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Analysis of the impact of China's manufacturing export trade on carbon emissions

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ABSTRACT

Since the Industrial Revolution, the emission of carbon dioxide and other greenhouse gases by human production activities has increased year by year, and the greenhouse effect has also increased. A series of problems, such as global warming, melting of the Antarctic continent, sea level rise and frequent occurrence of extreme climate, have attracted the attention of countries all over the world. As a developing country with the fastest economic growth rate, China's rapid economic growth is inseparable from the contribution of manufacturing industry. As an important engine of China's economic development, manufacturing industry inevitably brings environmental problems and a large number of greenhouse gas emissions while promoting rapid economic development. Therefore, manufacturing has become a major area for China to achieve its carbon emission reduction targets. With the "Made in China" to the world, the export trade of manufacturing industry plays a decisive role in China's total export trade and even the global trade. But whether the huge export demands will affect carbon emissions. Through the empirical study on carbon emissions of China's manufacturing export trade, the paper found that the increase of export demand of manufacturing industry will indeed bring a significant increase in carbon emissions, but also affected by some other factors. Finally, it provides reference for the high-quality development and export of China's manufacturing industry under the background of the target of “dual-carbon”.

KEYWORDS

Manufacturing; carbon emissions; Benchmark regression; export trade

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1. Introduction

In recent years, the global climate problem has become increasingly serious, especially the global warming is the most prominent problem. Various secondary disasters greatly interfere with human economic and social activities, and threaten the survival of human beings (Lee, Wang and Lou,2022). The increase of greenhouse gases is a major factor in global warming, and carbon dioxide is widely considered to be the main component of greenhouse gases. Therefore, solving the problem of carbon dioxide emissions has become an important problem for all countries to tackle climate change. At the same time, the World Bank report says there is no evidence that human society is able to adapt to a warming 4°C world. From the *Kyoto Protocol*, which limits greenhouse gas emissions from developed countries, to the *Copenhagen Accord*, which links carbon dioxide emissions to GDP, and to the *Paris Agreement*, which aims to control global temperatures, the climate problems are urgent and severe.

Since the reform and opening up, China's economy has developed rapidly, but also brought the continuous growth of energy consumption, which has caused huge environmental costs to the social development, making China became the world's largest carbon emitter (Zhou, Zhang and Qi, 2014). In September 2020, at the general debate of the 75th Session of the United Nations General Assembly, President Xi first made the “30,60” target for carbon emissions, that is, China's carbon dioxide emissions “strive to peak carbon emissions before 2030 and achieve carbon neutrality before 2060”. In the *2021 government work report*, it is proposed to “achieve carbon peak and carbon neutrality, promote green economic development, and formulate an action plan to peak carbon emissions before 2030”. For this reason, many scholars and experts are committed to studying China's carbon emissions, in order to provide policy references for China's carbon emissions reduction from different perspectives and in different directions. Among the many industries, the manufacturing industry is undoubtedly became the main field of research. Since China joined to the WTO in 2001, China has gradually become an important link in the global industrial chain division of labor, more and more integrated into the global value chain, focusing on the production and assembly fields, the trade mode has also changed to export-oriented processing trade, and Chinese manufacturing has begun to go global (Liu, Zong and Hynes, 2019).

With the continuous development of manufacturing exports and the increasing export volume, the carbon dioxide emissions in the manufacturing industry are also increasing. Manufacturing, the main source of China's economic growth, also accounts for a large share of China's energy consumption. Its carbon emissions account for a much higher share of total carbon emissions than in other industries (Lan, Sun and Pu, 2021; Jahanger et al., 2023). Through the research of micro subject-China's manufacturing enterprises found that the average carbon productivity level of China's manufacturing enterprises is still improving.

How to achieve the high-quality development of manufacturing industry and the reduction of carbon emissions are urgent problems to be solved in China to achieve the goal of “carbon peak” and “carbon neutral”. As “Made in China” can be seen everywhere today, the impact of China's manufacturing exports on carbon emissions has certain research significance. This paper explores the relationship between manufacturing export trade and carbon emissions, and the impact of manufacturing export trade on carbon emissions. At the same time, control variables are introduced to analyze the scale effect, FDI effect, technology effect and energy structure effect of manufacturing export trade on carbon emission. Strive to achieve the low-carbon development of manufacturing trade between economic development and environmental protection.

