

The Impact of Environmental Regulation on the Export Quality of China's Manufacturing Industry under the CBAM Framework

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Abstract: This paper selects the export data and input-output data of four high carbon emission manufacturing industries initially covered under the CBAM framework from 2001 to 2019, respectively uses Hausmann's method and DEA model to measure the manufacturing industry export quality and green total factor productivity, and explores the impact of environmental regulation on China's manufacturing industry export quality based on the individual fixed effect model. The results show that environmental regulation will have a positive impact on the export quality of high carbon emission manufacturing industry in terms of capital, labor, energy, green total factor productivity, etc. Further analysis shows that: the total amount of labor input is negatively related to export quality, while the total amount of capital input, energy input, green total factor productivity and export quality are positively related. The conclusion of this paper shows that supporting technology R&D, increasing capital investment and implementing industrial differentiation are important development path orientations to promote China's high carbon manufacturing industry to improve export quality.

Keywords: Environmental regulation; Export quality of manufacturing industry; DEA model.

1. Introduction

Improving the development quality of manufacturing industry is the core to improve the productivity level of a country and achieve high-quality economic development. Made in China 2025 clearly points out the strategic goal of building a manufacturing power and realizes the important transformation from extensive manufacturing with large resource consumption and high pollutant emissions to green manufacturing. In the government work report in 2022, promoting energy conservation and carbon reduction in manufacturing industries such as steel, nonferrous metals, petrochemical, chemical, building materials and realizing green and low-carbon development will be one of the priorities of the government's work in the future. Moreover, the successive introduction of environmental regulations represented by the domestic "carbon peak, carbon neutral" policy and the EU's proposed carbon border regulation mechanism indicates that there will be more strict environmental regulations in the future. Therefore, under the dual pressures at home and abroad, it is inevitable for China's manufacturing industry to change its development mode and improve its export quality. In this context, this paper explores the impact mechanism of environmental regulation on manufacturing export quality, which is of great significance to clarify the relationship between environmental regulation and manufacturing export quality, and to achieve high-quality development of manufacturing.

2. Literature Review

At present, the research on environmental regulation and manufacturing export quality mainly focuses on two aspects: whether there is a relationship between them and the impact

mechanism. At present, the academia generally recognizes that environmental regulation will have an important impact on the quality of the manufacturing industry. Among them, Wu Aidong and Li Xiang (2021) found that environmental regulation can promote the high-quality development of the manufacturing industry by building a benchmark regression, and according to the PVAR model results, it can play a positive role in the short term, while the long-term effect depends on the relative size of cost-benefit and compensation effect, and the long-term effect is uncertain[1]. Xie Jing and Liao Han (2017) used the SYSGMM method to empirically test the dynamic U-shaped impact of environmental regulation on the export quality of heavily polluted industries, that is, before the inflection point, environmental regulation cannot promote the improvement of export quality, and only when it exceeds the inflection point can it play a positive role[2]. In terms of the impact mechanism, Liu Jiayue and Xie Jing (2018) adopted a systematic GMM estimation method and found that environmental regulation will affect the upgrading of manufacturing industry export quality through the industry's factor input structure, and human capital investment, independent research and development, technology introduction and foreign investment participation will all play a positive role in improving the industry export quality with different key input structures[3]. In addition, scientific and technological innovation has been proved by many scholars to be one of the important factors affecting the development quality of manufacturing industry. For example, Liu Yijun and Fang Ziyang used the fixed effect model to prove the positive intermediary effect of scientific and technological innovation between environmental regulation and high-quality development of manufacturing industry[4]. Tang Xiaohua and Sun Yuanjun also proved the intermediary role of innovation effect and energy effect, and found that the

former is stronger than the latter after comparison[5].

