The impact of environmental regulations on export trade at provincial level in China: evidence from panel quantile regression

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Abstract

Based on panel data from 30 provinces in China from 2008 to 2017, this paper constructs a quantile regression econometric model to analyze whether China's environmental regulation has an impact on export trade and to verify whether the Porter hypothesis has been valid in China in recent years. The results show that in the short term, environmental regulations have a restraining effect on export trade, while in the long run, due to the existence of innovation efficiency, environmental regulations will change from having a restraining effect to a promoting effect on export trade. Strict environmental regulations will reduce the production cost of Chinese products, further improve the export competitiveness of Chinese enterprises, and promote export trade. The empirical results verify the conclusion that the Porter hypothesis is confirmed in China. The following three suggestions are proposed for China's exports to promote the win–win of China's green development and export trade: promote the realization of international and domestic double circulation, avoid becoming “pollution shelters” and support technological innovation in environmental protection industries.

Keywords Environmental regulation · Export trade · Porter hypothesis

Introduction

Since the environmental protection movement took off in the 1970s, governments around the world have actively implemented environmental regulations (Khalid et al. 2021). An increasing number of countries have incorporated environmental factors into an important part of trade regulation

(Baghdadi et al. 2013; Usman et al. 2021a). In 2019, the concentration of carbon dioxide in the global atmosphere reached the highest level in 3 million years, and air pollution poses a great threat to human health and even life (Qader et al. 2021; Usman et al. 2021b; Jahanger et al. 2021a, 2021b; Yang et al. 2021a, 2021b). As the world's largest exporter and the world's largest carbon emitter, the Chinese government has set higher requirements for energy conservation, emission reductions, and environmental regulations. Although China's ecological and environmental quality has generally improved, its performance in emissions and energy efficiency remains a significant challenge, according to the “Bulletin of China's ecological environment in 2019” (BCEE, 2019). As a means for the government to intervene in resource and environmental issues, environmental regulations play a fundamental role in solving the externalities of environmental pollution and correcting market failures. Integrating environmental regulations into the analytical framework of export trade can help transform the development mode of trade and thus contribute to solving the contradiction between export trade and the ecological environment. Many evidences show that there is a close relationship between environmental regulation and export

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trade in the country (Xu 2000; Dagar et al. 2021; Fang et al., 2019; Kamal et al. 2021).

With the concept of green development put forward, environmental regulations will be continuously improved. As a means of government intervention on resources and environmental issues (Ya'u et al. 2021), environmental regulation plays an irreplaceable role in solving the externalities of environmental pollution and correcting market failures. Integrating ecological regulation into the analysis framework of export trade can better change the mode of economic development and thus alleviate the contradiction between economic development and ecological environment (Usman et al. 2020a). At present, although the effect of environmental regulation has been improved, the overall effect is not satisfactory (Kamal et al. 2021; Zhao et al., 2021; Yang et al., 2020; Jahanger 2021a, 2021b; Qader et al. 2021). So, in the field of export, is environmental regulation helpful to China's export of goods and improve the export competitiveness of enterprises? If the answer is yes, will it have the same effect in the short term? Therefore, this paper brings environmental regulation into the analysis framework of export trade, and studies the impact of environmental regulation on export trade based on panel quantile model, in order to promote high-quality trade and achieve a win-win situation between environmental regulation and export trade.

Mechanistic analysis of the impact of environmental regulation on export trade

Environmental regulation and the transmission mechanism of export trade

From the point of view of the transmission path of production costs, under the influence of strict environmental regulations in a country, the internalization of enterprise environmental costs will lead to an increase in enterprise production expenditures (Guo et al., 2018). These expenses mainly include government emission pollution fines, environmental license fees and an enterprise's own environmental treatment costs, use of environmental protection equipment costs, and research and development of environmental protection technology costs (Snyder 2003; Usman and Hammar 2021). Under this premise, the enterprise will increase the internal

and external economic burden at the same time, resulting in an increase in production costs and then promoting the price of products (Richard and Manderson 2012; Usman and Jahanger 2021). However, restricted by the law of market prices, the income generated by the rising price of enterprise products cannot completely cover the environmental costs, which leads to constraints on the competitiveness of enterprise products in the international market (Rubashkina et al. 2015).

From the perspective of the technology innovation transmission path, in the short term, enterprises need to raise environmental internalization costs, pay pollution control costs, and cover technology R&D costs to adapt to environmental regulation standards (Hojnik and Ruzzier 2016), which leads to higher production and operation costs and weakens the price comparative advantage of enterprises (Maneschi 1992). The transmission mechanism of environmental regulation and export trade is shown in Fig. 1.

Mechanism of environmental regulation and export trade

The mechanism of the impact of environmental regulations on export trade can be analyzed in combination with three theories. First, according to Ricardo's comparative advantage trade theory (2012), when one country (assumed to be A) has stricter environmental regulations than another country (assumed to be B), higher production costs for related industries in country A will lead to the loss of its comparative advantage in the international market, which in turn results in a decline in exports. Because of the negative impact of environmental regulations on export trade, country B-related pollution-intensive enterprises will have gained a comparative advantage, and business will move from A to B, consistent with making countries with low environmental standards pollution havens. As a result, country A's exports of pollution-intensive products will decrease as environmental regulations increase production costs, internalizing environmental costs (Balsalobre-Loriente et al. 2021; Yang et al. 2021c). Second, neoclassical international trade theory expands on the traditional factor endowment theory (Ronald 1993; Intisar et al. 2020). Considering environmental resources as a factor of production, countries with environmental deregulation (assumed to be

Fig. 1 Environmental regulation and transmission mechanism of export trade

C) are rich in environmental resources, while countries with strict environmental regulations (assuming D) are relatively lacking in environmental resources. As a result, C countries have advantages over those with environmentally intensive products, thus its exports will increase, and exports of related products from D countries will decrease. Third, according to Porter and Linde (1995), Porter hypothesis, strengthening environmental regulations will increase the export competition pressure of enterprises, encouraging them to carry out technological innovation, which will improve export competitiveness.

