Czech University of Life Sciences Prague

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Diploma Thesis

The impact of environmental regulations on China's manufacturing export

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

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Economics and Management
Economics and Management

Thesis title

The Impact of Environmental Regulations on Export of the Chinese Manufacturing Industry

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Objectives of thesis

The aim of the diploma thesis is to determine the impact of environmental regulations on export of the Chinese ianufacturing Industry.

The aim will be fulfilled based on the partial aims. Then, several hypotheses will be defined and verified. Based on the results of and empirical analysis the final conclusions will be introduced.

Methodology

The diploma thesis will cover both theoretical and empirical part. Theoretical part will contain theoretical background of the selected topic as well as the methodological framework. Scientific literature will be used to prepare the literature overview. The empirical analysis will be based mainly on panel data analysis. Other suitable methods will be employed as well. Based on the empirical analysis the results will be presented and some recommendations will be suggested.

The proposed extent of the thesis

60-80 pages

Keywords

Environmental regulations, China, export, manufacturing industry

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Recommended information sources

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Declaration

I declare that I have worked on my diploma thesis titled “The impact of environmental regulations on China’s manufacturing export” by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break any copyrights.

In Prague on 30.03.2021 ______________________________

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The impact of environmental regulations on China's manufacturing export

Abstract

Environmental regulation is an effective tool to control environmental problems caused by foreign trade. Increasingly stringent environmental regulations may increase costs and thereby hinder trade growth. However, appropriate environmental regulation also can motivate technological innovation. According to the Porter hypothesis, the innovation compensation effect will even offset the enterprise loss caused by increased production costs, thus promoting export. At present, green transformation and green exports are the main strategies for China's manufacturing industry to achieve a win-win situation for environmental protection and export expansion. As such, it is significant to research the impact of environmental regulations on manufacturing export.

This study provides an empirical analysis based on the HOV model adopting balanced panel data of 16 sectors from China's manufacturing during 2005-2015. Moreover, material capital, human capital, technology input and FDI are simultaneously selected as independent variables to explore the impact of corresponding changes in these variables on export. The main results indicate that China's environmental regulations intensity play different roles in the manufacturing sectors with different pollution levels. Stricter environmental regulation improves the export of lightly polluted manufacturing sectors but hinders exports in intensive polluted sectors. There is no statistically significant evidence that environmental regulations play a role in moderate pollution manufacturing sectors' export. Meanwhile, other endowment factors also play various roles in the moderate and lightly pollution manufacturing sectors.

Keywords: Environmental regulation, China, manufacturing export, H-O-V model

Dopad ekologických předpisů na čínský vývoz z výroby

Abstrakt

Regulace životního prostředí je účinným nástrojem pro kontrolu environmentálních problémů způsobených zahraničním obchodem. Stále přísnější předpisy v oblasti životního prostředí mohou zvyšovat náklady a tím bránit růstu obchodu. Vhodná regulace v oblasti životního prostředí však může také motivovat technologické inovace. Podle Porter hypotézy bude inovační kompenzační efekt dokonce kompenzovat ztrátu podniku způsobenou zvýšenými výrobními náklady, a tím podpořit export. V současné době jsou zelená transformace a zelený vývoz hlavními strategiemi pro čínský zpracovatelský průmysl k dosažení situace prospěšné pro ochranu životního prostředí a exportní expanzi. Proto je důležité zkoumat dopad environmentálních předpisů na vývoz výroby.

Tato studie poskytuje empirickou analýzu založenou na modelu HOV přijímající vyvážená panelová data 16 sektorů z čínské výroby v letech 2005-2015. Kromě toho jsou materiální kapitál, lidský kapitál, technologický vstup a FDI současně vybrány jako nezávislé proměnné, aby se prozkoumal dopad odpovídajících změn těchto proměnných na export. Hlavní výsledky naznačují, že intenzita čínských environmentálních předpisů hraje ve výrobních odvětvích s různými úrovněmi znečištění různé role. Přísnější regulace životního prostředí zlepšuje vývoz lehce znečištěných výrobních odvětví, ale brání vývozu v intenzivně znečištěných odvětvích. Neexistují žádné statisticky významné důkazy o tom, že předpisy o životním prostředí hrají roli při vývozu výrobních odvětví s mírným znečištěním. Mezitím také jiné nadační faktory hrají různé role v průmyslových odvětvích s mírným a mírným znečištěním.

Klíčová slova: Regulace životního prostředí, Čína, export výroby, H-O-V modelka

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List of abbreviations

CNY	China Yuan
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
H-O	Heckscher-Ohlin
H-O-V	Heckscher–Ohlin–Vanek
IEA	International Energy Agency
ISIC	International Standard Industrial Classification
ISO	International Organization for Standardization
MA	Millennium Ecosystem Assessment
NBSC	National Bureau of Statistics of China
PACE	Pollution abatement and control expenditures
PI	Pollution Index
PTA	Preferential Trade Agreement
R&D	Research and development
S&T	Science and Technology
UN	United Nations
UK	United Kingdom
USD	United States dollar

1 Introduction

In the wake of increasingly intensifying modern industrial development, a massive expansion of economic activity has changed the global environment more drastically and extensively than ever before, which is a fatal bottleneck to sustainable development (Guerry et al., 2015). However, this has become a fatal bottleneck for the sustainable development of economic activities. For example, the Millennium Ecosystem Assessment amassed robust evidence to demonstrate that over 60% of the global ecosystems were degraded or used unsustainably caused by human activities (MA, 2005). As an essential driving source of rapid modern economic growth, foreign trade is not only the exchange of goods and services but also the exchange of natural resources and the ecological environment, which means international trade is inseparable from environmental issues (Xiong and Wu, 2021). The relationship between the environment and international trade is a significant issue for current and future human well-being and economic development. Nowadays, concern for environmental problems caused by international trade is at an all-time high, and this concern has speeded the global trend of increasingly stringent environmental regulations. In order to facilitate the transition to sustainable development, the “2030 Agenda” appeals to an advanced understanding of the relationship between environmental regulations and international trade (United Nations, 2015).

Since the implementation of the reform and opening-up policy, notably after it entered the World Trade Organization (WTO) in 2001, the export trade has experienced an explosive expansion in China. China’s exports trade’s gross value grew from 0.27 USD trillion in 2001 to 2.50 USD trillion in 2019, equaling about 4.3% and 13.2% of gross world exports, respectively (NBSC, 2020). However, this miracle-like growth comes with increasingly prominent resource and environmental problems. As the world's greatest carbon emitter, approximately 22% of China’s total annual carbon dioxide emissions generated from net exports (Qi et al., 2014). China’s carbon emissions reached a record high in 2018, up to 10 billion, accounting for 33% of global emissions (IEA, 2019).

Manufacturing industry plays a pillar role in China’s national economy, but its export's spectacular growth sparked an inevitable environmental deterioration. Most heavy polluting industries 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 environment pollution (Copeland and Taylor, 2004).

China actively participates in global value chains by capitalising on its comparative advantage of cheap labour, abundant raw materials, and a relatively complete industrial system. In the global value chain, however, China's manufacturing industry is more often engaged in middle and lower value-added production activities of the value chains, which is also the production link of high energy consumption and high pollution emissions. Therefore, this development model, which prioritizes economic growth and bears intensive environmental pollution costs in the early stage of industrial modernization, has led to the prominent phenomenon of high energy consumption and high pollution production in China’s manufacturing.

Environmental regulation stems from environmental externalities, property rights theory and welfare economics (Zhu et al., 2019). Most environmental resources are often regarded as public goods (non-rival and non-excludable), resulting in the inability of conventional market mechanisms to function in managing them fully. The reasons behind this limitation are the differences between environmental resource and traditional commodities, that is, its perceived isolation from the economic market. Hence, environmental regulation is an indispensable policy tool for regulators to control environmental problems and regulate economic activities to achieve the environmental and economic coordination and sustainable development (Pigou, 2013). Based on the context of economic globalization, environmental regulation has been a conventional and effective tool for a country to deal with environmental issues caused by foreign trade. Environmental regulation is frequently defined as a set of environmental measures imposed by governments or economic organizations to protect the environment that impacts international trade, which can be either mandatory or voluntary (Jiang, Wang and Li, 2018).

In China, policy discussions regarding promoting a green transformation 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 export scale in China’s manufacturing. While the environmental regulation is laudable, the link between it and domestic manufacturing export trade remains uncertain (Wang, Zhang and Zeng, 2016).

Popular thinking is that increasingly stringent environmental regulation will alleviate environmental pressures and provide opportunities for China’s manufacturing to speed a low-carbon transformation. At the same time, growing environmental compliance will facilitate upgrading the national environmental management level. However, there is an opposite claim that environmental regulation will result in trade loss the regulated manufacturing sectors. The economic explanation behind this claim is that stringent environmental regulation has created higher production costs that have challenged non-transformed polluting manufacturing businesses. In addition, environmental regulations show significant heterogeneity in different sectors of the manufacturing industry (Chen and Qian, 2020). Under such circumstance, it is critical to explore the environmental regulation's impact on manufacturing export.

For reacting to the research question, as well as reaching the defined objectives, the structure of the whole thesis is as follows. After this introductory Chapter, Chapter 2 outlines the research objectives and methodology used in this paper. In Chapter 3, the related literature on environmental regulations and the relationship between them and international trade are reviewed. Chapter 4 consists of two sections, which in the first section provides an overview of China's manufacturing exports and the present environmental regulation in China. China's manufacturing industry is classified, and its environmental regulation is measured in the second section. In Chapter 5, a panel model is adopted to do empirical analysis, including data treatment and variables. Chapter 6 provides a detailed discussion of empirical results. The last Chapter concludes the research.

2 Objectives and Methodology

2.1 Objectives

Environmental regulation is an effective means to solve environmental issues and control pollution problems caused by international trade. Since the 1970s, the relationship between environmental regulation and international trade has been extensively explored by scholars. More and more empirical research has incorporated environmental regulations into the analysis framework of trade's influencing factors.

In view of the above research background, this thesis's first objective is to establish the evaluation method for measuring environmental regulation intensity, using pollution discharge and pollution control expenditures. Besides, this study introduces a pollution index to classify different manufacturing sectors according to the degree of pollution. Then, the second objective is to uncover the influencing factors of manufacturing export volume and with a focus on the impact of environmental regulation.

Taking China's environmental regulation and China's manufacturing export as studied objects, this paper aims to:

(1) classify manufacturing by sector in China according to the pollution degree.

(2) estimate the changes in China's environmental regulation intensity over the period 2005-2015.

(3) measure the environmental regulation's impact on China's manufacturing export volume.

(5) regard related endowment factors as variables of China's manufacturing export volume to reveal their impacts.

2.2 Methodology

In this thesis, analysis consists of two main parts: the theoretical part and the empirical part. The first part is done by the following two methods.

Inductive analysis:

This study classifies and summarises the research results of environmental regulation and export relations by extracting, summarising, and comparatively analysing the fundamental theories and several works of literature related to the selected topic. Thereby provides a rational and necessary basis for a measurement model establishment to reveal environmental regulation's effect on China's manufacturing exports.

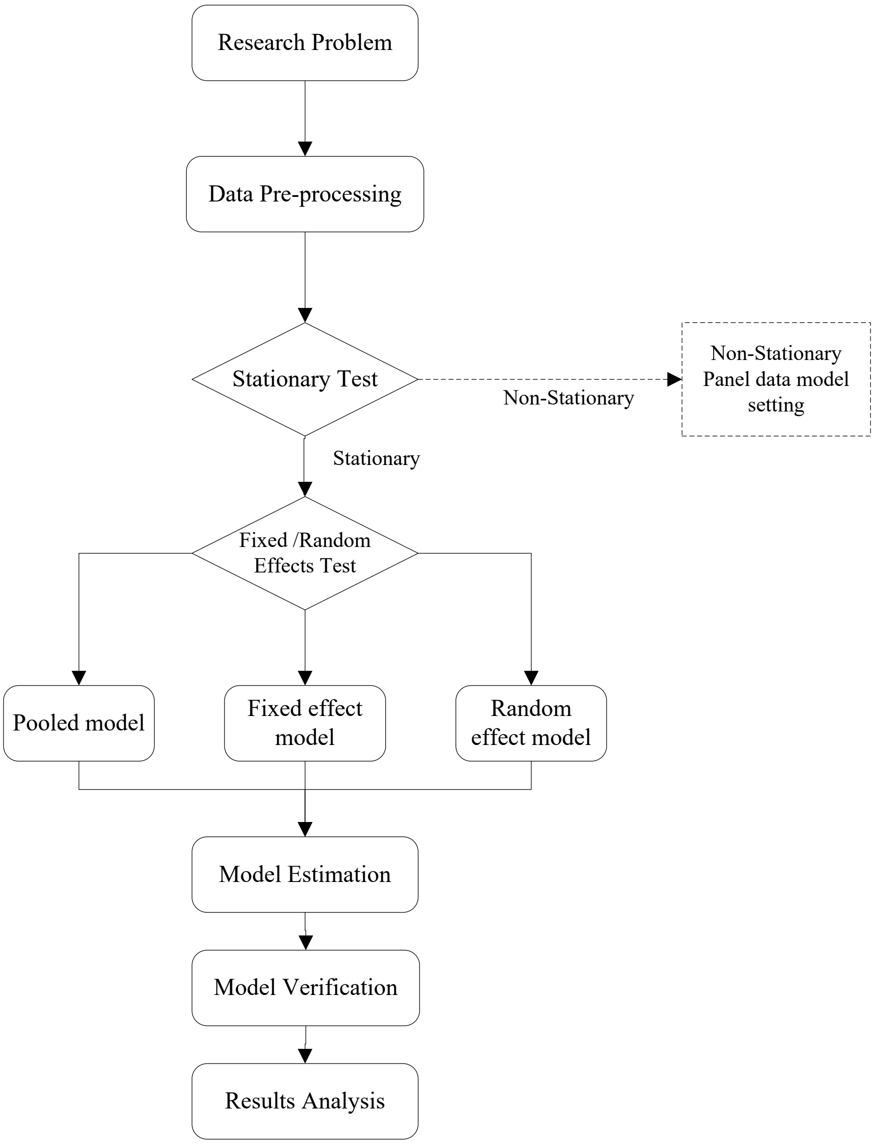
Statistical analysis:

Based on the data set collected and collated from the UN Comtrade database and various statistical yearbooks of China, this thesis carries out a statistical analysis of the manufacturing export's volume and structure in China. Then, China's manufacturing industry is classified by sector according to the pollution index. On the basis of previous research results, feasible methods are adopted to quantify China's environmental regulation intensity.

In the empirical part, the econometric method measures the impact of the manufacturing export influencing factors in China. This paper adopted a balanced panel, including 16 sectors of China's manufacturing from 2005 to 2015. Based on the Heckscher-Ohlin-Vanek (HOV) model, an empirical analysis of the relationship between independent variables manufacturing exports and the other five dependent variables is done by panel least squares.