At present, many scholars have done a lot of research and analysis based on different research perspectives, but there are still some limitations. First of all, scholars focus on the development quality of the manufacturing industry and pay less attention to the export quality. Export quality reflects a country's international competitiveness and comprehensive national strength. Focusing on and improving export quality will help China stabilize the international market share of manufacturing industry and promote economic development. Secondly, there are regional differences and industrial differences in the impact of environmental regulation on the export quality of manufacturing industry. The research on regional differences and spatial spillover effects has been relatively perfect, while the research on the impact of environmental regulation on the major heavy pollution and high export manufacturing industries is still insufficient. Therefore, this paper focuses on four high carbon manufacturing industries initially covered by the carbon border regulation mechanism to be implemented by the EU, calculates the export quality and green total factor productivity of manufacturing industries, and more accurately and clearly reveals the impact of environmental regulations on the export quality of major manufacturing industries by building an individual fixed effect model.

3. Impact Mechanism of Environmental Regulation on Export Quality of High Carbon Manufacturing Industry

3.1. Capital

Environmental regulation affects the export quality of enterprises through cost effect, innovation compensation effect and improving the quality of FDI. Under environmental regulations, enterprises will follow the cost effect. The increase in environmental taxes due to pollutants and the increase in production costs to reduce pollutant emissions will squeeze the funds for technology research and development and product production, resulting in a decline in product quality. With the improvement of environmental regulation, enterprises will carry out innovation compensation, actively carry out product innovation, technology research and development, and overall product optimization, so that products can adapt to environmental regulation standards while continuously improving the technical complexity of products, and improve the quality of export products, so that products can be loved by more consumers internationally[6]. At the same time, environmental regulation may also affect the quality of FDI. Under the implementation of environmental regulations, in order to meet the relevant conditions of environmental regulations, enterprises need to transfer funds for pollutant treatment in the short term, and invest R&D funds for technological innovation in the long term. More capital in the industry flows to technology R&D departments. This will greatly reduce the number of low-quality FDI that pursue short-term profits, while attracting high-quality FDI that is expected to provide more stable and sufficient financial support for the transformation and upgrading of China's high carbon manufacturing industry through technology upgrading, productivity improvement and long-term profits, which is conducive to improving the export quality of high carbon manufacturing industry[7].

3.2. Labor

Under strict environmental regulations, the high carbon emission manufacturing industry has led to the cross industry flow of production factors due to the reduction of industry investment returns. Taking labor force as an example, under the pressure of environmental governance, the production scale of high carbon emission manufacturing industry will remain relatively stable and may even decrease. On the one hand, the high cost of environmental governance makes the enterprise have to reduce other unnecessary production costs, so the enterprise will conduct a large number of layoffs. On the other hand, in order to improve labor productivity, the enterprise will replace simple unskilled labor with machinery and equipment, while more advanced skilled labor will remain in the enterprise. Therefore, environmental regulation will lead to a decline in the absolute number of labor in the high carbon manufacturing industry, and the relative employment ratio of skilled labor and unskilled labor in the labor structure will increase, which will promote the quality improvement of the export products of the high carbon manufacturing industry through the "capital skills complementary effect".

3.3. Energy

The impact of environmental regulation on the energy consumption structure of manufacturing industry is mainly reflected in the limitation of energy consumption and biased choice of energy consumption [8]. From the perspective of energy consumption restriction, environmental regulation will limit the production scale of high carbon manufacturing industry through a series of policies, carry out supply side reform, reduce production output, and thus lead to a decline in energy consumption; At the same time, in order to meet environmental standards for a long time, enterprises internalize the environmental costs generated by enterprises. The pressure of increased production costs will also lead enterprises to actively control output, reduce the use of more expensive energy, strengthen the use of more economical energy, and reduce energy consumption as a whole. From the perspective of biased choice of energy consumption, the obvious feature of China's high carbon manufacturing industry in terms of energy structure is that it has excessive demand for primary energy such as coal, but coal has disadvantages in terms of heat output and pollution emissions. In the future, enterprises will greatly reduce the use of coal and other energy to meet the requirements of environmental regulations. To sum up, strict environmental regulation is negatively related to energy consumption. As one of the most important production input factors in high carbon manufacturing, reducing the total energy is not conducive to improving export quality. However, to some extent, environmental regulation will promote enterprises to carry out technological R&D and innovation, improve the efficiency of energy utilization, and promote the coverage of export quality. Therefore, from the perspective of energy, the impact of environmental regulation on the export quality of high carbon manufacturing industry depends on the relationship between the reduction of the absolute total amount of energy and the improvement of energy utilization efficiency.

