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Pollution Emission Intensity and Domestic Value-Added Rate of Firms' Exports: An Empirical Analysis Based on China's Microdata

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Abstract

With the development of global economic integration, global value chains (GVC) have become the mainstay of the global economy. China's low-end embedded model relying on its labor advantage can no longer bring new economic benefits, and the ensuing environmental problems are intensifying. Therefore, there is an urgent need to explore a win-win path for the greening of China's economy and the improvement of GVC status. Using micro-firm data, the article explores the role of pollution emission intensity of China's firms in influencing the domestic value-added rate of their exports. The study finds that (1) the increase of pollution emission intensity of Chinese enterprises has a significant inhibiting effect on their export domestic value-added rate; (2) the pollution emission intensity of Chinese enterprises under different regions, different ownership and different trading methods has differentiated effects on their export domestic value-added rate. Among them, the pollution emission intensity of state-owned enterprises, enterprises in western regions and processing trade enterprises have a more significant inhibitory effect on the domestic value-added rate of their exports; (3) the increase of total factor productivity of enterprises can slow down the negative effect of enterprise pollution emission intensity on the domestic value-added rate of its export.

Keywords: Enterprise Pollution Emission Intensity, Export Domestic Value-Added Rate, Global Value Chain Embeddedness.

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1. Introduction

With the continuous development of the economy in recent years, the production process of manufacturing has gradually become global, and the global value chain (GVC) has become the mainstay of the global economy. After China's reform and opening up, it has actively participated in the division of labor in GVC by taking advantage of its indigenous natural resources and the comparative advantage of labor in a populous country. Relying on industrial and manufacturing production progress and expanding trade, China's embeddedness in GVC has been deepening. As the world's largest factory and trading country, China has achieved rapid growth of industry and manufacturing, thus driving the overall growth of the country's economy. China has reaped the benefits of rapid economic growth brought about by its deep integration into GVCs. However, as China gradually deepens its participation in the global value chain, the low-end embedded model of labor advantage is no longer able to bring about new economic development. Due to the accelerated consumption of natural resources, China has undertaken the transfer of high-polluting and high-energy-consuming industries and production chains from developed countries. The domestic environment has suffered serious deterioration and environmental problems have become increasingly serious (Humphrey and Schmitz, 2002). According to the national total pollution emission statistics in 2015, the emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X) and smoke (dust) generated by the industrial sector accounted for 83.73 %, 63.79 % and 80.14 % respectively. These have serious negative impacts on the natural environment, and the green sustainable development of the economy is also an issue that today's society needs to pay more attention to. Therefore, there is an urgent need to explore the win-win path between the green development of China's economy and the climb of its GVC status, and to start building China's green global value chain system.

Industrial enterprises are not only micro entities embedded in the global value chain, but also key emitters of pollutants. Current research by domestic and foreign scholars focuses mostly on the macro national and industry levels, and there are still gaps in the micro enterprise level. Therefore, exploring the impact of enterprises' pollutant emission intensity on the domestic value-added rate of exports can not only strengthen the understanding of environmental issues in China’s economy from the theoretical level, but also add new research perspectives. Furthermore, it has important practical significance for the green transformation and upgrading of enterprises, the sustainable development of China's future economy, and the construction of China's green global value chain system. This paper starts from the micro-enterprise perspective, measuring the pollution emission intensity and export domestic value-added rate of Chinese enterprises using the database of industrial enterprises and customs enterprise data from 2000 to 2013. The study of pollution emission intensity and export domestic value-added rate is also about embedding in the global value chain. Exploring its internal influence mechanisms and heterogeneity issues can enrich the current research on the linkage between environmental and economic issues in China.

2. Literature review

The environmental problems brought about by economic development have always attracted the attention of economists, and pollution emissions are an important part of environmental problems that cannot be ignored. Most of the existing research focuses on studying the influencing factors that cause pollution problems, and most of the issues are discussed from the macro level of the country or industry. Cherniwchan (2017) explored the relationship between NAFTA and environmental pollution from the perspective of trade liberalization. The study found that trade liberalization after the signing of NAFTA reduced particulate matter and sulfur dioxide emissions from affected factories. This is due to increased access to the Mexican market and increased opportunities to import intermediate inputs from Mexico. There are relatively few articles that study the causes of pollution problems from an enterprise perspective. Zhang et al. (2023) started from the micro perspective of enterprises and concluded that a clean production environment can reduce the intensity of enterprise pollutant emissions. At the same time, some scholars are focusing on exploring ways and methods to reduce pollution and emissions. Barrows and Ollivier (2021) found that even if foreign demand increases emissions through scale effects, exporting to foreign countries can reduce the emission intensity of enterprise production in developing countries. At the same time, endogenous production technology can also reduce corporate pollution emissions and improve corporate environmental performance. Other studies have shown that lowering trade barriers also has a significant inhibitory effect on corporate sulfur dioxide emission intensity (Forslid et al., 2018).

