Import Liberalization of Intermediates and Environment: Empirical Evidence from Chinese Manufacturing

Ling-Yun He and Liang Wang

1 College of Economics, and Institute of Resource, Environment & Sustainable Development Research, Jinan University, Guangzhou 510632, China; liangwang@stu2017.jnu.edu.cn
2 College of Economics and Management, Nanjing University of Information Science and Technology, Nanjing 210044, China
* Correspondence: lyhe@amss.ac.cn; Tel.: +86-181-4571-3770
† These authors contributed equally to this work.
‡ This project is supported by the National Natural Science Foundation of China (Grant Nos. 71874070 and 71573258), and the Key Project of China National Social Science Foundation (Project No. 15ZDA054).

Received: 11 March 2019; Accepted: 26 April 2019; Published: 5 May 2019

Abstract: This paper investigates how the import liberalization of intermediates affects firm-level pollution emissions. We divide the impact of freer import of intermediates on pollution emissions into induced scale, composition and technique effects and then develop interaction terms to examine these effects. Relying on a panel of plant-level data from China manufacturing sector for the period 2001 to 2007, we find freer import of intermediate inputs is conducive to pollution reductions at the plant level, lowering pollution via induced technique and composition effects and, in turn, increasing emission through induced scale effect. In summary, import liberalization of intermediate inputs can contribute to the better environmental performance of China manufacturing sector.

Keywords: import liberalization; intermediate inputs; pollution emissions

1. Introduction

With increased access to firm-level data on pollution emissions and other characteristics, the relationship between international trade and firms’ environmental performance has been discussed in aspects of productivity, local protection and exporting status [1–4]. However, the existing literature little explains the impact of import liberalization of intermediate inputs on firm-level pollution and potential influential channels. As the global value chains grow, the production process of the enterprise is increasingly dependent on intermediate inputs whose importance is becoming increasingly prominent, even affecting firms’ productivity and technology [5,6]. The relationship between imported intermediate products and firm-level environmental performance deserves further investigation. From the perspective of imported intermediate products, this paper studies the specific impact of import liberalization of intermediate products on firm-level pollution emissions.

To join the World Trade Organization (WTO), China implemented a series of trade liberalization reforms on tariff liberalization and non-tariff barriers reduction. The weighted import tariffs on intermediate inputs decreased from 13.9% in 2001 to 3.7% in 2007. China’s international trade has also made significant achievements. In 2010, China’s trade surplus was 183.1 billion dollars, with a total trade volume of 2974 billion dollars, becoming the biggest exporter. As one of the fastest growing countries during the period 1997 to 2017 with annual Gross Domestic Product (GDP) growth fluctuates from 6.9% to 14.21%, China is also facing severe environmental pollution problems. In 2007, China’s carbon dioxide (CO₂) emissions were 6.284 billion tons and became the world’s number one emitter,
accounting for 21.01% of the global total. Economic loss caused by particulate matter (PM$_{10}$) reached 64 billion dollars for China in 1997 [7]. The increase in total suspended particulates (TSPs) will cause the life expectancy loss of 500 million residents in northern China to exceed 2.5 billion years [8]. The environmental problems have brought substantial economic and welfare losses for China.

Over the past decades, there is a wide range of study focusing on the effects of international trade on the environment. While, due to the lack of disaggregated data on pollution emissions and plant characteristics, the existing literature is mainly concentrated in macro-level environmental responses to free trade, which hides individual environmental behavior. Besides, research on the relationship between trade and the environment featuring firm-level analyses pays little attention to the environmental impact of imported intermediates and its underlying mechanisms.

To verify the impact of the import liberalization of intermediate goods, we use weighted tariff data to measure the degree of import liberalization. After collection and process, we match the Chinese firm-level data with emission and tariff data to establish a data set covering years 2001 and 2007. We use this data set to empirically study the impact of import liberalization of intermediate goods on the firms’ pollution emissions. We begin our analysis by examining the overall impact of the import liberalization of intermediates on sulfur dioxide (SO$_2$), Soot, and chemical oxygen demand (COD) emitted by China manufacturing firms. We find that the freer import of intermediates significantly improves environmental performance from affected plants. Then, we analyze the potential mechanism for the import liberalization of intermediate products affecting firm-level pollution emissions. According to Grossman and Krueger [9], international trade can influence environmental consequences via scale, technique and composition effects. We decompose pollution reductions caused by freer trade of imported intermediates into induced scale, technique and composition effects. Our findings suggest increased access to imported intermediates can raise pollution emissions through the induced scale effect, but improve environmental quality by induced technique and composition effects.

This paper mainly contributes to two aspects: (1) We first use China firm-level data to examine the impact of the trade liberalization of intermediate imports on the pollution emitted by Chinese manufacturing plants. (2) We explain the underlying mechanism on how trade liberalization of imported intermediates influences firm-level environmental performance by introducing induced scale, technique and composition effects.

The remaining of this paper is as follows. The literature review is presented in Section 2. Section 3 provides the model and data. Section 4 offers empirical results and discussion. Section 5 concludes.

2. Literature Review

2.1. Determinants of International Trade Influencing Pollution Emissions

Since the 1990s, the relationship between trade and environment has caused constant concern, and there is no consensus on the environmental effects of trade liberalization. This sector provides a selective overview of how international trade affects pollution emissions.

Due to the lack of research on the effects of free trade on pollution emissions, many environmentalists worried that the implementation of the North American Free Trade Agreement (NAFTA) could pose an unprecedented challenge to Mexico’s environmental quality. Grossman and Krueger [9] proposed the decomposition of pollution emissions when studying the environmental Kuznets curve of NAFTA: scale, composition and technique effects. The scale effect means that merely increasing the scale of the economy will increase the pollution proportionally while maintaining the proportion of products and the level of technology. The composition effect means that more resources used to produce pollution-intensive products will generate more pollution while maintaining economic scale and production technology. If pollution-intensive industries grow faster than other industries, changes in industrial structure will increase pollution emissions. Under the premise of constant economic size and composition, changes in production technique related to pollution output will affect
pollution emissions. The final impact of trade on environmental quality depends on the combination of the three effects.