From the above analysis, it is found that environmental regulations have both inhibitory and promoting effects on export trade; whether regulations inhibit or promote exports depends on the comparison of the two forces. When the intensity of environmental regulation is weak, enterprises generally choose to internalize environmental costs into their production costs, resulting in a relative decline in export competitiveness and a relative contraction or no obvious impact on the scale of exports. When environmental regulation continues to strengthen, enterprises are forced to choose technological innovation, improve production efficiency or replace formerly polluting products with new products with long-term competitive advantages and export scale expansion. However, excessive environmental regulations will restrain the expected output of enterprises, leading to a loss of competitive advantage and a reduction in export trade. In summary, when environmental regulations are weak, their negative effect on exports is also weak. In contrast, when environmental regulations are intensified, their negative effect will gradually decrease, their positive effect will gradually increase, and the export scale will expand. However, when the intensity of environmental regulation is too high, the positive effect will disappear and turn negative. Based on the above analysis, we believe that there may be an inverted N-shaped relationship between environmental regulations and exports.

Because of the existence of production costs, the higher the cost of production pollution controls, the smaller the comparative price advantage of trade exports. With the increasing intensity of environmental regulations, the innovation compensation effect brought about by enterprises seeking technological innovation is greater than the negative effect of increased production costs, resulting in increasing export trade. To date, many scholars have successfully proven this conclusion, obtained an inverted U-shaped relation, verified its turning point existence, and used the environmental Kuznets curve to determine that there is an inverted U-shaped relationship between economic growth and environmental pollution. Environmental regulation can internalize external costs, promote export

trade, and improve social welfare, but successful theory can only be meaningful through multiple proofs of practice (Balsalobre-Lorente et al. 2021; Usman et al. 2020b).

This paper makes the following contributions. First, in a departure from the comparative advantage perspective largely used in previous literature, this study analyzes export competitiveness from the perspective of product quality, which can supplement existing research on the endogenous determinants of export competitiveness. Second, our study extends the stream of literature on the Porter hypothesis. We build a theoretical framework that reveals the internal relationship between environmental regulation and export quality and simultaneously provide empirical support for the Porter hypothesis. Third, for the methodological perspectives, this is the first study that is going to investigate the dynamic linkages between environmental regulation and export trade based on panel quantile regression. Panel quantile regression is given more efficient results because it stratifies the explanatory variables' distributional influence on predicted variables in different quantile ranges. When the central location of conditional distribution and tails vary with the covariates, quantile regression is appropriate. Because environmental regulation in various provinces is significantly different, the quantile regression can reveal the effect of explanatory variables on the distribution of environmental regulation. Fourth, we have used the instrumental variables (IV)-two-stage least-squares (2SLS) method to solve the endogeneity problem. Fifth, besides, the findings of this study have efficient policy implications in that the empirical evidence and hypothetical explanation of this article assist us to recognize the impact of these variables and give some decision-making and recommendations for the implication of environmental policies in the case of China.

Based on the influence of the Porter hypothesis in recent years, this paper will further verify whether the Porter hypothesis is applicable in the case of China. On the basis of systematically combing the literature on the impact of environmental regulations on export trade, this paper constructs a quantile regression model with the panel data of 30 provinces in China from 2008 to 2017 ("On the one hand, the data of industrial waste gas emissions and industrial solid waste production in various provinces have been stopped to be published; On the other hand, due to the time lag of the above-mentioned statistics from authoritative departments, the available and complete data of all provinces are up to 2017, so typical ten-year panel data are generally selected as the research time axis"), analyzes whether environmental regulation has had an impact on export trade in China, and further analyzes the degree, trend, and channel of environmental regulation on export trade.

Literature review

At present, there are still some differences in the influence of environmental regulations on export trade in academic circles, both in China and abroad. There are three main viewpoints.

The first is promotion theory, according to which environmental regulations have a positive impact on the competitiveness of enterprises. This view is based on the Porter hypothesis, Porter and Linde (1995) defined that when a country's environmental regulation intensity is high, the threshold of export trade is raised, and the market competitiveness of enterprises is weakened, placing great pressure on enterprises and forcing them to take the initiative to carry out technological innovation. Costantini and Mazzanti (2012) started from Porter's view (that is, environmental policies can foster international competitiveness by guiding technological innovation), applying a theory-based gravity model to the export dynamics of five manufacturing sectors classified by technology or environmental content to revealing a mechanism similar to Porter's: The results show that the overall effect of environmental policies seems to be harmless to the export competitiveness of the manufacturing sector, while specific energy tax policies and innovation efforts have a positive impact on the export flow dynamics. Galinato and Chouinard (2018) provide a framework for linking national and neighboring countries' quality management with institutional measures and the impact of environmental regulations of neighboring countries on one's own environmental regulatory rigor. Based on space panel Durbin models, the higher the quality of government agencies in a country, the more stringent the implementation of environmental regulations. In addition, the quality variables of institutional measures have a significant positive impact on the strictness of environmental supervision in neighboring countries. This paper believes that under the current development of China's economic level, environmental regulation will bring certain impact on China's trade exports, and its significance will be clear in the analysis below. The negative impact in the short term will be changed to positive promotion due to the existence of innovation efficiency, which is expected to basically verify the existence of the "Porter Hypothesis" in China.