In the context of global production division of labor, the domestic value-added rate of an enterprise's exports is one of the indicators to measure the enterprise's embeddedness in the global value chain. Existing literature mostly focuses on exploring the influencing factors of enterprises' embedding in global value chains and related import and export issues. The research of Dosi et al. (2015) was carried out from the perspective of technological level. Their research showed that the increasing technological level gap between countries will inhibit the improvement of domestic value-added rate of enterprises. In recent years, with the vigorous development of the current digital economy, some scholars have proven that investment in the digital economy can significantly promote the growth of the domestic value-added rate of manufacturing exports. In particular, the domestic value-added rate of exports of intermediate products will have a more obvious effect. promotion effect (Ding et al., 2021). Research by Wu et al. (2021) shows that changes in trade policy will have a positive impact on the domestic value-added rate of enterprises. The policy reform reduces the effective VAT rate of affected enterprises by increasing the deduction for fixed asset purchases, thereby significantly Increased the value-added rate of domestic exports of enterprises. Lu et al. (2022) found through research that foreign direct investment will have a negative impact on the domestic value-added rate of enterprises' exports. Using corporate innovation to measure the company's ability to capture value can play a significant role in the impact of foreign direct investment on DVAR. the regulating effect.

Current research on global value chain embedding and environment-related issues is carried out at the meso-industry level and the micro-enterprise level. The discussion of environmental issues can be roughly divided into two aspects: carbon emission issues and pollution emission issues. Chen et al. (2022) explored the impact of embedding in global value chains on carbon emissions from a Chinese perspective, and found that increasing the length of the forward production chain and improving the location index of the global value chain in the forward embedding model of the global value chain will help It is used to reduce the carbon emissions of a country's export products, and there is a significant difference between the forward embedding model and the backward embedding model. Research by Liu and Zhao (2021) shows that global value chain participation has a significant negative impact on embodied carbon emission intensity, and compared with developed countries, global value chain participation in developing countries has a negative impact on embodied carbon emission intensity. The impact is greater. Chen et al. (2021) found that the embeddedness of enterprises in the global environmental value chain will reduce the production efficiency of enterprises, and there are significant differences in the changes in production efficiency of enterprises with different profitability in the global environmental value chain. To achieve positive returns, Firm embeddedness can increase production efficiency, while firms achieving negative returns will reduce productivity. Wu et al. (2024) found that the embeddedness of enterprises in global value chains is conducive to reducing enterprises' sulfur dioxide emissions, and they found that scale effect and technology effect are the main mechanisms by which global value chain embeddedness affects enterprises' sulfur dioxide emissions. Some scholars have shown that as developing countries face severe environmental degradation, the effectiveness of environmental regulations can alleviate the harm and pressure caused by pollution problems to the economy to a certain extent. The establishment of a country's cleaner production standards can increase the export added value of domestic enterprises. rate (Sun, 2023). The study by Zhan et al. (2023) further found that the relationship between cleaner production standards and the domestic value-added rate of enterprises' exports is affected by the pollution level. The heavier the pollution level, the more positive the positive effect of cleaner production standards on the domestic value-added rate of enterprises' exports will be weakened. effect. Based on the above research, it can be seen that, first, current scholars have done a lot of research on the issue of pollution emissions and global value chain embedding from a macro perspective, but there are still some gaps in the exploration of the micro level of enterprises; second, in terms of environmental issues and global value chains, Regarding the issue of embedded correlation, most research perspectives focus on the industry's embedded position in the global value chain and its forward and backward connections. Few articles conduct research from the perspective of the domestic value-added rate of exports of enterprises. Therefore, this article uses the green development database, industrial enterprise database, and customs enterprise database to conduct matching and data analysis based on the micro perspective of enterprises. This article measures the company's embeddedness in the global value chain through the export domestic value-added rate, thereby exploring the issues of pollution emissions and embeddedness in the global value chain. And adding trade issues to the heterogeneity analysis perspective expands a new perspective in the field of pollutant emission intensity research.

3. Indicator Measurement and Typical Facts

3.1 The Measurement and situation analysis of Domestic value-added rate

This paper is based on the theory and calculation methods of Kee and Tang (2016) to derive and measure the expression of corporate exports from the micro-enterprise level. At the same time, this paper uses the China Industrial Enterprise Database and the China Customs Database to match based on enterprise codes. Taking the enterprise data from 2000 to 2013 as the research sample, based on the definition of the domestic value-added rate (*DVAR*) of Chinese enterprises' exports by Gao Xiang et al. (2018) and the data processing method of Zhang et al. (2013). The *DVAR* data of Chinese enterprises' export domestic value-added rate was measured.

Firstly, the firm's domestic value-added from exports (DVA_{ijt}) is defined as shown in equation (1).

$$DVA_{ijt} = \left(exp_{ijt}^{o} + exp_{ijt}^{p}\right) - \frac{\left(exp_{ijt}^{o}+exp_{ijt}^{p}\right)}{Y_{ijt}}\left(imp_{ijt}^{o} + imp_{ijt}^{p}\right) \tag{1}$$

Secondly, the expression of the firm's export domestic value-added rate ($DVAR_{ijt}$) is shown in equation (2).

$$DVAR_{ijt} = \frac{DVA_{ijt}}{exp_{ijt}} = 1 - \frac{\left(imp_{ijt}^{o}+imp_{ijt}^{p}\right)}{Y_{ijt}} \tag{2}$$

In the subscript of equation (2), *i*, *j* and *t* represent enterprise, industry and year respectively. The *o* and *p* in the superscripts represent enterprises engaged in general trade activities and enterprises engaged in processing trade activities. exp_{ijt} is used to represent the total export volume of company *i*, and imp_{ijt} is used to represent the import of intermediate goods of company *i*. Y_{ijt} represents the gross industrial output value of the enterprise.

