Cleaner by Association: How Trade with Developed Countries Improves Environmental Performance — Firm-Level Evidence from China

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Abstract

This paper examines whether trade with developed countries—where environmental standards are stricter and consumer awareness is higher—improves the environmental performance of export-oriented firms in China. We first develop a theoretical model tailored to export-driven firms, showing how exporting to environmentally stringent markets incentivizes greater pollution abatement efforts. Using matched firm-level environmental survey data and trade records, we analyze how export activity affects firms across four dimensions: pollution treatment ratios, energy and resource use, pollution intensities, and pollution-control expenditures. We further explore the mechanisms behind these effects, emphasizing abatement investments and the convergence of exporters' environmental practices with those of developed trading partners. The findings highlight positive environmental spillovers from trade with developed nations, offering broader implications for sustainable growth in developing economies amid shifting global value chains.

JEL Classification Codes: Q56, F18, O13

Keywords: Corporate Environmental Performance, Pollution Abatement, International Trade, Environmental Standards

Highlights

- We find that exportation to developed countries with stricter environmental regulations promotes firms' environmental performance in China
- A theoretical framework on pollution abatement for export-driven firms is developed
- A wide range of pollution abatement indicators is adopted, and export types are systematically distinguished
- We examine the mechanisms through spillover effects on pollution abatement investments and the convergence of environmental standards.

1 Introduction

Global manufacturing and supply chains increasingly connect developed and developing economies through trade, generating complex effects on developing countries that primarily produce labor-intensive goods. This paper examines how trade with developed countries—expected to have higher environmental standards—affects the environmental performance of firms in manufacturing-based economies, with a focus on pollution abatement investment and efficiency in China.

As the world's largest exporter and a key trading partner for both developed and developing nations, China illustrates both the economic benefits and environmental costs associated with the rapid expansion of international trade.[1] While trade brings valuable capital to developing countries, it also poses significant environmental challenges, aligning with the pollution haven hypothesis.[2] Empirical studies present mixed evidence regarding the pollution haven hypothesis in the Chinese context.(Dean et al., 2009; Cai et al., 2016; Yang et al., 2018) While increased exports inevitably lead to greater industrial pollution, the potential benefits of trade with environmentally stringent economies at the firm level remain underexplored. Stricter environmental regulations in developed countries may encourage domestic exporters to adopt cleaner production practices, mitigating some of the negative environmental consequences of trade.

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, trading partner countries enforce higher environmental standards for both domestically produced goods and imports (Bastiaens & Postnikov, 2017). Second, consumers in developed countries exhibit greater environmental awareness, which places pressure on importers and, in turn, raises environmental requirements for exporters (such as Chinese firms)(Copeland & Taylor, 1994; Antweiler et al., 2001). This hypothesis suggests that while total pollution in developing countries may rise due to increased economic production, pollution concentration could decline. This reduction may occur as exporters in these countries face market pressures and competition, driving them to adopt cleaner production methods—ultimately benefiting the environment in the long run.

The existing literature largely follows the framework proposed by Grossman & Krueger (1991, 1995),

[1] China's export value reached $\$3,513,237$ million in 2023. Source: The World Bank.

[2] The pollution haven hypothesis suggests that firms in developed countries with stricter environmental regulations may shift production to nations with more lenient policies. See Cole (2004), Copeland & Taylor (2004) and Kellenberg (2009).

which attributes pollution levels to three key effects: scale, composition, and technique. However, most following studies assess the environmental impact of trade from a macro perspective, typically at the country or city level (Grossman & Krueger, 1991; Prakash & Potoski, 2006; Frankel & Rose, 2005), or fail to fully account for the heterogeneity in firms' export behaviors (Antweiler et al., 2001; Jiang et al., 2014). Moreover, while the scale, composition, and technique effects may be interrelated, they do not necessarily capture firms' investments in pollution abatement or their efficiency in doing so. As such, the specific types of trade and the underlying mechanisms shaping exporters' environmental impact in developing countries warrant further investigation.

This paper addresses this gap by analyzing the relationship between a comprehensive set of environmental performance indicators and firms' detailed export 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 (NH4-N)) 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 aim to disentangle potential confounding factors that could bias the estimation results, focusing on both firm-level and policy-level factors. 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.

2 Literature Review

There is extensive literature on the relationship between international trade and environmental performance across various dimensions, primarily examining pollution production and transfer at the national or industry level. However, research on how international trade affects firms' environmental performance during production, particularly in developing countries that engage in exporting, remains more limited. Our hypothesis is supported by theoretical work such as Forslid et al. (2018), who propose a model in which firms engaged in export activities encounter greater opportunities and competition in international markets. Although the evidence is primarily based on developed countries, the model suggests that such firms adopt more efficient production methods and invest more in pollution abatement.

At the national and industry level, studies such as Copeland & Taylor (1994) and Antweiler et al. (2001) use open-economy macro models with firm-level production foundations to demonstrate how trade between developed (North) and developing (South) countries can promote pollution-reducing techniques and shift national output composition. This offers an alternative pathway to environmental improvements beyond economic growth. Firms in international markets face stricter environmental regulations and higher demand for sustainable products. Exporters adopting green production gain a competitive edge, driving further innovation (Antweiler et al., 2001) . However, such literature does not adequately address whether exporting firms in developing countries face different environmental pressures from trade partners compared to domestically focused firms. Moreover, pollution control requirements vary significantly by industry, firm size, and pollutant type, leading to different levels of investment. Regional policies—such as those based on administrative boundaries or drainage basins—further influence firm behavior (Liu et al., 2017). These complexities cannot be fully captured by existing theoretical models, underscoring the need for empirical analysis.