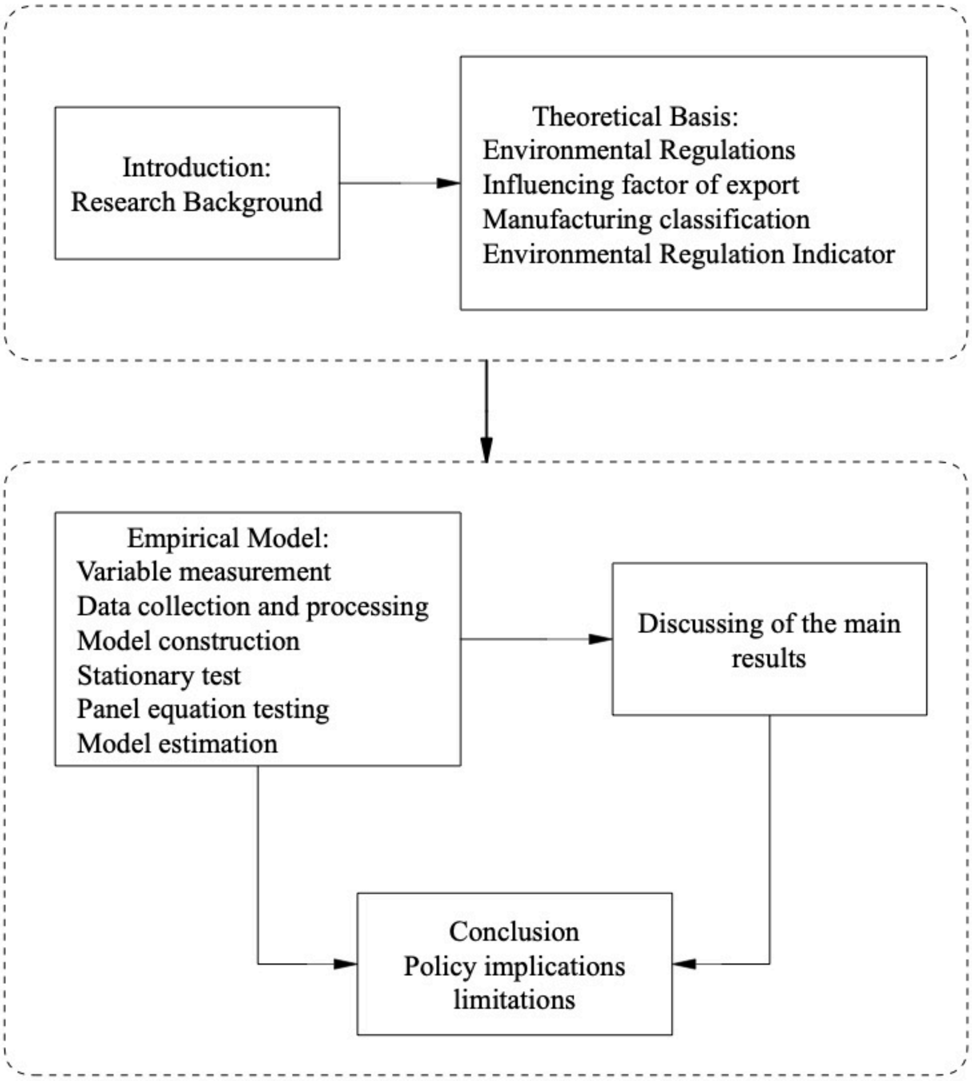
Generally, panel data is adopted to observe entities' behaviour (e.g., countries, regions, industries, companies, individuals, etc.) over the entire time range (Torres Reyna, 2007) and is also called cross-sectional time-series data. This study performs the unit root tests in terms of the stationarity test, including Levin–Lin–Chu test (LLC test) and PP-Fisher tests, to avoid spurious regression. Panel data models consist of two groups: the fixed effects model and the random effects model. In order to determine whether the fixed effects model or the random effects model is applied in this study, the Redundant Fixed Effects-likelihood Ratio Test and the Correlated Random Effects-Hausman Test are used to test the panel model after passing the stationarity test. This paper selects Eviews rev.10. as the primary calculation software. Specifically, panel data modeling framework is depicted in Figure 1.

Figure 1. Panel Data Modeling Framework



Source: Own computation

Figure 2. Analysis Framework of the Thesis



Source: Own computation

3 Literature Review

3.1 The Relationship between Environmental Regulation and International Trade

The research on international trade and environmental issues relations can be traced to the 1970s, and then has evolved in two waves. Developed countries initiated strict environmental regulations during the early 1970s, which triggered the first wave of research in this field. Then, the research output in this wave quickly peaked in the late 1970s. During the 1990s, the second research wave occurred, which mainly sparked by the debate on international trade agreements, including the North American Free Trade Agreement (NAFTA) and the Uruguay Round General Agreement on Tariffs and Trade (GATT) in the Uruguay Round. Despite extensive studies, conclusions on environmental regulation and international trade relations are inconsistent and even contradictory, depending on the different econometric models, indicators, data, and regions. The study findings of the effect of environmental regulation on foreign trade can be mainly grouped into three types: negative, promote, and uncertain effect.

3.1.1 Negative effect

From a neoclassical point of view, stricter environmental regulations may significantly increase production costs along with the internalization of pollution externalities, which is known as the “cost effects”. Under this conventional perspective, environmental regulations exert an additional economic burden on enterprises. Thus, the comparative advantage of the regulated object is adversely affected and result in a decline in international competitiveness and exports. As pointed out in the pollution heaven hypothesis, a transfer from countries with more stringent environmental regulations to countries with loose regulations may occur in intensively polluted industries (Walter and Ugelow, 1979). The existing literature extensively tested the pollution haven hypothesis from two perspectives: the environmental stringency’s impact on either the location of industrial plants or the international trade flows.

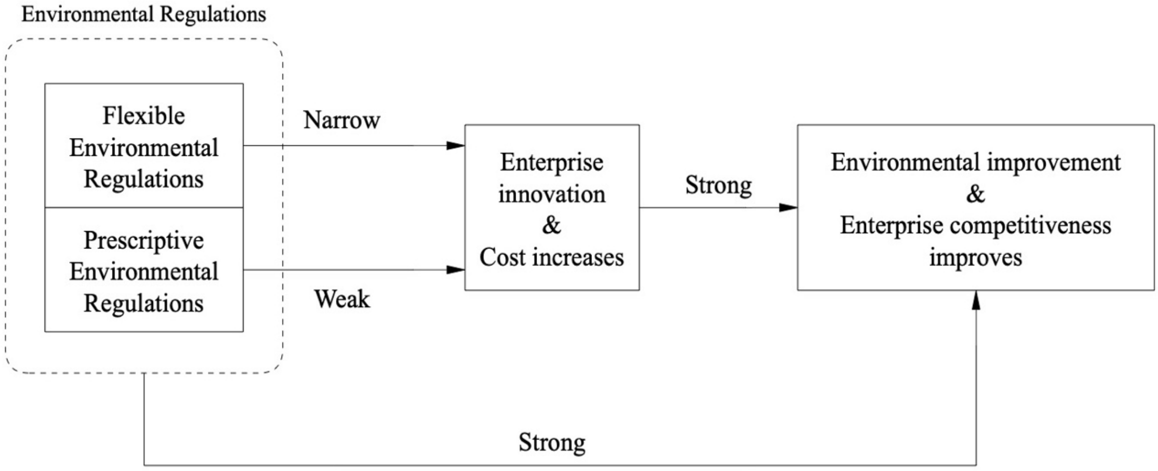
Cole, Elliott and Okubo (2010) confirmed that the intensity of environmental regulations plays an indispensable role in inducing Japan to become a net importer from China and non-OECD countries, suggesting there is kind of a negative impact caused by environmental regulations on the export competitiveness, thereby changing a country's total foreign trade. Hering and Poncet (2014) employed a panel data set covering 265 cities in China from 1997 to 2003, across various industries and types of companies, to exploit the causal relationship between stringent environmental regulations and enterprises export activities. The evidence they provided showed that stricter environmental regulation's implementation has motivated enterprises to redistribute export activities in various sectors. As a result, the pollution-intensive sectors are forced to cut exports due to environmental costs. Based on the carbon emission embodied in trade flows under environmental regulation, a pollution haven hypothesis validated model established by Cai et al. (2018). Taking the Belt and Road as an example, a cross-sectional data set in 2013 used in empirical research, including 64 countries, to verify that China has been a pollution haven to 22 developed countries. However, there is no evidence that the that European and US manufacturing were consistent with what pollution offshoring would suggest (Levinson,2010; Brunel,2017). In view of the cross-province variation in environmental regulations intensity, Shi and Xu (2018) estimated whether the pollution control plan targeted at primary pollutants discharge had affected the firm exports during the "Eleventh Five-Year Plan" period in China. The findings showed a cut down in new exporters acceding to the export market, resulting in the export possibilities and export volumes reduced in pollution-intensive industries located in provinces under stricter environmental pollution. To clarify the definite cause and effect between environmental regulation and enterprises' export performance, Zhang, Cui and Lu (2020) investigated how water pollution regulations influenced polluter's export decisions. They adopted an across-sectional data set of enterprise-by-product into the empirical analysis, and the results turned out that the enterprise's export would experience a reduction along with the stricter wastewater discharge standard. The reason behind this negative effect is that the lower productive enterprise was restraint from accession to the export market.

The research results of these negative effects, as mentioned above, reveals the critical influence of environmental regulation on export and a profound effect on the relocation of industrial production between developing and developed countries.

3.1.2 Positive effect

In contrast, a number of scholars argued that the impact of environmental regulation might not consistently negative on foreign trade. For example, the most famous theory is the Porter hypothesis, holding that proper environmental regulations are effective means to solve pollution externalities and simultaneously stimulate the regulated firm to innovate pollution control technologies and accordingly increase international competitiveness (Porter, 1991). This kind of positive effect is also known as the "innovation compensation effect", which to some extent can indirectly offset the enterprise's compliance costs, that is, the "cost effects" brought by environmental regulations. After that, Porter and Van der Linde (1995) further pointed out that stricter environmental regulation in the long term can facilitate achieving a win-win situation both in promoting environmental protection and maintaining economic profits.

Figure 3. Three versions of the Porter Hypothesis Chains



Source: Own computation, Jaffe and Palmer (1997)

From the propositions of Porter hypotheses, many scholars have tested this hypothesis and strengthen the argument that environmental regulations conducive to improve competitiveness and play a positive role in international trade. Jaffe and Palmer (1997) first classified the Porter Hypothesis, namely, "narrow", "strong" and "weak" three versions (Figure 3.). Firstly, the weak version shows that well-crafted environmental regulation, which primarily belongs to prescriptive regulation (e.g., technology-based standards), can trigger an enterprise's technological innovation (even when such an opportunity cost of innovation exceeds benefits). Secondly, the narrow version points out that flexible environmental regulations (e.g., market-based tools) enhance the enterprise's incentive to advocate green innovation activities compared with prescriptive regulations. Eventually, the strong version postulates that innovation stimulated by reasonable environmental regulation can offset the compliance costs, thereby improving the environmental quality as well as enterprise competitiveness and productivity.

Rubashkina, Galeotti and Verdolini (2015) provided empirical evidence to support the existence of Porter Hypothesis's weak version in European manufacturing. Based on an unbalanced cross-sectoral panel data spanning from 1997 to 2009, including 17 European countries' manufacturing sectors, they established the empirical model to investigate the environmental regulation's effect on innovation activity and productivity. The empirical result is consistent with the weak version, that is, positive effects on innovation. Using state-level panel data from the USA, Millimet and Roy (2016) empirically estimated the environmental regulation and export trade relations. The research results confirmed that well-designed environmental regulations are an important driving force for increasing industrial exporters' competitive advantage. Zhu et al. (2019) estimated the multiple effects of environmental regulations with different degrees of strictness on China's steel industry by using a computable general equilibrium model. The empirical results demonstrated that the total external environmental costs could not be compensated by the innovation arising from the present environmental regulations. However, increasingly strict environmental regulations will benefit China's steel industry's productivity and export in the long run. Brandi, Blümer and Morin et al. (2019) put a research spotlight on developing countries that faced the acute trade-off issues between environmental protection and international trade development. In the case of the environmental regulations in PTAs, they first thoroughly investigated the impact of these environmental provisions on foreign trade for developing countries. The findings confirmed that stricter environmental regulation would facilitate developing countries to increase green exports.

The research results of these positive effects, as mentioned above, uncovers that the Porter Hypothesis has been more verified in developed countries compared with developing countries. In most developing countries, the current environmental regulations cannot trigger a strong version of the Porter Hypothesis. There is still a long way to go to offset the environmental compliance costs with innovative activities.

3.1.3 Uncertain effect

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 little, uncertain or non-linear impact on trade. Through constructing a Heckscher–Ohlin–Vanek (HOV) model, consisting of 11 types of factor endowments, Tobey (1990) used an export data set covering 23 countries' five different industries conducted the empirical analysis on the export effect of environmental regulations. The result indicated that in developed countries, changes in the intensity of environmental regulations show unobvious effect on the export in terms of the pollution-intensive industries. Cole, Elliott and Shimamoto (2005) first used industry-level data set to establish the export impact of environmental regulations in case of US export. They selected data from 18 industries in the United States from 1978 to 1994 as a sample and empirically found that the specialization degree does not appear to decline in response to increasingly stringent environmental regulations in US dirty industries. The result suggested that the changes in environmental regulation's intensity have an inconspicuous influence on revealed comparative advantage. By adopting a panel data set spanning from 2001 to 2007, including 20 European countries, Arouri et al. (2012) estimated a gravity model to study whether stricter environmental regulation consistent with the EU could threaten Romania export competitiveness and exert a negative effect on export. According to the result that the small proportion of environmental costs on the total production costs, there is no evidence in favour of the pollution hypothesis that occurred in Romania.

3.2 Measurement Method of Environmental Regulation

As controversial research conclusions on the export effects of environmental regulations outlined above, it can be attributed to the fact that absence of a unified measurement method for environmental regulation (Wang, Zhang, and Zeng, 2016). An adequate indicator of environmental regulation stringency can usually accurately reflect the strictness and standardization of environmental regulations in a certain country or region. Therefore, employing an appropriate measurement method of environmental regulation is a difficult task in studying the environmental regulation's impact on export trade, thus directly affecting the result of subsequent empirical research. The existing kinds of literature have used various alternative measurement standards of environmental regulation intensity to achieve the quantification of the environmental regulation’s stringency. Pollution data are scarce, which leads to the research trend of constructing a proxy index that has developed from a single index to a multi-factor comprehensive index. At present, there are primarily the following six methods to quantify the intensity of environmental regulation in the existing literature:

3.2.1 Qualitative indicators based on questionnaire research

Mulatu (2018) classified the indicators of environmental regulation intensity into three types: qualitative descriptive indicators, quantitative indicators and comprehensive exponential indicators. The measure indicator outlined in this paragraph can be viewed as an input oriented qualitative indicator (Arouri et al., 2012). By extracting and collating information from the responses of 23 countries' governments to the questionnaires, Walter and Ugelow (1979) first established a qualitative environmental regulation index based on the questionnaire research. Under this measurement method, the intensity of a country's environmental regulations is encoded from 1 (strict) to 7 (loosen). After that, other studies applied this set of indicators to evaluate the environmental regulation stringency in various countries (Tobey, 1990; Van Beers and van den Bergh, 1997). However, this method is likely to reduce the "validity" of the estimate when performing multiple regression due to the limited number of sample countries.

3.2.2 The number of environmental regulations

The environmental protection policies, laws and regulations promulgated by a country’s government could be employed as an important indicator for evaluating the effectiveness of a region’s environmental regulation and supervision. The more quantity indicates higher stringency of environmental policy. For instance, Barbu et al. (2014) used the number of established and issued environmental regulations to measure environmental regulatory framework in UK, France and Germany. This method can more intuitively reflect the government’s emphasis on the environment, but it also has certain limitations due to the legislation’s binding does not necessarily equal the environmental regulations’ effective implementation. Assuming that a considerable gap existed between legislation and law enforcement, which suggests that the number of environmental regulations cannot accurately embody the stringency of environmental regulation in the regulatory region or department.

3.2.3 Density of pollutant emissions

The narrow sense of environmental regulations indicators the restrictions on pollution emissions in various industries. In early literature, another method is to measuring stringency of environmental regulations using either pollutant emission data or adjusted pollution reduction data. The more tolerate environmental regulation, that is, the more pollutant discharge will be produced in the industry, and vice versa. Cole and Elliott (2003) used the different pollutant emissions involved in all dirty industries to assess the stringency of environmental regulations. However, it's worth noting that the pollutant emissions tend to result from the comprehensive effect of the economic development level, industrial structure and environmental regulation intensity. Although this measurement method is easy to collect data, pollutant emissions may underestimate or overestimate the environmental regulation's intensity, thus it is far from an ideal proxy for environmental regulation.

