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# Are There the Impacts of Environmental Regulations on Manufacturing Export? Empirical Evidence from Chinese Manufacturing

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## Abstract

Environmental regulation is an effective tool to control environmental problems caused by foreign trade. Research conclusions are inconsistent on the relationship between environmental regulations and exports. Based on the Heckscher-Ohlin-Vanek model, this paper provides an empirical analysis for examination the effect of environmental regulations on manufacturing exports, adopting panel data of 16 sectors from China's manufacturing during 2005-2015. Material capital, human capital, technology input and foreign direct investment are simultaneously selected as independent variables to explore the export impact of corresponding changes in these endowments. The pollution intensity index was introduced to categorise different manufacturing sectors. Results indicated that China's environmental regulations intensity play different roles in the manufacturing sectors with different pollution levels. Stricter environmental regulation improves the export of intensive pollution manufacturing sectors but hinders exports in light pollution sectors. Meanwhile, other endowment factors also exert varying effects in the light, moderate and intensive pollution manufacturing sectors.

## Keywords

Environmental regulation, Heckscher-Ohlin-Vanek model, manufacturing export, China, pollution index.

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## Introduction

The massive expansion of economic activity has changed the global environment more drastically and extensively than ever before, threatening sustainable economic development (Cai and Ye, 2020). As an essential driving force of rapid modern economic growth, international trade and environmental issues are inseparable. International trade is not only the exchange of goods and services between two countries or regions but also the exchange of natural resources and the ecological environment (Xiong and Wu, 2021). Awareness of regulating the environmental problems caused by international trade has been growing in recent decades, intensifying the global trend of increasingly stringent environmental regulations. An advanced understanding of the relationship between environmental regulations and international trade has become a significant topic for current and future research on human well-being and sustainable economic development (United Nations, 2015).

Since entering the WTO in 2001, the export trade has experienced an explosive expansion in China. The gross trade volume of Chinese exports grew from 0.27 USD trillion in 2001 to 2.50 USD trillion in 2019, equalling about 4.3% and 13.2% of gross world exports, respectively (NBSC, 2020). China's manufacturing actively participates in the global value chain (GVC) to assume the "world factory" role in the international community, capitalising on cheap labour, abundant raw materials, and a relatively complete industrial system. As of 2019, China's export of manufactured goods exceeded 2.37 USD trillion, making it a mainstay of China's export growth. However, China's manufacturing sectors mainly engage in middle and lower value-added production activities in the GVC and lack a say in regulation-making. Most heavy polluted industrials have been relocated from developed countries to developing countries due to low-cost advantages and loose environmental regulation, which means a transfer occurred in ecological resources consumption and environmental pollution (Copeland and Taylor, 2004). As the world's greatest carbon emitter, approximately 22% of China's total annual carbon dioxide emissions are generated from net exports (Qi et al., 2014). Thus, there are substantial environmental risks hidden behind the prosperity of China's manufacturing export. In a new normal of China's economy, the development of manufacturing export has shifted to a more quality-oriented, heralding the growing importance of environmental regulation.

Environmental regulation stems from environmental externalities, property rights theory and welfare economics (Zhu et al., 2019). Generally, the environmental resource is taken as freely accessible public goods (non-rival and non-excludable), resulting in the ineffectiveness of conventional market mechanisms to manage them. To this end, environmental regulation is an indispensable policy measure for regulators to control ecological problems and regulate economic activities to achieve economic and ecological coordination and sustainable development (Pigou, 1924). In economic globalisation, environmental regulation has been a conventional and effective tool for a country to deal with environmental issues caused by foreign trade. Generally, environmental regulation is defined as a set of environmental measures imposed by governments or economic organisations to protect the environment that impacts international trade, either mandatory or voluntary (Jiang et al., 2018). Policy discussions regarding industrial upgrading and greening manufacturing in China recently focused on the alleged trade-off between economic development versus environmental protection. This complex trade-off is especially evident in disputes about the effect of environmental regulations on the export scale in China's manufacturing. As China's environmental regulation became increasingly mature, there is an emerging concern regarding its impacts on manufacturing export trade (Wang et al., 2016).

Neoclassical economics model, stressing upon the "cost increase" effects, assumed that stricter environmental regulations increase production constraints and compliance costs of the regulated enterprises, and ultimately weaken the comparative advantage (Palmer et al., 1995; Cole et al., 2010). The additional economic burden will cause difficulties in the production, operation and sales of enterprises (Hering and Poncet, 2014), thereby reducing the product competitiveness and ultimately resulting in a cut down in the export possibilities and export volumes (Shi and Xu, 2018; Zhang, Cui and Lu, 2020). The pollution heaven hypothesis holds that compliance costs tend to prompt intensively polluted industries to transfer from countries with stricter environmental regulations to less environmentally regulated countries, reducing the corresponding industrial's export (Walter and Ugelow, 1979; Levinson,2010; Brunel, 2017; Cai et al.,2018). Contrarily, many scholars hold another view that environmental regulations would play a positive role in developing export trade (Rubashkina et al., 2015; Millimet and Roy, 2016). The most representative of theses, the Porter hypothesis (Porter, 1991), postulates that the well-designed environmental regulations could effectively reduce contamination, accelerate enterprise technology innovation, thus stimulating innovation compensation effects. This positive effect ultimately offset compliance costs and improve enterprise competitiveness and economic performance. Growing environmental compliance would affect export development patterns to enhance productivity and product competitiveness through innovative compensation effects, then achieving a win-win situation in alleviating environmental pressures and export growth (Porter and Van der Linde, 1995). Extensive empirical analyses have validated the Porter hypothesis that environmental regulations could be a critical driving force for increasing green export (Brandi et al., 2019; Zhu et al., 2019). There are also many theoretical and empirical studies that neither supports harmful effects nor beneficial effects. These findings have shown that changes in environmental regulation have uncertain or non-linear impacts on trade (Cole et al., 2005; Arouri et al., 2012; Ouyang et al., 2020; Song et al., 2020). Quantitatively estimating the effects of Environmental regulation is thus of great practical significance for accelerating the green development of China's manufacturing and enhancing promoting sustainable development of its export.