The rest of this paper is as follows: the second part briefly reviews the relevant literature on manufacturing and carbon emissions; the third part introduces the empirical model and variable selection of this paper; the fourth part analyzes the empirical results; and the fifth part draws the conclusions.

2. Literature review

As the main source industry of carbon emissions, manufacturing industry plays an important role in the governance of carbon emissions problem, so there is a large number of literature related to the research on carbon emissions of manufacturing industry. This paper combs the relevant literature from the following aspects.

2.1. The impact of manufacturing industry on carbon dioxide emissions

Avenyo and Tregenna (2022) through the study of the relationship between manufacturing technology intensity and carbon emissions in developing economies, it is found that in developing economies, medium-tech manufacturing has lower carbon dioxide emissions than low-tech manufacturing; Yang, Wang and Hou (2021) investigate the impact of economic growth on CO_2 emissions in the manufacturing sub-sectors and find that manufacturing growth has led to a significant increase in CO_2 emissions. Lin, Moubarak and Ouyang (2014) has reached a similar conclusion. Continuous growth of manufacturing sectors stimulated more energy demands, leading to a surge in CO_2 emissions; technological innovation in manufacturing sectors had an important positive effect on energy conservation and emissions reduction in manufacturing (Cheng, Shao, Gao et al. 2020). Today, with the increasing development of service industry, the servitization of manufacturing is mentioned more and more frequently. (Huang, Zhang, Xiang et al. 2022; Zong and Gu 2022) proposes to integrate service elements with manufacturing production, while comparing the impact of the servitization of manufacturing on carbon emissions in developed and developing countries. The former found that the effect of servitization in developed countries on reducing embodied carbon emissions was greater than in developing countries, while the latter found that the effect of servitization manufacturing industry was more obvious for countries with low economic development. Meanwhile, the larger the scale of manufacturing industry, the more obvious the effect of carbon emissions reduction. Tang, Zhu, Luo et al. (2022) from the perspective of input-output, it analyzes the impact of servitization on the carbon emissions of manufacturing industry, and believes that servitization is a feasible way to coordinate the high-quality economic development with the sustainability of resources and environment. Lan, Sun and Pu (2021) research the manufacturing agglomeration pattern on the influence of some provinces, they divided the agglomeration into specialized agglomeration and diversified agglomeration, found that the manufacturing professional agglomeration improved the manufacturing level of carbon emissions in the local area, on the other hand, the improvement of diversified agglomeration level can reduce the level of carbon emissions in the surrounding areas.

2.2. The impact of export trade on carbon dioxide emissions

Salman, Long, Dauda et al. (2019) through the study of the relationship between the import and export and carbon emissions of the seven ASEAN countries, it is found that the increase of exports will promote the carbon emissions of ASEAN countries, that is to say, it will increase the carbon emissions. The impact of imports on carbon dioxide emissions is not significant. Al-Mulali and Sheau-Ting (2014) through the study between import and export trade and energy consumption, carbon dioxide emissions in 189 countries in six regions found a long-term positive correlation between import and export trade and carbon dioxide emissions. Abokyi, Appiah-Konadu, Tangato et al. (2021) for a study of manufacturing in Ghana found that increased trade openness expanded the development of polluting industries in Ghana and increased CO_2 emissions.

3. Methodology and Data

3.1. Benchmark regression model

For the study of manufacturing export trade on China's carbon dioxide emissions, select manufacturing carbon dioxide emissions as the explanatory variable, manufacturing export trade as the core variables, this paper based on the research method of Zong Y et al. select the manufacturing scale, technology level, foreign direct investment as a control variable, build the basic model, to reduce the influence of the variance, log of variables (Zong and Gu, 2022). The measurement model is as follows:

$$lnCO_{2t} = \beta_0 + \beta_1 lnEX_t + \beta_2 lnSc + \beta_3 lnFDI + \beta_4 lnT + \beta_5 lnJ + u_t \tag{1}$$

Where CO_2 represents the CO_2 emission of manufacturing; EX represents the export trade of manufacturing; Sc represents the scale of manufacturing; FDI represents the level of foreign direct investment in manufacturing; T represents the technology level of manufacturing; J represents the energy consumption structure of manufacturing; u represents the random disturbance; t represents the year.