Finally, in this paper, the data are reprocessed to identify the classification of different enterprises and adjust the coefficients to ensure the accuracy of the calculation results. The final expression is shown in equation (3).

$$DVAR_{ijt} = \begin{cases} 1 - \dfrac{imp_{ijt}^{o\_adj\_BEC}}{Y_{ijt}^{o}} - \sigma_{Kijt} - \sigma_{Mijt} & i \in o \\ 1 - \dfrac{imp_{ijt}^{p\_adj}}{Y_{ijt}^{p}} - \sigma_{Kijt} - \sigma_{Mijt} & i \in p \\ \zeta_o\left(1 - \dfrac{imp_{ijt}^{o_{adj_{BEC}}}}{Y_{ijt}^{o}}\right) + \zeta_p\left(1 - \dfrac{imp_{ijt}^{p_{adj}}}{Y_{ijt}^{p}}\right) - \sigma_{Kijt} - \sigma_{Mijt} & i \in m \end{cases} \tag{3}$$

Among them, *o*, *p* and *m* represent general trading enterprises, processing trade enterprises and mixed trading enterprises. The export share of general trade and the export share of processing trade in mixed trade enterprises are denoted by ζ_o and ζ_p respectively. In order to facilitate calculation, this paper does not consider the domestic return coefficient (σ_{Djt}) and the coefficient of double counting (σ_{Pjt}) calculated in the article of Gao et al. (2018). Finally, drawing on Kee and Tang (2016) approach, this paper also excludes the sample of firms with *DVAR* less than 0 or greater than 1.

As shown in Figure 1, the overall fluctuating upward trend in the domestic value-added ratio of enterprises' exports over the period 2000-2013 increased from 75.24 % in 2000 to 86.50 % in 2013. In 2003, the export domestic value-added rate of enterprises decreased. The reason for this is that China's accession to the WTO caused a negative impact on the price of domestic intermediate goods, which caused a downward fluctuation in the value-added rate. The upward trend after 2004, on the other hand, is due to the increasing proportion of domestic raw materials and services used as a result of the increase in China's processing and export production.

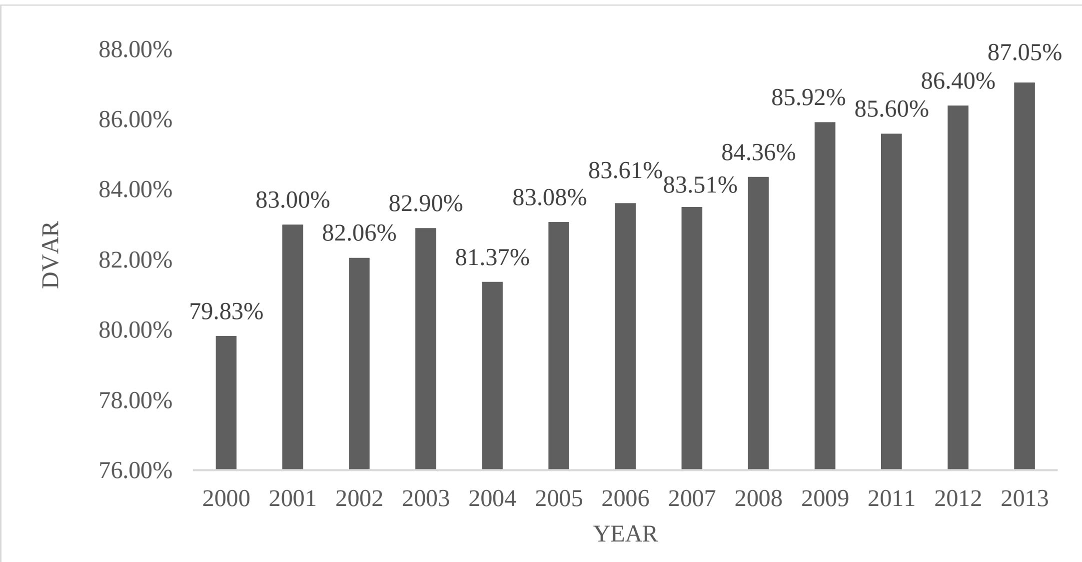

Figure 1: The changes in DVAR of exports from 2000 to 2013

From the overall situation shown in Figure 2, the export domestic value-added rate of enterprises in general trade is overall higher than that of processing trade and other enterprises. Among them, the overall domestic value-added rate of exports of enterprises in general trade showed a relatively stable trend, growing from 86.59 % in 2000 to 89.70 % in 2013, an increase of 3.11 %. The growth in the domestic value-added rate of exports of enterprises in processing trade and others was more volatile, rising from 68.35 % in 2000 to 79.63 % in 2013, an increase of 11.28 percentage points.