3.4. Green total factor productivity

According to the current academic research, we can find that there is a positive correlation between green total factor

productivity and export quality. This paper measures and analyzes the green total factor productivity of China's manufacturing industry, and as an important basis for predicting the impact of CBAM mechanism on it, it finds that the green total factor productivity of China's manufacturing industry has two characteristics from 2000 to 2019. First of all, from the perspective of the industry, the green total factor productivity of non-metallic mineral products manufacturing industry with weak technological progress is significantly backward, while the oil processing and manufacturing industry with high pollution and high emissions has significantly improved with the support of relevant national energy conservation and emission reduction policies. It can be seen that technological progress is the key link to improve industrial production efficiency in economic development. Secondly, from the perspective of time trend, the production efficiency of the manufacturing industry is still under constant exploration due to large fluctuations in each year. In the years when factor productivity was invalid, the level of technological progress was low. Therefore, high-tech investment is the source of improving the development quality of manufacturing industry. Based on the above calculation and analysis, it is preliminarily inferred that CBAM mechanism will play a positive role in the promotion of green total factor productivity of highly polluting manufacturing industry. The specific impact mechanism is as follows: CBAM mechanism takes into account carbon tariffs on export products, and domestic manufacturing industry is facing the pressure of emission reduction costs and transformation. Based on the above analysis, it is concluded that the key to improve the industrial comprehensive efficiency lies in the progress of technology and the efficiency of technology application. Therefore, in the long run, CBAM mechanism will force the transformation and upgrading of domestic manufacturing industry, improve green total factor productivity to a certain extent, and ultimately help improve the export quality of manufacturing industry.

4. Measurement and Analysis of Important Variables

4.1. Measurement and analysis of export quality status

With reference to Hausmann (2005) two-step method for measuring the complexity of export technology, this paper selects 42 countries whose total exports account for about 80% of the world's total exports and have complete trade data as sample countries, and calculates the complexity of export technology of industries initially covered by CBAM mechanism from 2001 to 2019, namely, petroleum processing and manufacturing, chemical raw materials and chemical products manufacturing, metal products manufacturing, non-metallic mineral products manufacturing. The export technology complexity of four high carbon emission manufacturing industries in non-metallic manufacturing industry. The export volume of products used and the total export volume of a country are derived from the data under the SITC Rec3.0 classification standard of the UN Comtrade database, and the per capita GDP is derived from the World Bank Open Data database of the World Bank. The specific formula is as follows:

$$PRODY_n = \sum_M \frac{\frac{x_{mn}}{X_m}}{\sum_M \frac{x_{mn}}{X_m}} \times Y_m \quad (1)$$

$$ESI = \sum_N \frac{x_{mn}}{X_m} \times PRODY_n \quad (2)$$

Where, m represents country, n represents product, $PRODY_n$ represents the export technical complexity of n products at the world level, X_{mn} represents the export of n products from country m , X_m is the total export of country m , Y_m is the per capita GDP of country m . ESI indicates the export technical complexity of an industry. The higher the value is, the higher the export quality of the industry is, and the lower the value.