Given the above research background, this paper adopts the industrial panel data covering 2005-2015 to quantitatively explore how environmental regulation influences China's manufacturing export and how the effect differs across manufacturing sectors with various pollution intensities. First, this study introduces a pollution index to classify China's manufacturing sectors according to the degree of pollution. Second, this research measures the intensity of China's environmental regulation by using pollution discharge and pollution control expenditures as the evaluation method. In addition, environmental regulation is incorporated into the analysis framework of trade's influencing factors based on the Heckscher-Ohlin-Vanek (HOV) model. In the end, this paper to uncover the effect of selected factor endowments (environmental regulation, material capital, human capital, technology input, foreign direct investment) on China's exports of different manufacturing sectors.

## Materials and methods

### Classification of manufacturing sectors

In the case of the data availability, this research was conducted based on the sector-level data. As the classification system of the manufacturing sector in the National Economic Industry Classification Code (GB/T4754-2002) is inconsistent with ISIC Rev.4, this research has integrated and matched the sector code following the industry consolidation in the existing literature, to achieve consistency among sector codes.

To distinguish the pollution intensity of different manufacturing sectors, there needs to be an industrial pollution emission index. Existing kinds of the literature showed that the method of measuring industrial pollution intensity mainly include Pollution abatement and control expenditures (PACE), the ratio of the emissions in the industrial added value, standardized emissions data and pollution emission index (Fu and Li, 2010). Due to the Chinese government not having statistics on the cost of pollution reduction by sector, this study used the last quantitative method of Fu and Li (2010) to evaluate the pollution intensity. Manufacturing pollution is mainly manifested in the discharge of wastewater, waste gas and some toxic solid wastes. Using a method of Kheder and Zugravu (2012), this research standardized three pollutant emission indexes for various sectors, then calculated the pollution intensity index.

Based on the following formulations (Table 1), the pollution intensity of different sectors in China's manufacturing industry from 2005 to 2015 was calculated. The higher the pollution intensity index, the greater the sector's pollutant emission intensity, and the heavier the burden on the environment. After ranking the 16 industries by the size of the pollution intensity index, the pollution degree of sector is categorised according to its comparison with the cut-off point 0,05 and 1: intensive, moderate, and light (Copeland and Taylor 2004; Fu and Li, 2010) (Table 2).

### Measurement of environmental regulation intensity

Various measurement methods have been used in the existing literature to quantify the stringency of environmental regulation, including qualitative indicators based on questionnaire research, the number of environmental regulations, the density of pollutant emissions, PACE, GDP per capita and Comprehensive indicators.

Measuring the level of environmental regulations

| Step | Calculation | Explanation |
|---|---|---|
| Pollution emission index (Fu and Li, 2010) | $PE_{ij}=P_{ij}/TV_i$ | $PE_{ij}$: pollution emission index of pollutant j in sector i |
| | | $P_{ij}$: emission volume of pollutant j in sector i |
| | | $TV_i$ : total output value of sector i |
| Standardize (Kheder and Zugravu, 2012) | $\overline{PE}_{ij} = \frac{PE_{ij} - Min(PE_j)}{Max(PE_j) - Min(PE_j)}$ | $\overline{PE}_{ij}$ : normalized pollutant emission index |
| | | $Max\ (PE_j)$: entire industrial maximum pollutant emission index of pollutant j |
| | | $Min\ (PE_j)$: entire industrial minimum pollutant emission index of pollutant j |
| Pollution intensity index (Fu and Li, 2010) | $PI_i=\sum_j^3 \overline{PE}_{ij}$ | $PI_i$ : pollution intensity of sector i |

Source: Own processing

Table 1: Pollution intensity index calculation steps.

| Class | Code | Section description | PI |
|---|---|---|---|
| Intensive pollution sector PI>1 | 11 | Manufacture of basic metals | 1.6975 |
| | 4 | Manufacture of paper and paper products | 1.6011 |
| | 10 | Manufacture of non-metallic mineral products | 1.3512 |
| | 7 | Manufacture of chemicals and chemical products | 0.9887 |
| Moderate pollution setctors 0.05<PI<1 | 6 | Manufacture of coke and refined petroleum products | 0.4593 |
| | 1 | Manufacture of food, beverages and tobacco | 0.2455 |
| | 8 | Manufacture of medicinal and pharmaceutical products | 0.1947 |
| | 2 | Manufacture of textiles, wearing apparel and leather | 0.1801 |
| | 3 | Manufacture of cork and wood products (except furniture) | 0.1601 |
| | 12 | Manufacture of favricated metal products | 0.1169 |
| Light pollution sectors PI<0.05 | 9 | Manufacture of rubber and plastics products | 0.0562 |
| | 14 | Manufacture of transport and related equipment | 0.0425 |
| | 15 | Manufacture of electronic and optical products | 0.0275 |
| | 16 | Manufacture of furniture | 0.0184 |
| | 13 | Manufacture of machinery and equipment | 0.0140 |
| | 5 | Printing and reproduction of recorder media | 0.0106 |