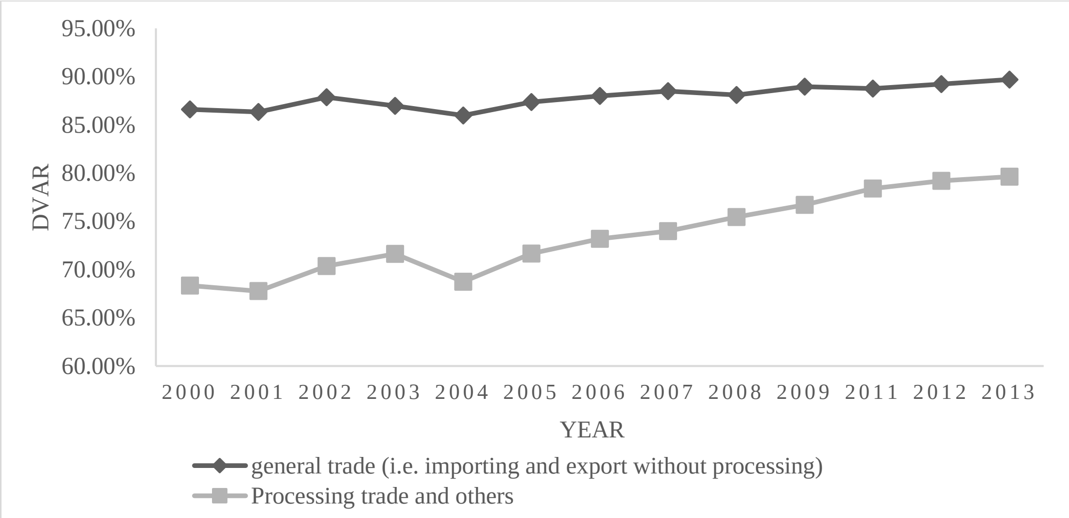

Figure 2: The DVAR of exports based on different modes of trade

As shown in Figure 3, the domestic value-added rate of exports of enterprises in the eastern region is lower compared with that in the central and western regions. However, its growth trend is more significant, increasing from 74.35 % in 2000 to 86.17 % in 2013, an increase of 11.82 %. The overall trend in the central region has developed more gently, showing slow growth since 2004, except for a slight decline in 2003. The western region, which saw two small peaks in 2003 and 2009, had a smoother overall trend and also showed slow growth.

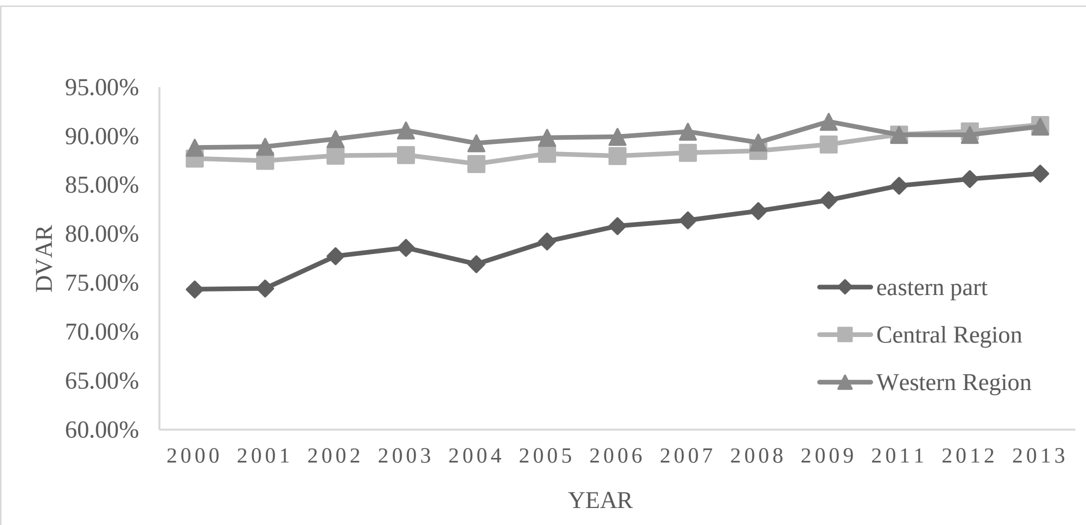

Figure 3: The DVAR of exports in different regions

3.2 The Measurement and situation analysis of pollution emission intensity indicators

This paper draws on the concept of using pollutant emissions per unit of gross industrial output value to express the pollutant emission intensity index *IEII* (Industrial emissions intensity index) first proposed by Wang et al. (2017). The calculation method is shown in equation (4).

$$IEII = \frac{value\ of\ pollutant\ emissions}{the\ gross\ industrial\ output} \tag{4}$$

Meanwhile, this paper draws on Jiang et al. (2014) used the sulfur dioxide emission intensity as the measure of pollution emission intensity. The main form of environmental pollution in China is air pollution dominated by coal smoke, which is determined by China's energy structure (Sheng et al., 2012). Since most of China's sulfur dioxide emissions come from coal burning, sulfur dioxide has always been one of the main pollutants in China's energy conservation and emission reduction goals. The environmental pollution problems caused by sulfur dioxide, such as acid rain, pose a great threat to human health and are closely watched by governments. For these reasons, sulfur dioxide has been chosen by scholars at home and abroad as a commonly used indicator when discussing environmental pollution problems (Antweiler et al., 2001). The intensity of sulfur dioxide emissions is selected in this paper. The sulfur dioxide emission intensity (so_2pfqd) indicator selected in this paper is borrowed from Lv et al. (2022). It is expressed as the ratio of sulfur dioxide emissions to the current year's price of industrial sales value, as in equation (5).

$$so_2pfqd = \frac{value\ of\ sulfur\ dioxide\ emissions}{value\ of\ Industrial\ sales\ output} \tag{5}$$

This paper analyses the pollution emission intensity of enterprises from multiple perspectives based on the matched data from the green development database, industrial enterprise data and customs enterprise database. As shown in Figure 4, the overall pollution emission intensity of Chinese enterprises shows a U-shaped trend of first decline and then slight increase. This may be due to the fact that with China's accession to the WTO, the large amount of foreign investment has promoted the upgrading of production processes and the improvement of energy efficiency, which has effectively reduced pollution emissions. However, with the outbreak of the global economic crisis in 2008, the center of gravity of the world's manufacturing industry gradually shifted to China, and the "pollution paradise" effect caused by the industrial shift may have contributed to the increase in pollution levels in 2013.