The export trade volume of manufacturing industry can reflect the foreign dependence of manufacturing industry. When goods are exported abroad, carbon emissions are often stay at home. According to the research results of Ghana, the improvement of trade openness expands the development of polluting industry in Ghana and increases the emission of CO_2 (Abokyi, Appiah-Konadu, Tangato et al., 2022). Therefore, exports are expected to be positively correlated with CO_2 emissions. In general, the larger the manufacturing industry consumes more energy, and the more CO_2. Zong and Gu (2022) through the research found that the increase in the size of manufacturing will also lead to the increase in carbon emissions, so the size of manufacturing is expected to be positively correlated with CO_2 emissions. As for the impact of foreign direct investment, there are two current views: the first is that foreign direct investment is biased towards developing countries with loose environmental regulation, that is, high pollution and high emission enterprises seeking “pollution shelters”; the second view is that foreign direct investment enterprises are high-tech enterprises with the purpose of seeking low-cost labor and transportation costs, and have technology spillover effect on developing countries. Therefore, the impact of FDI on CO_2 emissions should be judged according to the nature of foreign enterprises. Adom and Amuakwa-Mensah (2016) believe that the technology spillover effect of FDI can improve the energy efficiency of host enterprises, this view is also supported by the empirical results of Tang, Zhu, Luo et al. (2022), Wang, Wang and Ma (2022), where foreign investment has brought advanced clean technologies and more standardized and stricter production procedures, producing spillover effects that benefit the environment. At the same time, according to China's increasingly stringent market access system and environmental supervision, this paper expects the FDI level to have a positive impact on CO_2 emissions. As for technology, Zhou, Zhuo and Deng (2021) believe that the development of China's manufacturing industry is accompanied by energy consumption, serious environmental pollution, insufficient innovation and other problems, and technological innovation is the main way to achieve energy conservation and emissions reduction. Therefore, the higher the technical level, the stronger the energy saving and emission reduction ability, Lee and Zhang (2012) also found that improving technical efficiency can reduce the cost of carbon dioxide emission’s reduction through the empirical analysis, so as to play a role in reducing CO_2 emissions, and technological innovation has a significant positive impact on the high quality of the manufacturing industry. The development of the manufacturing industry has a high energy demand, and the development of China's manufacturing industry is based on a large amount of coal consumption. By researching the degree of influence of coal consumption and energy structure on carbon emissions, Jiang and Sun (2023) found that in the long term, coal consumption plays a decisive role in reducing carbon emissions. Therefore, this paper expects that coal energy consumption will be positively correlated with CO_2 emissions of manufacturing industry.

3.2. Date description and source

3.2.1. The emission of CO_2

Carbon dioxide emissions are calculated according to the guidelines issued by the Intergovernmental Panel on Climate Change (IPCC), and the difference between different literature using this method is the selection of final energy consumption types. Since the carbon dioxide generated by the combustion of fossil fuels accounts for about 90% of the total carbon dioxide emissions, this paper divides the final fossil energy consumption into coal, natural gas, coke, fuel oil, gasoline, kerosene, crude oil and diesel oil according to *the Yearbook of China Energy and Statistics.* According to the carbon emission coefficient method, and using the measurement method of other scholars, to calculate the carbon dioxide emissions of China's manufacturing industry (Wang, Yan, Ma et al., 2018; Hang, Wang, Zhou et al., 2019). The formula is as follows:

$$CO_2 = \Sigma E_i \times w_i \tag{2}$$

Where i is the type of energy, E_i represents the consumption of i energy, w_i represents CO_2 emission coefficient of i energy.

Energy consumption is consist of three parts: the terminal energy consumption, energy processing conversion loss and loss, but due to the terminal energy consumption is the largest proportion in the total energy consumption, and energy processing conversion loss and loss exist the data availability problem, so this paper mainly select terminal energy consumption to measure China's manufacturing energy consumption.

The emission of CO_2 per unit of energy depends on the carbon content and oxidation rate of the fuel. Therefore, the CO_2 emissions coefficient is calculated as follows:

$$W_i = NVC_i \times CC_i \times COF_i \times \frac{44}{12} \tag{3}$$

In the combustion process of fossil fuels, the molecular weight of carbon changes from 12 to 44, so the conversion coefficient of 44 / 12 is required to obtain the CO_2 emission coefficient.