3.2.4 Pollution abatement and control expenditures

One of the previous study's popular method is to adopt pollution abatement and control expenditures (PACE henceforth) as a proxy of environmental regulation stringency. Generally, PACE method is defined as a purposeful policy means to directly prevent, reduce, and eliminate residual pollution generated during the production procession or consumption of physical products and services (Brunel and Levinson, 2013). This kind of indicator for representing environmental policy stringency originated from a survey (Becker and Shadbegian, 2007), which aimed to collect operating costs and capital expenditures brought by pollution abatement in the U.S. manufacturing industry. Rubashkina, Galeotti and Verdolini (2015) used the PACE indicator to capture the response of European manufacturing to environmental regulations. A ratio of the pollution control investment on the total production added value was employed by Xie, Yuan and Huang (2017) and Pan et al. (2019) to evaluate the stringency of industrial command-and-control regulations. Meanwhile, as for the industrial market incentive environmental regulation in their research, the pollutant fees were used to assess the intensity. Obviously, the higher the indicator means the stricter environmental regulation this industry will face. However, there may be the potential endogeneity of PACE, leading to biased estimates of environmental regulation effects.

3.2.5 GDP per capita

Given that a national income per capita is highly correlated with the intensity of its environmental regulations (Dasgupta et al., 2001). Regarding the indirect indicators of environmental regulations, a lot of research has used GDP per capita as a measurable indicator. The standardized per capita income level was first employed by Busse (2004) as an endogenous proxy for measuring the strictness of environmental regulation within the WTO framework. Lu (2010) also selected the per capita income to construct an endogenous proxy for environmental regulations, which made it possible to explore how environmental regulation intensity changes affect the competitiveness of pollution-intensive goods. Since environmental regulations intensity and per capita income level have similar development trends in China, Zhang (2012) regarded China's GDP per capita as endogenous environmental regulations. Generally, this measurement method is more adapted to the analysis at the national and regional levels than the industry level.

3.2.6 Comprehensive indicators of environmental regulation

Recent empirical studies commonly applied a comprehensive measurement, integrating multiple proxies, to assess the environmental regulation’s stringency. To reflect the industrial environmental regulation’s stringency in China’s steel industry, Zhu et al. (2019) integrated the pollution abatement costs in the steel industry of various untreated pollutants caused during each production link. Nowadays, the measurement method of comprehensive index was widely used to assess the stringency of environmental regulation (Zhao and Sun, 2016; Albrizio et al., 2017; Li et al., 2019). To be specific, this measuring method is a multi-level comprehensive index system, usually consisting of one target layer and three sub-evaluation index layers, including wastewater, waste gas, waste solid, sometimes as well as several individual indicator layers.

3.3 Research Method

Various theoretical and empirical research have revealed that conclusions about the impact results of environmental regulations on international trade are inconsistent, largely depending on the particular research method selected. The empirical research methods for environmental regulation and international trade relations can be classified into three categories (Mulatu et al., 2001), including exploratory method, input-output analysis method, and econometric method.

3.3.1 Exploratory method

The exploratory method was initially put forward for testing the pollution paradise hypothesis, that is, to explore whether pollution-intensive industries have been transferred towards developing countries from developed countries. This hypothesis underlying presupposes that the industry relocation is triggered by relatively less stringent environmental regulations in developing countries (Mulatu et al., 2001, Jankowski, Fraley and Pebesma, 2014). This type of method provides some preliminary findings on the research field related to environmental regulations and international trade relations. However, it unable to involve other influencing factors potentially related to the changes observed in the existing relationship.

3.3.2 Input-output analysis method

The Input-Output model is used to evaluate trade flow, including kinds of products and services, between the various part of the economic system (e.g., nation, region, industry, sector, enterprise, etc.), thereby comprehensively reflecting their economic relations. Leontief (1970) first proposed the input-output analysis model to assess the pollutant discharge arising from direct inputs within the sector and intermediate inputs from external sectors. In this type of studies, environmental factors are added as vertical input, and environmental payment costs are added as horizontal output based on the traditional input-output matrices. In this way, research on the regulation-trade relation issue by calculating the overall abatement costs generated in the total foreign trades.

3.3.3 Econometric method

The so-called econometric method, usually on the basis of the Heckscher-Ohlin (H-O) model or the trade gravity model, is a popular option for analysing environmental regulations and international trade relations.

(1) Heckscher-Ohlin Model

The Heckscher-Ohlin (H-O) model, also known as the factor endowment theory, relies on the underlying presuppose: all countries have identical production technologies but the various intensity of factor endowments. Besides, there is factor endowments immobility among different countries, while perfect production factor mobility across various industries (Mulatu et al., 2001; Yang et al., 2017). From this, a country under free trade conditions should specialize in producing and exporting goods that require intensive consumption of relatively abundant resources. Therefore, the export trade scale can be expressed as a function of factor endowments. On the basis of the H-O model, Tobey (1990) introduced environmental resources as a new production factor to propose a multi-factor of Heckscher-Ohlin-Vanek (H-O-V) model and then used the qualitative environmental regulation indicators proposed by Walter and Ugelow (1979) to help with the research on the international trade impact of environmental regulations. Most such studies used a cross-section H-O-V model to investigate environmental regulations' effect on industrial export competitiveness, thereby performing the pollution haven hypothesis testing, namely test whether intensive pollution industries would be transferred from developed countries to developing countries. (Cole and Elliott, 2003; Cole and Elliott, 2010; Lu, 2010). Considering carbon emissions as a proxy of carbon factor endowment, Yan et al. (2020) establishes an extended environmental H-O-V model. Based on this empirical analysis, the flow patterns of carbon emissions embodied in the international trade within the global value chain perspective. Given the HOV model is based on the multilateral trade framework, suggesting there is a potential shortcoming that environmental regulation's different impacts on each trade flows would offset each other in this model when each group of bilateral trade flows converge to a multilateral trade flow.

(2) Trade Gravity Model

Another widely used econometric method is the trade gravity model, which is conventionally applied in the modelling of the bilateral trade framework. In the trade gravity model, trade flow is frequently expressed as an equation about the predicted supply (or demand) from the exporting (or importing) country, as well as considering some variables reflecting trade friction between the countries (Mulatu et al., 2001). For extracting the effect of environmental regulations intensity on trade, the trade gravity model treats environmental regulations as a trade resistance insert the equation. In view of the shortcoming of the H-O-V model mentioned above, Van Beers and Van den Bergh (1997) employed a trade gravity model to review the previous research of Tobey (1990) and verified his part of conclusions. After that, Jug and Mirza (2005) modified the trade gravity model of Van Beers and Van den Bergh (1997) for revealing the export effect of environmental regulations by using a sample of EU countries. Based on a gravity model, Arouri et al. (2012) examined whether the implementation of stricter environmental regulations exerted a negative effect on competitiveness and export in Romania. Yang et al. (2017) adopted a panel data set spanning from 2005 to 2014 and covering the top 30 trading partner countries of China's graphite resources export trade, to establish a trade gravity model. Meanwhile, they selected multiple indicators (GDP, population, graphite price, export duty refund in China, economic recession, etc.) to assess the environmental regulation's intensity, thereby uncovering how environmental regulations impact graphite export in China.

4 China’s environmental regulation and manufacturing

4.1 Overview of environmental regulations in China

Since the establishment of New China, the development of China’s environmental regulation has evolved in three periods. The first period is the initial stage starting in 1949. The first significant step was that China enacted the first Environmental Protection Act after attending the Human Environmental Conference in Stockholm in 1972, which suggested the initial formation of China's environmental regulatory system. The environmental regulation system in China was exemplified by the government proactively promulgated mandatory policies during the first period. The second period, namely development stage, occurred during the period from the late 1970s to the late 1980s. To solve the disadvantages of high cost and poor effect of mandatory environmental regulations, the government introduced market factors into the environmental regulatory system, and market incentive policies became increasingly popular. The third period came in the end of the 1990s to the present, a series of new forms of environmental regulation increasingly came into effect. The environmental regulations motioned in this thesis were not limited to mandatory regulations issued by the government. Generally, environmental regulations can be grouped into three different categories in China, that is, command-and-control environmental regulations, market-based environmental regulations and reluctant environmental regulations.

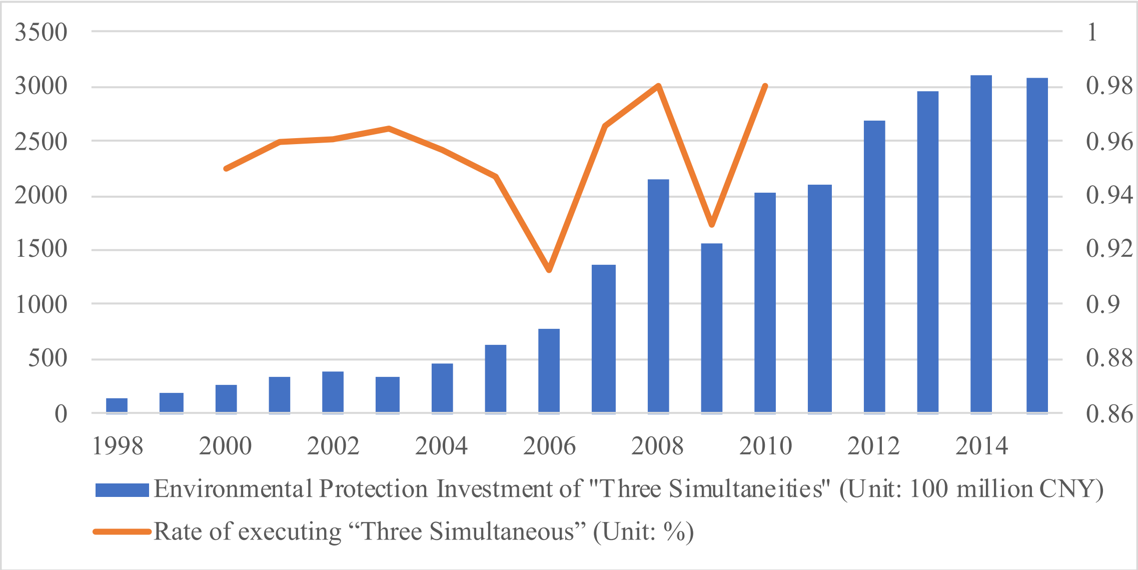
4.2 Command-and-control environmental regulations

The current environmental regulations system in China primarily relies on command-and-control means due to a lack of incomplete marketization tools. The command-and-control environmental regulations, also known as compulsory regulation measures, indicated that the government directly propose specific pollutant emission control standards to polluters in accordance with certain regulations and other environmental management normative documents, and ultimately achieve improving the ecological environment. Its main characteristics are technical, strict and mandatory. For polluters, they must be forced to abide by regulations and meet the environmental protection standards of the production process, otherwise, they would be punished or even face shut down. To date, the typical command-and-control environmental regulations in China are the followings.

(1) “Three Simultaneous” system

The earliest environmental regulation system in China, the "three simultaneous" system, was legally included in the ‘Environmental Protection Law of the People’s Republic of China’ in 1979. To comply with pollution emission regulations, all enterprises and institutions were simultaneously forced to design, establish and operate the pollutant control and prevention installations with each new, renew or extended construction project of the main body. In China, the environmental protection investment in the "three simultaneous" system of construction projects has become a significant component of direct investment in pollution control, accounting for 35% in 2015. From 2000 to 2015, the environmental protection investment in the "three simultaneous" system increased from 26 billion CNY to 309 billion CNY. In addition, the implementation rate of the "three simultaneous" system has also remained above 90%, indicating that this system has played a significant role in controlling new pollution sources. The data for the trend is shown in Figure 4. However, many shortcomings of this system, such as the long-time span of policy implementation, the inability to monitor all construction projects, and the underutilization of environmental protection facilities, may occupy part of the investment of small and medium-sized enterprises.

Figure 4. Implementation of “Three Simultaneous” system in China, 1998-2015

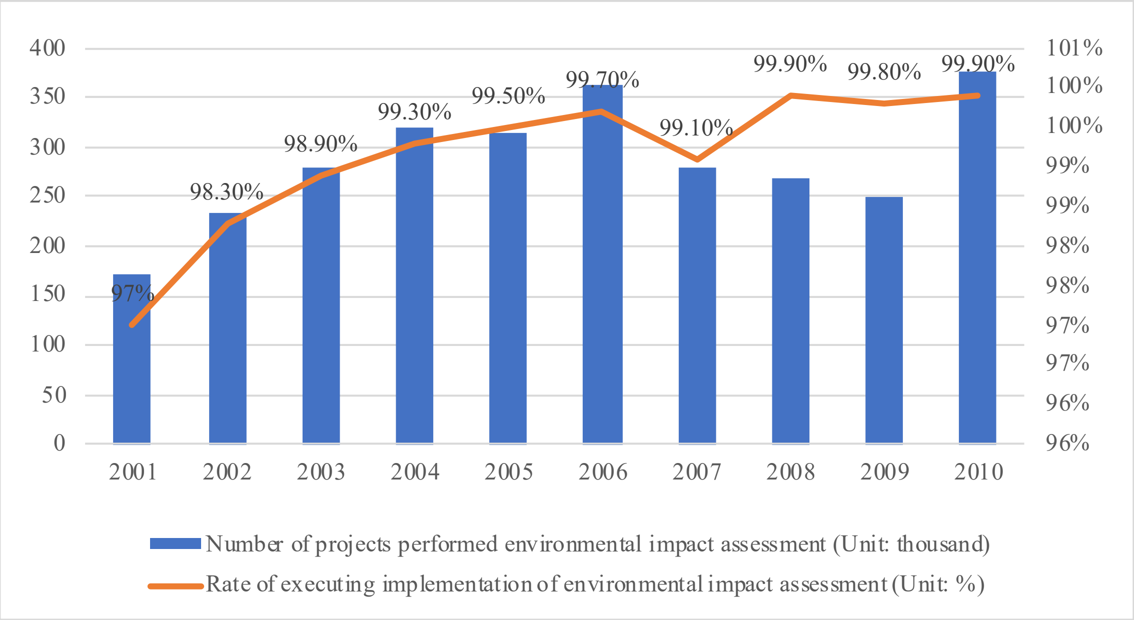


Source: Own computation, China Environmental Statistics Annual Report, 2000-2015
Note: Since 2011, the Ministry of Ecology and Environment of China has stopped counting the implementation rate of the "three simultaneous" system. “three simultaneous” refers to design, construction and use at the same time.

(2) Environmental impact assessment system

As a legal tool, the environmental impact assessment system is commonly used to investigate, predict and evaluate the possible environmental impacts of proposed construction projects, which is a critical element in the environmental regulation of China. Under the environmental impact assessment system, every construction project is required to propose pollutant control measures and submit them for approval in accordance with legal procedures prior to the actual construction activities. With the implementation of the environmental impact assessment system, enterprises increasingly incorporated it into their construction project planning and design. As demonstrated in Figure 5., the percentage for implementation of environmental impact assessment increased steadily year by year, up to 99.9% in 2010. In 2015, the total number of approved construction project environmental impact assessment documents reached 440 thousand. Nevertheless, the current disadvantages of the environmental impact assessment system, including inadequate punishments, failure of assessment system design and invalid participation, should be taken into account by the policymaker.

Figure 5. Implementation of Environmental impact assessment in China, 2001-2010



Source: Own computation, China Environmental Statistics Annual Report, 2002-2011

(3) Pollutant discharge permit system

According to the pollutant discharge permit system, energy-intensive and emission-intensive enterprises have to submit pollutant discharge declaration registration to regulatory departments before discharging various pollutants (e.g., water, gas, solids, etc.). After verification, pollutant discharge permits will be issued to enterprises that do not exceed the total prescribed discharge target and meet the pollutant discharge standards. While the pollutant discharge permit system helps make environmental management more scientific and quantitative, its implementation's object and intensity suffer from some defects. Due to most of the penalties under this system are warnings and fines, the largest polluter especially industry monopolies would pass discharge fees on to their consumers or pay fines in exchange for over discharge.