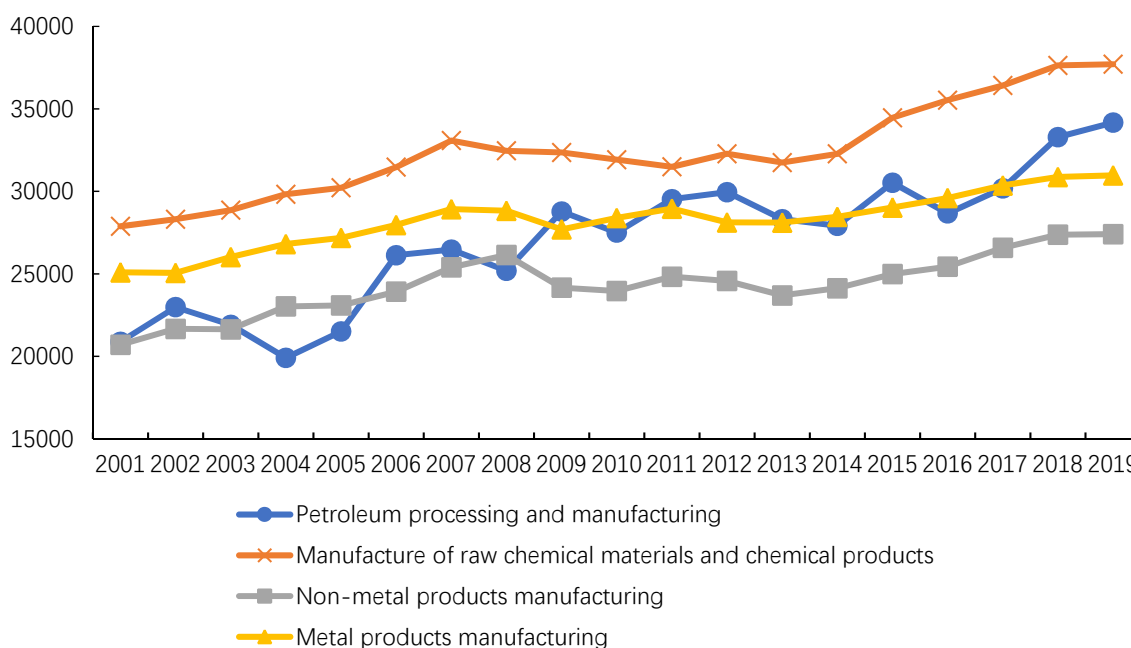


Figure 1. Changes in export technology complexity of manufacturing industry initially covered by CBAM mechanism

Figure 1 shows the changes in export technology complexity of petroleum processing and manufacturing

industry, chemical raw materials and chemical products manufacturing industry, metal products manufacturing

industry and non-metallic manufacturing industry from 2001 to 2019. It can be seen that the export quality of these four industries tends to increase on the whole, but the growth rate is different. Through calculation, it is found that the average growth rate of export technology complexity of petroleum processing and manufacturing industry from 2001 to 2019 was 3.08%, that of chemical raw materials and chemical products manufacturing industry was 1.72%, that of metal products manufacturing industry was 1.20%, and that of non-metallic manufacturing industry was 1.63%. Based on the absolute value of export technology complexity and the analysis of development growth rate in Figure 1, the export quality of petroleum processing products, chemical raw materials and chemical products is high, while the export quality of metal products and non-metallic products is low.

China's exports to the EU are mainly concentrated in mechanical and electrical products, textiles, metal products and chemicals. According to the industries covered by CBAM at the initial stage, China's petroleum processing and non-metallic manufacturing industries will be affected to some extent, but the metal products industry, chemical raw materials and chemical products industry will be more affected. The export quality of the industry is closely related to the resource endowment, technology level and capital investment used in product production, and technology factors play a crucial role in the process of improving export quality. While the export quality of the metal products industry is significantly lower than that of the chemical raw materials and chemical products industry, it can be preliminarily inferred that the technology investment and R&D investment of the metal products industry may be less,

the industrial development is more inclined to the extensive development model, and the carbon emissions of the industry are large. In the future, the impact of the European Union's carbon border adjustment mechanism (CBAM) will be greater than that of the chemical industry. In addition, according to the data of the National Bureau of Statistics, China's total steel output in 2021 will be 1.337 billion tons, and the export volume will be 66.9 million tons, accounting for 5% of the output, of which the export to the EU will account for 3.89%. Therefore, the future export situation of China's metal products will be more severe.