Early studies suggested comparative advantage was the core driver of international trade, and an extensive literature discusses whether environmental regulation is part of comparative advantage. Copeland and Taylor [10] developed a general equilibrium model to theoretically investigate the nexus between income, international trade, and environmental quality. The difference in environmental policy caused by the income gap between countries is one of the drivers of trade. Nations with higher real income demand for more stringent environmental regulation and expand in clean goods. Therefore, besides scale and technique effects that could be caused by economic growth, international trade additionally generates a structure effect, which is the key to determining whether trade will worsen environmental quality. Similarly, Chichilnisky [11] explained how differences in property rights trigger the trade. Environment as an input of production, countries with well-defined property rights will trade with those whose property rights on environmental resources are ill-defined. Exporting environmentally intensive items from nations with ill-defined property rights to the well-defined will lead to the former’s environmental deterioration.

With the emergence of firm heterogeneity theory that firms with high productivity tend to export and those with lower productivity are forced to exit the market [12,13], researches have examined how international trade affects pollution at firm level. Recent evidence suggests that improvement in productivity could lower emission intensities [14,15]. Together, these findings indicate that freer trade could contribute to lower emission intensities via entry and exit.

2.2. Environmental Effects of Trade

2.2.1. Evidence at Aggregated Level

Although there is a large amount of literature on the impact of trade on the environment, no clear consensus has yet been reached. In general, the impact of international trade on environmental pollution can be classified into three views. The first is that international trade is beneficial to the environment. The second is that international trade will cause an increase in environmental pollution. The third is that the relationship between trade and the environment is complex and uncertain.

The first view is supported by Antweiler et al. [16] who established a theoretical model and successfully divided the impact of trade liberalization on pollution emissions into scale, composition and technique effects. The empirical estimation on how the level of trade openness affects SO₂ emissions indicates that the impact of trade on the environment is favorable. Levinson [17] studied the reasons for the significant reduction in pollution emissions from U.S. manufacturing between 1987 and 2001. The results show that pollution reduction is caused by improvements in production technology and changes in product structure, with the technique effect accounting for the majority. Furthermore, Shapiro and Walker [15] studied the decline in pollution emissions from manufacturing in the United States from 1990 to 2008 and find that the adoption of abatement technologies is attributed to the environmental regulations.

Since standards for environment evaluation maintained by countries are not identical, environmental indicators for research may vary. Dean [18] constructed a simultaneous equations system based on the Heckscher-Ohlin (H-O) model to examine how trade liberalization would affect Chinese industrial COD discharge. By distinguishing the direct impact of international trade on the environment and the indirect impact of trade through income growth, she found trade liberalization will worsen the environment for the comparative advantage in pollution-intensive goods, but facilitate income growth to curb emissions growth. The net effect of trade on environmental quality is conducive to the improvement of environmental quality.

However, some scholars have empirically concluded that international trade is harmful to the environment. Cole [19] noticed that conclusions on the environmental effects of international trade appear to vary by pollutants. Therefore, energy consumption is used to reflect the direct impact of
trade on environmental quality. Using data on 32 countries between 1975 and 1995, he found that trade liberalization may increase energy use per capita for the average country.

With the continuous development of regional economic integration, the regional organization is bound to have a significant impact on the trade size, trade structure and trade price of member countries. Atici [20] examined the interaction between trade liberalization and carbon emissions for the Association of Southeast Asian Nations (ASEAN) and one of its most largest trade partners, Japan, between 1970 and 2006 and found the proportion of exports to GDP is positively correlated to CO$_2$ emission.

Works for the third view is more diverse in research samples and environmental indicators. Cole and Elliott [21] used data on four pollutants (CO$_2$, SO$_2$, nitrogen oxides (NO$_x$) and biochemical oxygen demand (BOD)) to decompose the effects of trade on the environment. They found that the trade-induced composition effect arising from differences in factor endowments and environmental policy is relatively small compared to other effects, and the net impact of trade on the environment varies by pollutant.

Managi et al. [22] argued that early work [16,21] did not consider the endogeneity problem of income which caused biased estimation results. They used differential GMM to study the overall impact of trade openness on environmental quality and found trade liberalization is beneficial to OECD countries but exerts detrimental effects on SO$_2$ and CO$_2$ emissions in non-OECD countries.

2.2.2. Evidence at Plant Level

Recently, with the availability of data concerning pollution emissions at plant level, scholars turn their perspectives into the micro-field to explore the connection between corporate activities and environmental performance. Martin [23] studied the changes in India’s tariff changes in Indian manufacturing companies’ greenhouse gas emissions and found that the reduction in intermediate input tariffs increased the energy efficiency of enterprises by 23%. Jiang et al. [4] study the determinants affecting the pollution emissions of Chinese manufacturing firms including ownership, local protection, property rights protection and other firm characteristics. Their findings suggest that less local protection and better property right protection will contribute to lower pollution intensity. Also, firms that are foreign-owned and domestic public-listed and employ highly educated tend to perform more environmentally. Cherniwchan [24] examine how trade liberalization between the U.S. and Mexico after brought by the implement of NAFTA affects firm-level pollution emissions in the U.S. manufacturing sector. His findings indicate that considerable reductions in PM$_{10}$ and SO$_2$ of U.S. manufacturing plants resulted from trade liberalization.

