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Environmental Regulation, Manufacturing International Competitiveness, and Industry Heterogeneity: Empirical Evidence from China

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ABSTRACT

In recent years, as the world's environmental regulations are strengthened, the development of ecological civilization has already become an irresistible trend. In the past, the economy was developed at the expense of the environment, and increasingly stringent environmental standards now exert an immediate effect on environmental protection. However, a consensus in academia about environmental regulation, whether affecting the economic development and international competitiveness of the industry or not, has yet to be reached. This study aims to reveal the relationship between environmental regulation and industrial international competitiveness in the context of the new era and whether the relationship has industry heterogeneity. Using the data of 26 manufacturing industries in China from 2005 to 2015 and the panel data regression model, the effect of environmental regulation on the international competitiveness of the manufacturing industry was analysed. Results show that environmental regulation and manufacturing international competitiveness, display an inverted "U"-shaped relationship. Currently, China lies on the left side of the curve, and moderately strengthening the environmental regulation is beneficial for the improvement of manufacturing industry international competitiveness. The effect of environmental regulation on the international competitiveness of the manufacturing industry is characterized by heterogeneity. Meanwhile, the turning point of the inverted "U" curve can be delayed by strengthening the environmental regulation in high pollution and research and development (R&D) intensity and competitive industries. In addition, foreign direct investment, human capital, and industrial scale have a positive impact on manufacturing industry international competitiveness. Meanwhile, patent quality and capital deepening have inhibitory effects. This study provides a theoretical basis for the government to implement strict environmental regulation policies and new concepts for their implementation.

INTRODUCTION

Boosting the coordinated development of economy and environment is a constant goal pursued by governments in each country. However, the rapid economic development is consistently accompanied by environmental pollution and ecological damage. For instance, China surpassed Japan as the world's second-largest economy in 2010. However, in the Environmental Performance Index: 2016 Report released by Yale University, China ranked 109^{th} with points 65.1 (180 countries in total) and is the second worst country in terms of air quality, which has become a severely afflicted area with excessive PM2.5. Meanwhile, China Environmental Status Bulletin 2016 revealed that air quality in 254 cities exceeded the standard level, which accounted for 75.1% of 338 prefecture cities and more. Apparently, China is confronting severe environmental pollution while making significant achievements in economic construction.

Recently, the Chinese government has paid increased attention to environmental protection, especially after the Paris Agreement took effect on November 4, 2016. China actively takes the responsibility of energy conservation and emission reduction, constantly increases the investment volume of industrial pollution regulation, and effectively controls environmental degradation. Additionally, China has proposed that the energy consumption per unit of GDP should drop by more than 3%, and discharge of main pollutants should continue to decline in the main expected goals of development in 2018. To protect the environment, the government restricts enterprise pollution and even imposes high discharge tax or suspends businesses for rectification or those with severe discharge of pollutants. On the one hand, the increasing pollution control cost of the enterprise will do harm to the long-term development of the manufacturing industry. On the other hand, industrial international competitiveness appears to be enhanced by stimulating enterprise technological innovation. Therefore, the relationship between environmental regulation and international competitiveness is uncertain. The study primarily addresses the question of how environmental regulation affects the industrial international competitiveness in the new era. Moreover, industries with various properties have varying levels of sensitivity to environmental regulation strength. For instance, industries with high pollution levels enormously spend on pollution control; those with high R&D intensity are strong in technological innovation, and competitive industries have increased impetus in technological innovation. Therefore, influence on industrial international competitiveness is varying. Accordingly, the second question in the study is whether the impact of environmental regulation on the industrial international competitiveness is characterized by heterogeneity.

STATE OF THE ART

On the relationship between environmental regulation and industrial international competitiveness, Porter et al. (1995) proposed the Porter hypothesis and argued that moderately strengthening environmental regulation could stimulate enterprise technological innovation. Afterward, other scholars engaged in heated discussions on this hypothesis, which mainly formed the following viewpoints.

First, strengthening environmental regulation can promote the industry's international competitiveness. Hamamoto (2006) posited that strict environmental regulation implementation could provide an orientation for enterprise technological innovation. Dong et al. (2011) corroborated that strengthening environmental regulation had a limited impact on the price change of Chinese trade and ranged within a controllable scope, such that a strict environmental regulation would be unable to reduce Chinese export competitiveness. Testa et al. (2011) and Yang et al. (2012) affirmed that strict environmental regulation could bring positive impetus for enterprises to increase advanced technological equipment and promote product innovation and further improve industrial competitiveness. Zhang et al. (2012) selected six environmentally sensitive industries from 2003 to 2009 and the bilateral trade date of seven main trade partners and studied the impact of endogenous and exogenous environmental regulations on the export competitiveness of the six industries. The results validated that the two types of environmental regulation present an inverted "U" shaped relationship with the international competitiveness of pollution-intensive industries. However, China is on the left side of the inflection point of exogenous environmental regulation and the right side of the inflection point of endogenous environmental regulation at the present stage. Fu et al. (2014) considered the five types of pollution-intensive industrial panel data in China and 18 trading partners from 2002 to 2010 for empirical testing and verified that moderately strengthening environmental regulation was beneficial to improve the international competitiveness of pollution-intensive industries. Fraj et al. (2015) verified that a positive correlation exists between positive environmental regulation and organizational competitiveness. López-Gamero et al. (2015) posited that voluntary environmental regulation policies and pressure exerted on stake holders were beneficial to industries to take active environmental regulation strategies. Tan et al. (2017) asserted that disadvantages outweigh the advantages for industries that avoided the government's environmental regulation by speculation. Hence, enterprises should actively adapt the local requirements and cope with them in a flexible manner.