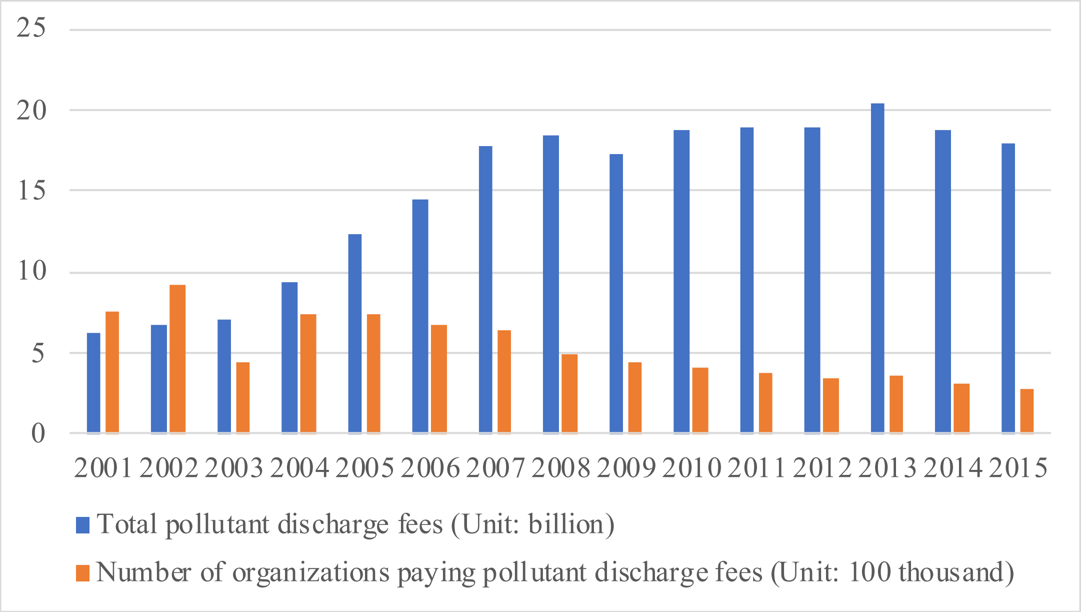
4.3 Market-based regulations

Using the invisible hand of the market, regulators introduce market mechanisms into institutional planning to form an environmental and economic policy with incentives and constraints. In China, the market economic reforms in the 1980s provide institutional foundations for China's government to exert stringent market-based environmental regulations, hence meeting green development demand. There two popular policies in China, namely pollutant discharge fees and tradable pollution emissions. By influencing industrial enterprises' costs and benefits, these regulations show economic incentives and result in some firm decreasing their pollutant discharge.

(1) Pollutant discharge fees

In 1982, China's pollutant discharge fee system was formally established, used to levy pollutant discharge fees on firms that discharge pollutants that exceed the prescribed standards. Simultaneously, if the waste released by the same firm contains more than two types of contaminants, the highest cost of these pollutants will be charged. As shown in Figure 6., the number of organizations paying pollutant discharges fees in China has gradually decreased from 2000 to 2015, suggesting that the increasingly firm's pollutant compliance rate. By contrast, the amount of funds received in the treasury is seen in growth, which means that regulations have tightened the effect on the control of pollution behaviour.

Figure 6. Implementation of pollutant discharge fees system in China, 2001-2015



Source: Own computation, China Environmental Statistics Annual Report, 2002-2016

(2) Tradable pollution emissions

As same as the pollutant discharge fee system, the tradable pollution emissions system also introduces market factors to ensure that the total pollutant emissions of all companies meet the required emissions. Regarding pollution emission rights as tradable products, firms that have achieved green production will sell excess emission rights to those over-emission firms, thus the cost of purchasing emission rights is viewed as the cost of polluting the environment. Due to imperfect environmental laws and regulations, and an immature pollution emission trading market, China's pollution emission trading system is still in its experimental stage and mainly implemented in some provinces, cities and regions.

4.4 Reluctant regulations

Compared with the above two types of environmental regulatory systems, China's reluctant environmental regulatory system is still in its infancy. Reluctant environmental regulations are not promulgated by the government but depend on the environmental awareness of market stakeholders. Different from the former two types of environmental regulations, policymakers such as legal institutions and government may not participate in the implementation of this policy, merely serving as auxiliary agencies to provide related assistance. Generally, they are mainly manifested in the use of some non-mandatory means come from various source, such as information devices, voluntary agreements, environmental label, environmental protocols, citizen participation, etc., to play a role in environment regulation.

(1) ISO 14000

The International Organization for Standardization (ISO) formulated ISO 14000 as a standard for environmental management in 1996 to manage the environmental responsibilities of firms and organizations. It aims to encourage enterprises to spontaneously prepare preventive measures and sustainable planning to reduce pollution in response to pollution and clean production issues, thus achieving the purpose of protecting the environment and controlling pollution. Nowadays, there is a growing affirmative attitude towards ISO 14000 from domestic enterprises. However, there are still many problems worth noting and improving in China's ISO14001 environmental management system certification. One of the more prominent problems is that the development of China's certification market is not yet complete, and the certification process of many standardized certification agencies is very irregular.

(2) China Environmental labelling Program

Environmental Label is normally used as a certificate issued by government and official rating agencies to manufacturers in accordance with certain environmental standards and prove that their products meet environmental protection requirements in all aspects of production, consumption, use, and recycling based on the life cycle of products. Therefore, products affixed with environmental labels are not only harmless to the environment, but also conducive to the regeneration and recycling of resources. In China, the environmental labelling Program, also known as green labelling, was initiated by the China Environmental United Certification Centre in 1993, providing an approach for public participation in China's green manufacturing and environmental improvement. Nowadays, certificated environmental label can facilitate Chinese export firms to avoid "green trade barriers", and strengthen their competitiveness in the international market.

Overall, rising concern about environmental pollution, promoting continuous improvement of China's environmental regulatory system. The development of market incentive and voluntary systems has made up for the insufficiency of the command-control policy system and enriched the current environmental regulatory tools in China. Despite the fact that the command-and-control system is the primary tool for environmental regulation in China, it is foreseeable that the market-based policies, which bring economic incentive, will be the main means of environmental regulation in the future.

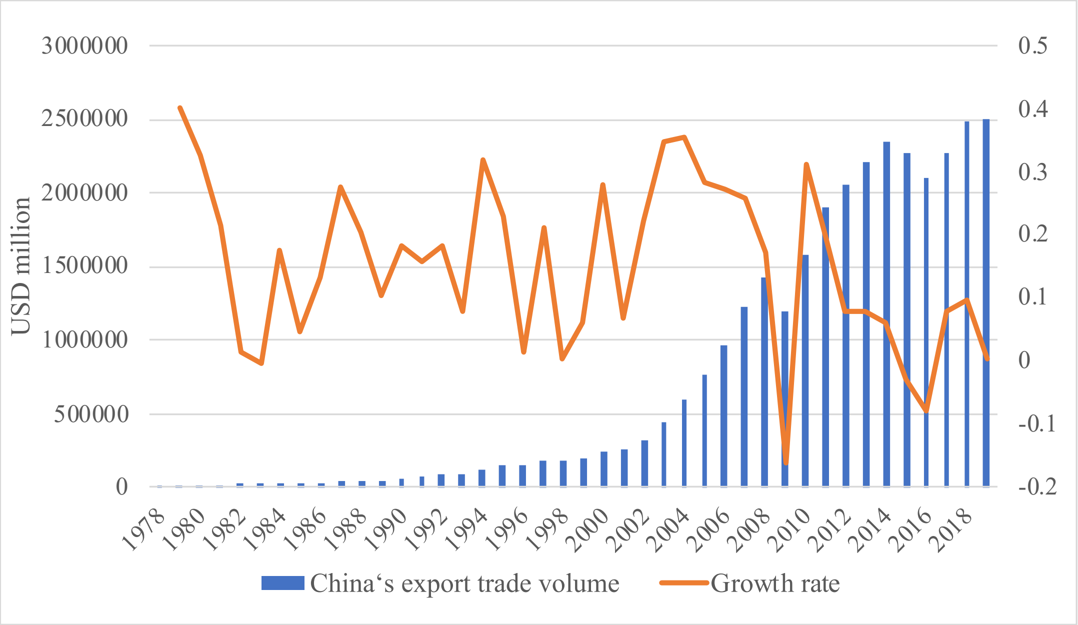
4.2 Overview of manufacturing trade in China

4.2.1 Overview of China’s export

Since the 1970s, China’s export trade volume has experienced unprecedented expansion brought by the reform and opening-up policy. As one of the “troikas” driving economic growth, export trade constitutes a significant driving force for China’s economic take-off. China’s export trade volume has boomed exponentially due to the increasingly improved trade openness and globalization. In 1978, China’s export trade volume was only 9.75 USD billion, ranking 32nd in the world’s export trade. In 2019, China’s exports trade was 2.50 USD trillion in 2019, equal to 13.2% of gross world exports and ranked first in the world’s international trade. Nowadays, China has become a recognized trading country and has made great contributions to the growth of the world economy.

Figure 7. depicts the changes in the number of China's total export trade volume and growth rate over the period from 1978 to 2019. In the early stage of China's economic system reform, the growth rate of China's export trade volume maintained at a relatively high level. Since China kept its place with the WTO in 2001, the growth rate reached a new peak. However, the trend decreased steeply in 2009, affected by the 2008 financial crisis. After that, the economy and trade have gradually recovered and prospered through macro-control measures from many aspects. The decline in the prices of major global commodities confirms the slow recovery of the world economy and the sluggish demand, resulting in a decline in China's export volume in 2015.

Figure 7. China's total export trade volume and growth rate, 1989-2019

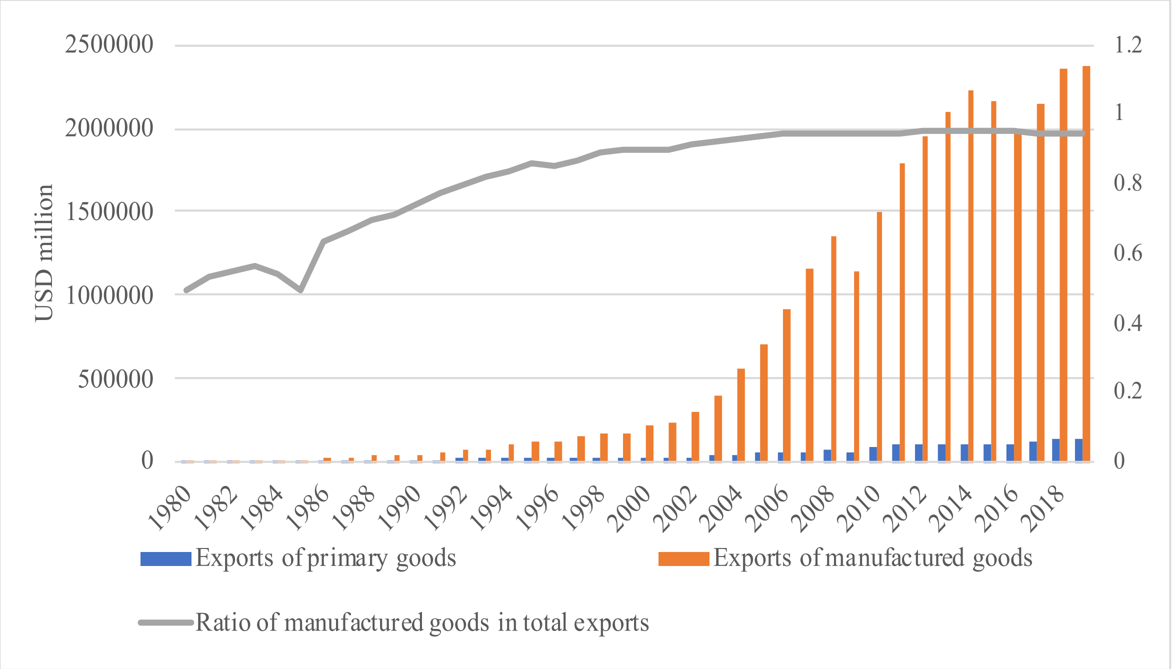


Resource: Own computation, National Bureau of Statistics of China, 1979-2019

4.2.2 China’s manufactured goods’ export

Under the Standard International Trade Classification (SITC), China’s export basket mainly consists of primary goods and manufactured goods. As shown in Figure 8., there is a rapid upward trend in the export volume of manufactured goods from 1980 to 2019. Since 2009, manufactured goods’ export volume has resumed growth after a short-term contraction caused by the financial crisis in 2008. It increased steadily and climbed to a peak in 2014, which then hit a trough in 2016. As of 2019, China's export of manufactured goods exceeded 2.37 USD trillion, making it an essential part of China's trade growth. In recent years, the growth rate of exports of manufactured goods has slowed down, suggesting that economic development in China has entered a new normal and export trade is experiencing weakness at the same time. Therefore, to further improve China’s manufacturing industry’s export level, it is necessary to carry out specific changes in the development strategy of China’s current export trade.

Figure 8. China's manufactured goods' exports and primary goods' exports, 1980-2019



Resource: Own computation, UN Comtrade

From 1980 onward, 49.70% of manufactured goods' export accounted for the total goods export, which then achieved at 94.64% in 2019. The proportion of China's manufactured goods' export has remained stable at 95% in the last decade. Accordingly, the percentage of China's primary goods' export was 50.31% in 1980, but 40 years later, there was only 5.40%. As the world's largest exporter, China export trade has obviously become a manufactured products-oriented export pattern. However, it is worth mentioning that the rapid prosperity of manufactured goods export must rely on domestic resources, energy and the ecological environment, suggesting huge environmental risks hidden behind the export flow.

Nowadays, the manufacturing industry has been a mainstay of China's national economy and international trade. Since the implementation of the reform and opening up more than 40 years, China has already possessed a certain level of technology and a relatively complete manufacturing system. After entered the WTO, China actively participated in the global production division of industry and quickly integrated into the global value chain (GVC), to assume the role of the "world factory" in the international community. To today, "Made in China" has become a specific label for China's exports.

China's manufacturing export structure is transitioning from labour-intensive products to capital- and technology-intensive products from the perspective of structural changes in China's manufacturing exports. For instance, the export proportion of labour-intensive products such as the textile industry, leather and apparel products industry has shown a downward trend. In contrast, the ratio of capital-intensive products to total manufacturing export, such as ferrous metal smelting and non-ferrous metal processing industries, saw an upward trend. Among various sectors' export of the manufacturing industry, communications equipment, computers and other electronic equipment manufactured goods exports have consistently accounted for the most significant proportion of China's merchandise exports, maintaining a 43% share of total exports in the last decade. Nevertheless, the proportion of products with high technical content and high added value is still not high among the technology-intensive products export. At present, with the disappearance of the demographic dividend, China's manufacturing exports are gradually getting rid of labour and resource-intensive characteristics and creating a transition from "made in China" to "created in China".

4.3 Manufacturing classification

4.3.1 Industry consolidation

In case of the data availability and the role of manufacturing in China's export trade, this empirical research conducted around industry-level data. The export data of the manufacturing industry in this study comes from the UN Comtrade database, which divides industries according to ISIC Rev.4. The original data (2004-2017) related to industry classification, such as pollutant emissions and output value by sector, comes mainly from the China Environmental Yearbook, the China Industry Statistical Yearbook and the China Industry Economy Statistical Yearbook. The manufacturing industry's classification system adopted in these yearbooks is the National Economy Industry Classification and Code (GB/T4754-2002) published by the National Bureau of Statistics (NBS).

Table 1. Correspondence of manufacturing sectors between ISIC Rev.4 and GB/T4754-2002

No.	Section description	ISIC Rev.4	GB/T4754-2002
1	Manufacture of food, beverages and tobacco	C10-C12	13-16
2	Manufacture of textiles, wearing apparel and leather	C13-C15	17-19
3	Manufacture of cork and wood products (except furniture)	C16	20
4	Manufacture of paper and paper products	C17	22
5	Printing and reproduction of recorder media	C18	23
6	Manufacture of coke and refined petroleum products	C19	25
7	Manufacture of chemicals and chemical products	C20	26, 28
8	Manufacture of medicinal and pharmaceutical products	C21	27
9	Manufacture of rubber and plastics products	C22	29, 30
10	Manufacture of non-metallic mineral products	C23	31
11	Manufacture of basic metals	C24	32, 33
12	Manufacture of fabricated metal products	C25	34
13	Manufacture of machinery and equipment	C27-C28	35,36,39
14	Manufacture of transport and related equipment	C29-C30	37
15	Manufacture of electronic and optical products	C26	40,41
16	Manufacture of furniture	C31	21

Source: Own computation, ISIC Rev.4, GB/T4754-2002.