Some research is motivated by the linkage between export status and firm-level pollution emissions. Forslid et al. [1] used theoretical models and empirical tests to study the relationship between firm productivity, export status, and corporate pollution reduction investment, and found that productivity and export status were inversely proportional to CO$_2$ emission intensity. Cui et al. [2] studied the export behavior of enterprises and corporate pollution behaviors and found that export enterprises have lower pollution emission intensity after controlling productivity and environmental regulation. Similarly, the effect of exporting decision on firms’ energy efficiency is complex. Expanding the energy consumption for higher production, while becoming an export can offset the increase in energy use by encouraging adoption of energy-efficient technologies [25]. Cui [26] applies environmental externalities and adoption of factor-biased technologies to trade models to study how corporate technology applications and export decisions are affected by trade openness and stringency of environmental regulations. It shows that the reduction in trade costs encourages companies to export, improve factor-biased technologies and force the least efficient companies out of the market. Holladay [3] studied how export conditions and import competition affect the level of pollution emissions of U.S. manufacturing plants during the period 1990 to 2006 and found that export companies have lower pollution intensity, and the degree of import competition will force small-scale enterprises, which are often pollution intensive, out of the market.
The existing literature rarely studies the impact of trade liberalization of intermediate goods on pollution emissions. Although Martin [23] and Cherniwchan [24] provide evidence on trade liberalization of intermediate inputs affecting corporate environmental pollution, the potential mechanism between freer imported intermediate inputs and pollution emission at plant level deserves further discussion.

3. Methodology and Data

3.1. Identifying the Effect of Trade Liberalization on Intermediate Inputs

The purpose of this paper is to study the impact of trade liberalization of intermediate inputs on pollution from Chinese manufacturers. First, we discuss an appropriate measure for the degree of trade liberalization of imported intermediates, then explore the mechanism for freer import of intermediate goods affecting pollution emissions at plant level.

3.1.1. Measuring Trade Liberalization of Intermediate Inputs

Early research [27,28] generally chose import penetration (ratio of imports to GDP) to measure trade liberalization standards, but more and more scholars have found that import penetration cannot accurately measure the level of trade liberalization. It is especially true for countries experiencing major trade policy reforms. Harrison [29] found that although the trade policy reform of Coate d’Ivoire in 1985 reduced average tariffs by 30%, import penetration remained stable. Besides, the tariff has been used as an indicator of the degree of trade liberalization [5,30]. In the 1990s, China accelerated the reform of the economic system and promoted the process of joining the WTO, and after implementing the WTO, implemented a series of tariff reduction policies to achieve trade liberalization. Figure 1 shows that the weighted import tariffs fell from 13.9% in 2001 to 3.7% in 2007, a decrease of 73.3%. Compared with import penetration, tariff could better portrays the degree of trade liberalization.

\[ T_{jt} = \frac{\sum_{k \in N_{jt}} a_{kt} \times T_{kt}}{\sum_{k \in N_{jt}} a_{kt}} \]  

where \( T_{jt} \) denotes China weighted tariff rate on import of intermediate inputs from industry \( j \) in year \( t \). Letting \( N_{jt} \) denote the number of intermediates used in production process from industry \( j \) in year \( t \). \( a_{kt} \) represents the Chinese import trade value of commodity \( k \) in year \( t \), and \( T_{kt} \) represents the Chinese import tariff of commodity \( k \) in year \( t \).

Figure 1. Import Tariff on Intermediate Inputs. Notes: Data sources: World Integrated Trade Solution (WITS).
3.1.2. Mechanism Test

To explain the mechanism of the impact of trade liberalization of intermediate goods on enterprise-level pollution emissions, we explored the three-effect model. Grossman and Krueger [9] first proposed the three effects of pollution emissions when studying the environmental Kuznets curve of NAFTA: scale, composition and technique effects, which inspires a large literature [16,21]. However, much of related work was implemented at the macro level. To apply the model at the enterprise level, we introduced induced three-effect model.

First, the import liberalization of intermediate inputs affects the environment by expanding the scale of economic activities. The production of firms requires the intermediate inputs, and the change in the degree of import liberalization of intermediate inputs will change the cost and quality of production inputs. The import liberalization of intermediate inputs will enable firms to obtain the same or better intermediate inputs at a lower cost, thus expanding the scale of production and leading to increased pollution emissions. Therefore, we conclude that the induced scale effect by import liberalization of intermediate inputs is positive.

Second, international trade affects the environment by changing the composition of economic activities [16,21]. International trade has altered the composition of factor inputs at the macro level and indirectly affects pollution emissions. Import liberalization of intermediate inputs may also change the input of factors at the firm level and affect pollution emissions. This paper chooses capital intensity to reflect the proportion of factor input of firms. Therefore, the impact of the import liberalization intermediate on firm-level emissions is uncertain, and these effects depend on changes in the composition of the inputs. In several studies, there is an assumption that capital-intensive industries are pollution-intensive industries, while labor-intensive industries emit fewer pollutants [16,21]. However, this does not apply to firms. Firms with high capital intensity may also invest in pollution abatement equipment to reduce pollution emissions. Therefore, the induced composition effect by import liberalization of intermediate inputs is uncertain.

Third, the import liberalization of intermediate inputs has changed production technology and thus affected the environment. Changes in the degree of liberalization of imported intermediate inputs may also cause firms to shift production technology and affect their pollution emissions. In this study, we use total factor productivity (TFP) to reflect the firms’ production technology. The relationship between intermediates and productivity has been demonstrated in the existing literature [31–33]. Specifically, the liberalization of imported intermediate inputs allows firms to obtain more high-quality and diversified intermediate inputs from abroad, which is conducive to firms to improve productivity. Increased productivity can reduce pollution emissions [2]. Therefore, the induced technique effect by import liberalization of intermediate inputs can reduce firm-level pollution emissions.

3.2. Empirical Specification

3.2.1. Import Liberalization of Intermediates and Firm-Level Pollution Emissions

In order to investigate the impact of imported intermediates on firm-level pollution emissions, we regard the tariff change of imported intermediates as the core variable. The basic model is as follows:

$$\ln E_{ijst} = \alpha_1 T_{jt} + X'\theta + \delta_j + \omega_s + \mu + \epsilon_{ijst}$$ (2)

$$X'\theta = \beta_1 \ln Nadd_{ijst} + \beta_2 \ln KL_{ijst} + \beta_3 \ln TFP_{ijst} + \beta_4 Finance_{ijst} + \beta_5 \ln Awage_{ijst}$$ (3)

where $E_{ijst}$ is the pollution emission level of manufacturing company $j$ in province $s$ at year $t$, including $SO_2$, Soot, and COD. $T_{jt}$ is the degree of import liberalization of intermediates as defined in Equation (1). $\delta_j$ is an industry fixed effect that captures factors at the industry level that affect firm-level pollution emissions, such as changes in industrial demand and policies. $\omega_s$ is a year fixed effect that captures the factors that lead to changes in firm-level pollution emissions due to changes in environmental policies in different years. $\mu$ is a province fixed effect that captures the factors that influence the
pollution emissions of firms at the provincial level, such as environmental policies. $\epsilon_{ijst}$ is the error term. The equation mainly focuses on the coefficient $\alpha_1$ of the core variable $T_{jt}$. $\alpha_1$ measures the percentage change of the firm-level pollution emissions caused by 1% increase in the import tariff of the intermediate inputs.