4.2. Measurement and analysis of green total factor productivity in manufacturing industry

Based on the DEA Malmquist index model, this paper calculates the green total factor productivity of the four manufacturing industries in China from 2001 to 2019 in an output oriented way, taking the fixed investment in assets, the average number of all employees and the total coal consumption as input variables, and the gross industrial output value of the industry as the expected output, Calculate the unexpected output according to the formula: unexpected output=(industrial pollution emissions gross industrial output value) * gross industrial output value of manufacturing industry. The data are from the website of the National Bureau of Statistics, China Statistical Yearbook, China Industrial Statistical Yearbook and China Environmental Statistical Yearbook.

Table 1. Green Total Factor Productivity of Manufacturing Industry under the CBAM Framework from 2000 to 2019

Industry	Petroleum processing	Chemical raw materials and chemicals	Metal	Non metal	Average value of tfpch
2001	1.11	1.30	0.96	0.99	1.091
2002	1.26	0.98	1.01	1.05	1.074
2003	1.30	1.23	1.35	0.97	1.211
2004	1.29	1.19	1.03	1.09	1.148
2005	0.90	0.78	1.07	0.69	0.859
2006	0.81	1.03	1.17	0.85	0.962
2007	1.15	1.07	1.24	1.06	1.13
2008	0.88	0.90	0.91	0.98	0.916
2009	1.19	0.97	0.91	1.01	1.022
2010	1.07	1.07	1.07	0.97	1.042
2011	1.09	1.15	1.42	1.12	1.192
2012	0.95	1.04	1.04	0.93	0.987
2014	0.78	0.88	1.00	0.58	0.808
2015	0.83	0.84	1.42	1.11	1.05
2016	0.99	0.98	1.38	1.01	1.088
2017	0.98	1.09	0.34	0.68	0.772
2019	2.45	1.10	1.02	1.08	1.412
Mean value	1.12	1.03	1.08	0.95	

As shown in Table 1, from the perspective of the manufacturing industry as a whole, the green total factor productivity of China's manufacturing industry represented by the above four industries was more than 1 between 2000 and 2019. From the perspective of industry segmentation, the petroleum processing and manufacturing industry has achieved an increase of 11.8%, mainly thanks to the introduction of the Outline of Medium and Long term Energy Development Plan (2004-2020) in 2004. The petroleum

processing and manufacturing industry seized the opportunity to accelerate the transformation and upgrading of the industry. However, the factor productivity of non-metallic manufacturing industry is relatively insufficient. From its decomposition value, the technological progress index is the most important factor, and the technological progress and innovation ability is the weak point of the industry development.

From the perspective of time series changes, green total

factor productivity has made progress in the period 2001-2019. From the perspective of breakdown items, it is mainly due to the 21.1% increase in technological progress, that is, the manufacturing industry has seized the opportunity of technological evolution and industrial development. At the same time, China has continued to implement pollution charge and other systems, and used the market to stimulate the manufacturing industry to carry out technological innovation, so as to promote the sustainable development of the manufacturing industry.

5. Empirical Regression Results and Model Test

5.1. Descriptive statistical analysis

This paper takes the export quality of the four industries

covered by the CBAM mechanism from 2001 to 2019 as the dependent variable, and the labor, energy, capital and green total factor productivity within the sample time range as the independent variable, and uses the panel model to analyze the relationship between the dependent variable and the independent variable. In terms of variable selection, export technology complexity is used to represent manufacturing export quality, capital stock is used to represent capital investment, average number of all employees in manufacturing is used to represent labor input, and total energy consumption in manufacturing is used to represent energy input. The capital stock, average number of employees and total energy consumption are from the Statistical Yearbook of China's Industrial Economy.

Table 2 shows the results of descriptive statistical analysis of model variables, listing the mean, standard deviation, minimum and maximum values of each variable.