Second, strengthening environmental regulation can restrain the improvement of industrial international competitiveness. Feichtinger et al. (2003) argued that enterprises paid additional discharge tax during the process of learning the technology to achieve the established emission reduction target because of aging production equipment and declined productivity. Therefore, strict environmental policies would impose a negative impact on industrial profit, and such a conclusion disproved the Porter hypothesis. Picazo-Tadeo et al. (2005) believed that environmental regulation reduced industrial productivity and was not conducive to enhancing industrial international competitiveness. Fu et al. (2010) confirmed that the relationship between environmental regulation and industrial international competitiveness displayed an inverted "U"-shaped relationship based on a regression analysis of panel data from 24 manufacturing industries. Currently, China is on the left side of the inflection point, which meant that environmental regulation had a negative correlation with industrial international competitiveness. Du (2014) proved that the relationship between environmental regulation and industrial international competitiveness displayed a "U"-shaped relationship based on the regression analysis of panel data from 26 manufacturing industries from 2004 to 2012. Currently, China is on the left side of the inflection point, which meant that strengthening environmental regulation would reduce industrial international competitiveness. Ren et al. (2015) studied the negative impact of environmental regulation on China's export trade from the perspective of national differences and proposed that environmental regulation was an important factor in the trade of China and developed countries.

Third, the relationship, which remains uncertain, between environmental regulation and industrial international competitiveness is affected by other factors. Hitchens (1999) elucidated that enterprises with good state of operation could aptly respond to environmental regulation and increased pollution control cost. In turn, environmental regulation is not the dominant factor of enterprise competitive disadvantages or advantages. However, enterprise environmental performance would become the key factor to its economic performance in the long run. Brunnermeier et al. (2003) corroborated that the average environmental patent application number was expected to increase by 0.04 percentage with every one million dollar increase in enterprise pollution control cost, with all other variables remaining unchanged. However, strengthening the relevant supervision and law enforcement activities of current laws and regulations would impose little influence on enterprise environmental innovation. Arouri et al. (2012) used the trade data in Romania and 19 countries of the European Union from 2001 to 2007 to study the impact of environmental regulation on export trade based on the trade gravity model. They affirmed that GDP was an important factor that affects trade and that strict environmental regulation would neither reduce the export volume in Romania nor affect its competitiveness in the European market. Xu et al. (2013) validated that the impact of environmental regulation on industrial international competitiveness was the result of the combined action of innovation and industrial agglomeration effects of environmental regulation, which varied with the industrial pollution level. Tang (2014) proposed that China's environmental regulation and trade competitiveness displayed an inverted "U" shaped relationship by analysing the effect of foreign capital participation and environmental regulation on trade competitiveness. However, China's position on the "U"-shaped curve was not indicated. Yu, et al. (2017a) verified that skill premium had a dual-threshold effect on the environmental regulation and international competitiveness of the manufacturing industries and that skill premium was conducive to exerting the facilitation of environmental regulation on industrial international competitiveness.

On the basis of the above-mentioned literature, many scholars deemed that environmental regulation could affect industrial international competitiveness. Scholars hold that a positive or inverted "U"-shaped relationship exists between these factors. However, the academia still holds different views on which side China is currently positioned on the inflection point. Meanwhile, industry differences are mainly concentrated on industries with various pollution levels. The current literature's lack of research on industrial heterogeneity is characterized by the impact of environmental regulation on industrial international competitiveness from the perspective of industrial R&D intensity and monopoly degree. On such bases, this study takes 26 manufacturing industries from 2005 to 2015 as samples to explore the impact of environmental regulation on industrial international competitiveness. In addition, this study explores whether or not industry heterogeneity, which is characterized by the impact of environmental regulation on industrial international competitiveness from the perspective of pollution level, industrial R&D intensity, and monopoly degree, exists.

RESEARCH METHODS

Model Specification

Currently, the mainstream models, such as Heckscher-Ohlin-Vanek (HOV) model (Cole et al. 2003, Tobey 1990) or on the gravity model (Grether et al. 2003, Harris et al. 2002), are used to study the relationship between environmental regulation and industrial international competitiveness. This study adopts the HOV model, adds environmental regulation factors to the H-O model, which is endowed with two factors, namely, capital and labour, and constructs the measurement model through the following two steps.