Although empirical evidence on whether and how international trade affects the environmental performance of exporting firms in developing countries during production is limited, numerous empirical studies have found broad positive impacts of international and regional trade on various aspects of the environment. 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 a production perspective, export markets often push firms to operate more efficiently and competitively. This pressure can drive the adoption of cleaner, more efficient production techniques as firms balance profitability with international standards. Porter & Linde (1995) argue that environmental improvements can reduce costs and enhance global competitiveness, though they do not provide direct evidence linking innovation specifically to environmental protection. Exporting firms may therefore develop innovations that benefit both the environment and economic performance.

Brunnermeier & Cohen (2003) find that exposure to international markets can encourage U.S. firms to improve environmental practices due to competitive pressures. However, cross-country evidence suggests that increased export activity may worsen environmental degradation, as firms prioritize profit maximization and production efficiency over sustainability (Copeland & Taylor, 2004).

Regarding pollution in industrial production, Jiang et al. (2014) examine its determinants in China. They find that foreign-owned and publicly listed domestic firms, firms in regions with weaker local protectionism, those under stronger property rights protection, and firms in industries with high absolute export values tend to have lower pollutant emissions.

3 Theoretical Framework

In this section, we develop a theoretical model to explain the mechanism behind our hypothesis: how trading with countries that have higher environmental standards and awareness can incentivize exporting firms to enhance their pollution abatement efforts. This model serves as the foundation for our empirical specification, providing intuition about the key factors and their expected influences.

Our approach is primarily inspired by the production and pollution abatement framework of Antweiler et al. (2001), while integrating the setting of Grossman & Krueger (1995) and the exporter production model of Melitz (2003). The framework assumes a relatively open economy with minimal trade frictions.

Consider an open economy consisting of N nations. Among them, one country serves as the main producer, supplying goods to both its domestic market and international markets. The remaining $N-1$ nations are divided into two groups: green nations, which are more economically developed and enforce stricter environmental regulations, and non-green nations, which are less developed and have more lenient environmental policies. The international market is assumed to be perfectly competitive, meaning the production decisions of any single firm do not affect market prices.

We focus on a representative producer in the main exporting country. This producer generates a total output of Y, allocating D units for domestic consumption and E units for export: $Y = D + E$.

The firm must adhere to domestic environmental standards while exporting to both developed countries with stricter regulations and higher environmental awareness and less developed countries with lower standards. Environmental awareness varies within high-standard countries and is generally linked to stronger economic indicators, which allows these markets to pay higher prices for products. In contrast, countries with weaker economies tend to have lower environmental standards and awareness. However, since the firm already meets domestic environmental requirements, it can also satisfy the import standards of these lower-standard markets. For analytical purposes, exports to such countries are treated similarly to the domestic market, as trade frictions—being highly uncertain and influenced by political factors—are not considered at this stage.

Production relies on two inputs: L and K. The unit costs of these inputs are w for L and r for K. The total production costs for the domestic and export sectors are denoted as $c^D(w, r)$ and $c^E(w, r)$, respectively. The product is homogeneous, meaning there is no differentiation in quality between domestic and exported goods.

For this analysis, the firm's production capacity is assumed to be fixed. Let I^E be the set of high-environmental-standard importing countries.

$$Y = \int_{i \in I^E} dE_i + D \tag{1}$$

Therefore, the total production cost at full capacity remains fixed. The firm's decision focuses on allocating output between the two markets.

Pollution generated during production is denoted as Z, with sector-specific emissions Z^D (from domestic production) and Z^E (from exports). Pollution can be reduced through abatement, which incurs costs and requires the same inputs (L and K). Therefore, abatement can be treated as an integral part of the production process. The net domestic and export production after abatement is:

$$D^N = D(1 - \theta^D) \tag{2}$$

$$E^N = E(1 - \theta^E) \tag{3}$$

where $\theta_D = D^A/D$ and $\theta_E = E^A/E$ represent the abatement intensity in each sector. Since we assume the products sold in the foreign and domestic markets are homogeneous, it is reasonable to expect that firms treat pollution abatement requirements similarly across both production lines. This is because the same products can be allocated to either market. Consequently, the input factors—L and K—are assumed to be used in the same proportion for production targeting both markets.

Since pollution is assumed to be proportional to output and abatement exhibits constant returns to scale, emissions can be expressed as:

$$Z^D = e(\theta^D)D \tag{4}$$

$$Z^E = e(\theta^E)E \tag{5}$$

where $e(\theta)$ represents emissions per unit of output, decreasing with higher abatement efforts (θ). We assume that abatement is always beneficial ($e'(\theta) = -\infty$) but subject to physical constraints ($e(1) > 0$).

Importantly, firms do not differentiate between production lines for domestic and foreign markets, meaning abatement intensity is uniform across both:

$$\theta = \theta^D = \theta^E = \frac{D^A}{D} = \frac{E^A}{E} \tag{6}$$

$$Z = Z^D + Z^E = e(\theta)(D + E) \tag{7}$$

In countries with stricter environmental regulations, pollution generates disutility, which manifests as an environmental tax on producers. While an importing country typically cannot directly tax emissions from foreign firms, it can impose penalties through regulatory measures or consumer preferences.

The exporting firm's profit is given by its revenue minus factor costs, abatement expenses, and environmental penalties:

$$\Pi^E = \int_{i \in I^E} p_i^N dE_i - wL^E - rK^E \tag{8}$$

where the net producer price for destination i is:

$$p_i^N = p_i(1 - \theta) - \tau_i e(\theta) \tag{9}$$

Here, τ_i represents the "environmental tax" imposed by the importing country.