Table 2. Descriptive Statistical Results of Variables

Variable	Mean	S.D.	Min	Max
Export technology complexity(Y)	27800.761	4025.371	19913.01	37706.395
Capital(lnK)	10791.624	10122.487	905.33	46575.62
Labor(lnL)	314.715	164.814	55.85	595.19
Energy(lnEC)	18844.547	14756.807	223.35	53972
Green total factor productivity(lnTFP)	1.045	0.256	0.338	2.452
Environmental regulation(lnEN)	24.668	21.598	0.382	78.712

5.2. Benchmark regression results

The four high carbon emission manufacturing industries covered under the CBAM framework are taken as individual individuals, and the relationship between environmental regulation and export quality is explored by building a model based on industry panel data from 2001 to 2019. The Chow test shows that the F statistic is 54.8374, which is greater than the critical value 2.7580. The LR test shows that the LR statistic is 89.731865, which is greater than the critical value 7.8147. It can be seen that the Chow test and the LR test reject the original hypothesis, and the model is a variable intercept

model. The Hausman test showed that the P value was less than 0.01, rejecting the original hypothesis, so the model was an individual fixed effect model.

$$\ln Q = c + \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln EC + \beta_4 \ln TFP + \beta_5 \ln EN + \varepsilon \quad (3)$$

Where, Q represents the quality of manufacturing exports, K represents capital investment, L represents labor input, EC represents energy input, TFP represents green total factor productivity, ε represents the random disturbance term, and the regression results are shown in Table 3.

Table 3. Results of benchmark regression

Variable	Individual fixed effect model
lnK	0.0813***
	[0.0159]
lnL	-0.0149
	[0.0788]
lnEC	0.0949***
	[0.0245]
lnTFP	0.0465
	[0.0273]
lnEN	-0.0549***
	[0.0155]
_cons	8.864***
	[0.2864]
N	68
adj.R-sq	0.7575
Number of industries	4

Note: *, **, *** respectively represent the significance level of passing 0.05, 0.01 and 0.001, and the brackets are standard errors.

It can be seen from Table 3 that for capital, it shows a significance of 0.001 level, and the regression coefficient value is $0.0813 > 0$, indicating that capital will have a

significant positive impact on export quality. However, capital has an impact on the export quality of enterprises through cost effect, innovation compensation effect and

improving the quality of FDI. Through the empirical results, it can be inferred that the positive impact of capital on innovation compensation effect and improving the quality effect of FDI in high carbon manufacturing exceeds the negative impact of cost efficiency. Therefore, under environmental regulations, high-quality investment in high carbon manufacturing will be increased to improve the export quality. For labor force, its regression coefficient is $-0.0149 < 0$, indicating that the impact of labor force on export quality is negatively correlated. Because there is no uniform standard for the division of skilled labor and unskilled labor, it is difficult to find the input of skilled labor, so this paper selects the number of all employees in manufacturing industry as the replacement variable of labor. However, the more the total labor input is, the more redundant labor input may exist under normal circumstances, that is, there are a large number of unskilled labor and less skilled labor, leading to a decline in the relative employment ratio of skilled labor and unskilled labor, which is not conducive to the improvement of export quality. However, under the pressure of environmental regulation, a series of national policies may be introduced in the future to adjust, guide the employees of high carbon manufacturing industry to gradually transfer to other industries, change the situation of redundant labor input, improve the relative employment ratio of skilled labor and unskilled labor, and improve production efficiency and export quality. For energy, it shows a significance of 0.001 level, and the regression coefficient value is $0.0949 > 0$, indicating that the total energy consumption will have a significant positive impact on export quality. And environmental regulation will lead to the reduction of energy input in high carbon

manufacturing industry. Therefore, from the perspective of energy, environmental regulation will lead to the decline of export quality to a certain extent. For green total factor productivity, there is no significant difference in the regression model, indicating that green total factor productivity has no impact on export quality. However, Shi Bingzhan, Shao Wenbo (2014), Fan Haichao and Guo Guangyuan (2015) all think that productivity is positively related to export quality. The reason for the difference in conclusions may be that there are fewer manufacturing industries selected in this paper, resulting in a certain error in calculating green total factor productivity. Environmental regulation takes the pollution emissions of the industry as a substitute variable, and the regression coefficient value of environmental regulation in the model is -0.0549 , which shows the significance of 0.001 level, indicating that the less pollution, that is, the greater the intensity of environmental regulation, the higher the export quality, and the environmental regulation will have a significant positive impact on export quality.

