(0.031)				
COD treatment ratio * TCZ			0.034*		0.029	
			(0.021)		(0.022)	
Ammoniacal nitrogen treatment ratio * TCZ				0.051**		0.050**
				(0.020)		(0.022)
Pollution treatment ratio						
SO2 treatment ratio	-0.044**					
	(0.017)					
dust treatment ratio		-0.011				
		(0.025)				
COD treatment ratio			-0.034**		-0.025*	
			(0.013)		(0.014)	
Ammoniacal nitrogen treatment ratio				-0.046***		-0.042**
				(0.017)		(0.018)
Two Control Zone	0.018*	-0.021	0.009	-0.002	0.020	0.004
	(0.009)	(0.025)	(0.012)	(0.016)	(0.014)	(0.019)
Firm size	-0.005	-0.004	-0.002	0.002	-0.001	0.002
	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
Years since operation	0.021	0.015	-0.005	-0.035	0.004	-0.028
	(0.017)	(0.021)	(0.018)	(0.023)	(0.018)	(0.024)
Years since operation^2	-0.005	-0.005	-0.002	0.002	-0.004	0.0003
	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
Industry fixed effects	X	X	X	X	X	X
Time fixed effects	X	X	X	X	X	X
Province fixed effects	X	X	X	X	X	X
Drainage basin fixed effects					X	X
Observations	4,200	2,213	4,496	2,987	4,298	2,834
R^2	0.217	0.352	0.208	0.175	0.228	0.192

Note: Standard errors in brackets and errors are clustered at the firm level. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. Columns 5-6 are the tests with drainage basin fixed effects controlled. The drainage basin dummy variables are according to the 2018 Coding Rules of Water Bodies for China's Surface-water Environment. Two Control Zone(TCZ) is a dummy variable. It equals 1 if the firm locates in the policy implementing region, which consisted of 368 cities in total and vice versa.