For the domestic and lower-standard overseas markets, the price is set at a fixed domestic price. Consequently, the profit in this segment can be expressed as:

$$\begin{aligned} \Pi^D &= p_D^N D - wL_D - rK_D \\ &= [p_D(1 - \theta) - \tau_D e(\theta)]D - wL^D - rK^D \end{aligned} \tag{10}$$

The market prices satisfy $\forall i \in I^E, \quad p_i > p_D$. The total profit is given by:

$$\Pi = \Pi^E + \Pi^D \tag{11}$$

Due to constant returns to scale, the output of an individual firm is indeterminate. However, for any given level of output, the first-order condition for the choice of θ implies:

$$e'(\theta) = -\frac{\int_{i \in I^E} p_i dE_i + p_D D}{\int_{i \in I^E} \tau_i dE_i + \tau_D D} \tag{12}$$

Hence, the pollution intensity function, which depends on production and price levels, can be expressed as $e(\theta) = e(\theta \mid Y, \mathbf{p})$.

By incorporating the previously stated assumption regarding the functional form of $e(\theta)$, we derive:

$$\frac{d\theta}{d\tau_i} > 0 \tag{13}$$

The monotonicity of the $e()$ function implies that, once the output structure is determined, there is a unique pollution abatement level that maximizes total profit. Consequently, if any market has higher stricter environmental standards, the firm will increase its pollution abatement efforts.

Next, we examine the supply and demand for pollution from the firm's perspective. We begin by noting that a firm's demand for pollution is implicitly defined by Equation 7. To express this demand in a form more suitable for empirical analysis, we define the economy's scale as the value of output at base-year world prices. Using standard notation, we denote this measure of scale, S, as

$$S = \int_{i \in I^E} p_i^0 dE_i + p_D^0 D \tag{14}$$

For analytical convenience, we normalize the domestic market price to 1, allowing us to express scale as $S = \int_{i \in I^E} p_i^0 dE_i + D$. This specification allows us to directly link pollution abatement efficiency on the basis of production scale, similar to Antweiler et al. (2001) and Cherniwchan et al. (2017). We continue to denote θ as the proportion of production allocated to pollution abatement. Consequently, pollution intensity can be expressed as $e(\theta \mid Y, \mathbf{p}) = e(\theta S)$.

From an empirical perspective, particularly for manufacturers, it is more practical to analyze pollution abatement efforts or efficiency rather than pollution intensity. We define pollution abatement efficiency, $a(\theta)$, as negatively correlated with pollution intensity. Assuming pollution abatement efficiency follows a Cobb-Douglas functional form, we specify

$$a(\theta) = A\theta^{\alpha} S^{\beta} \tag{15}$$

where A represents production techniques, capturing the efficiency of converting resources into pollution abatement.

Log-linearizing this function yields

$$\hat{a}(\theta) = \hat{A} + \alpha\hat{\theta} + \beta\hat{S} \tag{16}$$

This decomposition separates pollution abatement efficiency into three components: (1) pollution abatement techniques, which relate to production efficiency, abatement capabilities, and pollution types; (2) the proportion of investment in pollution abatement; and (3) firm-specific characteristics related to production scale.

Using the results from Equation 12, we can further decompose the pollution abatement term. The composition of pollution abatement investment can be expressed as a function of $\theta = \theta(\kappa, \tau)$, where κ denotes the proportion of exports directed to partners with stricter environmental standards. Specifically, we define $\kappa S = \int_{i \in I^E} p_i^0 dE_i$.

Thus, the composition effect is given by

$$\hat{\theta} = \varepsilon_\kappa \hat{\kappa} + \varepsilon'_\tau \hat{\tau} \tag{17}$$

Substituting this into our earlier equation, we obtain the final expression:

$$\hat{a}(\theta) = \hat{A} + \alpha\varepsilon_\kappa \hat{\kappa} + \alpha\varepsilon'_\tau \hat{\tau} + \beta\hat{S} \tag{18}$$

This equation has significant empirical implications, making it well-suited for a reduced-form estimation strategy. It suggests that pollution abatement efficiency can be expressed in a linear form, incorporating export activities and firm characteristics, including production.

Next, we extend the model to illustrate firm heterogeneity in production. Following Antweiler et al. (2001) and Copeland & Taylor (2004), we assume that each firm produces two types of output, denoted by X^K and X^L, using capital (K) and labor (L) as inputs. To generalize across industries, we simplify production into two representative types: one that is labor-intensive and polluting, and another that is capital-intensive and clean.

We assume that the composition of products in the domestic and export markets is the same, implying consistency in product mix across both markets. Let φ denote the share of production that is labor-intensive and polluting. As a result, only this portion of output is subject to environmental penalties.

Resources are allocated between production for export and for the domestic market. Since only the polluting share φ generates emissions, the firm's profit function is given by:

$$\Pi = \int_{i \in I^E} [p_i(1-\theta) - \tau_i \varphi e(\theta)] \, dE_i + [p_D(1-\theta) - \tau_D \varphi e(\theta)] \, D - wL - rK \tag{19}$$

The earlier result still holds: stricter environmental standards in export markets lead to greater pollution abatement by the firm. This follows from the first-order condition for pollution abatement investment:

$$e'(\theta) = -\frac{\int_{i \in I^E} p_i \, dE_i + p_D D}{\int_{i \in I^E} \tau_i \varphi \, dE_i + \tau_D \varphi D} \tag{20}$$

Given this structure, we can decompose the pollution abatement efficiency specification accordingly. Assuming the proportion of exports to stricter partners is fixed, firms only need to abate emissions from the polluting portion of production, φS. We then model pollution abatement effort as a function of capital intensity, regulatory stringency, and the share of dirty production:

$$\theta = \theta(\kappa, \boldsymbol{\tau}, \varphi) = \varepsilon_\kappa \hat{\kappa} + \boldsymbol{\varepsilon}_\tau' \hat{\boldsymbol{\tau}} + \varepsilon_\varphi \hat{\varphi} \tag{21}$$

Note that ε_κ and $\boldsymbol{\varepsilon}_\tau$ take different values than those in Equation 18; we use the same notation here to avoid redundancy, as the parameter definitions remain consistent. This yields the following expression for pollution abatement efficiency:

$$\hat{a}(\theta) = \hat{A} + \alpha \varepsilon_\kappa \hat{\kappa} + \alpha \boldsymbol{\varepsilon}_\tau' \hat{\boldsymbol{\tau}} + \beta \hat{S} + \gamma \hat{\varphi} \tag{22}$$

where $\gamma = \alpha \varepsilon_\varphi + \beta$.