To examine other factors affecting firm-level pollution emissions, we incorporate control variables $X'\theta$ into the above empirical model. $Nadd_{ijst}$ is the normalized gross value of industrial output, reflecting the scale of production. The larger the size of the firm, the more the output, capital and human resources it has. To avoid the multicollinearity between the firm’s scale and the productivity, we adopt the ratio of the industrial added value to the average annual industrial added value of the industry to construct the industrial normalized industrial added value. $KL_{ijst}$ is the capital intensity, which represents the abundance and usage ratio of the factors for production. Capital intensity can affect the level of pollution emissions. Antweiler et al. [16] used capital intensity to express the composition effect and found that the higher the capital intensity at the macro level, the greater the pollution emissions. However, whether this conclusion applies to the firm level is still uncertain. We use fixed assets per capita as the capital intensity. $TFP_{ijst}$ is the TFP of firms, representing the technique effect. Productivity plays an essential role in emissions abatement, and firms with high productivity are more likely to use pollution-abating technologies to reduce pollution emissions [2]. We use the Levinsohn and Petrin(LP) method to calculate the TFP of firms [34,35]. $Awage_{ijst}$ is the average wage, and firms with higher average wage can attract employees with higher production and management skills, thus affecting pollution emissions. $Finance_{ijst}$ indicates the proportion of interest and residence, which is used to describe the impact of credit constraints on environmental behavior at plant level.

3.2.2. Induced Three-Effect Decomposition Model

To explain the potential mechanism of firm-level pollution emissions, we adopted an induced three-effect decomposition model to show how the import liberalization of intermediate products affects firms’ pollution emissions through scale, composition and technique effects. We used the indicators of import liberalization of intermediate goods and the variables of three effects to construct interaction terms as induced three effects:

$$\ln E_{iskt} = \alpha_1 T_{jt} + \alpha_2 T_{jt} \times \ln Nadd_{ijst} + \alpha_3 T_{jt} \times KL_{ijst} + \alpha_4 T_{jt} \times TFP_{ijst} + X'\theta + \delta_j + \omega_t + \mu_s + \epsilon_{ijst}$$ (4)

In Section 3.1.2, we explored the impact of the import liberalization intermediates on the three effects and affect pollution emissions.

First, the import liberalization of intermediates will lead to an increase in the scale of production of firms, which will lead to a rise in firm-level pollution emissions. Therefore, we use the degree of import liberalization of intermediate goods and the scale of firms’ production to construct an interaction term to study the scale effect caused by changes in import tariffs of intermediate products. The coefficient $\alpha_2$ of the interaction term $T_{jt} \times \ln Nadd_{ijst}$ measures the percentage change of firm-level pollution emissions generated by the shift in the import tariff of the intermediates.

Second, the import liberalization of intermediate products will lead to changes in the factor proportion of firms, which will lead to changes in corporate pollution emissions. We use the degree of import liberalization of intermediate goods and capital intensity to construct an interaction term to examine the composition effect induced by changes in import tariffs of intermediate goods. $\alpha_3$ measures the percentage change of firms’ pollution emissions caused by the change of import tariffs of intermediate products.

Finally, the import liberalization of intermediates will increase the TFP of firms and lead to a decline in pollution emissions. We use the degree of import liberalization of intermediate goods and TFP to construct an interaction term to evaluate the technique effect caused by changes in import tariffs of intermediate products.
tariffs of intermediate goods. \( a_4 \) measures the percentage change of the pollution emission caused by the change of the import tariff of the intermediate inputs.

### 3.3. Data

This paper uses three data sets collected and processed from various sources: Chinese firm-level data from China industrial enterprises database, pollution emission coefficient data from China Statistical Yearbook, and import tariff data from WTO’s Tariff Download Facility. By compiling and matching these three data sets, we can get unbalanced panel data containing the characteristics of China’s manufacturing companies and their pollution emissions from 2001 to 2007. We choose the period 2001 to 2007 for several reasons. First, after China’s accession to WTO, the China tariff rates on intermediate inputs decreased significantly from 13.9% in 2001 to 3.7% in 2007. Thus, samples during this period can appropriately reflect the relationship between trade liberalization of imported inputs and firm-level environmental consequences. Besides, the China Statistical Yearbook did not provide complete and disaggregated industrial pollution emissions data before 2001, resulting in the inability to obtain pollution coefficients for each industrial sector. Last, there are data quality issues in China industrial enterprises database after 2007, such as repeated observations, changes in statistical standards, and the missing of key variables and enterprise codes. Details on descriptive statistics and data processing are presented as follows:

Table 1 shows the descriptive statistics of whole samples and the evolution of variables over the period 2001 to 2007. After China joined the WTO, the manufacturing industry has developed tremendously. The number of employed firms in 2007 is more than twice of that in the beginning. The emission of SO\(_2\) is significantly higher than the other two pollutants, but the average firm-level emissions are gradually decreasing. During this period, firms was shifting to capital-intensive production structures, and their productivity has increased dramatically.