Source: Own computation, the China Environmental Yearbook 2005-2016

Table 2: Ranking of the mean value of the sector's pollution intensity index (PI).

at the industrial level mainly depends on the response and compliance of economic entities in the industry. For the manufacturing industry, environmental regulation intensity could be quantified by controlling pollution emissions. Thus, this paper thereby integrated pollution control costs and pollution emissions when constructing indicators. By referring to previous literature method (Li and Li, 2017), the pollution control investment per unit of pollution discharge is employed as an indicator to measure the stringency of environmental regulation. In general, the higher the indicator, suggesting the more pollution control investment per unit of pollution emission, and the stricter the environmental regulation. The concrete calculation process of environmental regulation (ER) intensity is shown in the Table 3.

### Data sources and processing

Panel data model have been adopted in numerous literatures to observe economic entities' behaviour (e.g., countries, regions, industries, et al.) over the entire time range (Torres Reyna, 2007). This paper adopted a balanced panel, covering 16 sectors of China's manufacturing from 2005 to 2015. The utilised data for measuring the environmental regulation intensity is sourced from the China Environmental Statistical Yearbook, which only counts all the data related to the three types of waste pollutants in various sectors from 2005 to 2015. Because of data availability, the period of 2005-2015 was selected to truly capture environmental regulation's impact on manufacturing export in China. The variables (Table 4) employed by the research include environmental regulation intensity (ER), export trade volume (EX), material capital endowment (K), human capital endowment (H), technology input endowment (T), and foreign direct investment (FDI). To eliminate the unit inconsistency with other indicators, this paper uses the annual average exchange rate of CNY against the US dollar for transforming the export trade volume uniformly. In addition, using the price index (2005=100) to eliminate price fluctuations and obtain the actual export trade value. Eviews rev.10. was used as the primary calculation software.

### Empirical test of econometric model

- Stationarity Test: Panel data is also called cross-sectional time-series data. This study performs a unit root test on panel data stationarity before regression analysis to avoid spurious regression. Common root test and Individual root test are two mainly used methods for panel data stationarity testing in Eviews rev.10. Generally, Levin–Lin–Chu test (LLC test) and PP-Fisher tests are used to examine whether each series contains a unit root. Probabilities for Fisher test are computed using an asymptotic

| Step | Calculation | Explanation |
|---|---|---|
| Unit pollution control investment | $ER_{ij} = PC_{ij}/P_{ij}$ | $ER_{ij}$: Envorinment regulation (ER) intensity of pollutant j in sector i |
| | | $P_{ij}$: emission volume of pollutant j in sector i |
| | | $PC_{ij}$: pollution control investment of pollutant j in sector i |
| Standardize | $\overline{ER_{ij}} = \frac{ER_{ij}}{\sum_i^{16} ER_{ij}}$ | $\overline{ER_{ij}}$ : normalized ER intensity of pollutant j in sector i |
| | | $\sum_i^{16} ER_{ij}$ : sum of the ER intensity of pollutant j per unit output value of all sectors |
| ER intensity index | $ER_i = \sum_j^3 \overline{ER_{ij}}$ | $ER_i$: ER intensity of sector i |

Source: Own processing based on Li and Li (2017)

Table 3: ER intensity index calculation steps.

| Variables | Description | Operationalization | Unit | Data source |
|---|---|---|---|---|
| EX | sector's export trade | the export trade volume of each sector | CNY | UN Comtrade<br>the China Statistical Yearbook (2006-2016) |
| ER | environmental regulations' intensity | sector's pollution control and treatment investment/ sector's pollution discharge *100<br>(Li and Li, 2007) | % | the China Environmental Statistical Yearbook (2006–2016) |
| K | material capital | sector's fixed assets-net value / number of sector's employees<br>(Cole et al., 2005) | CNY per capita | the China Statistical Yearbook<br>the China Industry Statistical Yearbook<br>(2006–2016) |
| H | human capital | sector's science and technology personnel/ the total sector's employment *100<br>(Teixeira and Teixeira, 2014) | % | the China Statistical Yearbook on Science and Technology (2006–2016) |
| T | technology input | sector's enterprise R&D expenditure<br>(Zhai and An, 2020) | CNY | the China Statistical Yearbook on Science and Technology (2006–2016) |
| FDI | foreign direct investment | assets of sector's foreign-funded industrial enterprises / total assets of sector's industrial enterprises * 100 | % | The China Trade and External Economic Statistical Yearbook (2006–2016) |

Source: Own processing

Table 4: Variable description and data source.

Chi-square distribution, and LLC tests are computed assuming asymptotic normality. If P-value > 0.05, the panel data do not reject the null hypothesis of containing unit-roots, and the data are not stationary; otherwise, the panel data are stationary.

- Panel Equation Testing: Panel data models consist of two groups: the fixed effects model and the random effect model. The Redundant Fixed Effects-Likelihood Ratio Test and the Correlated Random Effect-Hausman Test are required to determine whether the empirical model uses a mixed effect model, a fixed effect model or a random effect model. First, the Redundant Fixed Effects-Likelihood Ratio Test: if the P-value of F statistic < 0.05, meaning that the null hypothesis is rejected, choose an individual fixed effect model; otherwise, establish the mixed effects model. Secondly, the Correlated Random Effect-Hausman Test: If the P-value of Chi-square statistic < 0.05, null hypothesis is rejected, an individual fixed effect model is selected; otherwise, choose the random effect model.