5.3. Heterogeneity test

It can be seen from the main regression model that capital investment has a significant role in improving the export quality of high carbon manufacturing industry, and will have an important impact on the utilization efficiency of human capital and energy and green total factor productivity. Therefore, capital investment is grouped to investigate the impact of environmental regulation on export quality under different capital inputs. The heterogeneity test results are shown in Table 4.

Table 4. Grouping Regression Results of Heterogeneity Test

Variable	group1 1	group1 2	group1 3
lnK	0.146* [0.0627]	0.141* [0.0589]	0.0417 [0.0212]
lnx2	-0.108 [0.1518]	0.0718 [0.2720]	0.0306 [0.1289]
lnx3	0.019 [0.0444]	-0.0109 [0.0614]	-0.00906 [0.0527]
lnx4	0.0237 [0.0715]	0.0615 [0.0669]	0.0298 [0.0286]
lnx5	-0.0368* [0.0479]	-0.0402* [0.0416]	-0.130*** [0.0311]
_cons	9.462*** [0.5739]	8.805*** [0.8657]	10.24*** [0.4690]
N	23	22	23
adj.R-sq	0.3711	0.2518	0.8358

Note: *, **, *** respectively represent the significance level of passing 0.05, 0.01 and 0.001, and the brackets are standard errors.

It can be seen from Table 4 that under different capital input groups, environmental regulation still plays a role in promoting export quality, and when the amount of capital input is large, the role of environmental regulation is more obvious. In addition, with the increase of capital investment, the impact of labor on export quality turns from negative to positive. This may be because the increase of investment can improve the quality of labor, that is, high carbon manufacturing industry may have more human capital, improve production processes and improve production efficiency. The impact of energy on export quality has changed from positive to negative, which may be due to the

improvement of energy utilization efficiency at a higher level of capital investment. Therefore, when the amount of energy input in the manufacturing industry is reduced in the future, the export quality can avoid a decline.

5.4. Robustness test

In order to test whether the results of the above main regression model are robust, that is, to verify the relationship and impact mechanism between environmental regulation and the export quality of high carbon emission manufacturing industry, this paper adopts the method of variable substitution for robustness test, and the test results are shown in Table 5.

Table 5. Regression Results of Robustness Test

Variable	Model1	Model2
lnK	0.0813***	0.417***
	[0.0159]	[0.1140]
lnL	-0.0149	0.341
	[0.0788]	[0.4274]
lnEC	0.0949***	0.329*
	[0.0245]	[0.1368]
lnTFP	0.0465	0.186
	[0.0273]	[0.2073]
lnEN	-0.0549***	-0.0691*
	[0.0155]	[0.0121]
_cons	8.864***	-1.424
	[0.2864]	[1.4872]
N	68	68
adj.R-sq	0.7575	0.8333
Number of industries	4	4

Note: *, **, *** respectively represent the significance level of passing 0.05, 0.01 and 0.001, and the brackets are standard errors.

With reference to Hausman's method, the main regression model calculates the export technology complexity of the manufacturing industry as a substitute variable for export quality. With reference to Feng Yuxia's (2013) research, it uses pollution emissions as a substitute variable for environmental regulation, and concludes that the smaller the pollution emissions, the stronger the role of environmental regulation, the higher the manufacturing industry's export quality. In the robustness test, the export delivery value of industrial enterprises in the four high carbon emission industries is used as a substitute dependent variable. When the export delivery value is larger, it indicates that the industry has a larger share in the international market, which can also be used as one of the criteria for judging export quality. The export delivery value is from the China Statistical Yearbook. On this basis, this paper adopts the individual fixed effect model for regression. It can be seen from Table 5 that, on the premise of changing the model dependent variables, the coefficient sign and significance of the core explanatory variable environmental regulation lnEN are basically consistent with the main regression model, and the effect of capital, energy, green total factor productivity on export quality is still positive, which shows that the main regression model in this paper has good robustness.