The second viewpoint is based on inhibition theory, in which environmental regulations have a negative impact on the competitiveness of enterprises. This view holds that the environment is also one of the factor endowments of a country. The introduction of a strict environmental regulatory system in China is expected to increase the production costs of enterprises, making them lose their price advantage and thus inhibiting the expansion of export trade. Bertarelli and Lodi (2019) adopted an international trade model of monopolistic competition to explain the heterogeneity of

enterprises in terms of productivity and theoretically examined the impact of introducing green technologies or maintaining advanced technologies with low pollution. Research shows that if all companies adopt pollutant technology, ecological taxes reduce emissions through selection mechanisms, resulting in the lowest production efficiency, forcing companies out of the market and inhibiting export tendencies. When adopting emission reduction technology, pollution sources can be reduced, and environmental taxes will actively affect ecological innovation tendencies and indirectly affect export tendencies. Cagatay and Mihci (2006) constructed an environmental sensitivity performance index to measure the intensity of a country's environmental regulation and tested 31 countries including developing countries and developed countries. The results show that the intensity of environmental regulation has a significant negative impact on exports. Shi and Xu (2018) compared the situation before and after the change of enterprises in industries with different pollution intensities in different provinces, and estimated the impact of environmental supervision on enterprises' exports. It is found that enterprises in pollution-intensive industries located in provinces with higher pollution reduction targets will reduce their export possibilities and export volumes due to stricter environmental regulations. However, the heterogeneity test shows that this effect is relatively small for state-owned enterprises and enterprises located in central and western China. Yang et al. (2017) demonstrate that the determinants of China's graphite export values include economical mass, export price, export duty refund, and language. Usman et al. (2021c) empirical results show that both environmental regulations and financial constraints have positive and negative effects, respectively.

The third point of view is that environmental regulations have little or no clear impact on export trade. Based on the data of 23 countries at different income levels, Tobey (2001) used the H–O model to test whether environmental regulation measures affect the terms of trade of some polluting commodities. The research shows that the export impact of environmental regulation measures on related pollution industries is not significant. Hafstead and Williams (2018) analyzed the impact of environmental policy on employment using a new general equilibrium two-sector search model. The study found that a pollution tax would lead to a significant reduction in employment in regulated polluting industries, but that this would be offset by an increase in employment in unregulated nonpolluting industries, so the overall impact is not evident. Li and Ramanathan (2018) examined the relationship between three different types of environmental regulation (command and control rules, market rules and informal rules) and environmental performance. Du and Li (2020) show that the negative effect of environmental regulation on pollution-intensive firms is stronger than that on clean enterprises. Liu and Xie (2020) findings reveal that

environmental regulation has a promotion export competitiveness of China's manufacturing industry; however, this effect is non-linear and displays a "U-shaped" tendency, indicating that certain prerequisites must be fulfilled to validate the Porter hypothesis. Pan et al. (2021) outcomes reveal that environmental regulation significantly promotes rather than restrains China's rare earth export.

Scholars try to find out some reasons in the non-uniform relationship between environmental regulation and export trade. Ederington and Minier (2003) think that many studies ignore that trade factors may affect the setting of a country's environmental regulation, setting environmental regulation as exogenous variable; then, Ederington et al. (2005) discovered a new reason: the similarity of environmental regulation levels between developed countries and the difficulty of moving pollution-intensive industries themselves. The rationale for the development of these three viewpoints can be discussed and analyzed from the following perspectives. The first is the heterogeneity of the research scope definition. The export trade of different regions has strong regional relevance, covering the degree of economic development and regional policy tendencies as well as involving the heterogeneity of time, space and industries. Second, some scholars who adhere to inhibition theory regard the environmental regulation variable as the endogenous given variable, and confuse the direct relationship between environmental regulation and export trade as an important reason for the difference in impact. Finally, the difference in the selected model method is also a factor that leads to insignificant results.

Overall, as scholars' understanding of environmental regulation and export trade relations have gradually deepened, the influence of environmental regulation on export trade in general can be summarized in two ways, although a few research areas still require additional work. One is the superiority of the intensity of environmental regulation measures, with what type of index to assess the intensity of environmental regulation. In previous research, a single indicator of environmental regulation tended to be used, which was not conducive to fully reflecting the influence of environmental regulations on export trade. Second, some of the research models established are based on the gravity model, in which the quadratic term of environmental regulation is directly introduced subjectively for analysis, ignoring the data coincidence of the existence of the inverted U shape relationship. Based on this, the main research idea of this paper lies in two aspects: first, three kinds of data are used to comprehensively measure the intensity of environmental regulation from 2008 to 2017; and second, the panel quantile model is used to analyze the impact of environmental regulations on export trade at the subpoints of 25%, 50% and 75%. In the process of quantile regression analysis, we choose three representative quantiles to avoid the chance that the data tend to have inverted U-shaped coincidence.

In addition, the quadratic term of environmental regulation is added into the model for robustness analysis, making the inverted U-shaped research conclusion more persuasive.

Empirical analysis of the impact of environmental regulation on export trade

Model selection and setting

Regression analysis has been widely used to analyze the influence of explanatory variables on explained variables. The most common method is mean regression analysis, although mean regression cannot measure all the whole distribution characteristics and will be affected by heteroscedasticity. Koenker and Bassett (1978) proposed quantile panel regression, which can effectively solve these two problems by measuring the range and distribution shape of multiple loci. Based on the regional differences in eastern, central and western China, it is necessary to analyze the characteristics of different regions, thus, this paper adopts the panel quantile model and establishes the regression model as follows:

$$\ln EXP_{it} = \alpha_{it} + \beta \ln ER_{it} + \delta X + \varepsilon_{it} \quad (1)$$

In formula (1), $\ln EXP$ represents the total export trade, α means the intercept term, $\ln ER$ denotes the intensity of environmental regulation, X signifies the other control variables, provinces t shows time, and ε means the random error term. Model (1) takes the logarithmic form of some variables to reduce the dimension, which is used to study the growth change of percentage points.