### 3.3.1. Plant Characteristics

The source of firm-level data in this paper is the China industrial enterprises database, which is established by the National Bureau of Statistics of China and used by many domestic and foreign
scholars because of its comprehensive and rich corporate financial data [36,37]. It counts all state-owned enterprises and non-state-owned enterprises with annual main business income above 5 million yuan (also called as the above-scale industrial firms). Due to lack of observations, this paper excludes Recycling and Disposal of Waste (code 43) and selects 29 manufacturing industries based on the 2-digit industry code of GB/T4754-2002 (China’s industry classification standard, See http://www.sac.gov.cn/Sacen/). Corresponding codes are presented in Table A1. Although the China industrial enterprises database contains numerous financial indicators, it still has many invalid observations that need to be further filtered and processed. Following the processing methods mentioned in the existing literature [38,39], we remove invalid observations according to the Generally Accepted Accounting Principles (GAAP): (1) Current assets outnumber total assets. (2) Total fixed assets are greater than total assets. (3) The net value of fixed assets is more than the total assets. (4) The company code is missing. (5) Invalid establishment time. (6) Excluding observations whose specific financial data is less than 0, such as the gross value of industrial output, wages, and fixed assets. After deleting the invalid observations, we obtained 1,528,744 samples. Finally, we deflate the required variables to the relevant index by 2001.

3.3.2. Environmental Data

Due to the difficulty in obtaining Chinese firm-level pollution emission data, we need to take measures to calculate corporate pollution emissions. Given the industrial enterprise database records all state-owned enterprises and non-state-owned enterprises whose annual main business income exceeds 5 million yuan and above, we can believe that large-scale enterprises in the same industry have similar technologies for production and abatement. We use the pollution data in the China Statistical Yearbook to construct emission coefficients, which is the annual emission per unit of industry-level output. Then we multiply the emission factor by the total output value of the enterprise to obtain corporate pollution emission data. We choose harmful pollutants including SO$_2$, COD, and Soot.

3.3.3. Tariff Data

WTO’s Tariff Download Facility provides the 2001–2007 tariff data of 6-digit HS code. According to Mao and Sheng [40], we first utilize the conversion tables offered by the United Nations to convert tariff data to the HS2002 version and the BEC classification standard to obtain the intermediate import volume, then combine the HS2002-ISIC (Rev3) and GB/T2002-ISIC (Rev3) conversion tables to build direct linkage between products and industries to calculate industry-level import tariffs.

4. Results and Discussion

4.1. Import Liberalization of Intermediates and Pollution Levels

4.1.1. Empirical Results

Table 2 reports the estimates based on Equations (2) and (3). Each column controls province, year and sector fixed effects. The pollutants reported in columns (1)(2), (3)(4) and (5)(6) are SO$_2$, Soot, and COD, respectively. The odd number is the regression results of only the change of the import tariff of the intermediate goods. The even column is the regression results after adding the control variables mentioned in the formula (3) to the odd column.

We first study the odd columns and find that when the control variables of Equation (3) are not considered, the increase in import tariffs of intermediate products will lead to a rise in corporate pollution emissions, with the biggest impact on COD, an increase of 2.2%, followed by Soot, an increase of 1.57%. The growth for SO$_2$ is the smallest, at 1.06%. In the even columns, control variables are added to represent the characteristics of the firms. $\alpha_1$ of each pollutant is higher than that of uncontrolled estimates. Without considering the characteristics of firms, we will underestimate the negative impact of the increase in import tariffs on intermediates on corporate pollution emissions.
Table 2. Import liberalization of intermediates and pollution levels.

|                  | SO₂   | Soot  | COD   |
|------------------|-------|-------|-------|
|                  | (1)   | (2)   | (3)   | (4)   | (5)   | (6)   |
| \( T_{jt} \)    | 0.011 \( ^a \) | 0.014 \( ^a \) | 0.016 \( ^a \) | 0.019 \( ^a \) | 0.022 \( ^a \) | 0.025 \( ^a \) |
|                  | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| ln \( RAdd_{ijst} \) | 1.070 \( ^a \) | 1.083 \( ^a \) | 1.098 \( ^a \) | 1.083 \( ^a \) | 1.098 \( ^a \) | 1.098 \( ^a \) |
|                  | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| ln \( KL_{ijst} \) | -0.079 \( ^a \) | -0.087 \( ^a \) | -0.095 \( ^a \) | -0.087 \( ^a \) | -0.095 \( ^a \) | -0.095 \( ^a \) |
|                  | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| ln \( TFP_{ijst} \) | -0.357 \( ^a \) | -0.375 \( ^a \) | -0.395 \( ^a \) | -0.375 \( ^a \) | -0.395 \( ^a \) | -0.395 \( ^a \) |
|                  | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| ln \( AWage_{ijst} \) | 0.128 \( ^a \) | 0.128 \( ^a \) | 0.119 \( ^a \) | 0.128 \( ^a \) | 0.119 \( ^a \) | 0.119 \( ^a \) |
|                  | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Finance\( _{ijst} \) | 0.041 \( ^a \) | 0.043 \( ^a \) | 0.0375 \( ^a \) | 0.043 \( ^a \) | 0.0375 \( ^a \) | 0.0375 \( ^a \) |
|                  | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Fixed effects    | YES   | YES   | YES   | YES   | YES   | YES   |
| Observations     | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 |
| \( R^2 \)       | 0.696 | 0.941 | 0.738 | 0.946 | 0.702 | 0.941 |

Notes: Table reports the estimated effects of import tariffs of intermediate inputs on the emissions of Soot, SO₂ and COD from China manufacturing plants. The dependent variable of each column is the log of pollution emissions. Fixed effects include sector, province and year fixed effects. Robust standard errors are reported in parentheses. Significance: \( ^a \) 1%.

Next, we look at the coefficients of the control variables: (1) The coefficient of the normalized gross value of industrial output is positive, indicating that in the case of controlling other variables, separately expanding the production scale of the firm will lead to an increase in firm-level pollution emissions. (2) Capital intensity is inversely proportional to pollution emissions. Companies with higher capital intensity may have more pollution abating equipment, resulting in lower pollution emissions. (3) The positive coefficient of TFP indicates that companies with higher TFP emit fewer pollutants. Companies with high productivity are more likely to use pollution abating technologies to reduce emissions [2]. (4) The average wage is proportional to pollution emissions. Firms with high average wages may have larger production scales and therefore have higher pollution emissions. (5) Financial constraints are inversely proportional to corporate pollution emissions. Enterprises with high financial constraints do not have the ability or less inclined to use pollution abating technologies, which leads to increased pollution emissions.