3.2.2. Source and descriptive statistics

CO_2 Emissions: The energy consumption of the manufacturing industry is from *the China Energy Statistical Yearbook* over the years, COF_i and CC_i are from *the Provincial Greenhouse Gas Inventory Compilation Guidelines* of the Climate Change Department of the National Development and Reform Commission, and NVC_i is from *the China Energy Statistical Yearbook*.

EX: Manufacturing exports come from the UN Comtrade. Manufacturing, in category 5, 6, 7, 8 by SITC classification standards. 5: Chemicals. 6: Manufacture goods classified chiefly by material. 7: Machinery and transport equipment. 8: Miscellaneous manufactured articles.

Sc: The larger the scale of manufacturing industry, the larger the proportion of exports may be. This paper uses the main business income of industrial enterprises above the size to measure the scale of manufacturing industry. Data are from *the China Statistical Yearbook.*

FDI: The FDI level is measured by foreign capital in large and medium-sized manufacturing enterprises. Data are from *the China Industrial Statistical Yearbook*, due to the lack of data in 2004, 2017 and 2018, the mean method is adopted for completion.

T: The technical level of manufacturing enterprises is measured by the internal expenditure of R&D funds of manufacturing enterprises. Data are from *the China Statistical Yearbook of Science and Technology.*

J: The coal consumption of manufacturing industry is used to measure the structure of energy consumption in manufacturing industry. Data are from *the China Energy Statistical Yearbook.*

Descriptive statistics for each variable are shown in Table 1.

Table 1. Descriptive Statistics.

Variables	Obs	Mean	Std.Dev.	Min	Max
LnCO2	20	9.231149	0.744231	7.998113	10.41297
LnEX	20	7.108169	0.732657	5.477200	7.802100
LnSc	20	13.18281	0.846460	11.44821	13.96307
LnFDI	20	9.589890	0.561563	8.341644	10.07795
LnT	20	8.759073	1.011981	6.949377	10.10206
LnJ	20	11.62788	0.434557	10.75193	12.09780

As can be seen from Fig.1, during the 20 years from 2001 to 2020, CO_2 emission of China's manufacturing industry showed the following two characteristics: (1) it showed an overall upward trend, from 29.75337 million tons in 2001 to 332.88704 million tons in 2020. (2) The change of CO_2 emissions during this period can be roughly divided into two parts: from 2001 to 2014, the CO_2 emissions from 29.75337 million tons in 2001 to 175.39211 million tons in 2014, an increase of about 489.5% and an average annual growth rate is 34.96%. After a short decline from 2014 to 2015, the growth rate began to slow down in 2015, from 161.78292 tons to 33,288704 tons in 2020, an increase of about 105.8%. The average annual growth rate is 21.16%. It was a big decrease from the previous stage.

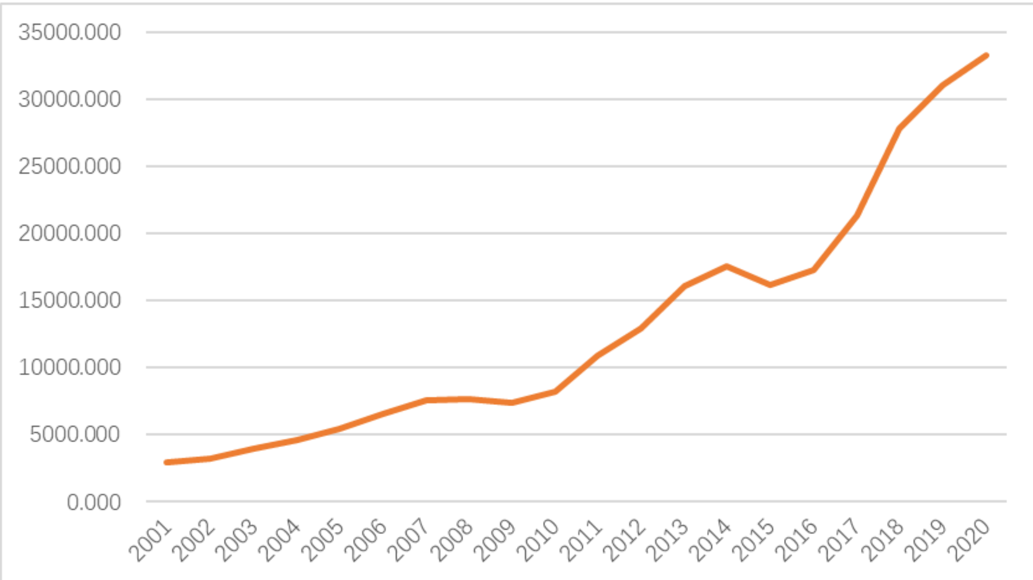

Figure 1. The CO_2 emission of manufacturing industry.