Selection of variables

Export trade volume (EXP) is the explained variable, indicating the total export trade and indicating the trade exports of different provinces in different years.

The intensity of environmental regulation (ER) is a core explanatory variable, indicating the impact indicators of environmental regulation in each province, that is, the discharge of industrial wastewater, the discharge of industrial sulfur dioxide and the output of industrial solid waste are taken as the impact indicators to measure the environmental regulation intensity (ER); for the purpose of more comprehensive and accurate measurement results of environmental regulations, environmental regulation evaluation indicators take into account the availability and timeliness of data. The impact index of environmental regulation intensity (ER) is the pollutant emission level, prediction and export trade symbol.

Other control variables include the amount of actual utilization of foreign capital (FDI), which indicates the ability of provinces to absorb foreign funds and is used to measure the intensity of foreign direct investment it is also an important explanatory variable, and the symbol of forecast and export trade is positive. Per capita gross domestic product (GDP), as the proxy variable of regional economies of scale, is expressed by the per capita gross domestic product of each province, and the forecast and export trade symbol is positive. Regional R&D investment (R&D), as the proxy variable of technological production innovation, can be regarded as the amount of innovation investment in a certain region. An increase in R&D investment can promote the birth of new products and industries, promote industrial optimization and upgrading, and the forecast and export trade symbols are positive. Total factor productivity (TFP) is used to measure the efficiency of technological progress. The total factor productivity index of China from 2008 to 2017 is calculated by using the data envelopment method, that is, the DEA-Malmquist index method. The symbol of forecast and export trade is positive.

Data sources and collation

From 2008 to 2017, panel data from 30 provincial regions of Mainland China (excluding Hong Kong, Macao, Taiwan and Tibet) were selected. These data are derived from the Ministry of Ecology and Environment (<https://www.mee.gov.cn/>), the China Statistical Yearbook (<http://www.stats.gov.cn/tjsj/ndsj/>), the China Environmental Statistics Yearbook (<https://kns.cnki.net/>), national data (<https://data.stats.gov.cn/>) and customs statistics (<http://www.custo.ms.gov.cn/>).

Environmental regulation (ER) intensity evaluation index measurement methods are different. If the pollutant emission data are not processed and directly put into the measurement model for regression, it will treat the data and raise two problems. First, all three pollutants are derived from pollution emissions from the industrial sector, which may be highly correlated and brought into a metrological model with collinearity problems (Usman and Makhadm 2021). Second, if the pollutant emissions are not dimensionless and simply aggregated, the explanatory variables are difficult to compare horizontally. Therefore, to avoid the above problems, this paper establishes the following relative indicators. The following formula indicates the relative emission level of j pollution in urban t :

$$POL_{xjt} = \frac{POL_{jt}}{\frac{1}{n} \sum_{i=1}^n POL_{jt}}, j = 1, 2, 3 \quad (2)$$

Add the three pollutant emission levels to the mean, that is, the pollution emission level in area t :

$$POL_{xt} = \frac{1}{3} (POL_{x1t} + POL_{x2t} + POL_{x3t}) \quad (3)$$

To objectively and comprehensively measure the pollutant emission level of China, this paper selects the median value of the comprehensive index of 30 provinces and autonomous regions of China as the data index of the pollution emission level of each province in that year (see Table 1).

Descriptive statistics of variables

Before carrying out the empirical study on the impact of environmental regulations on export trade, we will first use

Table 1 Pollutant emission levels of various provinces in China 2008–2017

Province	Year				
	2009	2011	2013	2015	2017
Beijing	0.20	1.14	0.55	0.46	0.47
Tianjin	0.61	1.56	1.68	1.81	1.95
Hebei	1.35	0.62	0.92	0.93	0.71
Shanxi	2.20	1.39	1.30	1.55	1.33
Neimenggu	0.87	0.50	0.51	0.70	1.00
Liaoning	0.44	0.40	0.47	0.52	0.70
Jilin	0.46	0.60	0.58	0.55	0.55
Heilongjiang	0.65	0.69	0.50	0.57	0.57
Shanghai	0.51	1.69	1.71	1.81	1.45
Jiangsu	1.30	0.33	0.40	0.40	0.35
Zhejiang	1.53	0.40	0.66	0.66	0.63
Anhui	0.34	0.54	0.46	0.46	0.43
Fujian	0.60	0.45	0.40	0.37	0.48
Jiangxi	0.61	0.43	0.53	0.56	0.37
Shandong	0.58	0.21	0.21	0.22	0.20
Henan	0.84	0.42	0.51	0.65	0.40
Hebei	0.87	0.71	0.75	0.72	0.66
Hunan	0.24	0.25	0.13	0.16	0.16
Guangdong	0.38	0.30	0.24	0.24	0.30
Guangxi	1.23	0.45	0.53	0.46	0.38
Hainan	0.09	0.42	0.16	0.17	0.17
Chongqing	1.98	3.79	3.90	4.11	3.12
Sichuan	0.74	0.49	0.36	0.37	0.33
Guizhou	1.85	1.42	1.06	1.18	1.85
Yunnan	1.81	2.09	1.71	1.29	1.48
Shaanxi	0.77	0.60	0.47	0.39	0.28
Gansu	1.45	1.24	1.26	1.44	1.29
Qinghai	2.43	2.78	3.10	2.23	3.28
Ningxia	1.28	2.73	3.75	3.93	3.47
Xinjiang	1.80	1.38	1.19	1.08	1.55

Due to incomplete data in some regions, data of Tibet, Hong Kong, Macau and Taiwan Province are not included. Due to the limited space, the pollutant emission levels of all provinces in all years are not listed

Stata 15 to carry out descriptive statistics and quantile statistical results of each variable and briefly summarize them in Table 2.