First, we test the impact of environmental regulation and other control variables on industrial international competitiveness. We assign industrial international competitiveness as the explained variable, environmental regulation as the core explanatory variable, and FDI, human capital, capital deepening degree, patent quality, industrial scale, and other indexes as the control variables. A nonlinear relationship with the inflection point may exist between environmental regulation and industrial international competitiveness. Hence, the quadratic term of environmental regulation is added. This study adopts the data of 26 manufacturing industries in China from 2005 to 2015 to construct the following panel data model:

$$RCA_{it} = C + \beta_1 ERI_{it} + \beta_2 ERI_{it}^2 + \beta_3 FDI_{it} + \beta_4 CD_{it} + \beta_5 PC_{it} + \beta_6 PT_{it} + \beta_7 lnSIZE_{it} + \delta_i + \varepsilon_{it} \quad ...(1)$$

In the equation (1), RCA_{it} denotes the industrial international competitiveness of the manufacturing industry, ERI_{it} is the environmental regulation index, and ERI_{it}^2 is the quadratic term of environmental regulation, which is used to reflect the uncertain impact of environmental regulation on industrial international competitiveness. FDI_{it} represents foreign direct investment, CD_{it} refers to capital deepening degree, PC_{it} denotes human capital, PT_{it} is patent quality, and $SIZE_{it}$ represents industrial scale. A logarithm is used when the value of $SIZE_{it}$ has no effect on the statistical relationship among variables because it is relatively large. i and t are the observed values of i industry in year t, and C is an intercept term. β_1, β_3, β_4, β_6 and β_7 are the regression coefficients of environmental regulation, FDI, capital deepening, human capital, patent quality, and industrial scale, respectively. β_2 is the regression coefficient of the quadratic term of environmental regulation and industrial international competitiveness, ε_{it} denotes the random disturbance term, and δ_i is the unobservable industry effect.

Second, we test whether the impact of environmental regulation on industrial international competitiveness is characterized by heterogeneity. Industrial pollution level, R&D intensity, and monopoly degree are taken as dummy variables, and the product term of environmental regulation and three dummy variables are used to illustrate the industrial differences of their relationship. The specific model is constructed as in Equations (2) to (4).

A measurement model in which the product terms of environmental regulation and industrial pollution level (*PLE*) are added:

$$RCA_{it} = C + \beta_1 ERI_{it} + \beta_2 ERI_{it}^2 + \beta_3 FDI_{it} + \beta_4 CD_{it} + \beta_5 PC_{it} + \beta_6 PT_{it} + \beta_7 lnSIZE_{it} + \delta_i + \varepsilon_{it} \quad ...(2)$$

A measurement model in which the product terms of environmental regulation and industrial R&D intensity (*RD*) are added:

$$RCA_{it} = C + \beta_1 ERI_{it} + \beta_2 ERI_{it}^2 + \beta_3 FDI_{it} + \beta_4 CD_{it} + \beta_5 PC_{it} + \beta_6 PT_{it} + \beta_7 lnSIZE_{it} + \beta_9 ERI_{it} \times RD_{it} + \delta_i + \varepsilon_{it} \quad ...(3)$$

A measurement model in which the product terms of environmental regulation and industrial monopoly degree (*MON*) are added:

$$RCA_{it} = C + \beta_1 ERI_{it} + \beta_2 ERI_{it}^2 + \beta_3 FDI_{it} + \beta_4 CD_{it} + \beta_5 PC_{it} + \beta_6 PT_{it} + \beta_7 lnSIZE_{it} + \beta_{10} ERI_{it} \times MON_{it} + \delta_i + \varepsilon_{it} \quad ...(4)$$

Data Sources

In the latest edition of the Industrial Classification of China's National Economic Activities (GB/T4754-2017), the manufacturing industry covers a total of 31 industries from processing of agricultural and sideline foods to manufacture of metal products, machinery, and equipment repairing. With the update in industry classification standards, the statistical calibre of various statistical yearbooks is different. In view of the integrity of the data, various industries are processed as follows: three industries with incomplete data such as "Other manufacturing," "Waste Gas Comprehensive Utilization Industry," and "Manufacture of Metal Products, Machinery and Equipment Repairing" are eliminated. To ensure the calibre consistency of statistical data, "Processing of Agricultural and Sideline Foods" and "Manufacture of Foods" are merged into "Manufacture and Processing of Foods"; "Manufacture of Rubber" and "Manufacture of Plastics" are merged into "Manufacture of Rubber and Plastics"; and "Manufacture of Automobile" and "Manufacture of Railway, Ship, Aerospace and Other Transportation Equipment" are merged into "Manufacture of Transportation Equipment". Finally, 26 industries are from "Manufacture and Processing of Foods" to "Manufacture of Measuring Instrument". All data are taken from China Industry Statistical Yearbook, China Statistical Yearbook on Environment, China Statistical Yearbook on Environment, China Statistical Yearbook on Science and Technology, and China Energy Statistical Yearbook from 2006 to 2016. The outlet data of various industries are processed on the basis of the comparison table between Standard International Trade Classification (Rev.3.0) summarized by Sheng (2002) and Industrial Classification Standards of China's National Economic Activities (GB/4757-2002) published by the National Bureau of Statistics. The Industrial Classification Standards of National Economic Activities 2002 (GB/4757-2002) is unified with the 2017 edition, and outlet data of various industries are derived from United Nations Comtrade Database. Table 1 provides the research samples.