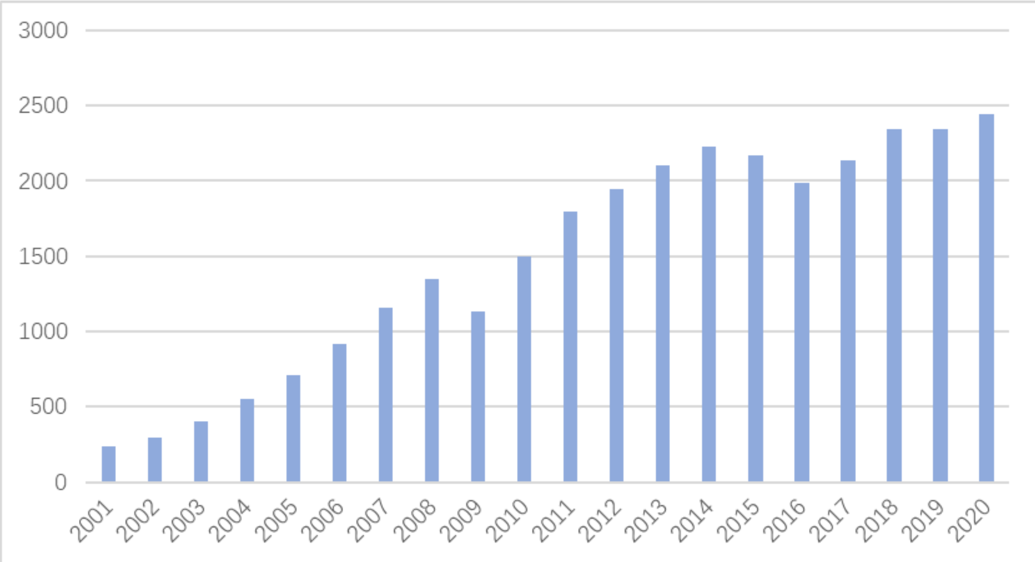

Figure 2. The trade volume of manufacturing export.

As can be seen from Fig.2, since China's accession to the WTO, China's manufacturing export trade has shown a growing trend, increasing from ＄239.176 billion in 2001 to ＄2445.7326 billion in 2020. During this period, there was a significant decline in 2008-2009 and 2015-2017. Perhaps due to the impact of the global financial crisis, exports were blocked, but the overall trend was increasing, the growth trend slowed down after 2014, and compared with the previous 14 years, the growth rate remained stable.

4. Empirical results and analysis

4.1. Results of unit root test

For the time series model, most of the economic time series are non-stationary, and regression the non-stationary time series as the stationary time series will cause the pseudo-regression problem. To avoid the pseudo-regression problem, the unit root test of the time series is required. We examined the robustness of the variables with the ADF test. According to the model in Section Three, in order to reduce the heteroscedasticity, the “ln” form of the variables is selected as the main research variables of the model, so it is necessary to test whether each variable is stable at the original sequence level. If it is not stable, the variables need to be treated differently, and test the robustness of the first order difference sequence and the second order difference sequence successively. Generally, the highest order does not exceed the second order.

Table 2. The result of Fisher-ADF unit root test.

Variables	Fisher-ADF
	At level
$LnCO_2$	-4.436428**(0.0150)
LnEX	-4.350262***(0.0034)
LnSc	-3.532841**(0.0185)
LnFDI	-5.774857***(0.0002)
LnT	-3.406784**(0.0256)
LnJ	-3.042277**(0.0488)

*Notes: p-values are in parenthesis; ***, **, * denote statistical significance at the 1%, 5%, 10% level.*

According to the test results of ADF, ln CO_2, lnSc, lnT, and lnJ are stable at 5% significance level, while lnEX, lnFDI are stable at 1% significance level, so the original sequence of each variable is stable at the level, and the pseudo-regression problem can be avoided in the empirical results.