This framework captures the heterogeneity in production structures across industries, even within a representative agent setup. It allows us to incorporate industry-level variation into the empirical specification while maintaining tractability in the theoretical model.

4 Data and Summary Statistics

This section outlines the empirical data used to translate the theoretical models discussed above into testable hypotheses. We assembled a matched dataset from multiple sources that not only captures the scale, composition, and technique effects emphasized by Grossman & Krueger (1991, 1995) and Copeland & Taylor (1994, 2004), but also offers detailed insights into firm-level pollution abatement investments, efforts, and efficiency. To bridge macro-level frameworks with firm-level behavior—and to illuminate the mechanisms behind our hypotheses—we draw on rich data covering corporate structures, production processes, and environmental performance from regulatory and monitoring sources.

Focusing on pollution abatement investment, efforts, and efficiency as the key drivers of pollution outcomes, we reinterpret the traditional three effects in this context. The scale effect is examined not only through firm size but also through additional structural characteristics that influence environmental outcomes. The composition effect, which is central to our analysis, enables a detailed look at production processes, including the generation of pollution and the adoption of abatement measures. This captures the balance between "dirty" and "clean" outputs. Lastly, the technique effect is reflected in two dimensions: production efficiency and the effectiveness of pollution control strategies.

4.1 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 NH4-N; 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.

To supplement the limited corporate structure information in the Pollution Survey data, we incorporate firm-level data from the China Industry Business Performance Database. Given the substantial variation in pollution generation and treatment practices across industries and production types, accounting for firm characteristics is essential to control for heterogeneity in production processes. The China Industry Business Performance Database provides detailed corporate information, including various asset categories, sales performance, revenue, profits, ownership structures, primary products, and industry classifications. However, the database only covers relatively large firms with assets exceeding 5 million *yuan*. As a result, some smaller firms in the Pollution Survey cannot be matched, and our analysis is restricted to those firms for which sufficient corporate information is available.

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. We present the details of a novel fuzzy matching method that we devise to match these three datasets in Appendix A1.

4.2 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. Building on Stern & Common (2001)'s classification approach, this study compares firms exporting to OECD countries, those exporting only to non-OECD countries, and non-exporters, 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. We first 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 deciles based on each firm's total assets and number of employees, ranking them from smallest to largest. The two figures exhibit the percentages of total exports comprised by agricultural, industrial, and miscellaneous exports to OECD countries in each group.[3] 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 decile 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.

[3] The group classification aligns with the goods classification used in the customs data.

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 NH4-N. 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.

5 Empirical Specifications and Baseline Results

This section examines the impact of trade activities on firms' environmental protection using empirical specifications and presents the baseline results. The empirical framework translates theoretical mechanisms outlined previously, particularly focusing on how exporting to countries with stringent environmental regulations compels firms to enhance their pollution abatement efforts.

We evaluate firm-level environmental protection from three distinct dimensions: pollution treatment measures, the cleanliness of firms' energy and resource use, and the pollution intensity of production processes. This analysis seeks to identify the primary relationship between firms' environmental protection practices and their export activities, while also addressing potential heterogeneity across corporate structures, industrial characteristics, and geographic factors. We use Propensity Score Matching (PSM) to clearly disentangle the environmental effects of exporting to OECD countries from correlations arising from corporate characteristics and export behaviors.

5.1 Baseline Model Specifications

We begin by extending the theoretical framework in Equation 16 to empirically test the basic hypothesis: whether exporting to more developed countries prompts firms to increase their efforts in pollution control. Specifically, we examine the relationship between OECD export values and pollution treatment ratios, while accounting for heterogeneity in pollution treatment practices. We denote $\hat{\theta}$ as the behavioral response associated with exporting to OECD countries. This initial analysis serves to validate the theoretical model and lays the foundation for more detailed investigations into the effects of different exportation schemes.

5.1.1 Baseline Specifications Regarding Air and Water Pollution Treatment

We study two air pollutants, $SO2$ and dust emission, and two water pollutants, COD and NH4-N.[4] The economic specification for air pollution abatement exists as follows:

$$\text{Pollution control}^{p}_{i,j,k,t} = \alpha^{p} + \boldsymbol{\beta}^{p}_{1}\,\text{OECD export}_{i,j,k,t} + \boldsymbol{\beta}^{p}_{2}\mathbf{X}_{i,j,k,t} + \eta_j + \mu_k + \tau_t + \varepsilon_{i,j,k,t} \tag{23}$$

where *Pollution 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 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 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

[4] 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.

control test, we also introduce the fixed effects of geography. This specification appears below:

$$\text{Water pollution control}^p_{i,j,b,k,t} = \alpha^p + \boldsymbol{\beta}^p_1 \text{ OECD export}_{i,j,b,k,t} + \boldsymbol{\beta}^p_2 \mathbf{X}_{i,j,b,k,t} + \eta_j + \xi_b + \mu_k + \tau_t + \varepsilon_{i,j,b,k,t} \quad (24)$$

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.