In studying the industry heterogeneity of the relationship between environmental regulation and industrial international competitiveness, this study uses the classification methods of industries with various properties with Shen (2012), Wang (2011) and Yue et al. (2010) for reference. This study classifies 26 manufacturing industries in China in terms of pollution degree, R&D intensity, and monopoly degree. Table 2 provides the detailed information.

Variable Definition

Revealed comparative advantage (RCA): Several indexes are used to measure industrial international competitiveness. This study adopts RCA, which was put forward by Balassa, an American economist, in 1965. RCA implies that industrial international competitiveness can be represented by the ratio of the export proportion of an industry (or a product) in a country to the export proportion of the industry (or the product) in the world. A large RCA refers to strong industrial international competitiveness. RCA is represented by the equation $RCA_{ij} = \frac{X_{ij} / X_{tj}}{X_{iw} / X_{tw}}$, where X_{ij} is the export value of industry or product i in country j, X_{tj} is the gross export of country j, X_{tw} is the export value of industry or product i globally, and X_{tw} is the gross export globally.

Environmental regulation index (ERI): The index that measures the environmental regulation is diversified. In the study of environmental regulation problems, scholars typically select an index from the three perspectives: unit discharge capacity (Fu et al. 2010, Du 2014), investment volume of unit industrial pollution regulation (Yu et al. 2017a,

Table 1: Research samples.

Serial No.	Name	Serial No.	Name
H1	Manufacture and Processing of Foods	*H14*	Manufacture of Medicines
H2	Manufacture of Wine, Drinks and Refined Tea	*H15*	Manufacture of Chemical Fibers
H3	Manufacture of Tobacco	*H16*	Manufacture of Rubber and Plastics
H4	Manufacture of Textile	*H17*	Manufacture of Non-metallic Mineral Products
H5	Manufacture of Textile Wearing and Apparel	*H18*	Smelting and Pressing of Ferrous Metals
H6	Manufacture of Leather, Fur, Feather and Related Products and Footwear	*H19*	Smelting and Pressing of Non-ferrous Metals
H7	Processing of Timber and Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products	*H20*	Manufacture of Metal Products
H8	Manufacture of Furniture	*H21*	Manufacture of General Purpose Machinery
H9	Manufacture of Paper and Paper Products	*H22*	Manufacture of Special Purpose Machinery
H10	Printing and Reproduction of Recording Media	*H23*	Manufacture of Transportation Equipment
H11	Manufacture of Articles for Culture, Education, and Sport Activities	*H24*	Manufacture of Electrical Machinery and Equipment
H12	Processing of Petroleum, Coal and Other Fuels	*H25*	Manufacture of Computers, Communication, and Other Electronic Equipment
H13	Manufacture of Raw Chemical Materials and Products	*H26*	Manufacture of Measuring Instrument

Table 2: Classification of industries with different properties.

Basis of classification	Industry property	Industry code
Pollution Level	Pollution Industry	H9, H12, H13, H14, H15, H16, H17, H18, and H19
	Cleaning Industry	H1, H2, H3, H4, H5, H6, H7, H8, H10, H11, H20, H21, H22, H23, H24, H25, and H26
R&D Intensity	High R&D Industry	H14, H21, H22, H23, H24, and H25
	Low R&D Industry	H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, H11, H12, H13, H15, H16, H17, H18, H19, H20, and H26
Monopoly Degree	Monopolized Industry	H3 and H12
	Competitive Industry	H1, H2, H4, H5, H6, H7, H8, H9, H10, H11, H13, H14, H15, H16, H17, H18, H19, H20, H21, H22, H23, H24, H25, and H26

Yu et al. 2017b), and ratio of GDP to energy consumption (Li et al. 2013, Song et al. 2014). A comprehensive index could not be built to study environmental regulation intensity after 2011 because the China Statistical Yearbook on Environment 2012 no longer publishes emission standards and the removal volume of wastewater and exhaust gas in sub-sectors. Therefore, environmental regulation is measured through unit pollution control expense and investment volume. Environmental regulation (ERI_1) is defined as (the annual operating expense of wastewater and exhaust gas in all industries + pollution control investment volume in all industries)/total industrial output value × 1000. It refers to pollution control expense per 1000 yuan of sales value, in which the larger the value, the stricter the environmental regulation. Furthermore, "GDP/energy consumption volume" is selected to replace environmental regulation for robustness test. To eliminate the volatility of data, the logarithm of this index, $lnERI_2$, is adopted.

Foreign direct investment (FDI): *FDI* introduced by the host country will not only make up for fund shortage but also enhance technological innovative ability and labour skills of human capital to raise labour productivity and industrial international competitiveness. FDI is introduced to the model in this paper as a control variable, and the ratio of the sum of Hong Kong, Macao and Taiwan (HMT) capital in paid-in capital and FDI to industrial output value is selected to measure the involvement level of foreign investment.

Capital deepening (CD): Capital deepening refers to the combined degree of physical and human capital, which are represented by the ratio of fixed assets-net value to employment figure at the end of the year in this paper. The large ratio means that the enterprise is capital-intensive industry, which has multiple advanced equipment. Subsequently, industrial international competitiveness can be strengthened through enhanced enterprise technology. Otherwise, the enterprise is a labour-intensive industry which enjoys sufficient labour force. Capital deepening is expected to have a positive correlation with industrial international competitiveness.