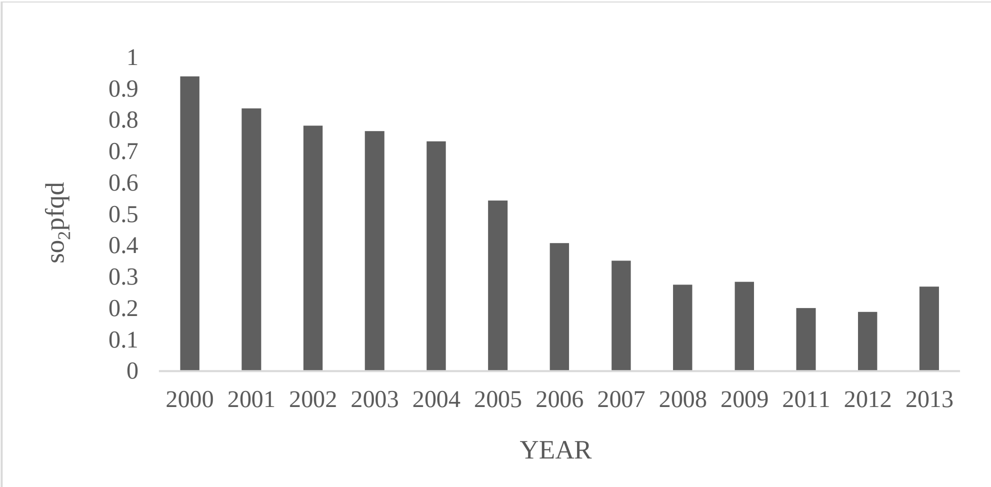

Figure 4: The changes in enterprise pollution intensity from 2000 to 2013

As can be seen in Figure 5, the pollution emission intensity of state-owned enterprises has been at a relatively high level. The pollution emission intensity of private enterprises is located in the middle region, showing smoother fluctuations. Foreign-funded enterprises are at a lower level of pollution emission intensity. This is due to the fact that foreign-funded enterprises possess more advanced knowledge and technology and have certain advantages in pollution control. Enterprises with three different ownership systems are all in a downward trend in the overall change. The pollution emission intensity of state-owned enterprises had a strong upward trend in 2003-2004.

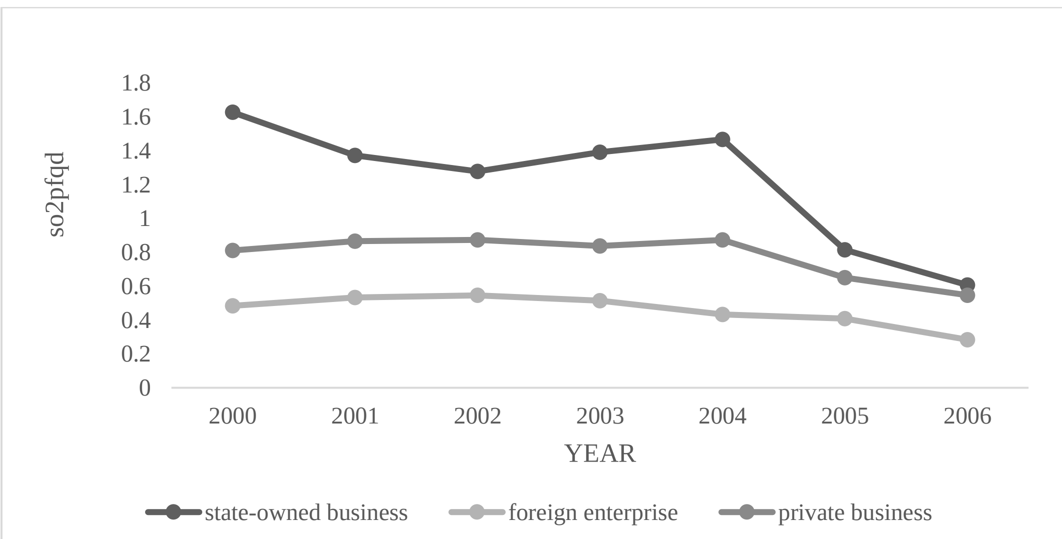

Figure 5: The enterprise pollution emission intensity in different ownership

As shown in Figure 6, the pollution emission intensity of enterprises in the eastern region has been at a low level and has fluctuated slowly. The central region had a peak in 2003-2004, and then showed a downward trend year by year after 2004. In the western region, the pollution emission intensity of enterprises was at a higher level than in the eastern and central regions, and declined sharply in 2000-2001. The reason for this is that the eastern region has better market competitiveness, and its level of technological development is in a more favorable position, while at the same time it has more perfect systems and policies. Therefore, under such a general environment, the technological level and economic strength of enterprises are stronger than in the central and western regions.