4.3.2 Sector classification

To distinguish the pollution intensity of different manufacturing industry 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 PACE, the ratio of the emissions in the industrial added value, standardized emissions data and pollution emission indexes (Fu and Li, 2010). Due to the Chinese government not having statistics on the cost of pollution reduction by sector, this thesis 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. The primary pollution emissions of different industries are various, for example, the paper industry especially releases wastewater, and the non-metallic mineral products industry mainly discharges waste gas. Therefore, the different pollutants of each sector cannot be directly added to the total amount. Using a standardized method of Kheder and Zugravu (2008), this thesis standardized three pollutant emission indexes for various sectors, then calculated the comprehensive pollutant emission index. The higher the industrial pollution emission index, the more serious the industry's pollution to the environment. The specific calculation process is as follows:

Step 1: calculate pollutant emission per unit output value of each industry of manufacturing (EP_{ij}).

$$EP_{ij} = P_{ij}/TV_i$$

Where EP_{ij} is the pollutant emission indexes for j pollutant in the sector i. P_{ij} is the j pollutant emission volume of sector i. TV_i is the total output value of sector i. i indicates the sector of manufacturing; j indicates the pollutant category, which are the discharge amount of wastewater, exhaust gas and toxic solid waste.

Step 2: standardize the pollutant emission indexes for various sector based on the standardized method.

$$\overline{EP_{ij}} = \frac{EP_{ij} - Min(EP_j)}{Max(EP_j) - Min(EP_j)}$$

Where $\overline{EP_{ij}}$ is the standardized pollutant emission indexes for for j pollutant in the sector i; $Max(EP_j)\ and\ Min(EP_j)$ represent the maximum and minimum emission of j pollutant per unit output value of all sectors.

Step 3: sum to get the industrial pollution intensity index (PI_i).

$$PI_i = \sum_{j}^{3} \overline{EP_{ij}}$$

Based on the above formulations, this thesis calculated the pollution intensity of different sector in China's manufacturing industry from 2005 to 2015. Using a weighted average method, the average pollution index of varying manufacturing sectors during the study period is finally obtained (see Table 2.). The higher the pollution index, the greater the sector's pollution emission intensity, and the heavier the burden on the environment.

Despite extensive studies, a unified standard for the classification of industrial pollution levels in previous related studies have not yet been fully established. In this thesis, referring to existing research (Fu and Li, 2010), the average pollution index of 16 departments is sorted by size. As results are shown in Table 2. that the pollution indices of the four sectors of basic metal processing industry, paper industry, non-metal manufacturing industry and chemical industry are all greater than 1, which is significantly higher than other sectors. This result is in agreement with literature conclusion by Copeland and Taylor (2004). By contrast, the lightly polluting sectors are mainly concentrated in high-tech industries and clean industries ($PI < 0.05$), such as machinery and equipment manufacturing, electronic science and education, and transportation equipment manufacturing. Generally, these technology-intensive industries have high technical added value, thus improving resource utilization and controlling environmental pollution through continuous technology upgrading. Except for specific heavy industries such as petroleum processing and metal manufacturing, classified as moderately polluting sectors ($0.5 < PI < 1$), there are also traditional labour-intensive processing industries of China's manufacturing and light industries such as food, tobacco processing, and textile industries.

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

Class	No.	Section description	PI
Intensive pollution sectors	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 sectors	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 fabricated metal products	0.1169
Lightly pollution sectors	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.

4.4 Measurement of environmental regulation intensity

4.4.1 Environmental regulation intensity indicator

As mentioned in the literature review, a variety of different measurement method 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.

Regarding the establishment of the environmental regulations intensity indicator, the measurement of the level of environmental regulations at the industrial level depends on the response and compliance of economic entities in the industry, compared to the research at the national or regional level. Therefore, limited by the complexity of economic entities and their activities, indicators of industrial pollution emissions and pollution control costs, reflecting the behavioural intentions of regulated companies, are widely used to measure environmental regulations' intensity at the industrial level. Due to the cost of industrial pollution control accounts for a tiny proportion of the total industrial production value, using pollution control costs per unit of output as an indicator may lead to underestimation of the intensity of environmental regulations.

For the manufacturing industry, environmental regulation mainly controls pollution emissions, so this thesis integrated pollution control costs and pollution emissions when constructing indicators. By referring to previous literature’s method (Li and Li, 2017), the pollution control investment per unit of pollution discharge is employed as an indicator to measure the stringency environmental regulations. In general, the higher the indicator, suggesting the higher pollution control investment per unit of pollution emission, and the stricter the environmental regulation. The concrete calculation process is as follows:

Step 1: Calculate the pollution control investment per unit of pollutant discharge by the sector.

$$ER_{ij} = PC_{ij}/P_{ij}$$

Where ER_{ij} is the environmental regulation intensity for j pollutant in the sector i. P_{ij} is the j pollutant emission volume of sector i. PC_{ij} is the pollution control investment of j pollutant in sector i. i indicates the sector of manufacturing; j indicates the pollutant category, which are the discharge amount of wastewater, exhaust gas and toxic solid waste.

Step 2: Standardize the results of the previous step.

$$\overline{ER_{\imath\jmath}} = \frac{ER_{ij}}{\sum_{i}^{16} ER_{ij}}$$

Where $\overline{EP_{\imath\jmath}}$ is the environmental regulation intensity for j pollutant in the sector i; $\sum_i ER_{ij}$ is the sum of the environmental regulation intensity for j pollutant per unit output value of all sectors.

Step 3: Sum up to get the industrial environmental regulation intensity index (ER_i).

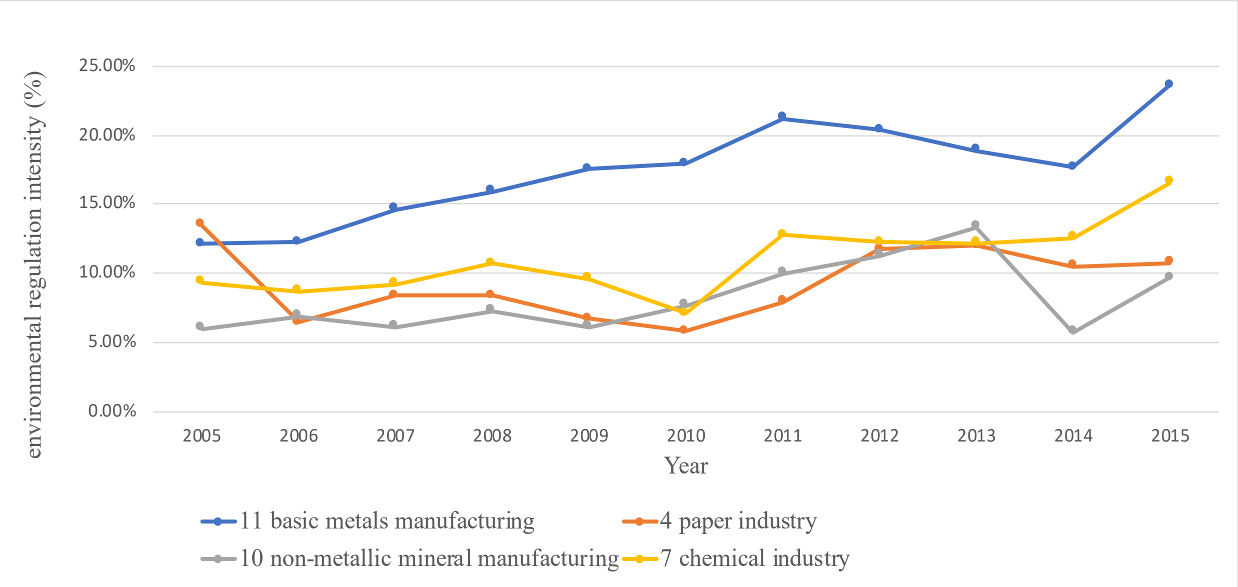
$$ER_i = \sum_{j}^{3} \overline{ER_{\imath\jmath}}$$

4.4.2 Intensity of China’s Manufacturing Environmental Regulations

As shown in Figure 9., 10. and 11., 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 moderately polluting industries, and the environmental regulations intensity in the intensive polluting industries and the lightly polluting industries are in the same range. Due to this heterogeneity between industries, changes in the intensity of environmental regulations may impact manufacturing exports.

From the perspective of changing trends (See Figure 9.), environmental regulations in the intensive polluting sectors have 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 regulations in pollution-intensive sectors has been increasing in recent years.

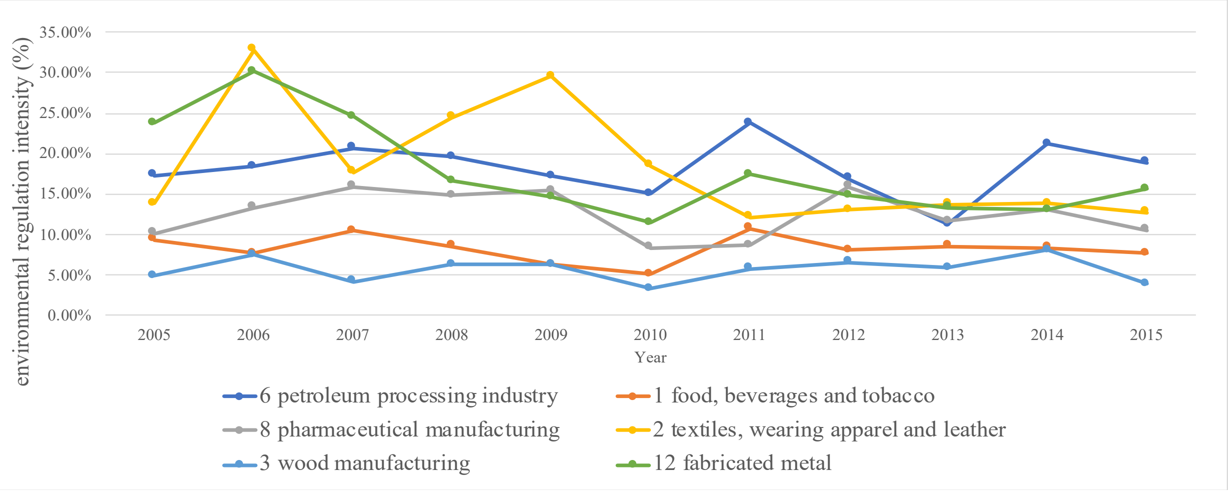
Figure 9. Environmental regulation intensity in intensive pollution sectors, 2005 - 2015



Data: Own computation, the China Environmental Yearbook, the China Industry Statistical Yearbook, the China Industry Economy Statistical Yearbook, 2006-2016

From a numerical point of view, the intensity of environmental regulations has always been relatively high in moderately polluting sectors (See Figure 10.). Especially, resource-intensive and labour-intensive manufacturing, such as the petroleum processing industry, textile and apparel industry, and fabricated metal manufacturing industries, have always highlighted China's pollution control, emission reduction and energy conservation. Nevertheless, the wood processing industry, which is also energy-intensive and polluting, has not received sufficient attention.

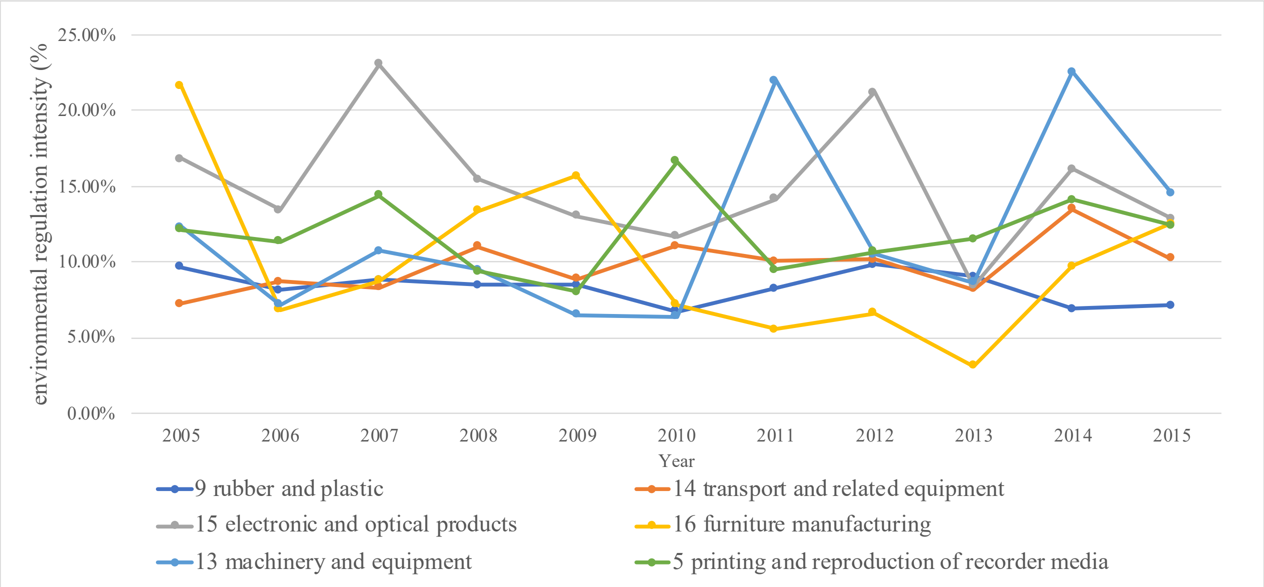
Figure 10. Environmental regulation intensity in moderate pollution sectors, 2005 - 2015



Data: Own computation, the China Environmental Yearbook, the China Industry Statistical Yearbook, the China Industry Economy Statistical Yearbook, 2006-2016

Furthermore, Figure 11. indicated that the environmental regulations of other lightly polluting sectors remain at a relatively low level, except the machinery and equipment manufacturing, electronic equipment, and optical product manufacturing industries. Meanwhile, the intensity of environmental regulations in lightly polluting industries 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: affected by China's “11th, 12th, and 13th Five-Year Plan”, the intensity of environmental regulations in these industries fluctuates with economic development and new environmental policy orientation. Therefore, China should increase its attention to lightly polluting sectors, stabilize its environmental regulations at a certain level instead of reducing monitoring as weak pollution emissions.

Figure 11. Environmental regulation intensity in lightly pollution sectors, 2005 - 2015



Data: Own computation, the China Environmental Yearbook, the China Industry Statistical Yearbook, the China Industry Economy Statistical Yearbook, 2006-2016

5 Empirical model

5.1 Heckscher–Ohlin–Vanek Model

For studying the effect of environmental regulation intensity on the export of various countries, regions and industries, there are two main ways to make an analysis: One is to treat environmental regulations as endogenous variables affiliate into the theoretical framework of comparative advantage. The other is to add environmental factors to the Heckscher–Ohlin (H-O) model, thereby obtain an extended model, namely, the environmental Heckscher-Ohlin-Vanek (H-O-V) model.

According to the setting of the Heckscher–Ohlin (H-O) model and Ricardo's comparative advantage theory, trade specialization is usually determined by the composition of factor endowments. A country should specialize in exporting goods that intensively employ relatively abundant resources. Under a traditional H-O model framework, production factors refer to the three primary forms of capital, labour and technology. The production activities of each sector in the manufacturing industry cannot be separated from the input of capital, labour, and technological factors. At the same time, this production activity will also produce pollution emissions and affect the environment. In this way, the environmental regulations can be treated as a kind of economic factor endowment invested by the enterprise during their production procession.

The H-O-V model is initiated by Tobey (1990) on the basis of the H-O model. It is a model of multiple countries, multiple commodities and multiple elements. The H-O-V model emphasizes that under free trade conditions, a country becomes a net exporter of relatively abundant factors, and export trade are expresses as a function of factor endowments. The traditional H-O-V model has the following form:

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

where the subscripts i, t and k denote the sector, year and factors respectively. ε is a random error, and β_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.