Human capital (HC): Highly qualified employers with abundant professional skills will be conducive to improve the management level of the industry and integrate resources effectively to enhance the resource utilization rate and industrial international competitiveness. Therefore, human capital is an important factor that influences international competitiveness. HC is represented by the proportion of R&D personnel in various industries in this study.

Patent quality (PT): With the development and improvement of intellectual property system, the government and enterprises gradually realize the importance of patents. After overseas market entry, enterprises with a strong sense of patent portfolio will be free from patent disputes. Meanwhile, patent number can be used to measure the technological innovative ability of an enterprise. Patent is an important factor that influences industrial international competitiveness. Therefore, the quantity of industrial patent application can be used for measurement (Yu et al. 2017a), and the ratio of patent number to application quantity is adopted to represent it.

Industry scale (lnSIZE): The larger the industry scale, the more evident the scale effect, which is conducive to lower production cost and good communication and service platform for enterprises. The logarithm of sales value per capital is adopted in the study to represent the industry scale.

Dummy variable: Heterogeneity characterizes the impact of environmental regulation on the international competitiveness of the manufacturing industry. Therefore, pollution level (PLE), R&D intensity (RD), and monopoly degree (MON) will be separately discussed in this study. Each dummy variable equals 1 or 0. The cleaning, high R&D intensity, and competitive industries take on a value of 1; and pollution, low R&D intensity, and monopolized industries take on a value of 0. Table 3 lists the definitions for each index.

RESULTS AND DISCUSSION

This study employs the measuring software Eviews 9.0 for empirical testing, and regression analysis of sample data will be discussed in three subsections. First, the unit root test of panel data and descriptive statistical analysis on the variables are conducted. Second, the effect environmental regulation of 26 manufacturing industries on industrial international competitiveness, and whether industry differences exist by adding dummy variables are analysed. Lastly, the environmental regulation index with the logarithm of "GDP/energy consumption volume" ($lnERI_2$) is replaced and the robustness test on the empirical results is conducted.

Unit root test and basic statistics of panel data: Before conducting the panel data regression analysis, we test whether or not the panel data used in this study are stable. If the sequence is unstable, then spurious regression will occur. To ensure the robustness of the results, the Levin, Lin, and Chut (LLC), Breitung, Im-Pesaran-Shin, ADF-Fisher, and PP-Fisher tests are employed in this study with the intercept and trend terms to conduct the stationary test on the studied variables (Table 4). The results affirm that except for FDI, all other variables have passed the LLC test and reject the null hypothesis at the 1% significant level, which indicate that these variables do not have a unit root under such circumstances and are stationary series. In the ADF-Fisher test with the intercept and trend terms, FDI rejects the null hypothesis at the 5% significant level, which indicates that FDI does not have unit root at this time. In the test with only the intercept term included, FDI passes the LLC and PP-Fisher tests. Therefore, all variables are stationary series as a whole, and regression analysis can be conducted.

Descriptive statistics analysis is conducted on data characteristics of the research variables, such as sample observation, mean, minimum, and maximum values, median and standard error. Table 5 presents the results.

Regression result analysis of panel data model: This study adopts the variable intercept OLS method. The data of the 26 manufacturing industries in China from 2005 to 2015 are first tested using the F-test. The F-value is 946.1058 and rejects the null hypothesis at the 1% significant level, which implies that the fixed effects model is better than the pooled cross-section model. The Hausman test results support the fixed effects model with a goodness-of-fit over 99%, which denotes good explanatory power. Table 6 provides the regression results. Model I is the regression result of the impact of environmental regulation on industrial international competitiveness. Models II-IV are regression results of pollution level, R&D intensity, and monopoly degree, respectively. Furthermore, the industry differences of the relationship between environmental regulation and international competitiveness are studied.

In Model I, the influence of the environmental regulation on industrial international competitiveness is positive; but the quadratic term is negative, and both reject the null hypothesis at the 1% significance level. The result shows that the relationship between environmental regulation and manufacturing international competitiveness displays an inverted "U" shape. It means that the influence of environmental regulation on industrial international competitiveness is promotion first then inhibition, which verifies the inflection point of the non-linear relationship between them.

In other control variables, FDI has significantly positive influence on industrial international competitiveness. For each 1-unit increase in FDI, industrial international competitiveness will increase by 0.8079 unit, which indicates

Table 3: Definition of indexes.

Type	Name	Symbol	Definition
Explained Variable	Industrial International Competitiveness	*RCA*	The export proportion of an industry in China/export proportion of the industry globally
Core Explanatory Variable	Environmental Regulation	*ERI*	Sum of annual operating expenses of wastewater and exhaust gas and pollution control investment volume in sub-sector / total industrial output value × 1000
	Pollution Level	*PLE*	The cleaning industry is 1, pollution industry is 0
	R&D Intensity	*RD*	High R&D intensity industry is 1, middle and low R&D intensity industry is 0
	Monopoly Degree	*MON*	Competitive industry is 1, monopolized industry is 0
Control Variable	Foreign Direct Investment	*FDI*	Sum of HMT capital in paid–in capital and FDI / industrial output value
	Capital Deepening Degree	*CD*	Fixed assets-net value/employment figure at the end of the year
	Human Capital	*HC*	Proportion of R&D personnel in various industries
	Patent Quality	*PT*	Patent number / patent application quantity
	Industrial Scale	*lnSIZE*	Logarithm of sales value per capital

Table 4: Unit root test of panel data.