Empirical testing and results analysis

Correlation test of variables

Above, the correlation between variables is verified by correlation, and the correlation between variables is verified by the Pearson correlation number method. The following Table 3 shows the correlation test between export trade volume (ln EXP) and environmental regulation intensity (ln ER) of the explanatory variables, the actual utilization of foreign capital (ln FDI), gross domestic product (ln GDP), R&D investment (ln RD) and total factor productivity (TFP). The correlation test results are reflected in Table 3 as below:

According to the results of the correlation test, there is a significant positive correlation between export trade volume and actual utilization of foreign capital, GDP, R&D innovation and total factor productivity, while there is a significant negative correlation between export trade volume and environmental regulation intensity. The correlation coefficient between variables is less than 0.8, so we can see that there is no multiple collinearity problem in the model; that is, the

establishment of this model is meaningful, and it is beneficial to study the influence of environmental regulation intensity on export trade.

Choice of panel estimation regression model

By comparing the mixed regression, fixed effect regression and random effect regression models, this paper draws the conclusion that mixed regression should be used, on the premise that the LM test accepts the original hypothesis that there is no individual effect. At the same time, three representative loci were selected to estimate the panel quantile regression of the model to distinguish the impact of environmental regulation on export trade in cities of different provinces and to explore its impact on export trade. The results are reported in Table 4.

Solution of endogeneity problem

To ensure the validity and reliability of the above measurement model, the most basic requirement is that it overcomes its possible endogeneity problems. According to the research content of this paper, there are two main endogeneity problems. The first possible endogeneity problem lies in the reverse causality between the intensity of environmental regulation in various regions of explanatory variables and

Table 2 Descriptive statistics of variables

Variable	Mean	Maximum value	Minimum value	Standard deviation	25%	50%	75%
Export trade	16.405	20.443	12.055	1.766	15.136	16.321	17.449
Environmental regulation intensity	−0.294	1.414	−2.544	0.775	−0.782	−3.893	0.261
Actual utilization of foreign capital	10.451	16.709	4.598	2.162	9.328	10.522	11.361
Gross domestic product	9.303	11.404	6.045	1.133	8.496	9.576	10.095
R & D inputs	8.757	11.537	5.703	1.095	8.223	8.784	9.378
Total factor productivity	0.887	1.090	0.680	0.055	0.855	0.886	0.921

Table 3 Correlation test for variables

Variable	Export trade	Environmental regulation intensity	Actual utilization of foreign capital	Gross domestic product	R & D inputs	Total factor productivity
Export trade	1.0000					
Environmental regulation intensity	−0.2532 (0.0000)	1.0000 (0.0000)				
Actual utilization of foreign capital	0.3225 (0.0000)	−0.3986 (0.0000)	1.0000			
Gross domestic product	0.3340 (0.0000)	−0.3775 (0.0000)	0.6245 (0.0000)	1.0000		
R & D inputs	0.1320 (0.0223)	−0.3745 (0.0000)	0.5184 (0.0000)	0.6181 (0.0000)	1.0000	
Total factor productivity	0.0186 (0.7485)	−0.0988 (0.0876)	0.4599 (0.0000)	0.4134 (0.0000)	0.3759 (0.0000)	1.0000

Significant levels indicated in parentheses

Table 4 Panel model estimation results of environmental regulation on export trade

Variable	25%	50%	75%	2SLS
Environmental regulation intensity	−0.364* (0.205)	−0.298* (0.173)	−0.289 (0.189)	−0.324*** (0.161)
Actual utilization of foreign capital	0.861 (0.090)	0.196** (0.076)	0.271*** (0.083)	0.194*** (0.066)
Gross domestic product	0.525*** (0.179)	0.586** (0.151)	0.579*** (0.165)	0.494*** (0.115)
R & D inputs	−0.181 (0.170)	−0.383*** (0.143)	−0.479*** (0.156)	−0.283** (0.112)
Total factor productivity	−5.567* (0.2.959)	−4.765* (2.497)	−4.667* (2.725)	−5.370*** (2.08)
Constant term	15.920*** (2.375)	16.367*** (2.005)	17.671*** (2.188)	16.932*** (1.66)

Upper corner *, **, *** at 10%, 5%, and 1% passed the test at a significant level, and the parentheses in the table are standard errors. Due to space limitations, the environmental regulation factor at the 10% level is −0.333, and the standard error is 0.231. At 90%−0.139, the standard error of 0.219 is not listed in the table

the export trade of enterprises under interpretation. The second is the endogeneity problem caused by the omission of an important influence variable. In light of the first possible situation, from the point of view of China's current national conditions, the explanatory variables are more exogenous variables in the intensity of environmental regulation in various regions of China, and enterprises are more likely to be passive recipients of government environmental policies, instead of formulators of policy. For the second possible situation, we identified some influential factors emphasized in the existing literature as much as possible in the metrological equation. At the same time, by using the Stata to carry out the metrological practice, we test whether there is any omission problem to ensure that the integrity of the model further obtains the impact of different regions and different years of environmental regulation intensity on enterprise exports. At the same time, due to the endogenous nature of environmental regulation, variables will cause errors in the estimation results. This paper finally decides to adopt the first-order lag term of environmental regulation (ER) as a tool variable of environmental regulation. The model is estimated by the tool variable method, and the rationality test result of the tool variable is obtained by the two-stage least square method (2SLS) to overcome the endogeneity of environmental regulation. The estimated results are listed in the last column of Table 4.