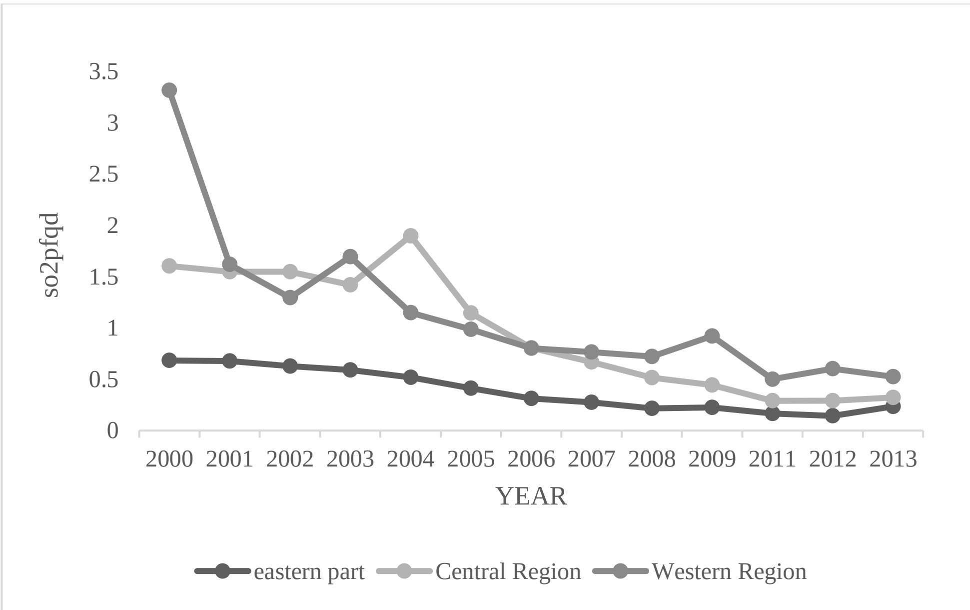

Figure 6: The enterprises pollution emission intensity in different regions

4. Model, Indicator Selection and Data

4.1 Model

This paper is based on the production activities of Chinese enterprises embedded in the global value chain, and focuses on the impact of the pollution emission intensity of enterprises on the domestic value-added rate of their exports. This paper chooses a two-way fixed-effects econometric model to study the impact of corporate sulfur dioxide (SO_2) emission intensity on the domestic value-added rate of Chinese enterprises' exports, using corporate SO_2 emission intensity as the indicator for measuring pollution emission intensity. According to the previous analysis, the econometric model is shown in equation (6).

$$DVAR_{it} = \alpha_0 + \alpha_1 so_2pfqd_{it} + \alpha_2 Z_{it} + \lambda_t + \mu_i + \varepsilon_{it} \tag{6}$$

Among them, the subscripts *i* and *t* represent industry and year, respectively; the explanatory variable $DVAR_{it}$ represents the export domestic value-added rate of Chinese enterprise *i* in period *t*; the core explanatory variable so_2pfqd_{it} represents the sulfur dioxide emission intensity; the control variable *Zit* is the other factors affecting the export domestic value-added rate of Chinese enterprises, λ_t is the year fixed effect, μ_i is the province fixed effects, ε_{it} is the random error term.

4.2 Indicator Selection

4.3 Core explanatory variable

The core explanatory variable of this paper is the pollution emission intensity of Chinese enterprises (so_2pfqd), which is selected to measure the pollution emission intensity of enterprises by the ratio of sulfur dioxide emissions to the current year price of industrial sales value.

4.3.1 Core explained variable

The core explained variable in this paper is the domestic value-added rate of Chinese firms' exports ($DVAR_{it}$), which represents the domestic value-added rate of Chinese enterprises *i*' exports during the period *t* and is used to reflect the embeddedness of enterprises in the global value chain.

4.3.2 Control variables

(1) The *age* of an enterprise, expressed as the logarithm of the current year minus the year of its establishment. The age of the enterprise can reflect the maturity of the enterprise in terms of production technology and management level, and can reflect a certain competitive advantage that the enterprise has.
(2) Enterprise size (*scale*), expressed as the logarithm of the number of people employed by the enterprise. The size of the enterprise can measure the enterprise economies of scale, the enterprise through the scale effect can affect its production link or export link of the marginal cost of the high and low, and thus affect the enterprise's exports of domestic value-added rate.
(3) Export intensity (*exprint*), expressed as the ratio of the value of exports delivered by the enterprise to the current year's price of industrial sales output. Export intensity can reflect the overall operating efficiency of the enterprise.
(4) *Capital_intensity*, measured as the logarithm of the ratio of the total fixed assets of the enterprise to the number of employees. Capital_intensity can reflect the level of production technology and equipment, but also reflects the competitive strength of capital possessed by the enterprise.
(5) Foreign direct investment (*fdi*). Expressed through the sum of foreign capital in the paid-in capital of the enterprise and the capital of Hong Kong, Macao and Taiwan. OFDI can have an impact on the domestic value-added rate of exports by increasing the inflow of foreign intermediate goods and technology spillovers.

(6) Regional total factor productivity (*dqtfp*): an important indicator of the level of technological development within a given region.