Variables	Test method				
	LLC	Breitung	Im-Pesaran-Shin	ADF-Fisher	PP-Fisher
RCA	-6.488***	4.650	0.069	57.130	62.495
ERI_1	-9.354***	-3.471***	-3.674***	110.367***	159.911***
ERI_1^2	-11.904***	-2.923***	-5.475***	139.691**	182.188***
ERI_2	-5.220***	1.066	0.615	45.711	62.281
ERI_2^2	-5.607***	0.870	0.527	46.920	53.300
FDI	-0.281	8.803	-0.031	69.866**	31.194
(*FDI*)	-6.526***	-	-0.680	63.640	90.004***
CD	-6.374***	-2.260**	-2.156**	79.631***	90.108***
HC	-10.663***	-9.367***	-1.824**	72.647**	122.596***
PT	-15.573***	-2.822***	-5.090***	139.961***	167.266***
lnSIZE	-3.456***	2.938	2.972	25.220	46.360

Note: ** and *** indicate that the corresponding null hypothesis is rejected at the 5% and 1% level of significance, respectively. The lag phase of the unit root test is automatically selected by the Schwarz standard.

that FDI is an important factor in enhancing industrial international competitiveness, and introducing foreign capital will enhance this competitiveness. HC has a significantly positive influence on industrial international competitiveness. For each 1-unit increase in HC, industrial international competitiveness will increase by 1.2132 unit, which indicates that enhancing industrial international competitiveness is vital. Therefore, great importance should be attached to the cultivation of scientific and technological talent. Industry scale also has a significantly positive influence on industrial international competitiveness. For each 1-unit increase in industrial scale, industrial international competitiveness will increase by 0.1034 unit, which indicates that the medium industry scale can provide a good communication environment and service condition.

However, capital deepening has a significantly negative influence on industrial international competitiveness, which is inconsistent with theoretical expectations, although it is possible because capital accumulated rapidly in the early stages of Chinese economic development with bad-quality labour force and low production efficiency. With further development of the economy, capital accumulation reached a new level. However, surplus labour supply decreased and optimal resource allocation destroyed, which hindered the improvement of international competitiveness. Therefore, a balanced development of physical capital and talent supply should be emphasized. On the one hand, enterprises and governments can attract, cultivate, and retain high-quality talents, improve the comprehensive quality of other employers through technical and educational training, and raise talent supply by improving the minimum wage standard, social benefit, training, and promotion system.

Table 5: Descriptive statistics analysis of variables.

Variables	Sample	Mean	Min	Max	Median	Standard error
RCA	286	1.2936	0.1444	3.6398	0.9970	0.9986
ERI_1	286	1.5995	0.0564	9.2529	0.6421	1.9103
ERI_1^2	286	6.1950	0.0032	85.6158	0.4124	13.2427
$\ln ERI_2$	286	5.0332	1.4195	8.0042	5.0430	1.5685
$\ln ERI_2^2$	286	27.7849	2.0150	64.0671	25.4316	15.4415
FDI	286	0.0559	0.0061	0.3619	0.0508	0.0373
CD	286	3.6110	0.4815	14.9137	2.9725	2.5430
HC	286	0.0512	0.0045	0.1430	0.0432	0.0326
PT	286	0.3101	0.0390	0.7549	0.2904	0.1512
lnSIZE	286	14.0772	12.5174	15.6048	14.1089	0.6175

Table 6: Regression results of environmental regulation and manufacturing international competitiveness.

Variable	Model I	Model II	Model III	Model IV
C	-0.3887***(-3.1805)	-0.6588***(-6.8227)	-0.3556**(-2.4293)	-0.2042(-1.6057)
ERI_1	0.0683***(4.6306)	0.0666***(4.4644)	0.0636***(4.3348)	0.0671***(4.8024)
ERI_1^2	-0.0095***(-5.0604)	-0.0088***(-4.6781)	-0.0092***(-4.8905)	-0.0084***(-4.4811)
FDI	0.4621***(2.8733)	0.3113**(2.4925)	0.4902***(2.7247)	0.7300**(2.3227)
CD	-0.0114***(“5.3379)	-0.0162***(-6.5250)	-0.0108***(-3.7463)	-0.0108***(-4.7321)
HC	1.2132***(6.6143)	1.1880***(7.5002)	1.0856***(7.7921)	1.1392***(6.4035)
PT	-0.1712***(-2.3645)	-0.1751***(-2.7416)	-0.1880***(-2.6901)	-0.2102***(-3.1555)
lnSIZE	0.1164***(12.5342)	0.1515***(15.7653)	0.1071***(8.3369)	0.0728***(9.3769)
ERI × PLE		-0.0524***(-5.0938)		
ERI × RD			0.0946***(2.5502)	
ERI × MON				0.0912***(4.0813)
Adjusted R^2	0.9919	0.9920	0.9916	0.9929
F-value	1085.934	1066.688	1023.140	1206.289
D-W Value	0.8985	0.8889	0.9189	0.9499
Sample Size	286	286	286	286

Note: ***, ** and * indicate that the corresponding null hypothesis is rejected at the 1%, 5% and 10% levels of significance, respectively. The value within brackets is *t*.