4.1.2. Robustness Check

To ensure the robustness and reliability of the results in Table 2, we take additional regression. After China’s accession to the WTO in December 2001, China implemented a series of trade liberalization reforms. There were differences in trade policies between 2001 and the following years. Changes in China’s trade policy after China’s accession to the WTO may lead to a misleading conclusion. In order to prevent such trade policy differences from affecting the estimates, we re-estimate the Equations (2) and (3) by removing the samples of 2001. Table 3 shows the results of the robustness tests. For the convenience of comparison, columns (1), (3) and (5) are listed as regression results in columns (2), (4) and (6) of Table 2. Columns (2), (4) and (6) are results based on observations without 2001. After emitting the sample of 2001, we find that the signs of the results remain unchanged, and the coefficients are similar to that in baseline estimates. It shows that the changes in China’s trade policy before and after China’s accession to the WTO make no distortion to the regression results.
Table 3. Robustness checks.

|       | SO₂   | Soot  | COD   |
|-------|-------|-------|-------|
|       | (1)   | (2)   | (3)   | (4)   | (5)   | (6)   |
| T_jt  | 0.014ₐ | 0.001ₐ | 0.019ₐ | 0.017ₐ | 0.025ₐ | 0.018ₐ |
|       | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| ln Redis_jst | 1.070ₐ | 1.075ₐ | 1.083ₐ | 1.084ₐ | 1.098ₐ | 1.094ₐ |
|       | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| ln Kijst | −0.079ₐ | −0.082ₐ | −0.087ₐ | −0.088ₐ | −0.095ₐ | −0.093ₐ |
|       | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| ln TFPijst | −0.357ₐ | −0.368ₐ | −0.375ₐ | −0.381ₐ | −0.395ₐ | −0.395ₐ |
|       | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| ln Averageijst | 0.128ₐ | 0.127ₐ | 0.128ₐ | 0.127ₐ | 0.119ₐ | 0.120ₐ |
|       | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Financeijst | 0.041ₐ | 0.041ₐ | 0.043ₐ | 0.04ₐ | 0.038ₐ | 0.038ₐ |
|       | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Fixed effects | YES | YES | YES | YES | YES | YES |
| Observations | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 |
| R² | 0.941 | 0.941 | 0.946 | 0.948 | 0.941 | 0.943 |

Notes: Table reports the estimated effects of import tariffs of intermediate inputs on the emissions of Soot, SO₂, and COD from China manufacturing plants. The dependent variable of each column is the log of pollution emissions. Fixed effects include sector, province and year fixed effects. Robust standard errors are reported in parentheses. Significance: ₐ 1%.

4.2. Mechanism Test

According to the analysis of Section 4.1.1, we can interpret that the import tariff reduction of intermediate inputs is conducive to the pollution reduction of Chinese manufacturing enterprises, but the specific mechanism is still unknown. Besides, we also explored the relationship between the three effects and corporate pollution emissions. An increase in the size of enterprises will lead to increased pollution, while the increase in capital intensity and TFP will help reduce pollution. This part will further discuss the underlying mechanism of pollution reduction caused by import liberalization of intermediates via induced three effects proposed in Section 3.2. Table 4 shows the results of Equations (3) and (4). For comparison, Columns (1), (3) and (5) in Table 4 are the results in columns (2) and (4) (6) of Table 2. Columns (2), (4) and (6) in Table 4 are the estimates using interaction terms.

Table 4. Mechanism tests.

|       | SO₂   | Soot  | COD   |
|-------|-------|-------|-------|
|       | (1)   | (2)   | (3)   | (4)   | (5)   | (6)   |
| T_jt  | 0.141ₐ | −0.051ₐ | 0.019ₐ | −0.066ₐ | 0.025ₐ | −0.070ₐ |
|       | (0.000) | (0.001) | (0.000) | (0.001) | (0.000) | (0.001) |
| T_jt × ln RAddijst | −0.007ₐ | −0.009ₐ | −0.010ₐ | (0.000) | (0.000) | (0.000) |
| T_jt × ln Kijst | 0.002ₐ | 0.003ₐ | 0.004ₐ | (0.000) | (0.000) | (0.000) |
| T_jt × ln TFPijst | 0.012ₐ | 0.015ₐ | 0.016ₐ | (0.000) | (0.000) | (0.000) |
| Control variables | YES | YES | YES | YES | YES | YES |
| Fixed effects | YES | YES | YES | YES | YES | YES |
| Observations | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 | 1,528,744 |
| R² | 0.941 | 0.941 | 0.946 | 0.947 | 0.941 | 0.942 |

Notes: Table reports the estimated effects of import tariffs of intermediate inputs on the emissions of Soot, SO₂, and COD from China manufacturing plants. The dependent variable of each column is the log of pollution emissions. Fixed effects include sector, province and year fixed effects. Robust standard errors are reported in parentheses. Significance: ₐ 1%.
The estimates reported in Table 4 provide further evidence that import liberalization of intermediates can affect plant-level pollution emissions via three effects. The coefficients of interest are \(\alpha_2\), \(\alpha_3\) and \(\alpha_4\) measuring the induced scale, composition and technique effects by the change of import tariff of intermediates.

First, we discuss the induced scale effect. According to the results in Table 4, \(\alpha_2\) is negative and significant at the level of 1%, indicating that the increase in tariffs will reduce corporate pollution emissions through induced scale effect. Because the production of firms requires intermediate inputs, the rise in the tariff means a rise in cost for firms to obtain the imported intermediates, which ultimately leads to the reduction in production scale. As the scale of production and the pollution emissions are positively correlated, the increase in tariffs will lead to a decline in corporate pollution through the induced scale effect. In other words, the liberalization of import trade of intermediate goods will increase firms’ pollution emissions.