6. Conclusions and Suggestions

This paper calculates the export quality of the four manufacturing industries initially covered by the CBAM framework from 2001 to 2019, analyzes the changes in the export quality of China's major high carbon emission manufacturing industries in the past, and predicts the possible impact of the implementation of the CBAM mechanism on China's manufacturing exports in the future. On the basis of theoretical analysis, this paper makes an empirical analysis on the mechanism of environmental regulation affecting high carbon emission manufacturing industry, and draws the following conclusions:

First, there are differences in the export quality of the industries initially covered by CBAM. Based on the analysis of the absolute value and growth rate of export technology complexity, the export quality of the petroleum processing products manufacturing industry improved the most from

2001 to 2019, with higher export quality, followed by the chemical raw materials and chemical products manufacturing industry, and the export quality of the metal products manufacturing industry and non-metallic products manufacturing industry was relatively low. The metal products, chemical raw materials and chemical products manufacturing industry are the main export products of China to the EU. In the future, after the CBAM mechanism officially takes effect, it may exert great pressure on the export situation of the metal products manufacturing industry. Second, the green total factor productivity of the industries initially covered by CBAM fluctuates greatly. The main reasons for the decline of green total factor productivity in some years are the low value of technical efficiency and the instability of the industrial technology utilization efficiency. Therefore, technology is an important factor restricting the development of China's high carbon manufacturing industry and the improvement of export quality. Third, CBAM mechanism will affect the export quality of high carbon emission manufacturing industry from capital, labor, energy, green total factor productivity and other aspects. Through regression analysis, it is found that the total amount of labor input is negatively related to the export quality, while the total amount of capital input and energy input is positively related to the export quality. Under strict environmental regulations, the labor input in high carbon manufacturing will be reduced, the relative employment ratio of skilled labor and unskilled labor will be increased, high-quality capital will be directed to the technology R&D department of high carbon manufacturing, and the export quality of manufacturing will be improved. At the same time, environmental regulation will also lead to a decline in the absolute amount of energy input, which will hinder the improvement of export quality.

Based on the above conclusions, this paper puts forward the following suggestions to deal with the strict environmental regulation represented by the EU CBAM mechanism.

First, support technology research and development, improve energy utilization efficiency, improve export quality, and offset the negative impact of the reduction of total energy consumption. Environmental regulation restricts energy input, and the reduction of energy input will also affect the quality

of export products. Therefore, under the condition of environmental regulation, enterprises should actively carry out technological research and innovation, introduce advanced energy-saving and emission reduction technologies, increase the use of clean energy, research and upgrade production processes that minimize energy consumption, improve energy utilization efficiency, make the positive effect of improving energy utilization efficiency greater than the negative effect of reducing total energy, and effectively improve the quality of export products.

Second, increase capital investment and support the transformation and upgrading of high carbon industries. Under the environmental regulation, manufacturing enterprises need a lot of funds to carry out technological transformation and process upgrading. Therefore, they should increase capital investment, guide high-quality capital to flow to the technology research and development department of high carbon emission manufacturing industry, introduce advanced equipment, and at the same time, introduce high-quality human capital, improve the employment ratio of skilled and unskilled labor, and strengthen research and development and technological innovation, Support enterprises to continuously optimize production processes and transform and upgrade high carbon industries, so as to transform the production mode to low carbon, reduce pollution at the source, and improve export quality. Under the long-term strict environmental regulations, the high carbon manufacturing industry can obtain sustainable competitiveness in the international market only by upgrading as soon as possible.

Third, implement the industrial differentiation policy. Scientific optimization of the spatial layout of manufacturing industry, based on resource and location advantages, accelerate industrial transformation and upgrading, and achieve balanced and leapfrog development of industries. We should give priority to industries with large export volume, poor export quality and insufficient competitiveness to support their development. The metal manufacturing industry is one of the important industries that China exports to the EU, but its development is weak and is greatly affected by the CBAM mechanism. The government can provide necessary policy and financial support for metal manufacturing

enterprises to comprehensively improve the export quality from capital, labor, energy and other aspects.

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