Result of panel model estimates

First, we pay attention to the influence of the coefficient of environmental regulation on export trade; whether it is a mixed regression or a 25% and 50% quantile, the impact coefficient of environmental regulation on export trade is tested at a significant level of 10%, and the coefficients are negative, from 2008 to 2017. The environmental regulation

of China's export trade volume has a significant negative effect on the country's industrial waste, that is, the higher the degree of environmental regulation, the greater the inhibition of export trade. By studying the changing trend of the environmental regulation coefficient at each quantile level, it can be concluded that the environmental regulation coefficient first rises and then decreases in an inverted U shape, and peaks slightly left. At the same time, it can be found that the influence coefficient of environmental regulation intensity on the quartiles of 10%, 75%, and 90% has not passed the test at the significance level of 1% of the environmental regulation intensity. It is clear that environmental regulation can affect export trade only to a certain extent; the effect of too low or too high environmental regulation intensity on environmental regulation is not significant, and the influence range is −0.364 to −0.298. Xie et al. (2020a, b), and Usman et al. (2020c) also reveal similar findings.

Specifically, we can explain that the impact of environmental regulation on export trade has a certain cost effect; environmental regulation measures have an impact on export trade only to a certain extent, which is in line with real economic law. The main reasons are that pollution control, clean energy utilization, and pollution disposal costs are related, the corresponding production cost is improved, the competitiveness of enterprises is weakened, export trade is restrained to some extent, and the impact of environmental regulation on export trade is thus not significant. Through 25% and 50% of the loci, we also know that environmental regulation has an impact on export trade in this range because environmental regulation will bring comparative advantages to China's trade exports. This is in line with the current economic reality of the country. At present, the continuous development of the country's economic level has led to an increasingly high level of material consumption, and the demand for material products promotes an increase in supply. When supply

exceeds demand, this will lead to an increase in production and will drive exports. From the information that 50% of the loci are significant and 75% and 90% of the loci are not significant, we can see that environmental regulation has no significant impact on export trade at this quantile. Thus, it can be concluded that appropriate environmental regulations have a certain impact on export trade and generally present an inverted U shape, which proves that the Porter hypothesis holds. Supporting Porter's hypothesis means that reasonable environmental regulations can stimulate innovation, as advanced technology not only reduces the cost of pollution abatement but also counteracts it. So, Porter's hypothesis also implies a win–win relationship between environment and economic development.

In general, in the mixed regression model, the impact of the actual utilization of foreign capital, economic growth, R&D investment, and total factor productivity on export trade at a significance level of 5% is significant, which means that environmental research on trade can also be discussed from these aspects. From the results of quantile panel regression, we can see that the actual utilization of foreign capital does not hold up at 25% of the loci, and the increase in the loci is increasingly significant. The higher the quantile, the stronger the significance level. In the sense of the whole, the actual utilization of foreign capital, GDP, R&D investment, and total factor productivity can promote China's export trade.

Robustness analysis

Taking the lag phase variable as the tool variable, the endogeneity problem is tested, and it is found that the regression results of the tool variable and the original variable are basically consistent, so it can be considered that the results of this study are robust. Combined with the structure of environmental regulation and export trade, this paper proves the stability of the model by using the quadratic term of environmental regulation instead of environmental regulation. The results of the mixed regression and the panel quantile regression are shown in Table 5.

From the above regression analysis results and environmental regulation regression results, we can see that the quadratic term of environmental regulation is established as an alternative to the intensity of the environmental regulation model. At the same time, through the relationship between the quadratic term of environmental regulation and export trade, we can obtain the U-shape relationship between environmental regulation and export trade.

Heterogeneity analysis

Because environmental regulation and export trade are not significant at 75% and 90% of the loci, we further explore and study them, combined with the specific characteristics of China's vast territory. The disharmony between environmental regulation and the economic development level of eastern, central, and western China may lead to the regression not being significant. To this end, we further explore the reasons for the nonsignificance; the data is divided geographically into the eastern, central, and western three regions of China for the subregional regression test, and the regression results are shown in Table 6.

From the regression results in Table 6, the impact of environmental regulation intensity on export trade in the eastern and central regions is negative at a significance level of 10%. It can foster some backward mechanisms to promote innovation, thus bringing some degree of competitive advantage to export trade and the promotion of exports. Generally, the impact of environmental regulation on the eastern region is similar to the overall trend, showing an inverted U-shaped relationship, but the central region has difficulty realizing innovation mechanisms because of the influence of the ability to innovate on economic development. Environmental regulation in central China has no great impact on export trade. However, the environmental regulation coefficient in the western region is not significant, which reflects the obvious regional heterogeneity of the impact of environmental regulation on export trade. At the same time, we can see that the export trade volume in the western region is not related to the intensity of environmental regulation.