Table 1: Description of model-related variables

	Variable symbol	Hidden meaning	Variable Definition (Method of calculation)
Explanatory variable	*DVAR*	Domestic value-added rate of firms' exports	Logarithmic value of the current year minus the year the enterprise was established plus 1
Explanatory variable	so_2pfqd	Pollution emission intensity	Sulphur dioxide emissions/industrial sales value in current year prices
Control variable	*age*	Age of business	Logarithmic value of the current year minus the year the enterprise was established plus 1
	scale	Enterprise size	ln (number of persons engaged)
	exprint	Export Intensity	Delivered value of exports/industrial sales value at current year prices
	capital_intensity	capital intensity	Industry gross value added/industry gross product
	fdi	overseas foreign direct investment (OFDI)	Foreign capital + Hong Kong, Macao and Taiwan capital
	dqtfp	Regional total factor productivity	

4.4 Data description

The data used in this paper regarding the export domestic value-added rate come from the industrial enterprise database and the customs enterprise database of the EPS Global Statistical Data Analysis Platform of Tsinghua University Library, and the data related to the pollution emission intensity come from the Green Development Database. In this paper, the data from 2000 to 2013 are selected as the research object, and the overall data of 2010 is excluded due to missing data. Based on the enterprise code, this paper matches the database and calculates the domestic value-added rate and pollution emission intensity of enterprises' exports, and forms the overall panel data after vertical matching and removes duplicated values and missing values in the data to form the final panel data.

5. Results and Discussion

5.1 Benchmark regression results

Table 2 reports the results of the benchmark regression. The effect of firms' pollution intensity on their domestic export value added ratio is significantly negative at the 5 % confidence level, with a coefficient of -0.002. The results suggest that an increase in firms' pollution intensity will have a dampening effect on their domestic export value added ratio. The reason for this may be that the negative externalities on the environment in the production process will further exacerbate the low-end lock-in effect of enterprises embedded in the global value chain, thus inhibiting the increase in the domestic value-added rate of exports. The control variables are all significant at the 1% confidence level, which can show that the model selected in this paper has a reasonable structure and the regression method selected has a certain degree of persuasiveness and credibility.

Table 2: Results of benchmark regression

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
so_2pfqd	0.001	0.001	0.001	-0.001	-0.001	-0.002*	-0.002**
	(1.04)	(0.48)	(0.38)	(-0.66)	(-0.62)	(-1.94)	(-1.96)
age		0.030***	0.032***	0.027***	0.026***	0.017***	0.017***
		(25.85)	(26.40)	(23.01)	(21.67)	(14.26)	(14.27)
scale			-0.006***	-0.004***	-0.006***	-0.004***	-0.004***
			(-7.44)	(-5.43)	(-7.92)	(-5.31)	(-5.34)
exprint				-0.112***	-0.127***	-0.110***	-0.110***
				(-46.11)	(-50.53)	(-43.61)	(-43.61)
capital_intensity					-0.016***	-0.010***	-0.010***
					(-22.08)	(-13.92)	(-13.91)
fdi						-0.007***	-0.007***
						(-42.96)	(-42.92)
dqtfp							0.013***
							(4.11)
Constant	0.807***	0.733***	0.763***	0.811***	0.910***	0.943***	0.918***
	(171.60)	(128.62)	(110.79)	(119.99)	(115.40)	(119.76)	(93.08)
province effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
vintage effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	45431	45431	45431	45431	45431	45431	45431
R2	0.089	0.100	0.101	0.149	0.159	0.184	0.184

*** p<0.01. ** p<0.05. * p<0.1.

5.2 Endogeneity

The production chain of a firm is one of the main sources of environmental pollution, and the pollution caused by production may also have an impact on the firm's embeddedness in global value chains. In order to solve the endogeneity problem caused by the possible existence of bidirectional causality in the model, this paper adopts the two-stage least squares method and selects the intensity of wastewater emission of enterprises (*fspfqd*) and the intensity of sulfur dioxide emission based on the measure of industrial gross output value (so_2pfqd1) as the instrumental variables to be tested. The calculation formula is shown in equation (7) and (8).

$$fspfqd = \frac{value\ of\ wastewater\ discharge}{value\ of\ Industrial\ sales\ output} \tag{7}$$

$$so_2pfqd1 = \frac{value\ of\ sulfur\ dioxide\ emissions}{the\ gross\ industrial\ output} \tag{8}$$

As shown in Table 3, column (1) shows the results of the original regression model, and column (2) shows the results of the two-stage least squares regression with wastewater emission intensity and sulfur dioxide emission intensity based on industrial output value as instrumental variables. From the results, it can be seen that the KP LM statistic rejects the original hypothesis of "insufficient identification of instrumental variables" at the 1% level, and the KP Wald F statistic rejects the test of weak identification of instrumental variables. These two results can show that the selection of instrumental variables is valid and the core explanatory variable, enterprise pollution emission intensity, is significantly negative at the 5% confidence level. This indicates that after overcoming the endogeneity problem, firms' pollution emission intensity still has a significant inhibitory effect on their export domestic value -added rate.