5.1.2 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:

$$\text{Energy/Resource structures}^e_{i,j,k,t} = \alpha^e + \boldsymbol{\beta}^e_1 \text{ OECD export}_{i,j,k,t} + \boldsymbol{\beta}^e_2 \mathbf{X}_{i,j,k,t} + \eta_j + \mu_k + \tau_t + \varepsilon_{i,j,k,t} \quad (25)$$

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.

$$\text{Reclaimed water ratio}_{i,j,b,k,t} = \alpha^W + \boldsymbol{\beta}_1^W \text{ OECD export}_{i,j,b,k,t} + \boldsymbol{\beta}_2^W \mathbf{X}_{i,j,b,k,t} + \eta_j + \xi_b + \mu_k + \tau_t + \varepsilon_{i,j,b,k,t} \quad (26)$$

5.1.3 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.

$$\text{Pollution intensity}^p_{i,j,k,t} = \alpha^p + \boldsymbol{\beta}_1^p \text{ OECD export}_{i,j,k,t} + \boldsymbol{\beta}_2^p \mathbf{X}_{i,j,k,t} + \eta_j + \mu_k + \tau_t + \varepsilon_{i,j,k,t} \quad (27)$$

$$\text{Pollution intensity}^p_{i,j,b,k,t} = \alpha^p + \boldsymbol{\beta}_1^p \text{ OECD export}_{i,j,b,k,t} + \boldsymbol{\beta}_2^p \mathbf{X}_{i,j,b,k,t} + \eta_j + \xi_b + \mu_k + \tau_t + \varepsilon_{i,j,b,k,t} \quad (28)$$

5.2 Baseline Results on Environmental Protection and OECD Exportation

5.2.1 Post-production Pollution Treatment

This section presents the empirical results following the specifications in Section 5.1. In addition, to rule out the concern over the endogenous problem that 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.This helps alleviate concerns that export behaviors are merely driven by firm size or other 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.

However, the PSM matching slightly increases the standard errors of the coefficients associated with firm characteristics. This suggests that these characteristics are indeed related to export activity, although the effects remain marginal, as the significance levels do not change after matching. It is also important to note that the firms in the dataset are above the designated size, which means that size-related characteristics may play a limited role in constraining export participation for these firms.

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 NH4-N 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 NH4-N estimations show almost the same value except in the PSM group with no drainage basin fixed effects controlled for the impact on NH4-N, 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 NH4-N.

5.2.2 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 NH4-N 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.

5.2.3 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 NH4-N. 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.

6 Empirical Mechanism Analysis

In this section, we further investigate the causal relationship between export activity and environmental protection efforts by extending our baseline theoretical results with empirical analysis. While the baseline estimation offers an initial view of the correlation proposed in the theory, we deepen the analysis by examining the mechanisms through which exports to developed countries influence firms' environmental practices. Specifically, we explore how variations in environmental regulations and awareness across trading partners shape these dynamics. Our analysis proceeds from two perspectives. First, we examine the potential spillover effects of stringent environmental standards in developed countries on firms' investments in pollution control. Second, we assess the extent to which exporters align their environmental practices with the regulatory frameworks of their developed-country destinations, highlighting a potential convergence in environmental standards.

6.1 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:

$$
\begin{aligned}
I^P_{i,k,t} &= M^P_k + r_{i,k,t} \cdot y_{i,k,t} \\
&= M^P_k + (c^P_k + o^P_{i,k,t}) \cdot y_{i,k,t} \\
&= M^P_k + (c^P_k + z^P_k \cdot \frac{OECD_{i,k,t}}{y_{i,k,t}}) \cdot y_{i,k,t}
\end{aligned}
\tag{29}
$$

where $I^P_{i,k,t}$ stands for the investment in pollutant P control of firm i in industry in year t, and M^P_k 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^P_k 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, $c^P_k \cdot y_{i,k,t}$ 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 $o^P_{i,k,t}$ regarding the portion of production value, and the spillover portion $o^P_{i,k,t}$ 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^P_k.

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^P_k 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^P_k and z^P_k is in an industrial mean.

$$
\Delta I^P_{i,k,t} = c^P_k \cdot \Delta y_{i,k,t} + z^P_k \cdot \Delta OECD_{i,k,t} \tag{30}
$$

[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.

6.2 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:

$$\text{Weighted OECD export value}^{z}_{i,j,k,t} = \sum_{c=1}^{C} EPI_{c,t} \cdot \text{OECD export value}^{z}_{i,j,k,t} \tag{31}$$

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.

7 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.

7.1 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 NH4-N.

[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 NH4-N 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.

7.2 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. 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.

7.3 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. Moreover, most policies are implemented at the industry level rather than targeting a small number of specific firms.

The most direct method that the government can use to control trade activities is through import and export taxes (e.g. tariffs). 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 to reflect the mutual effects from the exportation and government regulations.[5] Following Eisenbarth (2017), we construct another interaction term of the VAT rebate rates and pollution intensities of $SO2$, COD, and NH4-N 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

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

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.

7.4 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 NH4-N, 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.

8 Conclusion

This paper contributes to the literature by investigating how international and regional trade influence environmental performance in developing countries, with a focus on exporting firms. We develop a theoretical model linking export behavior to environmental outcomes, positing that firms exporting to developed countries face stronger environmental pressures due to more stringent regulations and higher expectations from foreign consumers. Using detailed firm-level data from China (2011–2013), we empirically test this hypothesis by examining pollution treatment, resource use, emissions, and environmental control expenditures, matched with granular customs data on export destinations and product categories.