Table 7: Inflection points of different industries and average values of environmental regulation in 2015.

Industry	Inflection point	Average values	Correlation	Exceeds the inflection point of all industries
All Industries	3.59	1.42	Positive	–
Cleaning Industry	0.81	0.42	Positive	No
Pollution Industry	3.78	3.32	Positive	Yes
High R&D Industry	8.60	0.41	Positive	Yes
Low R&D Industry	3.46	1.73	Positive	No
Competitive Industry	9.42	1.36	Positive	Yes
Monopolized industry	3.99	2.15	Positive	Yes

On the other hand, they should strengthen cooperation, promote the development of artificial intelligence (AI), big data, internet+, and other high technologies, and guarantee the high utilization efficiency of physical capital in the case of the reduced labour force.

Unlike previous research, patent quality has a negative correlation with industrial international competitiveness. The number of patent application in China ranks first in the world, and the patent for invention proportion is increasing. Patent quality has been raised but will be unable to increase international competitiveness. Patents for invention in China can possibly fail to convert scientific and technological value to economic value, and give full play to its driving force on industrial development. Then, resources are wasted and harm the improvement of international competitiveness. Therefore, the government should encourage enterprise to foster high-value patents, build a patent pledge platform and improve the patent transfer

Table 8: Robustness results using lnERI2.

Variable	Model I	Model II	Model III	Model IV
C	-0.9134***(-3.0368)	-0.4064(-1.3587)	-1.0163***(-3.3458)	-0.8978***(-2.6075)
$lnERI_2$	0.2756***(4.5044)	0.2491***(3.5681)	0.2451***(3.0979)	0.2405**(2.2252)
$lnERI_2^2$	-0.0203***(-6.1341)	-0.0040(-0.6523)	-0.0194***(-3.7998)	-0.0186***(-2.7284)
FDI	0.8079***(2.9005)	0.3941**(2.2332)	0.8438***(2.8389)	0.8736***(2.9528)
CD	-0.0249***(-5.3427)	-0.0298***(-6.7854)	-0.0239***(-3.3573)	-0.0244***(-3.1319)
HC	1.0354***(6.9990)	1.1339***(4.7458)	0.9251***(4.9060)	1.0109***(4.0985)
PT	-0.2529***(-2.6120)	-0.2099***(-3.1603)	-0.2399***(-3.3573)	-0.2444***(-3.1319)
lnSIZE	0.1034***(3.8138)	0.0976***(3.6743)	0.1114***(4.5256)	0.1038***(3.9570)
ERI × PLE		-0.1920***(-4.9834)		
ERI × RD			0.0968***(3.5872)	
ERI × MON				0.0214(0.5183)
Adjusted R^2	0.9902	0.9907	0.9901	0.9897
F Value	901.4076	918.4928	864.4688	830.6116
D-W Value	0.8804	0.8698	0.9170	0.8854
Sample Size	286	286	286	286

Note: ***, ** and * indicate that the corresponding null hypothesis is rejected at the 1%, 5% and 10% levels of significance, respectively. Values within brackets denote *t*.

Table 9: Inflection points of different industries in robustness test.

Industry	Inflection points environmental regulation	Average value of in 2015	Correlation point of all industries	Exceeds the inflection
All Industries	6.79	5.47	Positive	–
Cleaning Industry	7.14	6.21	Positive	Yes
Pollution Industry	34.89	4.07	Positive	Yes
High R&D Industry	8.81	5.50	Positive	Yes
Low R&D Industry	6.32	5.46	Positive	No
Competitive Industry	7.04	5.45	Positive	Yes
Monopolized Industry	6.46	5.47	Positive	No

mechanism. Enterprises should pay close attention to market demand and focus on technological innovation at the same time to achieve unity in patent technological and economic values. Colleges enjoy abundant research resources and high potential-value patents for invention. However, they have limited patent transferability. Consequently, the government should actively guide and promote cooperation between enterprises and colleges, build a patent exchange platform, dig the potential value of patents, realize the transfer of high-quality to high-value patent, and give full play to the driving force of high-value patent on economic growth and improvement in industrial international competitiveness.