Table 5 Environmental regulation impact on export trade panel model estimation results

Variables	25%	50%	75%	2SLS
Second term of environmental regulation intensity	0.296*	−0.298*	0.270**	0.0310***
Actual utilization of foreign capital	0.863	0.135*	0.252***	0.923***
Gross domestic product	0.436**	0.573***	0.573***	0.241***
R & D inputs	−0.003	−0.158	−0.313**	−0.0739
Total factor productivity	−4.669	−5.708**	−3.994	−0.0268
Constant term	14.306***	15.904***	15.691***	12.64***

Superscripts *, ** and *** indicate that they pass the test at significance levels of 10%, 5% and 1%, respectively

Table 6 Results of panel model estimation on the impact of environmental regulation on export trade

Variable	Regional	25%	50%	75%	2SLS
Environmental regulation intensity	Eastern	− 0.614** (0.308)	− 0.303 (0.417)	− 2.225 (0.327)	− 0.596*** (0.195)
	Central	− 0.631 (0.547)	− 0.503 (0.512)	− 0.411 (0.405)	− 0.312*** (0.0338)
	West	0.212 (0.383)	0.072 (0.309)	0.184 (0.389)	2.420*** (0.223)
Actual utilization of foreign capital	Eastern	0.145 (0.148)	0.352 (0.201)	0.619 (0.157)	2.271*** (0.273)
	Central	− 0.254 (0.195)	0.073 (0.182)	0.079 (0.143)	0.097*** (0.037)
	West	0.181 (0.122)	0.084 (0.099)	0.133 (0.124)	0.332* (0.174)
Gross domestic product	Eastern	0.278 (0.233)	− 0.026 (0.316)	− 0.105 (0.248)	− 0.026 (0.019)
	Central	0.416 (0.431)	0.504 (0.404)	0.504 (0.404)	0.131 (0.078)
	West	1.083*** (0.259)	0.956*** (0.209)	1.139*** (0.263)	0.399*** (0.116)
R & D inputs	Eastern	− 0.559** (0.246)	− 0.434 (0.334)	− 0.726*** (0.263)	− 0.533*** (0.0697)
	Central	0.707 (0.969)	1.082 (0.908)	0.273 (0.716)	0.123 (0.184)
	West	− 2.223 (0.249)	− 0.191 (0.201)	− 0.151 (0.253)	− 0.596*** (0.193)
Total factor productivity	Eastern	4.537 (5.199)	3.838 (7.046)	5.198 (5.536)	0.598 (0.559)
	Central	− 6.269 (6.737)	7.182 (6.311)	− 3.262 (4.979)	− 3.625 (3.837)
	West	− 5.323 (3.901)	− 4.920 (3.158)	− 4.827 (3.961)	− 0.784** (0.395)
Constant term	Eastern	11.407*** (3.884)	12.970*** (5.264)	13.505*** (4.136)	12.854*** (5.685)
	Central	13.201 (10.089)	− 4.741 (9.451)	11.922 (7.456)	11.109*** (3.547)
	West	10.534*** (3.841)	12.633*** (3.109)	11.224*** (3.900)	12.654*** (5.245)

Superscripts *, ** and *** indicate that they pass the test at significance levels of 10%, 5% and 1%, respectively; the parentheses are standard errors

In terms of actual utilization of foreign capital, gross domestic product (GDP), R&D investment, and total factor productivity (TFP), we can see that the actual utilization of foreign capital does not have a significant impact on export trade in the eastern, central or western regions of China. Nevertheless, the benchmark regression in the eastern region is significant, indicating that the heterogeneity of actual utilization of foreign capital has little impact on exports. In terms of gross domestic product (GDP), we can see that the gross domestic product (GDP) in the eastern and central regions of China is not significant at all loci, indicating that the GDP in the central and eastern regions has no significant impact on export trade. Regarding R&D investment, R&D investment and exports in the eastern region are generally significant, showing a general trend of first positive and then negative,

which originates from the innovation of knowledge and technology (Usman et al. 2021d). Innovation can only have a significant advantage in the previous period, thus generating a competitive advantage for exports. In terms of total factor productivity, the total factor productivity in the three regions of the east, middle, and west has no significant impact on export trade volume.

The western region is rich in natural resources such as minerals, energy, and land. The main export products are resource-based products such as ores, coal and rare metals. Compared with the central and eastern regions, the technical level of new products is slightly less advanced (Xie et al. 2020a, b). Even the same products will lack competitiveness due to geographical location, so we can only choose to develop resource-intensive and labor-intensive industries.

Under the current export mode, the western region obtains development funds by exporting resource-intensive and labor-intensive products to developed countries, while the central and eastern regions also transfer some high-energy-consuming products to the western region by taking advantage of their geographical advantages and scientific and technological advantages. Therefore, the main policy areas of environmental regulation include formulating environmental standards, pollutant emission standards and technical standards, and establishing a system of sewage charges or taxes and a system of emission rights trading (Fang et al., 2019; Usman and Hammar 2021; Usman et al. 2021e; Zhang et al. 2021). It will definitely have an adverse impact on the trade development of western provinces that rely more on energy consumption and pollution emissions. Therefore, according to the current development situation, the growth of export trade in western regions will not have a good impact on the environmental quality.

Conclusions and policy implication

Main findings

By using panel quantile regression, this paper analyzes whether environmental regulations affect export trade and through what channels, and draws the following conclusions: (1) the environmental regulation coefficient shows that the intensity of environmental regulation has a nonlinear influence on export trade and shows the characteristics of an inverted U; and (2) the actual utilization of foreign capital, GDP and total factor productivity can promote China's export trade. Specifically, the impact of China's GDP of the central and eastern regions on export trade is generally higher than that of the western development level. The Belt and Road policy has created favorable trade conditions for Southwest and northwest China, but due to various factors, such as topography and climate, there is still room for growth in the western region to promote trade development.