4.2. Benchmark regression results.

The OLS was used to perform an empirical analysis of the model in the Section 3. Each control variable was added to the model one by one, and the results are shown in Table 3.

From Table 3, the model was overall significant, except the variables of lnFDI and lnJ are significant at the 5% level, all of the other variables were significant at the 1% level. In addition, regarding the sequence correlation and heteroscedasticity of the model, no sequence correlation and heteroscedasticity were found according to the LM test and the White test.

Table 3. The result of OLS.

Variables	(1)	(2)	(3)	(4)
Constant	2.536586***	0.802762	10.89075***	7.538535***
	(0.640822)	(3.047348)	(1.047440)	(1.657528)
LnEX	0.941813***	0.548318	1.164101***	1.106838***
	(0.089701)	(0.681696)	(0.207365)	(0.181775)
LnSc		0.343694	-0.891283***	-1.241952***
		(0.590044)	(0.186934)	(0.217698)
LnFDI			-0.753012***	-0.628019**
			(0.241180)	(0.215888)
LnT			1.031694***	1.036171***
			(0.074930)	(0.065151)
LnJ				0.614401**
				(0.253872)
Obs.	20	20	20	20
R^2	0.859636	0.862382	0.906178	0.995150
Adjusted R^2	0.851838	0.846192	0.888587	0.993418
F Statistic	110.2378***	53.26538***	51.51198***	357.2199***

*Notes: Standard errors are in parenthesis; ***, **, * denote statistical significance at the 1%, 5%, 10% level.*

Table 4. The result of LM test and White test.

	obs R-squared	p-value
LM test	5.156221	0.0759
White test	3.745151	0.5867

(1) In terms of manufacturing exports. According to Table 3, regardless of the control variable, export trade can show a significant positive correlation with CO_2 emissions at 1%, indicating that the increase in manufacturing exports results in increased manufacturing CO_2 emissions, this is consistent with our previous expectations.

(2) In terms of the size of manufacturing enterprises, Sc has a significant negative correlation for CO_2 emissions at the 1% level, indicating that the expansion of the size of manufacturing enterprises significantly reduces the emission of CO_2, which is contrary to our previous expected results. The possible reason lies in the economy of scale brought by the expansion of enterprise scale, which reduces the unit product cost of enterprises, invests more capital into production technology innovation, so as to improve the efficiency of energy utilization and the ability to deal with risks, and reduce the emission of CO_2.

(3) In terms of manufacturing FDI, the FDI showed a significant negative correlation for CO_2 emissions at the 5% level, indicating that the increase in FDI will bring about a reduction in manufacturing CO_2 emissions, which is also consistent with what we expected before. Here we need to mention the "pollution halo" hypothesis, contrary

to the familiar "pollution paradise" hypothesis, the "pollution halo" hypothesis refers to the FDI, foreign-invested enterprises in developed countries due to strict environmental supervision in the home country, thus forming a complete and strict production management system and environmental protection concept. When it invests in the host country's factories, it will have a positive impact on the environmental protection of the host country through technology spillover and knowledge diffusion. The inflow of foreign capital through market access has higher production technology and process process, to a certain extent, promote China's domestic manufacturing enterprises to learn advanced technology, improve production efficiency, reduce carbon emissions in the production process, and even replace some backward enterprises with high pollution and high emissions, so as to improve China's environmental quality.

(4) In terms of the technical level of manufacturing enterprises, T showed a significant positive correlation with CO_2 emissions at the level of 1%, indicating that the internal expenditure of R&D funds is positively correlated with the CO_2 emission of manufacturing enterprises, and also contrary to the previous expectations. The possible reason is limited by the availability of data, this paper choose the enterprise R&D funds internal spending to measure technology level, but the utilization of R&D funds, and the R&D funds whether used for the related technology research and development of energy conservation and emissions reduction or not, it depends on the enterprises. Maybe the R&D founds put into the field of emissions is limited, but more money are put into the production field, so that it failed to achieve the effect of emissions reduction, but stimulate the CO_2 emissions.