Our theoretical model predicts that trade with partners enforcing stricter environmental standards incentivizes firms to invest more in and improve the efficiency of pollution abatement. We formalize this relationship by deriving a theoretical expression that distinguishes the effects of export activity from inherent firm characteristics. The theoretical model also provides the foundation for our reduced-form empirical specifications, allowing us to isolate the effects of export exposure, regulatory stringency, and firm-level factors on environmental performance.

Our empirical strategy accounts for heterogeneity across industries, provinces, geographic conditions, and corporate structures to identify the specific role of trade with developed countries. We find that exports of industrial goods to developed countries are strongly associated with higher treatment rates across all four major pollutants. A 1% increase in exports to OECD countries is linked to at least a 1% increase in the treatment of $SO2$ and dust, and a 2% increase in the treatment of COD and NH4-N. However, trade does not significantly alter firms' energy structures, though OECD exporters tend to recycle more industrial water and use coal with lower sulfur content. In terms of emissions, these firms demonstrate cleaner air pollution outcomes, but we find no statistically significant differences in water pollution. Notably, a 1% increase in

OECD exports reduces $SO2$ and dust pollution density by 0.012 and 0.042 tons per 10 million *yuan*.

We further examine the underlying mechanisms through two empirical strategies: investment in pollution abatement and convergence in environmental practices between Chinese exporters and their developed-country trade partners. After controlling for industry-specific factors, we find that firms exporting to OECD countries invest 9.33%, 1.96%, and 4.17% more in desulfurization, dust collection, and wastewater treatment, respectively, than firms that do not. Additionally, we observe convergence in environmental performance, as measured by the Yale Environmental Performance Index (EPI), suggesting that exporters to more environmentally stringent countries adapt their practices accordingly. These findings provide indirect evidence that such firms face higher pressure to improve environmental performance.

To validate the robustness of our results, we conduct several checks. First, we replace absolute OECD export values with export intensity ratios to control for scale effects. To address endogeneity concerns, we show that observed improvements are not driven by superior firm characteristics such as profitability or managerial efficiency. We also rule out alternative explanations based on policy incentives by demonstrating that industry-level VAT policies do not explain firm-level pollution abatement. Lastly, we examine re-export activities as a placebo test, further supporting our hypothesis that environmental pressure arises from direct engagement with developed-country markets.

Our findings have important policy implications for environmental governance in developing countries. We show that trade with developed economies can generate positive environmental spillovers, as access to capital and markets with higher environmental standards compels firms to improve pollution control. These results support the idea that deeper integration with environmentally advanced trading partners can drive cleaner production, not merely greater production. Encouraging firms to engage with such partners may help raise environmental standards across industries, particularly in export-oriented economies. Although our analysis focuses on China, the conclusions are broadly applicable to other developing countries—especially in Southeast Asia—that are increasingly integrated into global value chains. China's experience offers a valuable reference point for economies seeking to align industrial growth with environmental sustainability through international trade.

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

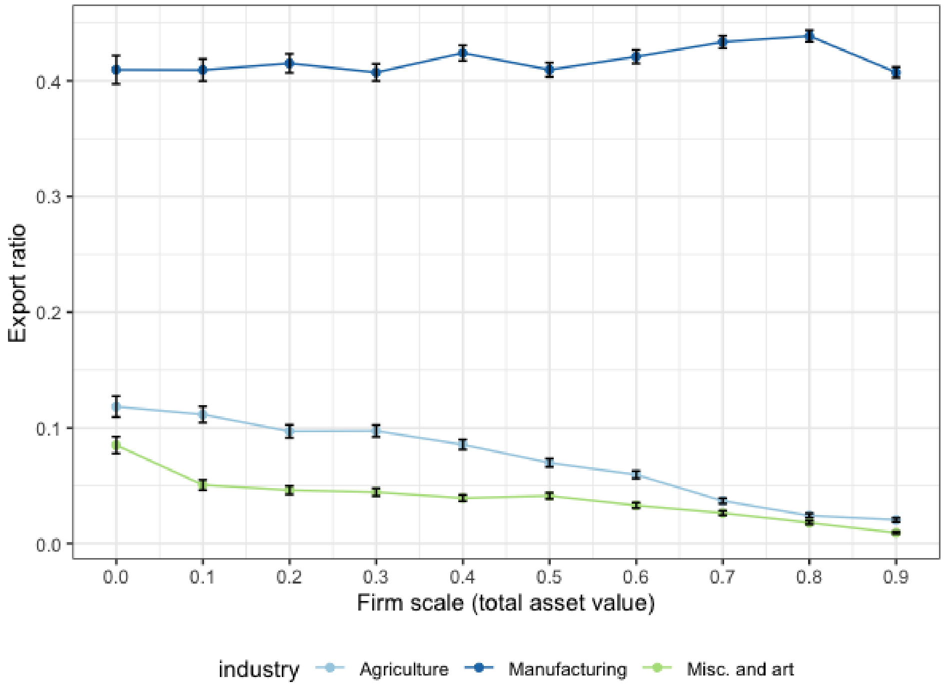

Figure 2: The export ratios of different goods to OECDs in different quantiles (employee number)