In general, environmental regulation and export trade have a negative impact in the short term. Because of the existence of innovation efficiency, when environmental regulation is raised to a certain extent, it will change from having an inhibition effect to having a promotion effect. Then, strict environmental regulations will reduce production costs, further improve export competitiveness and promote export trade. The empirical results verify the conclusion that there is a Porter hypothesis in China. Strict environmental regulation brings competitive pressure to enterprises and drives enterprises to take the initiative to carry out technological innovation to compensate for the losses caused by the increase in production costs resulting from the internalization of environmental costs. This can improve product

quality to a certain extent, optimize product structure, and promote the transformation and green upgrading of products.

Policy implications

During the 13th five-year plan period, decisive achievements were made in building a prosperous society in an all-around way, pollution prevention and control efforts were increased, and the ecological environment was obviously improved. However, China's development is still in an important period of strategic opportunities, and China's export industry is in a period of internal and external difficulties. The outbreak of COVID-19 in 2020 disrupted the pace of China's exports. With the integration of the global economy and environment, the research focusing on the environmental regulation and export trade of China's provinces is of great significance to many other sovereign countries in the world with comparable economic and trade output. If they want to apply the research results of this paper to many international situations where they seek to strengthen trade or improve the ecological environment. Based on the current economic situation and the empirical results of the regression analysis, we can confirm the Porter hypothesis in China's exports from 2008 to 2017. This paper puts forward the following policy suggestions to further promote the development of China's export trade:

Actively promoting trade to achieve a double international and domestic cycle

The COVID-19 pandemic has increased the uncertainty of the global economic market. The Fifth Plenary session of the 19th CPC Central Committee firmly proposed building a domestic cycle as the main economic body and actively promoting the opening pattern of the international and domestic double cycles. Against this backdrop, in order to promote export controls for the international market, we need to strengthen the supervision of export enterprises in terms of business qualifications, product standards, and quarantine protocols. It is also necessary to adjust the original model of trade and exports toward contactless exports through electronic data platforms through the automation of exports, construction of modern contactless logistics system, improving the quality of China's exports, and establishing a brand image of China's export. In terms of the domestic market, the expansion of domestic demand requires national policies that can provide the necessary support to enterprises that have struggled to survive during the epidemic and formulate differential subsidy policies in light of the current environmental situation in China. Such policies could entail setting a series of criteria and subsidizing multiple environmental standards for light and moderate pollution areas and industries so that enterprises and employees can receive

“import bag” dividends, rewarding industries and enterprises with high levels of environmental awareness, establishing a system of reward and punishment, and encouraging internal adjustments in pollution-intensive industries. At the same time, we should encourage staff consumption, alleviate the backlog of demand in the international market affected by the pandemic, and promote the circular development of the international and domestic market economy.

Avoid becoming a “pollution shelter”

As one of the factor endowments of a country, the environment in the western region of China has its characteristic advantages and disadvantages. Under the strategy of “western development” and the “Belt and Road” project to promote development, loosening environmental regulation policies may reduce the production costs of enterprises in a short period of time and promote export trade. The “Belt and Road” strategy has brought new development opportunities to the western region, narrowed the differences between the eastern and western regions, initiated the regional characteristics of the western region, developed an industrial cooperation system with the “Belt and Road” countries, expanded two-way trade with the “Belt and Road” countries, while combining the “going out” foreign expansion strategy of Chinese enterprises with the arrival of international business and adhering to the environmental approach of “green, open and clean”, and promoted multiparty cooperation. We will consolidate the existing “Belt and Road” commitment to cooperation and trust, actively promote mutual recognition of import and export credit during the epidemic, speed up the progress of import and export customs review, and accelerate multilateral trade cooperation and exchange. Avoiding becoming a “pollution shelter” is an important goal in the western region of China. To achieve this objective, it is necessary to (1) internalize environmental costs from the domestic market, minimize the export of traditional extensive resource-consuming economic development in exchange for environmental benefits, and follow the path of sustainable development; and (2) from the international market, to firmly adhere to the new policy of Refusing Foreign Garbage, give full play to the regional characteristics of the western region, promote economic development from the perspective of green buildings and characteristic culture, and avoid becoming a pollution shelter.

Supporting technological innovation in environmental protection industries

One of the purposes of environmental regulation is to make enterprises feel the pressure of competition through strict environmental regulation standards, encourage

positive and effective green technological innovation, enhance the core competitiveness of enterprises, and promote the development of a green economy. In addition to tangible capital, we should break through technology monopolies, speed up the circulation of technology, and obtain technology spillover effects. Only the joint efforts of the government and enterprises can effectively maintain the effective operation of environmental protection with economic development. Therefore, the government should start with the following actions: (1) in the short term, make appropriate subsidies to certain industries to help enterprises through the early buffer stage and promote the optimization of production technology; (2) pay attention to the training of key technology and scientific research personnel, introduce competition incentive mechanisms into the training of scientific research personnel, stimulate green innovation and create vitality; (3) on this basis, give full play to the role of environmental policy tools, encourage the promotion of energy savings and emission reduction technology, actively promote the development of environmental protection industry technology, and promote the development of the clean market; and (4) enterprises should take the initiative to introduce green equipment and technology, actively engage in innovative practices, and actively transform and upgrade their products to green environmental protection.

Based on the data of provinces from 2008 to 2017, this paper uses a quantile regression model to explore the influence of environmental regulation on China’s export trade and presents an inverted U-shaped relationship, which proves the existence of the Porter hypothesis. However, the measurement units of environmental regulation are different and still need to be discussed from many aspects. At the same time, the scale effect, technical effect, and structural effect of environmental regulation are still worthy of further study. This paper is limited to the theme and does not repeat it.

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