### Model establishment

Heckscher-Ohlin (H-O) model has become a popular option for analysing environmental regulation and international trade relations. Trade specialisation usually depends on the composition of factor endowments, according to the setting of the H-O model and Ricardo's comparative advantage theory. Under a traditional H-O model framework, the production factor input of each sector mainly consists of capital, labour, and technological endowment. In conjunction with this, production activity will also produce pollution emissions and affect the environment. Environmental regulation could be treated as a kind of economic factor endowment invested by the enterprise during their production procession, thereby establishing an extended environmental Heckscher-Ohlin-Vanek (H-O-V) model (Tobey, 1990; Cole and Elliott, 2003; Cole and Elliott, 2010). It is a model of multiple countries, multiple commodities and multiple elements. The H-O-V model emphasises that a country becomes a net exporter of relatively abundant factors under free-trade conditions, export is expressed as a function of factor endowments. The traditional H-O-V model has the following form:

$$EX_{i,t} = \sum_{k=1}^{k} \beta_k F_{i,t,k} = \beta_0 + \beta_1 F_{i,t,1} + + \beta_2 F_{i,t,2} + \ldots + \beta_k F_{i,t,k} + \varepsilon \quad (1)$$

where the subscripts i, t and k denote the sector, year and factors respectively. ε is a random error, and $\beta_k$ is the estimated coefficient of each explanatory variable. $EX_{i,t}$ indicates the export trade scale of sector i in year t, $F_{i,t,k}$ is the k factor endowment of sector i in year t.

Export (EX) trade in this study is expressed as a function of environmental regulation intensity (ER), material capital endowment (K), human capital intensity (H), technology input element (T) and foreign direct investment (FDI). In this study, all variables are processed in logarithm (ln) to alleviate the multicollinearity and heteroscedasticity. The specific regression model is established as Equation 2

$$ln\, EX_{it} = \beta_0 + \beta_1 lnER_{it} + + \beta_2\, ln\, K_{it} + \beta_3 lnH_{it} + + \beta_4\, ln\, T_{it} + \beta_5 lnFDI_{it} + \varepsilon \quad (2)$$

where the subscripts i and t denote the industry and year, respectively. $\beta_0$ is a constant term, $\varepsilon$ is a random error, and $\beta_{1-5}$ is the regression coefficient of each explanatory variable. $EX_{it}$ indicates the export trade volume of each i in year t; $ER_{it}$ is the environmental regulations intensity of sector i in year t; $H_{it}$ is the human capital intensity of sector i in year t; $K_{it}$ is the material capital intensity of sector i in year t; $T_{it}$ is the research and development investment of sector i in year t; and $FDI_{it}$ is the foreign investment of sector i in year t.

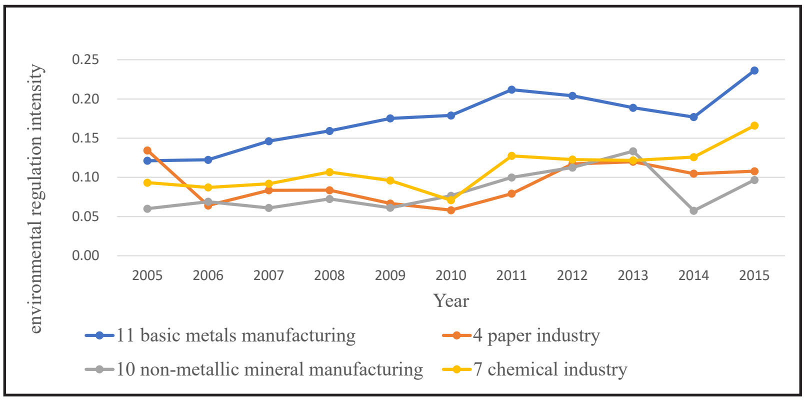
## Results and discussion

### Measurement results of environmental regulation intensity

As shown in Figure 1, 2 and 3, there are differences in the stringency of the environmental regulation between manufacturing sectors with different pollution intensities. The highest environmental regulation intensity is shown in the moderate pollution sectors. The intensity of environmental regulations in the intensive and light pollution sectors is in the same range. Due to this heterogeneity between industries, changes in the intensity of environmental regulations may affect manufacturing export.

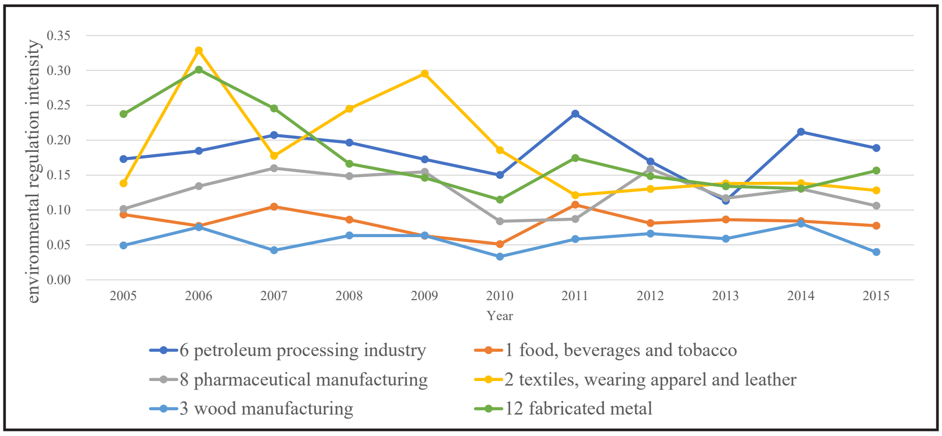
Figure 1 depicts that environmental regulation in the intensive pollution sectors has been continuously strengthened, showing a steady upward trend from 2005 to 2015. At the beginning of international trade development, China's heavy industry traded at the expense of the environment in exchange for economic expansion. Although the operating cost of pollution control continues to increase, it cannot keep up with the increase in production pollution emissions. Therefore, the intensity of environmental regulations has been in a relatively weak position compared with other sectors. However, as the world's awareness of environmental issues continues to increase, various countries' environmental regulations are simultaneously upgrading standards, leading to China's suffering from green trade barriers in its export trade. After that, China's heavy industry is gradually regaining its attention to the environment, and the intensity of environmental regulation in the intensive pollution sector has been increasing in recent years.