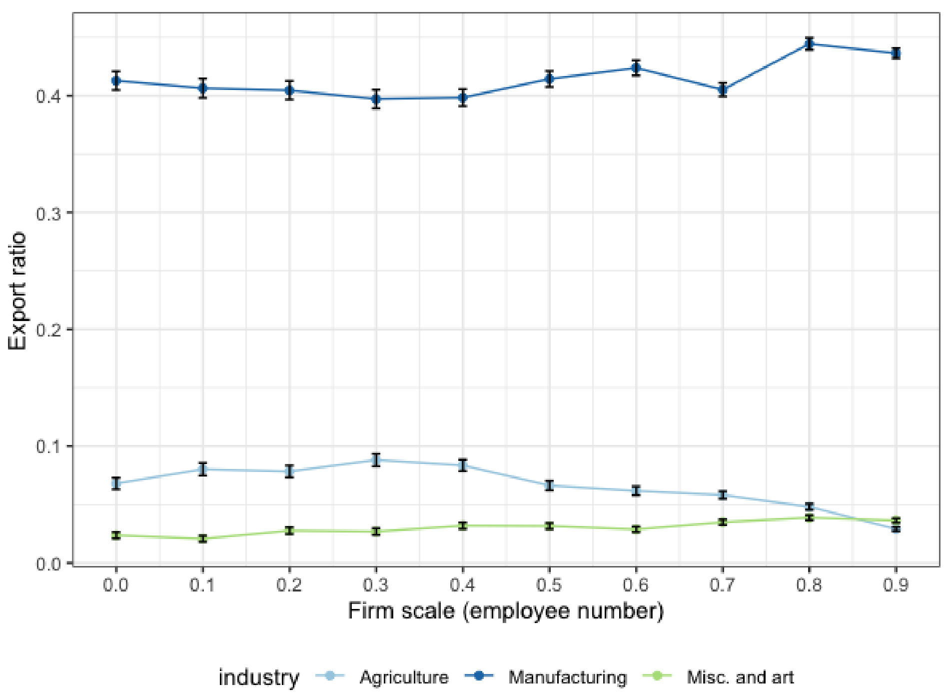

Figure 3: Pollution treatment efficiencies across industries

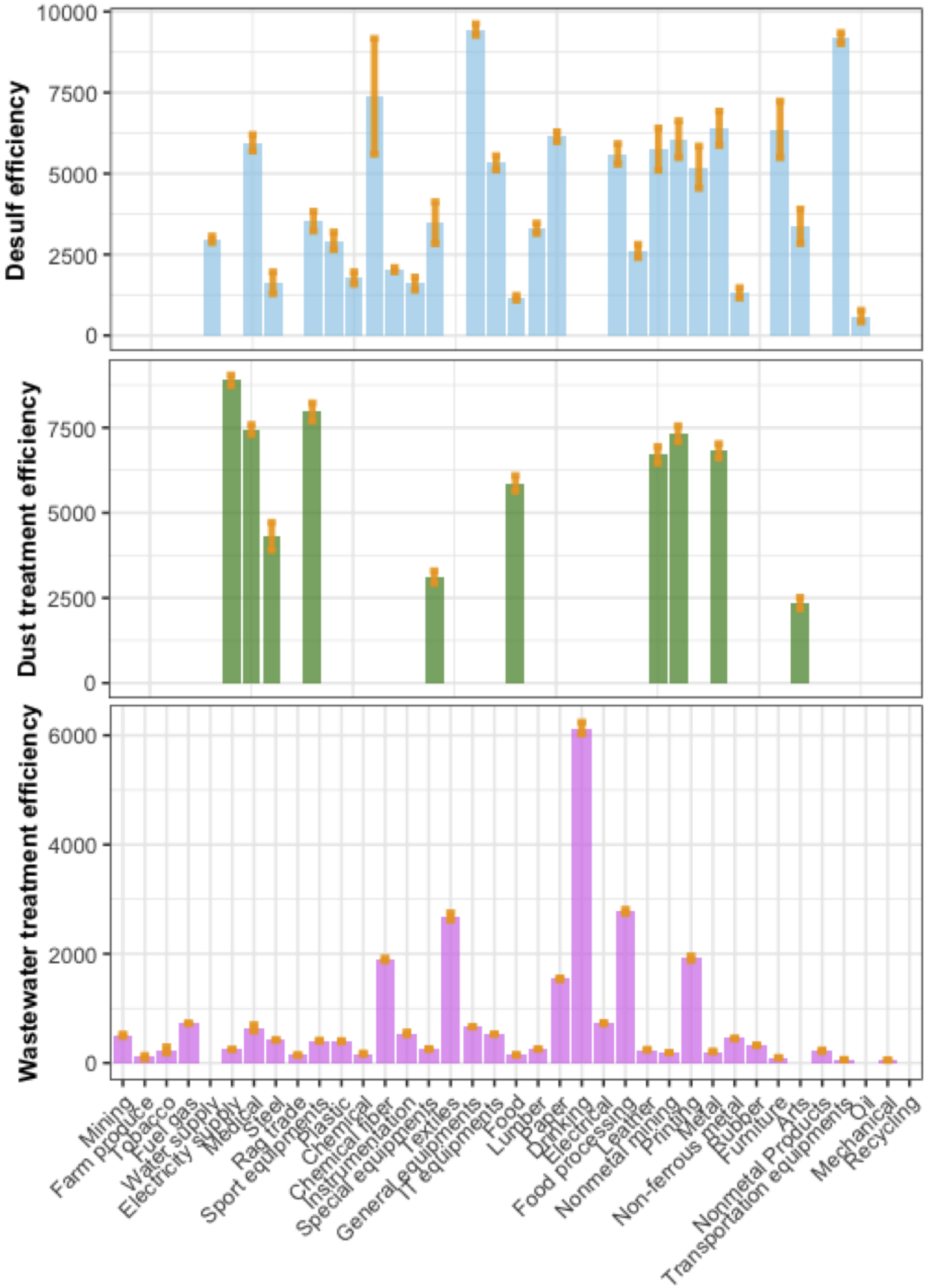

Table 1: Summary statistics

	Full samples	Samples with OECD exports	Samples with only non-OECD exports	Difference1	Non-exporter	Difference2
Corporate characteristics						
Total assets (K *yuan*)	376,791	572,696	441,073	131,623***	322,050	250,646***
Employee number	507	790	640	150***	426	364***
Profitability (sale profit/sales)	9.88%	4.16%	3.38%	0.79%***	11.69%	-7.53%
SOE ratio	9.29%	6.24%	6.60%	-0.36%	10.22%	-3.98%
Pollution and treatment						
SO2 produced (ton)	762	177	258	-82*	909	-732***
SO2 treatment ratio	9.30%	9.18%	8.88%	0.31%	9.34%	-0.16%
Dust produced (ton)	16673	1250	5644	-4394***	19564	-18314***
Dust treatment ratio	73.15%	75.54%	72.59%	2.95%***	72.74%	2.80%***
COD produced (ton)	369	612	367	244	296	315
COD treatment ratio	49.74%	55.00%	53.62%	1.38%**	47.91%	7.09%***
NH4-N produced (ton)	22	18	17	1	23	-5*
NH4-N treatment ratio	30.09%	32.19%	32.66%	-0.47%	29.14%	3.05%***
Energy and resource structures						
Coal consumption (ton)	65,857	14,605	19,639	-5,034**	76,831	-62,226***
Fuel consumption (ton)	1312	911	843	67	1475	-564
Gas consumption (10K m^3)	1,332	1,350	743	607	1,357	-7
Electricity Usage (10K KW/h)	8,639	2,348	3,829	-1,481	10,516	-8,169*
Industrial water usage (ton)	3,403,527	1,833,992	1,484,852	349,140	3,910,411	-2,076,419***
Reclaimed water usage ratio	27.51%	19.93%	19.07%	0.86%**	29.93%	-10.00%***
Coal sulfur ratio (%)	100.20%	91.63%	98.69%	-7.06%***	101.77%	-10.14%***
Coal dust ratio (%)	21.19%	20.27%	20.52%	-0.25%	21.37%	-1.10%***
Pollution control expenditure						
Desulf expenditure (K *yuan*)	320	65	67	-2	389	-324***
Dust collect expenditure (K *yuan*)	114	57	81	-24	127	-70***
Wastewater processing expenditure (K *yuan*)	98	113	112	1	93	20**
Number of firms	66,086	14,034	3,299		51,861	

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	NH4-N	COD	NH4-N	COD	NH4-N	COD	NH4-N