Second, we discuss the induced composition effect. \(\alpha_3\) is positive and significant at the level of 1%. According to Table 3, we know that the increase in capital intensity is conducive to reducing firms’ emissions. We can infer that rising import tariffs on intermediate goods will cause companies to reduce capital accumulation and lead to increased corporate pollution. On the other hand, the import liberalization of intermediates will abate firms’ pollution emissions.

Third, we explain the induced technique effect. \(\alpha_4\) is positive and significant at the level of 1%, meaning that the technical effect caused by the increase in import tariffs on intermediate goods has increased corporate pollution. Since there is a negative correlation between TFP and pollution emissions, we can infer that the import liberalization of intermediates will promote TFP. Easier access to imported intermediate inputs enables firms to obtain more high-quality and diversified intermediates to enhance their production technologies and reduce pollution emissions. The import liberalization of intermediate inputs will reduce firm-level pollution emissions.

Altogether, the import liberalization of intermediate inputs can affect firms’ pollution emissions in three ways. The cumulative impact reduces firm-level pollution emissions, specifically reducing pollution emissions through technique and composition effects, but increasing pollution emissions through scale effect. Given the combined effects, our results suggest that tariff reduction on imported intermediates following China’s accession to WTO played an essential role in pollution alleviation.

5. Conclusions

With the development of international trade and the deepening of the international division of labor, intermediate goods have gradually become essential trade goods with their critical and indispensable role in the production. To date, research has discussed the importance of intermediates in many areas such as productivity, economic growth and business cycle [6,41–44]. However, scant evidence of the firm-level environmental consequences of import liberalization of intermediates has been found.

In this paper, we investigate the relationship environmental performance at plant level and freer import of intermediates. Our estimation empirically demonstrates how one of the most remarkable episodes of trade liberalization in China, China’s accession to WTO, affected pollution emissions of Chinese manufacturing enterprises through imported intermediates. Our analysis relies on the Chinese industrial enterprises database, China Statistical Yearbook, and Tariff Download Facility to establish an unbalanced panel data containing plant characteristics and pollution emissions of Chinese manufacturing. We explore and explain the underlying mechanism for freer import intermediate inputs influencing firm-level environmental consequences.

Our results indicate that import liberalization of intermediate inputs acts as a pivotal part in the clean-up of China’s manufacturing sector. We find the increased access to imported intermediates will lead to a fall in pollution emissions at plant level. Furthermore, we discuss the underlying mechanism of the improved environmental performance following import liberalization of intermediates. We decompose the changes in pollution emissions into induced scale, composition and technique
effects. The freer import of intermediates will expand the scale of production, thus increasing pollution levels. Besides, in response to trade liberalization of imported intermediates, manufacturing plants will choose a relatively capital-intensive production structure which emits less pollution. Additionally, increased access to imported intermediates help affected firms obtain high-quality and diversified intermediates more efficiently, then triggers technology updates and reduce pollution emissions.

Although existing literature explaining how trade liberalization of imported intermediates are scarce and the findings of our research add new evidence and sight to it, there are certain limitations in this study. This paper finds that decreases in tariffs of intermediates can lead to lower emission levels, facilitating better environmental consequences via induced technique and composition effects while deteriorating plant environmental performance through induced scale effect, but we cannot ensure there are no other unobserved paths for import liberalization of intermediates affecting firms’ pollution levels. Besides, due to the lack of tariff data on exported intermediates, this paper only discusses the environmental consequences of import liberalization. Therefore, the future directions of our research can be focused on exploring the environmental results of intermediates driven by potential unobserved paths and export liberalization.

**Author Contributions:** L.-Y.H. is a full professor of energy economics and environmental policies. L.W. is a research associate supervised by L.-Y.H. The authors contribute equally in the project. L.-Y.H. and L.W. had the idea for and designed this research. L.W. calculated and analyzed the results under L.-Y.H.’s supervision. L.-Y.H. and L.W. co-wrote the manuscript.

**Funding:** This project is supported by the National Natural Science Foundation of China (Grant Nos. 71874070 and 71573258), and the Key Project of China National Social Science Foundation (Project No. 15ZDA054).

**Acknowledgments:** The authors would like to thank QIU Lu-Yi, LIU Li, OU Jia-Jia, LIN Xi, GENG Meng-Meng, and all other colleagues from both China Agricultural University and JinNan University, for all their warm helps, constructive suggestions and pertinent comments.