From a numerical point of view, the environmental regulation intensity has always been relatively high in moderate pollution sectors (Figure 2). Especially, resource-intensive and labour-intensive industries, such as the petroleum processing industry, textile and apparel industry, and fabricated metal



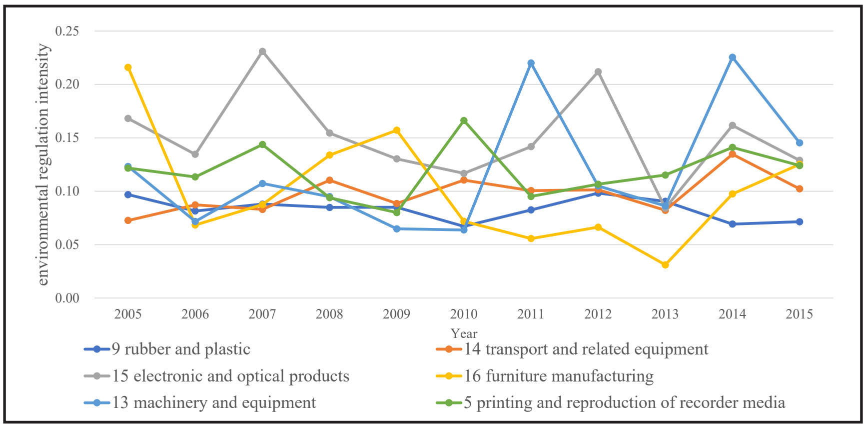

Source: Own computation

Figure 1: Environmental regulation intensity in intensive pollution sectors, 2005 – 2015.




Source: Own computation

Figure 2: Environmental regulation intensity in moderate pollution sectors, 2005 - 2015.




Source: Own computation

Figure 3: Environmental regulation intensity in lightly pollution sectors, 2005 – 2015.

manufacturing industries, have always highlighted China's pollution control, emission reduction and energy conservation.

Nevertheless, the wood processing industry, also energy-intensive and polluting, has not received sufficient attention. Furthermore, Figure 3 indicated that the stringency of environmental regulation of other light pollution sectors remains relatively low level, except the machinery and equipment manufacturing, electronic equipment, and optical product manufacturing industries. Meanwhile, the environmental regulation intensity of light pollution sectors has been fluctuating, and most sectors have undergone several changes in the process of falling first and then rising. The reason behind this phenomenon might be that: influenced by China's "11th, 12th, and 13th Five-Year Plan", the environmental regulation intensity of these sectors fluctuates with economic development and new environmental policy orientation. Therefore, China should increase its attention to light pollution sectors and stabilize its environmental regulation at a certain level instead of reducing monitoring measures since weak pollution emissions.

### The results of Stationarity Test

As Table 5 shows the unit root test results, the P-value of all series in the sector's model of different pollution levels is less than 0.05. Thereby, all series reject the null hypothesis of "contain unit roots" at the 5% significance level. Hence, all variables in this model belong to the stationary series of the same order, suggesting that the model's regression analysis is feasible in this paper.

### The results of Fixed/Random Effects Test

The results of the Redundant Fixed Effects-Likelihood Ratio Test for three different pollution intensity sectors are shown in Table 6. All the P-values of all sample models is less than 0.05, which rejects the null hypothesis at the significance level of 5%, indicating that the fixed effects model is better than the mixed effects model. As shown in the Hausman test results in Table 7, the fixed-effects model is selected. Therefore, individual fixed effects models should be established for these three sets of sample data based on the above two test results.

| Variables | Statistical method | LLC | PP-Fisher | Results |
|---|---|---|---|---|
| Panel I: Intensive pollution sector's model | | | | |
| lnEX | (I,T,1) | 0.0000 | 0.0000 | stable |
| lnER | (N,N,1) | 0.0000 | 0.0000 | stable |
| lnK | (I,N,1) | 0.0001 | 0.0026 | stable |
| lnH | (I,T,1) | 0.0000 | 0.0008 | stable |
| lnT | (I,T,1) | 0.0000 | 0.0000 | stable |
| lnFDI | (I,N,1) | 0.0116 | 0.0002 | stable |
| Panel II: Moderate pollution sector's model | | | | |
| lnEX | (I,T,0) | 0.0000 | 0.0000 | stable |
| lnER | (I,T,0) | 0.0000 | 0.0000 | stable |
| lnK | (I,T,0) | 0.0000 | 0.0000 | stable |
| lnH | (I,T,0) | 0.0000 | 0.0000 | stable |
| lnT | (I,T,0) | 0.0000 | 0.0000 | stable |
| lnFDI | (I,T,0) | 0.0000 | 0.0014 | stable |
| Panel III: Light pollution sector's model | | | | |
| lnEX | (I,T,1) | 0.0001 | 0.0007 | stable |
| lnER | (I,T,1) | 0.0000 | 0.0028 | stable |
| lnK | (I,T,1) | 0.0000 | 0.0036 | stable |
| lnH | (I,T,1) | 0.0000 | 0.0000 | stable |
| lnT | (I,T,1) | 0.0000 | 0.0001 | stable |
| lnFDI | (N,N,1) | 0.0000 | 0.0000 | stable |