In this paper, export trade volume by sector in manufacturing (EX) is expressed as a function of factors, including environmental regulation intensity (ER), material capital endowment (K), human capital intensity (H), technology input element (T) and foreign direct investment (FDI), and to investigate the determinants of export trade. Since the variable data of EX, K and T are absolute quantities, to alleviate the multicollinearity of the variables and the heteroscedasticity of the equation while not changing the variables' main characteristics, logarithm processing is performed on them to reduce the fluctuation range. The specific model is established below:

$$\ln EX_{it} = \beta_0 + \beta_1 ER_{it} + \beta_2 \ln K_{it} + \beta_3 H_{it} + \beta_4 \ln T_{it} + \beta_5 FDI_{it} + \varepsilon$$

where the subscripts i and t denote the industry and year, respectively. β_0 is a constant term, ε is a random error, and β_{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.

5.2 Data sources and variable description

The empirical analysis of environmental supervision’s imapct on export trade relies on the availability of data. As explained in the previous chapter, the data used for measuring the environmental regulation intensity of different manufacturing sectors in this paper consists of the waste discharge volume and pollutant treatment costs of various manufacturing sectors. These data come 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. In view that the environmental regulation intensity is the primary variable studied in this paper, export trade volume, material capital endowment, human capital endowment, technology input endowment, foreign direct investment (FDI), these factors are also selected with a time span of 2005-2015.

A balanced panel data spans from 2005 to 2015 and includes 16 sub-sectors of China's manufacturing was selected in this paper. The sources of these raw data collected from different public databases and Statistical Yearbook, including the United Nations Comtrade Database, the China Trade and External Economic Statistical Yearbook (2006–2016), the China Statistical Yearbook (2006-2016), the China Industry Economy Statistical Yearbook (2006–2012), the China Industry Statistical Yearbook (2013–2016), the China Statistical Yearbook on Science and Technology (2006–2016).

Export trade volume by sector in manufacturing

Existing research on the relationship between environment and trade mostly chooses international competitiveness, trade comparative advantage and export technology complexity to discuss the indirectly impact of environmental regulation on trade. This research selects the sector's export trade volume in China's manufacturing to measure export trade (EX). In order 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. Additionally, using the price index (2005=100) to eliminate price fluctuations and obtain the actual export trade value.

Data source: The United Nations Comtrade Database, The China Statistical Yearbook

Environmental regulation intensity

Drawing on the previous literature, the proportion of the sector's pollution control and treatment investment on the sector's pollution discharge is adopted as an indicator to measure the intensity of environmental regulations. The higher the indicator, the higher the pollution control investment per unit of pollution emission, and the stricter the environmental regulation. The sector's industrial environmental regulation intensity index (ER_i) calculated above are used to evaluate the environmental regulation stringency.

Data source: The China Environmental Statistical Yearbook

Material capital endowment

According to the factor endowment theory, material capital endowment is a critical element that affects an industry's economic development. With more physical capital stock, the industry has more machinery and equipment, which means that production costs are relatively lower. This study measures material capital endowment in the various sector by taking the proportion of the sector's fixed assets-net value on the number of employees by sector (Cole et al.,2005).

Data source: The China Statistical Yearbook, the China Industry Economy Statistical Yearbook, the China Industry Statistical Yearbook

Human capital intensity

Human capital endowment, reflecting the knowledge and skills that employees input to the organization, is formed through education and professional training. Since human capital is an inherent characteristic of human beings and flow through the market at the same time, it is difficult to assess human capital endowment. In this paper, the percentage of science and technology personnel in the total employment of various industries is employed to measure human capital, and this proxy variable is similar to that used by Teixeira and Tavares-Lehmanna (2014).

Data source: The China Statistical Yearbook on Science and Technology

Technology input element

Based on the Porter hypothesis, Technological innovation is a critical factor to extract the relationship between environment regulations and export trade. Research and development (R&D) investment has always been the key factor to influence the sector's production efficiency (Tobey, 1990). Therefore, technology input can be inferred as a driving force for export trade. This study measures the technology input through the expenditures of R&D and S&T activities (Zhai and An, 2020).

Data source: The China Statistical Yearbook on Science and Technology

Foreign direct investment (FDI)

Foreign direct investment can provide the host country with more available funds and bring advanced equipment and technology to the investment area. It can promote the technological upgrade of the host country's enterprises, thereby expanding the scale of their export trade. This paper measures the foreign direct investment by taking the ratio of assets of enterprises invested by foreign investment (include Hong Kong, Macao and Taiwan businessmen) to total industrial investment.

Data source: The China Trade and External Economic Statistical Yearbook

5.3 Research hypotheses and model

5.3.1 Hypotheses

Drawing on the existing research on the influencing factors and the impact of environmental regulation mentioned above in this paper, the hypotheses are proposed below:

Hypothesis 1

Environmental regulations exert a positive effect on China's manufacturing sector export trade while other influencing factors remain unchanged.

Hypothesis 2

Material capital endowment positively effects on China's manufacturing sector export trade while keep other influencing factors remain unchanged.

Hypothesis 3

Human capital intensity positively effects on China's manufacturing sector export trade while keep other influencing factors unchanged.

Hypothesis 4

Technology input positively impacts China's manufacturing sector export trade while keep other influencing factors remain unchanged.

Hypothesis 5

Foreign direct investment positively impacts China's manufacturing sector export trade while keep other influencing factors unchanged.

5.3.2 Model construction

Economic model

The formula of the economic model is built as follows:

$$EX = f(ER, K, H, T, FDI)$$

Econometric model

The formula for the econometric model is shown below:

Intensive pollution sectors

$$\ln y_{1t} = \gamma_1 x_{1t} + \gamma_2 x_{2t} + \gamma_3 \ln x_{3t} + \gamma_4 x_{4t} + \gamma_5 \ln x_{5t} + \gamma_6 x_{6t} + u_{1t} \qquad \text{(equation 1)}$$

Moderate pollution sectors

$$\ln y_{2t} = \gamma_7 x_{1t} + \gamma_8 x_{2t} + \gamma_9 \ln x_{3t} + \gamma_{10} x_{4t} + \gamma_{11} \ln x_{5t} + \gamma_{12} x_{6t} + u_{2t} \qquad \text{(equation 2)}$$

Lightly pollution sectors

$$\ln y_{3t} = \gamma_{13} x_{1t} + \gamma_{14} x_{2t} + \gamma_{15} \ln x_{3t} + \gamma_{16} x_{4t} + \gamma_{17} \ln x_{5t} + \gamma_{18} x_{6t} + u_{3t} \qquad \text{(equation 3)}$$

Table 3. Description of selected variables in Econometric model

Variables	Symbol in Eviews	Description	Unit
1. Dependent Variables			
y1t	EX	Sector’s export trade volume	CNY
2. Independent Variables			
x1t		unit vector	
x2t	ER	environmental regulations intensity	%
x3t	K	material capital endowment	CNY/person
x4t	H	human capital	%
x5t	T	technology input	CNY
x6t	FDI	foreign direct investment	%
3. Stochastic Variable			
u_{3t}			

Source: own computation

5.4 Data analysis

5.4.1 Correlation Matrix

5.4.1.1 Correlation Matrix of Intensive pollution sector's model

Table 4. The correlation coefficient of equation 1, including observations 2005-2015

	LNEX	ER	LNK	H	LNT	FDI
LNEX	1					
ER	0.637772	1				
LNK	0.726509	0.896615	1			
H	0.797097	0.765103	0.764224	1		
LNT	0.958624	0.725562	0.787492	0.899345	1	
FDI	-0.712845	-0.510708	-0.299577	-0.47828	-0.662641	1

Source: Own computation of Eviews 10. results

According to the correlation matrix (Table 4.). There is no perfect correlation between explanatory variables, but the high level of multicollinearity among the independent variables is a vital concern. When the correlation coefficient between two independent variables > 0.8, it means that there is multicollinearity between them. As shown in Table 4., the correlation coefficient between ER(x_{2t}) and LNK (x_{3t}), H(x_{4t}) and LNT(x_{5t}), which is equal to 0.896615 and 0.899346 respectively. To resolve this problem, the first difference method is adopted to get rid of it and get a new model as follows.

$$\ln y_{1t}= \gamma_1 x_{1t} + \gamma_2 x_{2t} +\gamma_3 \, d\ln x_{3t} + \gamma_4 x_{4t} + \gamma_5 d\ln x_{5t} +\gamma_6 x_{6t} + u_{1t} \qquad \text{(equation 4)}$$

Table 5. The correlation coefficient of equation 4, including observations 2005-2015

	LNEX	ER	dLNK	H	dLNT	FDI
LNEX	1					
ER	0.694535	1				
dLNK	0.055044	-0.167056	1			
H	0.807649	0.790944	-0.144677	1		
dLNT	0.071386	0.043869	-0.235153	0.237677	1	
FDI	-0.719532	-0.559721	-0.08154	-0.454338	0.008883	1

Source: Own computation of Eviews 10. results

In Table 5., the new correlation matrix shows that there is no perfect correlation between explanatory variables, but the multicollinearity of variables was eliminated.

5.4.1.2 Correlation Matrix of Moderate pollution sector's model

Table 6. The correlation coefficient of equation 2, included observations 2005-2015

	LNEX	ER	LNK	H	LNT	FDI
LNEX	1					
ER	0.253081	1				
LNK	-0.158646	0.038708	1			
H	-0.497934	0.037485	0.339729	1		
LNT	0.324285	0.105808	0.186441	0.43588	1	
FDI	0.433185	-0.023566	-0.557402	-0.157716	0.221021	1

Source: Own computation of Eviews rev. 10. results

As shown in Table 6., the correlation coefficient of the moderate pollution sector's model suggests that there is no signal of the high level of multicollinearity among the independent variables in equation 2.

5.4.1.3 Correlation Matrix of Lightly pollution sector's model

Table 7. The correlation coefficient of equation 3, including observations 2005-2015

	LNEX	ER	LNK	H	LNT	FDI
LNEX	1					
ER	0.958624	1				
LNK	0.121579	0.121579	1			
H	0.526486	0.526486	0.585313	1		
LNT	0.692093	0.692093	0.551834	0.693651	1	
FDI	0.027671	0.027671	-0.168771	-0.074311	0.025777	1

Source: Own computation of Eviews rev.10. results

As shown in Table 7., the correlation coefficient of the lightly pollution sector's model suggests that there is no signal of the high level of multicollinearity among the independent variables in equation 3.

5.4.2 Stationary test

In order to avoid spurious regression, the balanced panel data should perform a unit root test on the stationarity of time series data before regression. Common root test and Individual root test are two mainly used methods for panel data stationarity testing in Eviews rev.10. The common root test method mainly includes Levin–Lin–Chu test, Breitung test and Hadri Lagrange multiplier (LM) test. As for the Individual root test, there is commonly

Fisher test and Im–Pesaran–Shin test (2003). In this paper, Levin–Lin–Chu test (LLC test) and PP-Fisher tests are used to examine whether each series contains a unit root.

H0: Panels contain unit roots

H1: Panels are stationary

If P-value > 0.05, suggesting that the null hypothesis is accepted and the data are not stationary, otherwise they are stationary.

5.4.2.1 Stationary test of Intensive pollution sector's model

Table 8. Result of stationary test of equation 4

Variables	Statistical method	LLC	PP-Fisher	Results
lnEX	I&T	0.0000	0.0036	stable
ER	I&T	0.0000	0.0089	stable
dlnK	I	0.0062	0.0026	stable
H	I&T	0.0000	0.0008	stable
dlnT	I&T	0.0000	0.0000	stable
FDI	I&T	0.0000	0.0002	stable

Source: Own computation of Eviews rev. 10. results

Note: "I" means that Individual intercept is included in test equation; "T" means that Individual linear trend is included in test equation

As Table 8. showed the unit root test results, the P-value of all series in the intensive pollution sector's model is less than 0.05. Therefore, all series reject the null hypothesis of "contain unit roots" at different significance levels. Hence, all variables in this model belong to the stationary series of the same order, which means that the model's regression analysis is feasible in this paper.

5.4.2.2 Stationary test of Moderate pollution sector's model

Table 9. Result of stationary test of equation 2

Variables	Statistical method	LLC	PP-Fisher	Results
lnEX	I	0.0000	0.0194	stable
ER	I&T	0.0000	0.0000	stable
lnK	I&T	0.0031	0.0045	stable
H	I&T	0.0000	0.0004	stable
lnT	I&T	0.0000	0.0000	stable
FDI	none	0.0000	0.0002	stable

Source: Own computation of Eviews rev.10. results

Note: "I" means that Individual intercept is included in test equation; "T" means that Individual linear trend is included in test equation

As shown in Table 9., the P-value of all series in the moderate pollution sector's model is similarly less than 0.05. Therefore, all series reject the null hypothesis of "contain unit roots" at different levels of significance. Hence, all variables in this model belong to the stationary series of the same order, which means that the model's regression analysis is feasible in this paper.

5.4.2.3 Stationary test of Lightly pollution sector's model

Table 10. Result of stationary test of equation 3

Variables	Statistical method	LLC	PP-Fisher	Results
lnEX	I	0.0000	0.0000	stable
ER	I	0.0000	0.0000	stable
lnK	I&T	0.0047	0.0036	stable
H	I&T	0.0000	0.0036	stable
lnT	I&T	0.0000	0.0002	stable
FDI	I&T	0.0000	0.0001	stable

Source: Own computation of Eviews rev.10. results
Note: "I" means that Individual intercept is included in test equation; "T" means that Individual linear trend is included in test equation

Table10. shows that the P-value of all series in the lightly pollution sector's model is less than 0.05. Therefore, all series reject the null hypothesis of "contain unit roots" at different significance levels. Hence, all variables in this model belong to the stationary series of the same order, which means that the model's regression analysis is feasible in this paper.

5.4.3 Panel Equation Testing

To establish an effective balanced panel data 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.

Step 1: The Redundant Fixed Effects-Likelihood Ratio Test is performed on each sample model to choose the mixed effect model or the fixed effect model.

H0: the individual specific effects are correlated with the independent variables, establish the mixed effects model.

H1: establish the individual fixed effect model.

If P-value < 0.05, meaning that the null hypothesis is rejected, an individual fixed effect model is selected, otherwise the mixed effects model is used. The P-value in this research is calculated from the software of Eviews rev.10.

Step 2: The Correlated Random Effect-Hausman Test is performed on each sample model to choose the fixed effect model or the random effect model.

H0: the individual specific effects are uncorrelated with the independent variables, establish the random effects model.

H1: establish the individual fixed effect model.

If P-value < 0.05, null hypothesis is rejected, an individual fixed effect model is selected, otherwise the random effects model is used. The value of P is calculated in the same software of Eviews rev.10.

The experimental results of the Redundant Fixed Effects-Likelihood Ratio Test for three different pollution intensity sectors are shown in Table11. All the P-value 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. The Hausman test results are shown in Table12. Similarly, the P-value of the three models is below 0.05, a fixed effect 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.

Table 11. The experimental results of the Redundant Fixed Effects-Likelihood Ratio Test

	Effect test	Statistic	Prob
Intensive pollution sector's model	Cross-section F	57.7856	0.0000
	Cross-section Chi-square	87.3514	0.0000
	Period F	13.7874	0.0000
	Period Chi-square	75.7264	0.0000
	Cross-section/Period F	32.9514	0.0000
	Cross-section/Period Chi-square	117.7217	0.0000
Moderate pollution sector's model	Cross-section F	258.3927	0.0000
	Cross-section Chi-square	223.8386	0.0000
	Period F	6.9574	0.0000
	Period Chi-square	61.6809	0.0000
	Cross-section/Period F	110.1506	0.0000
	Cross-section/Period Chi-square	239.5871	0.0000
Lightly pollution sector's model	Cross-section F	219.7493	0.0000
	Cross-section Chi-square	200.9282	0.0000
	Period F	3.5274	0.0027
	Period Chi-square	35.0555	0.0001
	Cross-section/Period F	92.6362	0.0000
	Cross-section/Period Chi-square	210.5540	0.0000

Source: Own computation of Eviews rev.10. results

Table 12. The experimental results of the Correlated Random Effect-Hausman Test

Model	Chi-Sq.Statistic	Prob.
Intensive pollution sector's model	35.6661	0.0001
Moderate pollution sector's model	35.8334	0.0000
Lightly pollution sector's model	17.6749	0.0034

Source: Own computation of Eviews rev.10. results

5.4.4 Estimations

The estimation results of equation 4, 2 and 3 on the actors affecting China's manufacturing export trade volume are shown in Table 13.