**Conflicts of Interest:** The authors declare no conflict of interest.

**Appendix A**

**Table A1.** List of manufacturing sectors of GB/T 4754-2002.

| Code | Manufacturing Sector                                                                 | Code | Manufacturing Sector                                                                 |
|------|--------------------------------------------------------------------------------------|------|--------------------------------------------------------------------------------------|
| 13   | Processing of Food form Agricultural Products                                       | 28   | Manufacture of Chemical Fibers                                                      |
| 14   | Manufacture of Foods                                                                | 29   | Manufacture of Rubber                                                                |
| 15   | Manufacture of Beverages                                                            | 30   | Manufacture of Plastics                                                              |
| 16   | Manufacture of Tobacco                                                              | 31   | Manufacture of Non-metallic Mineral Products                                         |
| 17   | Manufacture of Textile                                                              | 32   | Smelting and Pressing of Ferrous Metals                                              |
| 18   | Manufacture of Textile Wearing Apparel, Footware and Caps                            | 33   | Smelting and Pressing of Non-ferrous Metals                                          |
| 19   | Manufacture of Leather, Fur, Feather and Related Products                           | 34   | Manufacture of Metal Products                                                       |
| 20   | Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm and Straw Products | 35   | Manufacture of General Purpose Machinery                                             |
| 21   | Manufacture of Furniture                                                            | 36   | Manufacture of Special Purpose Machinery                                             |
| 22   | Manufacture of Paper and Paper Products                                              | 37   | Manufacture of Transport Equipment                                                   |
| 23   | Printing, Reproduction of Recording Media                                           | 39   | Manufacture of Electrical Machinery and Equipment                                    |
| 24   | Manufacture of Article for Culture, Education and Sport Activity                     | 40   | Manufacture of Communication Equipment, Computers and Other Electronic Equipment     |
| 25   | Processing of Petroleum, Coking, Processing of Nuclear Fuel                         | 41   | Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work |
| 26   | Manufacture of Raw Chemical Materials and Chemical Products                          | 42   | Manufacture of Artwork and Other Manufacturing                                        |
| 27   | Manufacture of Medicines                                                            | 43   | Recycling and Disposal of Waste                                                      |
References
1. Forslid, R.; Okubo, T.; Ulltveit-Moe, K.H. International Trade, CO\textsubscript{2} Emissions and Heterogeneous Firms; CEPR Discussion Paper No. 8583; Center for Economic Policy Research (CEPR): London, UK, 2011.
2. Cui, J.; Lapan, H.E.; Moschini, G. Are Exporters More Environmentally Friendly than Non-Exporters? Theory and Evidence; Iowa State University Department of Economics Working Paper No. 12022; Iowa State University: Ames, IA, USA, 2012.
3. Holladay, J.S. Exporters and the Environment. Can. J. Econ. 2016, 49, 147–172. [CrossRef]
4. Jiang, L.; Lin, C.; Lin, P. The Determinants of Pollution Levels: Firm-Level Evidence from Chinese Manufacturing. J. Comput. Econ. 2014, 42, 118–142. [CrossRef]
5. Holladay, J.S. Exporters and the Environment. Can. J. Econ. 2016, 49, 147–172. [CrossRef]
6. Grossman, G.M.; Krueger, A.B. Environmental Impacts of a North American Free Trade Agreement. Natl. Bur. Econ. Res. 1991, 39. [CrossRef]
7. Chichilnisky, G. North-South Trade and the Global Environment. Am. Econ. Rev. 1994, 84, 851–874.
8. Cole, M.A. Does Trade Liberalization Increase National Energy Use? Econ. J. 2006, 92, 108–112. [CrossRef]
9. Cole, M.A.; Elliott, R.J. Determining the Trade-Environment Composition Effect: The Role of Capital, Labor and Environmental Regulations. J. Environ. Econ. Manag. 2003, 46, 363–383. [CrossRef]
10. Managi, S.; Hibiki, A.; Tsurumi, T. Does Trade Openness Improve Environmental Quality? J. Environ. Econ. Manag. 2009, 58, 346–363. [CrossRef]
11. Martin, L.A. Energy Efficiency Gains from Trade: Greenhouse Gas Emissions and India’s Manufacturing Sector; Mimeo: Berkeley, CA, USA, 2011.
26. Cui, J. Induced Clean Technology Adoption and International Trade with Heterogeneous Firms. *J. Int. Trade Econ. Dev.* 2017, 26, 924–954. [CrossRef]

27. Beyer, H.; Rojas, P.; Vergara, R. Trade Liberalization and Wage Inequality. *J. Dev. Econ.* 1999, 59, 103–123. [CrossRef]

28. Yu, M. Trade Liberalization and Productivity: Evidence from Chinese Firms. *Econ. Res. J.* 2010, 12, 97–110. (In Chinese)

29. Harrison, A.E. Productivity, Imperfect Competition and Trade Reform: Theory and Evidence. *J. Int. Econ.* 1994, 36, 53–73. [CrossRef]

30. Bas, M.; Strauss-Kahn, V. Input-Trade Liberalization, Export Prices and Quality Upgrading. *J. Int. Econ.* 2015, 95, 250–262. [CrossRef]

31. Halpern, L.; Koren, M.; Szeidl, A. Imported Inputs and Productivity. *Am. Econ. Rev.* 2015, 105, 3660–3703. [CrossRef]

32. Parsons, C.R.; Nguyen, A.T. Import Variety and Productivity in Japan. *Econ. Bull.* 2009, 29, 1947–1959.

33. Goldberg, P.; Khandelwal, A.; Pavcnik, N.; Topalova, P. Trade Liberalization and New Imported Inputs. *Am. Econ. Rev.* 2009, 99, 494–500. [CrossRef]

34. Levinsohn, J.; Petrin, A. Estimating Production Functions Using Inputs to Control for Unobservables. *Rev. Econ. Stud.* 2003, 70, 317–341. [CrossRef]

35. Wooldridge, J.M. On Estimating Firm-Level Production Functions Using Proxy Variables to Control for Unobservables. *Econ. Lett.* 2009, 104, 112–114. [CrossRef]

36. Song, Z.; Storesletten, K.; Zilibotti, F. Growing like China. *Am. Econ. Rev.* 2011, 101, 196–233. [CrossRef]

37. Hsieh, C.T.; Klenow, P.J. Misallocation and Manufacturing TFP in China and India. *Q. J. Econ.* 2009, 124, 1403–1448. [CrossRef]

38. Cai, H.; Liu, Q. Competition and Corporate Tax Avoidance: Evidence from Chinese Industrial Firms. *Econ. J.* 2009, 119, 764–795. [CrossRef]

39. Feenstra, R.C.; Li, Z.; Yu, M. Exports and Credit Constraints under Incomplete Information: Theory and Evidence from China. *Rev. Econ. Stat.* 2014, 96, 729–744. [CrossRef]

40. Mao, Q.; Sheng, B. Trade Liberalization and Chinese Firms’ Export Behavior: Does WTO Entry Facilitate Export Participation? *China Econ. Q.* 2014, 13, 647–674. (In Chinese)

41. Liu, Q.; Qiu, L.D. Intermediate Input Imports and Innovations: Evidence from Chinese Firms’ Patent Filings. *J. Int. Econ.* 2016, 103, 166–183. [CrossRef]

42. Kim, K.; Kim, Y.S. How Important is the Intermediate Input Channel in Explaining Sectoral Employment Comovement over the Business Cycle? *Rev. Econ. Dyn.* 2006, 9, 659–682. [CrossRef]

43. Hulten, C.R. Growth Accounting with Intermediate Inputs. *Rev. Econ. Stud.* 1978, 45, 511–518. [CrossRef]

44. Basu, S. Intermediate Goods and Business Cycles: Implications for Productivity and Welfare. *Am. Econ. Rev.* 1995, 85, 512–531.

© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).