Note: "I" means that individual intercept is included in test equation; "T" means that individual linear trend is included in test equation; "N" means not including intercept/trend item; "0" or "1" means to test for unit root in level or in 1st difference.
Source: Own computation of Eviews 10. result

Table 5: Result of stationary test.

| Effect test | Statistic | Prob. |
|---|---|---|
| Panel I: Intensive pollution sector's model | | |
| Cross-section F | 97.4239 | 0.0000 |
| Cross-section Chi-square | 111.7988 | 0.0000 |
| Period F | 3.8983 | 0.0028 |
| Period Chi-square | 41.3488 | 0.0000 |
| Cross-section/Period F | 64.1656 | 0.0000 |
| Cross-section/Period Chi-square | 155.6311 | 0.0000 |
| Panel II: Moderate pollution sector's model | | |
| Cross-section F | 263.088 | 0.0000 |
| Cross-section Chi-square | 224.9875 | 0.0000 |
| Period F | 5.7175 | 0.0000 |
| Period Chi-square | 54.1215 | 0.0000 |
| Cross-section/Period F | 133.7995 | 0.0000 |
| Cross-section/Period Chi-square | 252.1137 | 0.0000 |
| Panel III: Light pollution sector's model | | |
| Cross-section F | 584.6469 | 0.0000 |
| Cross-section Chi-square | 263.4557 | 0.0000 |
| Period F | 14.1297 | 0.0000 |
| Period Chi-square | 93.7649 | 0.0000 |
| Cross-section/Period F | 669.5290 | 0.0000 |
| Cross-section/Period Chi-square | 357.2206 | 0.0000 |

Source: Own computation of Eviews rev.10. results

Table 6: The experimental results of the Redundant Fixed Effects-Likelihood Ratio Test.

| Panel Model | Chi-Sq.Statistic | Prob. |
|---|---|---|
| Intensive pollution sector's model | 27.5066 | 0.0000 |
| Moderate pollution sector's model | 45.9447 | 0.0000 |
| Lightly pollution sector's model | 38.1566 | 0.0000 |

Source: Own computation of Eviews rev.10. results

Table 7: The experimental results of the Correlated Random Effect-Hausman Test.

## The estimation results

Table 8 provides the empirical results of three different pollution intensity sectors' panel models to demonstrate how the selected factors affect China's manufacturing export trade volume. As for model verification, the coefficient of determination $R^2$ and adjusted $R^2$ verified the regression predictions fit the data with relatively high accuracy. The statistically significant regression in these models can be found from the high value of the F-statistic. The concrete analysis is as follows in the Table 8.

## Environmental regulation intensity

As empirical results are shown in Table 8, the environmental regulation variable's regression coefficient in the intensive pollution sector's model is negative and statistically significant at the 5% significance level. This result shows that environmental regulation has not positively impacted the export in intensive pollution sectors. The moderate pollution sector's estimation result indicates that environmental regulations harm exports, but this adjustment effect is not significant. The regression coefficient of the environmental regulation variables in the light pollution sector's model is positive and significant at the 5% significance level, which means a significant positive correlation between environmental regulation and exports in the light pollution sector. According to the construction of environmental regulation intensity indicators in the previous chapter, the higher the pollution control operation cost per unit of pollution discharge, the more stringent

| Variables | Panel I | Panel II | Panel III |
|---|---|---|---|
| Constant | 16.7162*** | 9.2312*** | 3.7412*** |
| | (8.6890) | (4.5928) | (6.8620) |
| lnER | -0.0932** | -0.0782 | 0.0856** |
| | (-1.1708) | (-1.0149) | (2.4490) |
| lnK | 0.6072*** | -1.0147** | 0.2871** |
| | (2.9879) | (-2.5111) | (2.4692) |
| lnH | 0.3630 | -0.0549*** | -0.0266 |
| | (0.7115) | (-0.7226) | (-0.9913) |
| lnT | 0.5751** | 0.3490** | 0.4857*** |
| | (2.6783) | (2.0984) | (4.1095) |
| lnFDI | 0.1629 | 0.1278 | 0.3663* |
| | (0.7319) | (2.0310) | (1.7190) |
| Total pool observations | 44 | 66 | 66 |
| R-squared | 0.9235 | 0.9931 | 0.9942 |
| Adjusted R-squared | 0.8825 | 0.9885 | 0.9932 |
| F-statistic | 22.5254 | 281.3833 | 945.8201 |

Notes: The numbers above brackets are regression coefficients. The t-value of T is in parentheses. * = significant at 10%; ** = significant at 5%; *** = significant at 1%.

Panel I: Intensive pollution sector's model; Panel II: Moderate pollution sector's model; Panel III: Light pollution sector's model.

Source: Own computation of Eviews rev.10. results

Table 8: The empirical results of Panel Least Squares.

the environmental regulation. The estimated regression coefficients imply that for each one percent increase in the environmental regulation intensity, export in light and intensive pollution sector will gain 0.0932 percent reduction and 0.0856 percent increase respectively. Therefore, to a certain extent, the rigorous intensity of the environmental regulation is conducive to export trade's growth of light pollution sector in China's manufacturing industry but hinder exports in intensive pollution sectors. Since no statistically significant results have been achieved, the impact is uncertain for the moderate pollution sectors.