Table 13. The empirical results of Panel Least Squares

Variables	Equation 4	Equation 2	Equation 3
Constant	6.201481*** (22.46175)	6.596587*** (8.357033)	2.365975*** (3.946903)
ER	-0.034572** (-2.317497)	-0.003873 (-0.718140)	0.054092*** (3.802666)
lnK	0.092814 (0.116892)	-0.834683*** (-3.721858)	0.231058 (1.510861)
H	0.039436 (0.790009)	0.034195* (1,702103)	-0.497851*** (-9.403013)
lnT	0.215818 (0.918153)	0.291833** (2.311078)	0.498278*** (4.784019)
FDI	0.003734 (0.345261)	0.001547 (0.612770)	0.032231*** (3.381752)
Total pool observations	40	66	66
R-squared	0.990863	0.992067	0.726012
Adjusted R-squared	0.983802	0.988542	0.703180
F-statistic	140.3345	281.3833	31.79755
Prob. (F-statistic)	0.000000	0.000000	0.000000
Breusch-Pagan LM	0.0023	0.2089	0.0803

Source: Own computation of Eviews rev.10. results
Notes: The numbers above brackets are regression coefficients. The value of T is in parentheses. * = significant at 10%; ** = significant at 5%; *** = significant at 1%.

5.4.5 Model verification

5.4.5.1 Economic verification

In terms of model verification, the first part is economic verification to test whether the variables' regression coefficients are consistent with the traditional economic point of view. The signs of variables ER in equation 4 and 2, lnK in equation 2, H in equation 3 are inconsistent with the predicted relationship between them and the independent variable lnEX, thus resulting in that these variables being rejected before further analysis.

5.4.5.2 Statistical verification

(1) Goodness of fit

Intensive pollution sector's fixed effect model

The coefficient of determination: $R^2 = 0.990863$

The adjusted R-squared：$R_{adj}^2 = 0.983802$

It means that the regression predictions fit the data with 99.1% accuracy, and over 98.3% of data can be explained by this model. They are greater than 0.8, so model can be viewed as suited for data. In other word, 99.1% of the dependent variable export volume of the intensive pollution sector in china can be explained as independent variables.

Moderate pollution sector's fixed effect model

The coefficient of determination: $R^2 = 0.992067$

The adjusted R-squared：$R_{adj}^2 = 0.988542$

It means that the regression predictions fit the data with 99.2% accuracy, and over 98.9% of data can be explained by this model. They are greater than 0.8, so model can be viewed as suited for data. In other word, 99.2% of the dependent variable export volume of the moderate pollution sector in china can be explained as independent variables. In addition, based on the high value of the F-statistic with 281.3833, statistically significant regressions in this model can be found.

Lightly pollution sector's fixed effect model

The coefficient of determination: $R^2 = 0.726012$

The adjusted R-squared：$R_{adj}^2 = 0.703180$

It means that the regression predictions fit the data with 72.6% accuracy, and over 70.3% of data can be explained by this model. In other word, 72.6% of the dependent variable export volume of the moderate pollution sector in china can be explained as independent variables. Compared with the previous two models, the coefficient of determination and the adjusted R-squared of this model are lower. But these number are more than 50%, indicating the model is suitable.

(2) Statistically significant of parameters

H0: Significant

H1: Insignificant

If P-value < 0.05, null hypothesis is rejected at the significance level(α)=0.05, otherwise null hypothesis is accepted. The value of P is calculated from the software of Eviews rev.10.

Intensive pollution sector’s fixed effect model

As demonstrated in Table 13., the P-value of ER variable in equation 4 is less than α=0.05, even less than α=0.01. Therefore, the determinant of China's manufacturing export volume in intensive pollution sector mainly is the environmental regulation. Unfortunately, other variables, including lnK, H, lnT and FDI, are not shown statistically significant in this model even if at the significance level (α)=0.1.

Moderate pollution sector’s fixed effect model

As shown in Table 13., the determinant factors of China's manufacturing export volume in the intensive pollution sector include lnK, H, lnT, all of which reached statistically significant at various significant level. The P-value of lnK and lnT variables are less than α=0.05, especially lnK variable’s P-value even less than α=0.01. That is, the lnK and lnT variables are shown statistically significant in this model at the significance level (α)=0.05. Moreover, H variable’s P-value greater than α=0.05 but less than α=0.1, suggesting H variable is statistically significant at 10% level of significance. Unexpectedly, no statistically significant observed with ER and FDI variables.

Lightly pollution sector’s fixed effect model

Table 13. shows that the P-value of ER, H, lnT and FDI variables are less than α=0.05, even less than α=0.01. That is, the determinants of China's manufacturing export volume in intensive pollution sector include ER, H, lnT and FDI, all of which reached statistically significant in this model at 1% level of significance. Meanwhile, lnK is not shown statistically significant in this model.

5.4.5.3 Econometrical verification

In term of residual diagnostics, model can only be corrected during model estimation through white cross-section method, due to panel data cannot be performed heteroscedasticity test in Eviews rev. 10.

The residual in a panel data model is conventionally assumed to be an independent term on the cross-section. However, it is worth noting that cross-sectional dependence should be taken into account in the panel regression, avoiding estimate loss and invalid test statistics. In this paper, the Breusch-Pagan LM test is adopted to perform panel cross-section dependence test.

The null hypothesis H0 to be tested is that:

H0: No cross-section dependence (correlation) in residuals. That is, the errors for different cross-sectional units are all uncorrelated.

H1: There is the cross-section dependence (correlation) in residuals.

If P-value < α, the null hypothesis is rejected; otherwise, it is not rejected.

As observed in Table 13., the P-value of the test statistic for equation 2 and 3 are both great than 0.05, then the null hypothesis is not rejected. There is no cross-section dependence in the Moderate and Lightly pollution sector's fixed effect model. Meanwhile, the P-value of equation 1 is less than 0.05, indicating that reject the null of no cross-section dependence at 5% level of significance.

6 Results and Discussion

Environmental regulation intensity

As empirical results are shown in Table 13., the environmental regulation variable's regression coefficient in the intensive pollution sector's model is -0.034572 and significant at 5% level of significance. This result shows that environmental regulation has not exerted a positive impact on 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. Therefore, Hypothesis 1 is not accepted in the models of intensive pollution sectors and moderate pollution sectors. The regression coefficient of the environmental regulation variables in the lightly pollution sector's model is 0.054092 (significant at the 1% level of significance), which means a significant positive correlation between environmental regulation and exports in the lightly pollution sector. Therefore, Hypothesis 1 was accepted in the lightly pollution sector's model.

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 the environmental regulation. Therefore, to a certain extent, the stringent intensity of the environmental regulation is conducive to export trade's growth of lightly pollution sectors in China's manufacturing industry but hinder exports in intensive polluted sectors. Since no statistically significant results achieved, the impact is uncertain for the moderate pollution sectors.

The above analytical results can confirm that changes in China's environmental regulations intensity play different roles in manufacturing sectors with different pollution levels. As discussed in the existing literatures, environmental regulations can show different effect results based on different economic theoretical models. The two most popular theories are the Pollution Paradise Hypothesis and the Porter Hypothesis. Under the pollution paradise hypothesis, which holds that strict environmental regulations will lead to a growth in the production costs of heavy pollution enterprises and weaken export competitiveness, resulting in a decline in trade exports. That is the so-called “cost effects”. Nevertheless, the Porter hypothesis holds that well-organized environmental regulations will effectively encourage enterprises to increase the export competitiveness of manufactured goods through technological innovation and green transformation. As such, 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”. Therefore, the influencing results of environmental regulations on export primarily depend on the trade-off between cost and innovation compensation effects.

The above analytical results can confirm that changes in China's environmental regulations intensity play different roles in manufacturing sectors with different pollution levels. As discussed in the existing literatures, environmental regulations can show different effect results based on different economic theoretical models. The two most popular theories are the Pollution Paradise Hypothesis and the Porter Hypothesis. Under the pollution paradise hypothesis, which holds that strict environmental regulations will increase the production costs of highly polluting enterprises and weaken export competitiveness, resulting in a decline in trade exports. That is the so-called “cost effects”. 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. As such, these firms can break through the green trade barriers set by developed countries and further expand the export scale. Driven by cost effects, there is no obvious evidence to verify that stricter environmental regulations can improve export trade growth in the intensive pollution sector, which refutes Porter's hypothesis.

As far as lightly pollution sectors are concerned, especially the mechanical and electrical industries, China started relatively late in the field of environmental regulation, and China’s current pollution reduction-oriented regulatory tools have limited effect on environment controlling of these relatively clean industries. Generally, lightly pollution sectors in China’s manufacturing are labour-intensive industries or high-tech industries. The proportion of fixed assets in these sectors’ firm is generally low, suggesting that the cost of technological innovation is not a heavy economic burden. Therefore, these sectors can quickly highlight innovation compensation effects with the implementation of environmental regulations. With the increasingly strict environmental regulations, the lightly pollution sectors have accelerated their industrial upgrading and further moved towards green transformation. As such, the empirical evidence shows that the more stringent environmental regulations exert a greater “innovation compensation effects” than the “cost effect” on lightly pollution sectors, thus benefit export volume.

Overall, this study confirmed the heterogeneous impact of environmental regulations on manufacturing exports in China. Besides, it can be observed that the impact of environmental regulations 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 the accumulation of 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 13. reveals that the regression coefficient of the material capital endowment variable in equation (2) is -0.834683 (significant at the 1% level of significance), suggesting reject Hypothesis 2. The regression coefficient of the material capital endowment is positive in the intensive pollution sectors and lightly pollution sectors, which is consistent with the hypothesis. However, this positive impact of the material capital endowment on exports is not statistically significant, thus also reject hypothesis 2.

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 per capita capital's rise negatively affects the moderate pollution manufacturing sector's export. 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. With capital accumulation increasing, the demographic dividend gradually disappears, and the surplus labour supply tends to be tight. Under this circumstance, the optimal resource allocation of capital and labour cannot be achieved, and exports thereby fall instead of rising with capital accumulation. However, China's foreign trade structure is currently in a critical period of 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 13., the human capital intensity variable's regression coefficient in the intensive pollution sector's model is 0.039436, which is not significant, suggesting that the positive effect of human capital intensity on the intensive pollution sector's export is not statistically significant. Therefore, Hypothesis 3 is not accepted in the models of intensive pollution sectors. However, the positive correlation between the human capital intensity and the moderate pollution sector's export is significant at 10% level of significance, supporting Hypothesis 3. In the lightly pollution sector's model, the regression coefficient of human capital intensity is -0.497851, which is significantly higher than 1%. That is, the lightly pollution sector's export would decrease with the increasing intensiveness of human capital, which is contrary to prediction. Hence, Hypothesis 3 is not accepted.

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 ability and innovation ability. Industries with rich human capital are more capable of adapting and responding to environmental regulations. Human capital exerts a positive effect on promoting China's moderate 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 lightly 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. 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 the lightly polluting manufacturing sector exerts a negative influence on the exports within the industry.

Technology input element

Table 13. demonstrates a significant positive correlation relationship between the technology input and the export of various manufacturing sectors, which is consistent with the hypothesis. In the intensive pollution sector’s model, the technology input’s regression coefficient is 0.215818, which is not statistically significant, rejecting Hypothesis 4. In the moderate pollution sector’s model, the technology input variables’ regression coefficient is 0.291833, significant at the 5% level of significance. Therefore, the moderate pollution sector’s model accepts Hypothesis 4. Similarly, Hypothesis 4 supported by the lightly pollution sector’s model, based on the regression coefficient of technology capital intensity is -0.498278 (significantly higher than 1%). Besides, this variable's coefficient is relatively high, which proves that technology input is an essential factor affecting China's manufacturing exports.

Relying on low-cost advantages, which is accompanied by a large number of environmental costs cannot maintain ongoing competitiveness in fierce international trade. From the perspective of sustainable development, increasing R&D investment to carry out technological innovation, is conductive to update production equipment, improve product innovation, win high added value, and ultimately gain export competitiveness. In this paper, the technology input element variable is measured by research and development (R&D) investment in the industry. For moderate pollution sector and the lightly pollution sector, technology input exerts a positive impact on these in China’s manufacturing industry. 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 (FDI)

As shown in Table 13., there is a positive correlation between foreign direct investment and the export of various manufacturing sectors, which is consistent with the hypothesis. Nevertheless, this positive effect of foreign direct investment is not statistically significant in the intensive pollution sector and moderate pollution sector’s export. In the lightly pollution sector’s model, the foreign direct investment variables’ regression coefficient is 0.032231, significant at the 1% level of significance. Therefore, the intensive pollution and moderate pollution sector’s model reject Hypothesis 4, while the lightly pollution sector’s model accept this hypothesis.

Foreign direct investment plays a significant positive role in promoting exports in the lightly pollution manufacturing sector but shows no significant positive impact on the intensive and moderate pollution manufacturing industries. Foreign direct investment has failed to promote the export trade of heavy and lightly polluting industries. That results can be attributed to the time lag. Foreign direct investment's spill over effect has not been fully exerted, and domestic-funded enterprises have not yet benefited from it. Therefore, except for lightly polluting industries, FDI has not exerted an impact on the growth in manufacturing export trade. The positive effects are that the introduction of foreign investment can 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.

7 Conclusion

With environmental problems become 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 still at an early stage, meaning its intensity is far weaker than in developed countries. In this context, this research investigated the environmental regulation's impact on China's manufacturing export, thereby verifying whether to accept the Porter Hypothesis exist in China's manufacturing.

Considering the heterogeneity of industry, this paper divides the manufacturing industry into intensive pollution, moderate pollution and lightly pollution industries according to the pollution degree. 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 Heckscher–Ohlin–Vanek model. The main research conclusions obtained are as follows:

Based on the previous literature, the representative effects of environmental regulations on export trade are mainly categorised into the "cost effects" and "innovation compensation effects". The "cost effects" is based on the Pollution Paradise Hypothesis and holds that stricter environmental regulations will increase the production costs of highly polluting enterprises, resulting in a decline in trade exports. The "innovation compensation effects" is based on the Porter Hypothesis and claims that well-organized environmental regulations can effectively encourage enterprises to increase the export and offset the environmental cost through technological innovation. Hence, the export impact of environmental regulations depends on the trade-off between cost and innovation compensation effects.

The empirical result confirmed that changes in China's environmental regulations intensity play different roles in manufacturing sectors with different pollution levels. The environmental regulation is conducive to export trade's growth of lightly pollution sectors in China's manufacturing industry but hinder exports in intensive polluted 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 empirical evidence in this paper shows that material capital has a statistically significant adverse impact on the export in moderate pollution sectors, while human capital and technological input play a statistically significant positive role in increasing exports. Besides, human capital has played a statistically significant adverse role in the export of lightly pollution sectors, while technological input and foreign direct investment show a statistically significant positive effect.

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

The above conclusions reveal several implications for policy making: First, the main component of China's manufacturing exports is generally processing and manufacturing industrial products. Most of them belong to 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 the export structure 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, as well as pay attention to the efficiency of capital utilization and the integration of capital, labour, and technology.

Due to the author’s research ability and 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. In view of the data limitations, this paper only considers China’s domestic environmental regulations. Future research can analyze the export impact of differences in domestic and foreign environmental regulations.