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	NH4-N	COD	NH4-N
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 NH4-N 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	NH4-N	COD	NH4-N
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	NH4-N	COD	NH4-N
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	NH4-N	COD	NH4-N
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	NH4-N	COD	NH4-N
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)	
NH4-N 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)	
NH4-N 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	NH4-N	COD	NH4-N
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.

Appendix

A1 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.[6] 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 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,[7] 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.

A2 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

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

[7]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 $length * 2 - 3$

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.

[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]

A3 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.

A4 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)[8]. 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

[8] 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

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 NH4-N 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.

Figure A1: Distribution of Dust Production

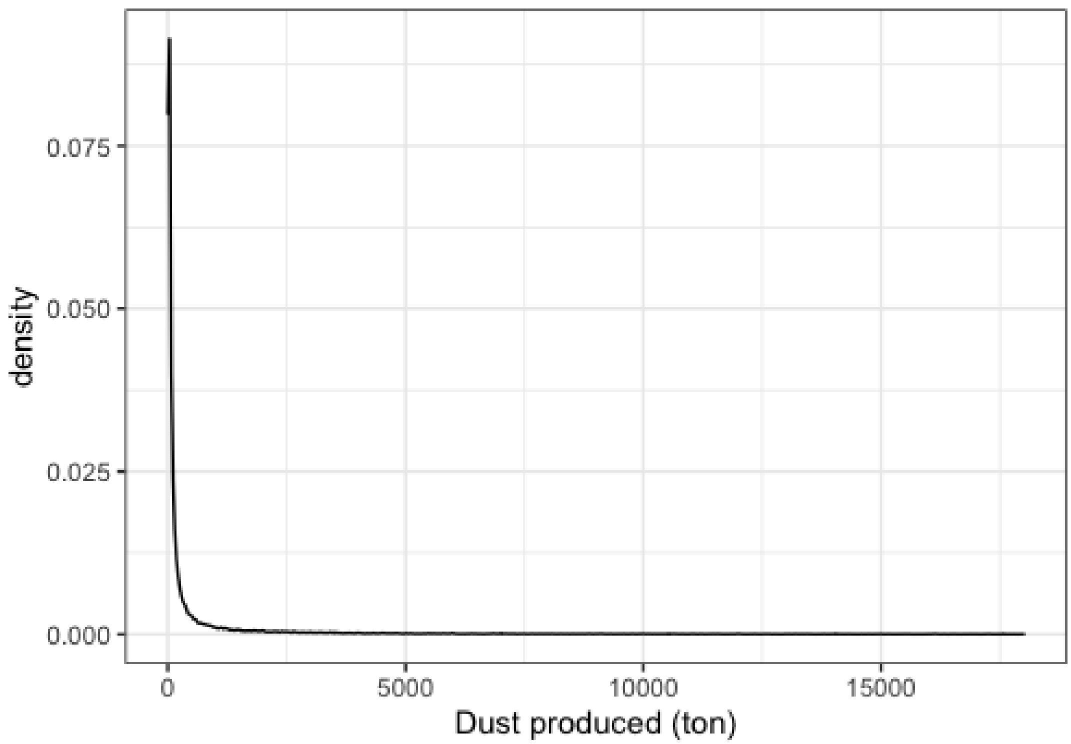

Table A1: OECD exports and dust treatment in different quantiles

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	NH4-N	COD	NH4-N
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)	
NH4-N 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)	
NH4-N 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.