In Models II-IV, the influence and orientation of each variable are similar to those in Model I. Which clearly shows that the relationship between environmental regulation and manufacturing international competitiveness displays an inverted "U" shape. However, pollution industry, high R&D intensity, and monopoly degree will delay the inflection point of the inverted "U" curve. The inflection point in Model I is 3.59. The mean value for the 26 manufacturing environmental regulation is 1.42 in 2015 and lies on the left side of the inflection point. It means that the stricter the environmental regulation, the higher the manufacturing international competitiveness. Therefore, the government should continue to implement environmental protection policies, emphasize supervision and punishment in areas with severe air pollution, and enhance the investment volume of pollution regulation to raise its GDP proportion. It should maintain the forward supply-side reform, implement the policy of suspending operations for those highly-polluting enterprises with high energy consumption, and accelerate the transition of China's economy from high-speed to high-quality. In Model II, the inflection point of the cleaning industry is approximately 0.81. The inflection point of pollution industry is 3.21. The average value of environmental regulation of the cleaning and pollution industries are 0.42 and 3.32, respectively. Both lie on the left side of the curve. In Model III, the inflection point of high R&D industry is 8.60, whereas that of the low R&D industry is 3.46. The average values for the high and low R&D industries in 2015 are 0.41 and 1.73, respectively. The inflection point of high R&D is a little far from the average, which indicates that the profit brought about by environmental regulation and technological innovation exceeds the increasing environmental cost. The inflection point of the competitive industry is 9.42, whereas that of the monopolized industry is 3.99. The average values of the competitive and monopolized industries in the 26 manufacturing industries are 1.36 and 2.15, respectively. Table 7 presents the detailed results.

Results show that industrial heterogeneity will influence the inflection point of the inverted "U" shaped relationship between environmental regulation and manufacturing international competitiveness. Therefore, the inflection points of pollution industry, high R&D industry, competitive, and monopolized industries are larger than those of all industries, and moderately strengthening environmental regulation is beneficial to enhance industrial international competitiveness.

Robustness test: Through regression analysis, the relationship between environmental regulation and manufacturing international competitiveness displays an inverted "U"-shaped relationship. For the verification of the influence of environmental regulation on industrial international competitiveness, the environmental regulation index as measured from the perspective of pollution regulation investment is replaced by "GDP/energy consumption in all industries". Its logarithm is adopted and denoted as $lnERI_2$ because the ratio value is large. The robustness test (Table 8) is conducted to analyse the influence of environmental regulation on industrial international competitiveness using $lnERI_2$. The results are basically consistent with those in Table 6, which lead to the inverted "U"-shaped relationship between environmental regulation and manufacturing international competitiveness. On the left side of the inverted "U" curve, industrial international competitiveness is enhanced with the increase in environmental regulation, whereas the right side shows that it will be weakened with the increase in environmental regulation. At present, China lies on the left side of the inverted "U" curve.

By calculating the inflection points of varying industries in robustness test (Table 9), China's current environmental regulation level is located on the left side of the inverted "U" curve, which means that China's current manufacturing industrial international competitiveness will be enhanced with the increase in the strength of environmental regulation. The results of two regression analyses show that the pollution, high R&D intensity, and competitive industries delay the inflection point, and the impact of environmental regulation on international competitiveness is characterized by heterogeneity from the perspective of pollution level, R&D intensity, and monopoly degree. Therefore, the government should differ their treatment according to concept when implementing environmental regulation. By moderately strengthening environmental regulation of the pollution, high R&D intensity, and competitive industries, enterprise innovation will be encouraged to achieve united profit and social benefit. The cleaning, low R&D, and monopolized industries are sensitive to environmental regulation. Therefore, the government should implement less strict environmental regulation and reduce the negative influence of environmental regulation on industrial international competitiveness.

CONCLUSION

This study mainly analyses how environmental regulation affects the international competitiveness of manufacturing industries and whether such an impact is characterized by industry heterogeneity. Regression analysis is conducted using the panel data of 26 manufacturing industries from 2005 to 2015. The following conclusions are then obtained:

First, an inverted "U" shaped relationship exists between environmental regulation and international competitiveness of manufacturing industries. On the left side of the inflection point, the international competitiveness of manufacturing industry is increasingly improved with the increase in environmental regulation, whereas the right side denotes that international competitiveness is decreased with the increase in environmental regulation. China is currently on the left side of the inflection point. Thus, moderately strengthening environmental regulation is beneficial to improve the international competitiveness of the manufacturing industry in China, which verifies the rationality of the Porter hypothesis from the perspective of the industry.

Second, the impact of environmental regulation on industries' international competitiveness is characterized by industry heterogeneity. Such a difference is mainly reflected in the time of inflection points, which are affected by pollution level, R&D intensity, and monopoly degree.

Third, FDI, human capital, and industrial scale impose positive impact on manufacturing industrial international competitiveness. However, patent quality and capital deepening impose a negative impact on manufacturing industrial international competitiveness. Therefore, China should pay increased attention to technological innovation, high-value patent fostering, and rational allocation of talents and physical capital, while focusing on foreign capital introduction, appropriately expanding the industrial scale, and talent introduction.

In conclusion, this study verifies that a strict environmental regulation in China is conducive to improving industrial international competitiveness and providing a theoretical foundation such that governments can carry out the strict environmental regulation policies. Meanwhile, the governments should implement environmental regulation policies in accordance with pollution level, R&D intensity, and monopoly degree. Nevertheless, this study centres on China's current situation and the lack of exploration of differences in the impact of environmental regulation on industrial international competitiveness at the national level. Moreover, the influence of various environmental regulation policies, such as command-and-control, economic incentive, and corporation-and-persuasion, on industrial international competitiveness should be emphasized for further study to provide governments with specified and clear policy suggestions.

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