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9 Appendix

Table a. Correspondence of manufacturing sectors

Sector No.	Section description	Sector No.	Section description
1	food, beverages and tobacco	9	rubber and plastics products
2	textiles, wearing apparel and leather	10	non-metallic mineral products
3	cork and wood products (except furniture)	11	basic metals
4	paper and paper products	12	fabricated metal products
5	printing and reproduction of recorder media	13	machinery and equipment
6	coke and refined petroleum products	14	transport and related equipment
7	chemicals and chemical products	15	electronic and optical products
8	medicinal and pharmaceutical products	16	furniture

Table b. The volume of industrial wastewater discharge in China's manufacturing by sector

(unit: million tons)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	2080	1964	2574	2794	2695	2758	2638	2898	2381	2674	2636
2	1998	2320	2632	2717	2788	2857	2865	2808	2409	2366	2275
3	66	52	48	47	61	50	35	48	30	53	54
4	3674	3744	4246	4077	3926	3937	3823	3427	4007	2755	2367
5	16	12	20	17	18	16	13	14	11	16	19
6	681	703	731	705	664	700	796	875	760	840	848
7	3876	3855	3730	3500	3409	3514	3298	3097	4447	2945	2942
8	401	430	429	480	527	526	486	572	474	557	533
9	84	94	106	113	112	120	122	128	165	123	126
10	482	431	403	358	328	323	261	294	826	283	284
11	2037	1895	1887	1743	1550	1481	1546	1350	22845	1167	1233
12	211	224	333	283	313	302	299	336	566	334	336
13	351	323	303	347	338	344	281	274	242	283	286
14	247	257	220	285	274	262	284	288	247	293	295
15	260	318	368	376	393	409	472	506	550	544	613
16	8	9	18	18	19	21	7	6	5	9	9

Table c. The volume of industrial waste gas emissions in China's manufacturing by industry (unit: billion cu.m.)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	447	603	714	728	951	1103	1058	924	1015	1082	1024
2	366	430	400	406	401	361	539	370	340	350	344
3	90	88	206	120	149	157	326	271	281	320	569
4	412	540	641	532	611	770	1709	615	672	670	666
5	7	5	7	10	14	11	25	25	25	25	34
6	913	1023	1219	1423	1580	1871	2176	2038	2135	2129	2207
7	1877	2257	3367	2449	2641	2851	3327	3281	3377	4401	3880
8	113	89	114	145	129	160	360	299	174	314	368
9	114	124	180	183	156	179	413	294	376	394	431
10	4986	6513	6778	6815	7887	8726	12985	12329	12034	12846	12469
11	6937	9044	10555	13116	12304	14723	20511	19267	20564	21786	21363
12	85	145	229	216	194	208	887	508	548	568	645
13	260	234	263	394	721	543	623	439	496	482	604
14	195	289	399	403	367	418	595	567	648	652	726
15	207	257	310	390	393	692	625	604	657	713	846
16	31	29	34	23	12	13	29	28	62	41	33

Table d. The volume of industrial solid waste discharge in China's manufacturing by sector (unit: 10 thousand tons)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	2533	2663	3049	3469	3594	3758	3661	3805	3828	3732	3402
2	805	802	773	921	859	885	784	782	775	758	777
3	155	134	160	170	170	210	344	229	236	255	239
4	1243	1596	1797	1800	1939	2321	2483	2168	2055	2170	2248
5	8	8	10	11	16	13	22	21	21	27	50
6	1841	1779	2407	4439	2994	3513	3951	3672	3398	3745	3804
7	9575	10528	12139	12403	12968	14820	26913	26968	28255	29377	33207
8	243	258	317	353	346	406	309	312	281	324	356
9	135	143	186	198	205	215	208	238	184	196	225
10	3237	4224	4164	3944	4359	5161	5950	6781	7073	6915	7551
11	28285	34693	36106	38656	40981	46799	52648	52026	55257	55525	55914
12	121	227	403	322	506	364	472	523	910	625	726
13	688	386	405	585	747	865	429	459	438	460	369
14	337	572	390	524	506	562	574	534	552	562	582
15	154	161	155	201	199	197	101	351	103	152	164
16	42	33	21	18	16	18	13	12	14	12	13

Table e. Pollution Intensity Index (PI) of China's Manufacturing by Sector

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	$\overline{PI}$
1	0.267	0.256	0.288	0.295	0.264	0.270	0.220	0.228	0.181	0.219	0.212	0.246
2	0.160	0.173	0.171	0.193	0.188	0.191	0.199	0.197	0.140	0.180	0.189	0.180
3	0.205	0.143	0.205	0.131	0.126	0.124	0.179	0.139	0.134	0.149	0.226	0.160
4	1.490	1.542	1.648	1.610	1.604	1.665	1.838	1.538	1.567	1.570	1.538	1.601
5	0.007	0.003	0.008	0.003	0.009	0.004	0.019	0.019	0.010	0.013	0.021	0.011
6	0.338	0.297	0.386	0.558	0.492	0.483	0.429	0.449	0.453	0.519	0.649	0.459
7	0.922	0.872	0.990	0.922	0.867	0.854	1.072	1.078	1.083	1.097	1.119	0.989
8	0.203	0.198	0.204	0.234	0.197	0.209	0.199	0.201	0.122	0.186	0.191	0.195
9	0.041	0.040	0.051	0.052	0.041	0.043	0.067	0.063	0.072	0.071	0.077	0.056
10	1.431	1.455	1.434	1.351	1.301	1.309	1.310	1.352	1.351	1.288	1.282	1.351
11	1.483	1.463	1.481	1.625	1.614	1.663	1.639	1.644	2.311	1.812	1.937	1.697
12	0.059	0.080	0.121	0.091	0.105	0.086	0.176	0.123	0.168	0.131	0.147	0.117
13	0.032	0.016	0.010	0.014	0.028	0.019	0.007	0.008	0.008	0.007	0.006	0.014
14	0.041	0.057	0.045	0.052	0.034	0.032	0.037	0.042	0.043	0.042	0.042	0.043
15	0.007	0.012	0.012	0.018	0.021	0.038	0.027	0.040	0.036	0.042	0.051	0.028
16	0.057	0.038	0.035	0.016	0.003	0.006	0.003	0.005	0.027	0.011	0.001	0.018

Note:
$\overline{PI}$= mean value of the industrial pollution intensity index (PI)

Table f. The volume of China's manufacturing exports by sector (unit: USD 100 million)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	261	299	351	383	378	472	580	605	648	688	676
2	1202	1522	1822	2001	1823	2254	2680	2799	3108	3284	3123
3	76	99	114	115	93	112	132	141	145	162	158
4	39	54	71	77	76	96	129	137	160	178	188
5	11	14	20	25	24	27	31	35	37	38	39
6	209	214	236	365	228	304	363	348	376	387	317
7	408	484	632	816	641	885	1167	1135	1187	1325	1285
8	14	15	21	29	35	45	54	59	62	66	69
9	233	296	365	414	359	496	663	773	849	904	860
10	123	155	183	226	205	272	340	397	454	491	548
11	447	699	966	1229	614	893	1181	1203	1247	1488	1407
12	124	154	189	211	157	215	268	288	313	355	359
13	3220	4140	5288	6108	5370	6986	7995	8632	9444	9718	9586
14	284	384	550	707	601	889	1091	1084	1002	1048	1072
15	284	356	407	476	426	566	660	794	818	810	811
16	224	280	359	428	389	506	593	779	864	934	985

Table g. Intramural expenditure on R&D in China's manufacturing by sector (unit: CNY100 million)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	122	50	165	257	151	147	240	322	376	428	462
2	86	46	136	182	108	112	180	221	262	292	349
3	6	3	9	19	10	6	14	19	27	33	43
4	30	15	52	63	37	37	56	76	88	96	108
5	7	2	11	17	11	10	19	25	30	34	37
6	42	16	51	61	37	44	63	82	89	107	101
7	224	118	361	523	302	288	529	617	727	822	873
8	77	53	117	184	135	123	211	283	348	390	441
9	52	35	99	141	86	93	136	173	199	228	243
10	51	26	71	146	82	81	140	164	215	246	278
11	360	218	643	864	427	521	703	899	934	973	933
12	34	21	64	108	66	62	111	187	230	251	283
13	453	403	822	1299	923	897	1396	1604	1876	2084	2213
14	365	167	538	743	490	582	785	913	1052	1213	1340
15	449	367	694	902	676	744	1062	1188	1402	1562	1793
16	3	3	7	11	7	4	9	15	22	27	33

Table h. The ratio of foreign direct investment to total investment by sector (unit: %)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	27.83	27.30	25.56	23.72	25.51	23.95	22.94	21.27	16.71	18.62	16.20
2	19.29	24.06	31.13	42.47	56.86	65.05	72.14	31.05	27.24	27.62	26.48
3	27.87	26.19	20.25	17.47	19.64	18.61	17.12	13.82	10.15	8.65	8.76
4	38.36	37.98	38.13	34.02	38.19	35.98	41.39	38.86	42.33	41.03	39.50
5	26.21	25.85	24.84	24.64	27.86	26.01	28.56	22.33	22.11	22.66	19.97
6	5.87	5.22	4.48	4.47	7.19	6.43	5.31	4.53	4.23	4.11	5.41
7	21.70	21.38	23.16	23.71	26.15	26.93	26.80	25.10	22.94	23.95	22.54
8	18.44	19.60	18.88	20.76	22.25	21.94	22.57	19.38	17.04	14.54	12.92
9	46.62	44.75	40.48	42.34	45.25	41.80	42.36	12.60	17.93	32.55	27.93
10	21.35	20.37	19.75	19.33	20.82	17.95	17.65	14.92	15.13	12.29	11.37
11	10.09	10.92	11.85	11.58	11.58	11.83	5.94	9.71	9.43	9.42	8.13
12	4.39	5.35	7.19	11.37	15.46	18.70	22.07	21.88	22.84	21.22	17.95
13	30.19	28.33	27.96	26.43	29.73	28.59	26.45	23.97	22.33	20.45	21.73
14	6.03	7.33	11.36	18.96	27.69	35.22	41.20	25.25	24.29	24.19	23.75
15	53.72	57.47	55.40	54.20	61.19	56.50	56.75	47.69	51.22	48.30	44.17
16	46.72	42.50	41.54	41.71	45.18	39.07	43.31	30.24	25.88	29.17	24.09

Table i. Material capital per capita in China's manufacturing by sector (unit: CNY100 million per capita)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	1.24	1.32	1.46	1.56	1.70	1.85	2.08	2.18	2.38	2.60	2.85
2	0.48	0.51	0.56	0.62	0.67	0.73	0.83	0.95	1.03	1.11	1.20
3	0.69	0.73	0.77	0.86	0.96	1.08	1.26	1.36	1.52	1.23	1.84
4	1.84	1.97	2.08	2.23	2.44	2.67	3.08	3.32	3.66	3.85	4.04
5	1.13	1.18	1.25	1.31	1.37	1.45	1.55	1.60	1.71	1.88	1.97
6	4.21	4.93	5.32	5.81	7.58	8.09	8.34	9.34	9.45	10.28	10.95
7	2.09	2.39	2.61	2.79	3.25	3.51	4.00	4.43	4.91	5.51	6.08
8	1.62	1.66	1.71	1.85	1.95	2.02	2.11	2.30	2.58	2.82	3.13
9	0.92	0.96	1.02	1.08	1.14	1.22	1.46	1.62	1.94	2.07	2.21
10	1.15	1.27	1.40	1.60	1.87	2.11	2.49	2.71	2.95	3.11	3.36
11	2.80	3.31	3.68	4.13	4.85	5.12	5.25	5.66	5.78	6.27	7.02
12	0.67	0.71	0.79	0.91	1.09	1.20	1.44	1.79	1.88	2.43	2.16
13	0.77	0.83	0.91	1.06	1.24	1.38	1.55	1.67	1.89	2.05	2.21
14	1.40	1.56	1.73	1.94	2.15	2.19	2.40	2.44	2.64	2.79	3.05
15	1.04	1.03	1.07	1.11	1.18	1.38	1.18	1.32	1.45	1.51	1.57
16	0.47	0.52	0.60	0.61	0.70	0.72	0.85	0.99	1.10	1.23	1.34

Table j. The intensity of environmental regulation in China's manufacturing by sector (unit: %)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	9.35	7.72	10.47	8.62	6.30	5.11	10.74	8.11	8.63	8.40	7.74
2	13.82	32.86	17.76	24.50	29.53	18.57	12.12	13.02	13.79	13.84	12.80
3	4.92	7.53	4.23	6.34	6.35	3.32	5.83	6.61	5.89	8.05	3.97
4	13.44	6.41	8.35	8.36	6.67	5.81	7.92	11.72	11.99	10.47	10.78
5	12.16	11.34	14.37	9.39	8.00	16.72	9.51	10.65	11.51	14.10	12.40
6	17.30	18.47	20.73	19.66	17.25	15.01	23.79	16.95	11.31	21.20	18.87
7	9.33	8.71	9.19	10.68	9.59	7.09	12.74	12.27	12.17	12.58	16.60
8	10.14	13.40	15.98	14.84	15.47	8.38	8.70	15.90	11.69	13.03	10.61
9	9.68	8.15	8.79	8.48	8.50	6.71	8.25	9.82	9.05	6.92	7.14
10	6.00	6.89	6.10	7.25	6.12	7.65	9.99	11.25	13.33	5.75	9.67
11	12.12	12.24	14.62	15.93	17.52	17.90	21.19	20.41	18.88	17.69	23.63
12	23.74	30.10	24.55	16.62	14.62	11.48	17.44	14.84	13.39	13.07	15.64
13	12.32	7.17	10.72	9.49	6.48	6.37	22.00	10.49	8.62	22.54	14.53
14	7.26	8.72	8.30	11.03	8.85	11.04	10.05	10.14	8.21	13.47	10.22
15	16.81	13.45	23.09	15.44	13.03	11.67	14.17	21.18	8.41	16.16	12.89
16	21.60	6.84	8.75	13.38	15.71	7.18	5.57	6.63	3.11	9.74	12.52

Table k. The employment in China’s manufacturing by sector (unit: million)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	4.52	4.78	5.19	6.02	6.39	6.96	6.94	7.46	7.97	8.30	8.25
2	11.66	12.39	12.97	13.84	13.24	13.71	12.31	12.35	12.38	12.56	12.08
3	0.83	0.92	1.06	1.31	1.31	1.42	1.29	1.33	1.38	2.00	1.41
4	1.30	1.35	1.38	1.52	1.53	1.58	1.47	1.44	1.40	1.38	1.35
5	0.67	0.69	0.72	0.82	0.82	0.85	0.71	0.82	0.92	0.96	0.98
6	0.74	0.77	0.81	0.86	0.85	0.92	0.96	0.95	0.95	0.97	0.93
7	3.83	4.01	4.26	4.75	4.82	5.18	5.01	5.22	5.43	5.46	5.39
8	1.23	1.30	1.37	1.51	1.60	1.73	1.79	1.94	2.09	2.22	2.30
9	2.63	2.84	3.12	3.53	3.58	3.86	3.48	3.41	3.35	3.42	3.40
10	4.18	4.26	4.48	4.99	5.09	5.45	5.17	5.43	5.69	5.95	5.90
11	4.18	4.33	4.61	4.99	5.01	5.37	5.33	5.77	6.21	6.14	5.67
12	2.23	2.48	2.73	3.27	3.19	3.45	3.12	3.42	3.72	3.80	3.81
13	9.42	10.17	11.26	13.29	13.31	14.78	14.18	14.34	14.51	14.82	14.55
14	3.52	3.75	4.09	4.73	4.98	5.74	5.79	5.97	6.14	6.71	6.63
15	5.28	6.04	6.95	7.94	7.76	8.98	9.44	9.65	9.85	10.14	10.14
16	0.71	0.84	0.91	1.04	0.99	1.12	1.06	1.11	1.16	1.20	1.20

Table l. The number of S&T personnel in China’s manufacturing by sector (unit: thousand)

Sector No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	60	21	84	122	73	61	101	121	137	154	157
2	87	26	102	134	72	64	105	131	143	149	165
3	6	1	7	14	6	2	8	10	12	15	18
4	16	5	21	29	17	15	21	27	31	35	34
5	5	2	7	13	8	7	12	15	17	18	19
6	24	7	24	29	14	14	18	21	20	23	22
7	124	50	166	240	150	114	196	225	255	278	286
8	52	25	73	128	90	71	119	142	163	183	27
9	29	11	44	78	44	45	61	83	87	99	97
10	46	15	53	92	55	43	75	88	109	117	116
11	204	67	266	318	181	174	231	319	344	366	351
12	25	10	37	67	44	35	58	98	113	123	123
13	334	157	447	722	493	415	660	767	847	921	908
14	211	93	271	326	198	219	287	339	391	421	434
15	239	135	346	519	351	353	452	536	568	600	610
16	2	1	5	8	5	3	7	11	13	16	17