As discussed in the existing literature, environmental regulations can show different effect results based on theoretical economic models (Ouyang et al., 2020). Under the pollution paradise hypothesis, the cost effects of strict environmental regulations will increase compliance costs of highly polluting enterprises and weaken export competitiveness, resulting in a decline in trade exports (Palmer et al., 1995; Walter and Ugelow, 1979). However, the Porter hypothesis holds that well-organized environmental regulations can effectively encourage enterprises to increase the export competitiveness of manufactured goods through technological innovation and green transformation (Porter, 1991). These firms can break through the green trade barriers set by developed countries and further expand the export scale. That is the so-called "innovation compensation effects" (Porter and Van der Linde, 1995). Therefore, the influencing results of environmental regulations on export primarily depend on the trade-off between cost and innovation compensation effects. In this study, there is no obvious empirical evidence that, driven by cost effects, stricter environmental regulation can improve export trade growth in intensive pollution sectors to refute Porter's hypothesis.

China started relatively late in environmental regulation of the light pollution manufacturing, especially the mechanical and electrical industries. China's pollution reduction-oriented regulatory tools currently have limited effect on the environment controlling these relatively clean industries. Generally, manufacturing sectors with light pollution degrees in China mainly are labour-intensive industries or high-tech industries. The proportion of fixed assets in these sectors' firms is typically low, suggesting that the cost of technological innovation is not a heavy economic burden. Therefore, these sectors can quickly incur innovation compensation effects with the implementation of environmental regulation. With the increasingly strict environmental regulation, the light pollution sectors have accelerated their industrial upgrading and further moved towards green transformation. This empirical study shows that the more stringent environmental regulations exert greater "innovation compensation effects" than the "cost effect" on lightly pollution sectors, thus benefiting export volume.

Overall, this study confirmed the heterogeneous impact of environmental regulations on manufacturing exports in China. It also found that the effect of environmental regulation on exports is not apparent compared to the other independent variables from the perspective of the coefficient value. This result indicates that traditional comparative advantages and factor endowments show more decisive than environmental regulation when analysing the influencing factors of China's manufacturing exports. Therefore, China's manufacturing exports are still highly likely to depend on accumulating the industry's material capital and its technological development.

### Material capital endowment

There is a significant negative correlation between the material capital endowment and the export of moderate pollution sectors. Table 8 reveals that the regression coefficient of the material capital endowment variable in panel II is negative and statistically significant, implying the export of moderate pollution sector will reduce 1.0149 percent with a one percent increase in material capital endowment. The regression coefficient of the material capital endowment is positive and statistically significant in the intensive and light pollution sectors, which is consistent with the traditional economic viewpoint. The estimated percent increase in the export of light and intensive pollution sector are 0.6072 and 0.2871with a one percent increase in material capital endowment.

In this research, the material capital endowment variable is measured by material capital per capita. This variable shows a significant adverse effect in the moderate pollution sector, indicating that the rise of per capita capital negatively affects the export of the moderate pollution manufacturing sector. The reason behind this result is that labour-intensive industries are still play-dominated roles in the endowment factor structure. As the largest developing country, China's abundant factor endowment lies in its labour force. China's manufacturing exports have benefited from the demographic dividend for a long time, leading to export competitiveness concentratedly shown in labour-intensive industries (Wang and Zhang, 2019). With capital accumulation increasing, the demographic dividend gradually disappears, and the surplus labour supply tends to be tight (Yu and Wang, 2021). Under this circumstance, the optimal resource allocation of capital and labour cannot be achieved, and exports fall instead of rising with capital accumulation. Currently, China's foreign trade structure is in a critical transition from labour-intensive to capital-intensive. Thus, the material capital factor is impossible to be ignored in China's manufacturing development.

### Human capital intensity

As reported in Table 8, the positive effect of human capital intensity on the light pollution sector's export is not statistically significant. However, the negative correlation between the human capital intensity and the moderate pollution sector's export is significant at a 1% significance level. The percentage change in the moderate pollution sector's export is -0.0549 resulting from a one percent change in human capital intensity. In the intensive pollution sector's model, the regression coefficient of human capital intensity is negative but not significant. Contrary to traditional views, the moderate and intensive pollution sector's export would decrease with the increasing intensiveness of human capital.

This paper uses the proportion of high-tech personnel to the industry's number to measure human capital intensity. The higher the human capital intensity, the higher the amount of scientific and technological (S&T) personnel in the industry with solid adaptability, adjustment, and innovation (Ouyang et al., 2020). Enterprises with rich human capital are more capable of adapting and responding to environmental regulations. Human capital positively promotes China's light pollution manufacturing sector's export, which means the increase in the proportion of high-tech personnel can significantly enhance the industry's technological innovation and progress, thereby enhancing export competitiveness. On the contrary, human capital intensity plays a negative role in China's moderate and intensive pollution manufacturing sector's export. The fact behind this result is that the distribution of scientific and technical personnel in different sectors in China's manufacturing is unreasonable, some human capital is in a rigid state, and the overall human capital utilization efficiency is not high (Song et al., 2020). Although the ratio of S&T personnel in the manufacturing industry increases, there is a lack of patents focusing on pollution control, emission reduction, and energy saving in terms of innovation output. Therefore, increasing human capital investment in moderate and intensive pollution manufacturing sector negatively influences the exports within the industry.