(5) Regarding the energy consumption structure, J showed a significant positive correlation with CO_2 emissions at the 5% level. This shows that the higher the coal consumption, the CO_2 emissions will increase significantly. This is consistent with our expected direction of the effect.

4.3. Robustness test

In order to test the robustness of the empirical study result, this paper replaced the core explanatory variable to repeated the model regression analysis, and the manufacturing export trade dependence (X) replaced the export trade volume (EX), and the other control variables remained unchanged to verify the impact of export trade dependence on carbon emissions. The results of the resulting robustness regression analysis are shown in Table Table 5.

Table 5. Manufacturing export trade for carbon emissions robust test.

Variables	
Constant	6.898205***
	(1.881918)
LnX	0.803511***
	(0.162736)
LnSc	-0.914030***
	(0.248985)
LnFDI	-0.543558**
	(0.245136)
LnT	1.610577***
	(0.124094)
LnJ	0.575607*
	(0.294422)
Obs.	20
R^2	0.993545
Adjusted R^2	0.991240
F Statistic	430.9918***

*Notes: Standard errors are in parenthesis; ***, **, * denote statistical significance at the 1%, 5%, 10% level.*

As can be seen from Table 5, the increase of manufacturing export trade dependence will increase the emission of manufacturing CO_2, and the coefficient symbol is consistent with Table 3. The model after replacing the core explanatory variable is still significant on the whole, and the other explanatory variables did not change significantly except the variable of coal consumption, so the empirical research result are robust on the whole.

5. Conclusions

With the proposal of “Made in China 2025”, higher requirements are put forward for China's manufacturing industry. This paper studies the manufacturing CO_2 emissions by taking the manufacturing export volume as the core explanatory variable, and at the same time, it adds the control variables such as manufacturing scale, foreign direct investment level, technology and coal energy consumption. Finally, through the empirical analysis, it is found that the manufacturing export trade volume, technology level and coal energy consumption can promote the CO_2 emission of the manufacturing industry, but the scale of the manufacturing industry and the level of foreign direct investment have a restraining effect on the CO_2 emissions. According to the results, the following suggestions are proposed for the development of China's manufacturing industry:

(1) Export trade: A large amount of export demand exports goods abroad, but leaving CO_2 at home, which depends on China's manufacturing export trade structure in some extent. China's manufacturing industry is moving closer to the upper of the global value chain, moving to China's “intelligent manufacturing” development. Sun, Li, Ma et al. (2019) divide the manufacturing industry into three categories: labor-intensive, resource-intensive and technology-intensive. It is founded that improving the position of technology-intensive manufacturing in the global value chain has a more significant impact on CO_2 emissions reduction. Therefore, improving the position of export manufacturing products in the global value chain have a great significance to China's domestic CO_2 emissions reduction.

(2) Scale of manufacturing industry: Economy of scale also plays a positive role in the carbon emissions reduction of manufacturing industry. Although the expansion of scale will inevitably lead to the increase of energy consumption, the reduction of unit cost and the improvement of technical level can not be ignored. The larger enterprises need to have a greater sense of social responsibility, and the stronger the state will supervise them, which will play a positive role in CO_2 emissions reduction under the combined actions of internal and external factors.

(3) FDI: At the current stage of development, investment is still an important factor in economic development in our country, under the increasingly strict environmental regulation, the spillover effect of foreign direct investment on the environment technology is larger than the pollution effect. Therefore, at the same time of opening wider to the outside, the strict market access standards for foreign investment and pollution audit mechanism for China's environmental protection is very necessary.

(4) Technical level: There is no doubt that the improvement of technology level is the key to the manufacturing industry from “manufacturing” to “intelligent manufacturing” in China. However, the amount of investment in R&D funds can not really represent the level of technology, whether the R&D funds are really transformed into technological achievements? And whether the technological achievements are effectively applied to the production process? These are also indispensable links.

(5) Coal resource consumption: As we all known the combustion of fossil fuels is the main channel of the source of greenhouse gases, which is given priority to the coal. China as a big country of coal energy user, the application of coal is very wide, especially in manufacturing, so looking for alternative clean energy, reducing the use of coal for manufacturing carbon reduction are very important.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

Author contributions

Yujing Wang: Conceptualization, Writing, Drafting-original draft. Xiaoyi Fu: Data collection, Empirical estimations. Yu Teng: Writing-review, Editing.

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