### Technology input element

Table 8 demonstrates a significant positive correlation between the technical factor input and the export of various sector manufacturing, consistent with the Porter hypothesis. A one percent increase in technology input element leads to a 0.5751, 0.3490 and 0.4857 percent increase in the export of light, moderate and intensive pollution sector. The positive regression coefficient of the technology input variable is statistically significant in the light, moderate and intensive pollution sector at 5%, 5% and 1% significance levels separately. These coefficients are relatively high among other dependent variables in the three models, proving that technology input is an essential factor affecting China's manufacturing exports.

Relying on low-cost advantages, China made compelling achievements in its manufacturing export. However, accompanied by many environmental costs, it cannot maintain ongoing competitiveness in fierce international trade. For achieving sustainable development, increasing R&D investment to carry out technological innovation is conducive to updating production equipment, improving product innovation, winning high added value, and ultimately gaining export competitiveness. This paper measures the technology input element variable by research and development (R&D) investment in the industry. For the various pollution sector of manufacturing, technology input exerts a positive impact on China's manufacturing sector. As such, the consensus that "science and technology are the primary productive forces" has been verified in the field of manufacturing export trade.

### Foreign direct investment

There is a positive correlation between foreign direct investment and the export of various manufacturing sectors. Nevertheless, this positive effect of foreign direct investment is not statistically significant in the light and moderate pollution sector's export. In the intensive pollution sector model, the promotion effect of foreign direct investment variables on exports is statistically significant, and the export will increase 0.3663 percent with a one percent increase in foreign direct investment.

It shows that foreign direct investment has failed to play significant positive impact on the light and moderate pollution manufacturing industries. That result can be attributed to the time lag, foreign direct investment's spillover effect has not been fully exerted, and domestic-funded enterprises have not yet benefited from it. Still, foreign direct investment plays a significant positive role in promoting the export of relatively heavy pollution industries, that is introducing FDI to provide necessary financial support for industrial development in case of lacking domestic capital. Besides, foreign direct investment is often accompanied by advanced science and technology, which promote the absorption of advanced technology by the invested country. Simultaneously, it facilitates the connection with the investor's home country market, thereby indirectly promoting the growth of exports. Therefore, except for intensive pollution sectors, FDI has not exerted a significantly impact on the growth in manufacturing export trade.

## Conclusion

With environmental problems becoming increasingly prominent, many countries have gradually designed and implemented various environmental regulations to control pollutant discharge and solve environmental issues. However, China's environmental regulation has been a late start and is still at an early stage, meaning its intensity is far weaker than in developed countries. This research investigated the environmental regulation's impact on China's manufacturing export. Considering industry heterogeneity, this paper divides the manufacturing industry into intensive pollution, moderate pollution and light pollution sectors according to the varied pollution degrees. Besides, adopting the environmental regulation intensity indicator constructed by Li and Li (2017) to proxy the environmental regulation variables. Using a balanced panel that spans over a period from 2005 to 2015 and includes 16 of China's manufacturing sectors, this research provided an empirical analysis based on the H–O–V model. The main research conclusions obtained are as follows:

The empirical result confirmed that changes in China's environmental regulations intensity play different roles in manufacturing sectors with varying pollution levels. The environmental regulation is conducive to export trade's growth of intensive pollution sectors in China's manufacturing industry but hinder exports in light pollution sectors. In the case of the moderate pollution manufacturing sectors, there is no statistically significant evidence to confirm that environmental regulations play a role in these sectors' export.

Compared to other endowments of production factors, environmental regulation is a weak significant factor in China's manufacturing export trade. The material capital has a statistically significant positive impact on export in light and intensive pollution sectors but has a statistically significant adverse impact on export in moderate pollution sector. The human capital plays a statistically significant negative role in moderate pollution sector's export. For various pollution sector's export, the technological input human capital shows a statistically significant positive effect. In the intensive pollution sector's export, foreign direct investment plays a statistically significant positive role.

With the accumulation of material capital elements, manufacturing can effectively improve the infrastructure, upgrade the equipment and expand the production scale, ultimately increasing exports. The input of technological capital and human capital can magnify this effect at the same time. Therefore, the manufacturing industry in China can increase products competitiveness by raising capital and technology input. However, it is worth noting that improving the utilisation efficiency of each endowment is necessary by adjusting and optimising the product factor's input ratio.

The above conclusions reveal several implications for policymaking: First, the main component of China's manufacturing exports is generally processing and manufacturing industrial products. Most of them are high energy consumption, high pollution, high emission industries, and low-end manufacturing. It's necessary to optimize the export structure, develop green trade, and promote it to transform to high added value and low resource consumption. Furthermore, formulate industry-differentiated environmental policies rather than blindly strengthen the intensity of environmental regulations. Based on the characteristics of different pollution types in the manufacturing industry and China's current economic and social production development needs, differentiated environmental policies and methods should be adopted to manage problem issues. Second, the innovation compensation impact of environmental regulation depends on the cooperation of labour and capital. In the fierce international competition, the manufacturing industry in China should pay attention to the expansion of capital scale and pay attention to the efficiency of capital utilization and the integration of capital, labour, and technology.

Due to the data availability, there are several limitations of this study that should be considered. There would be a certain underestimation of the intensity of manufacturing environmental regulations since the lack of data on the treatment cost of industrial solid waste by sector. The potential endogenous problems in environmental regulations will have a certain impact on the empirical test results. Because of the data limitations, this paper only considers China's domestic environmental regulation. Future research can analyze the export impact of differences in domestic and foreign environmental regulations.

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