Table 3: Endogenous processing

	(1)	(2)
	regression (chemistry)	instrumental variable
so_2pfqd	-0.002**	-0.003**
	(-1.96)	(-2.52)
age	0.017***	0.017***
	(14.27)	(14.39)
scale	-0.004***	-0.004***
	(-5.34)	(-5.40)
exprint	-0.110***	-0.111***
	(-43.61)	(-43.63)
capital_intensity	-0.010***	-0.010***
	(-13.91)	(-13.93)
fdi	-0.007***	-0.007***
	(-42.92)	(-42.78)
dqtfp	0.013***	0.014***
	(4.11)	(4.23)
Constant	0.918***	0.918***
	(93.08)	(92.74)
Kleibergen-Paap rk LM		53.381
P-value		(0.000)
Kleibergen-Paap rk Wald F		466.739
province effect	Yes	Yes
vintage effect	Yes	Yes
N	45431	45134
R2	0.184	0.185

*** $p<0.01$. ** $p<0.05$. * $p<0.1$.

5.3 Robustness Tests

In this paper, the model is further tested for robustness by three methods: transforming the explanatory variables, adding control variables, and time-phased sample regression. First, the explanatory variables are replaced with the instrumental variables measured above, respectively. Columns (2) and (3) of Table 4 show the robustness test results of sulfur dioxide emission intensity ($so_2\ pfqd1$) and corporate wastewater emission intensity (*fspfqd*) based on the industrial GDP measure, respectively. Secondly, this paper chooses the provincial urbanisation rate (*cit*) as the added control variable. The urbanisation rate is an important indicator reflecting the level of urbanisation and showing the progress of urbanisation, which can reflect the progress of the process of industrial development and transfer in a country or region. The development of urbanisation can promote outward foreign direct investment by enhancing the accumulation of intangible and tangible capital of enterprises, and the tangible capital accumulation of enterprises has a more obvious effect (Caves, 1996). And OFDI has an obvious causal relationship with the division of labor position of enterprises in the global value chain. Therefore, it can be included as an added control variable in the regression model, and the results are shown in column (4). Third, a time-period sample regression is conducted. The sub-sample after 2008 is selected for robustness test to exclude the possible impact of financial crisis on the model, and the results are displayed in column (5) of Table 4. From the regression results, it can be seen that the pollution emission intensity of Chinese firms still plays a significant inhibitory effect on their export domestic value-added rate, which can further verify the robustness of the model.

Table 4: Robustness test results

	(1)	(2)	(3)	(4)	(5)
	regression (chemistry)	varying the explanatory variables	varying the explanatory variables	Adding control variables	Sample by time period
so_2pfqd	-0.002**			-0.002**	-0.014***
	(-1.96)			(-1.99)	(-3.25)
so_2 pfqd1		-0.002***			
		(-2.59)			
fspfqd			-0.001***		
			(-6.18)		
age	0.017***	0.017***	0.017***	0.017***	0.017***
	(14.27)	(14.30)	(14.42)	(14.15)	(7.36)
scale	-0.004***	-0.004***	-0.004***	-0.004***	-0.003**
	(-5.34)	(-5.35)	(-5.55)	(-5.34)	(-2.16)
exprint	-0.110***	-0.110***	-0.110***	-0.110***	-0.093***
	(-43.61)	(-43.62)	(-43.65)	(-43.45)	(-23.01)
capital_intensity	-0.010***	-0.010***	-0.010***	-0.010***	-0.006***
	(-13.91)	(-13.91)	(-13.91)	(-13.73)	(-6.45)
fdi	-0.007***	-0.007***	-0.007***	-0.007***	-0.005***
	(-42.92)	(-42.98)	(-43.07)	(-42.87)	(-23.56)
dqtfp	0.013***	0.013***	0.014***	0.012***	0.002
	(4.11)	(4.11)	(4.23)	(3.82)	(0.34)
cit				-0.003***	
				(-7.86)	
Constant	0.918***	0.918***	0.920***	1.182***	0.936***
	(93.08)	(93.08)	(92.95)	(34.11)	(52.99)
province effect	Yes	Yes	Yes	Yes	Yes
vintage effect	Yes	Yes	Yes	Yes	Yes
N	45431	45431	45134	45431	14990
R2	0.184	0.184	0.185	0.185	0.128

*** $p<0.01$. ** $p<0.05$. * $p<0.1$.

Columns (2) and (3) of Table 4 show the regression results of the robustness test for the replacement explanatory variables of SO_2 emission intensity *so2pfqd1* and wastewater emission intensity *fspfqd, which are measured by* the gross industrial output value. Comparing with the original regression results in column (1), it can be seen that both replacement variables are significantly negative at the 1% confidence level, indicating that the original model is more robust. Column (4) shows the robustness test regression results after adding the control variable provincial urbanisation rate (*cit*). The explanatory variables are still significantly positive at the 5% confidence interval, the impact coefficients remain unchanged, and the provincial urbanisation rate is significantly negative at the 1% confidence level, which proves that the research results are robust.

5.4 Heterogeneity Analysis

5.4.1 Analysis of Regional Heterogeneity

Due to the differences in policy preferences and resource endowments, this paper explores the effect of pollution emission intensity on the export value-added rate of firms located in different regions. According to the provinces to which the enterprises belong and the National Development and Reform Commission's criteria for dividing the regions into East, Central and West, the sample data for the selected sample period are added to a dummy variable indicating the East, Central and West regions to analyze the heterogeneity of the enterprises. Table 5 demonstrates the results of the subsample regression for enterprises in different regions. Among them, the effect of pollution emission intensity of enterprises in the western region on the domestic value-added rate of their exports is significant at the 5 % confidence level and has a coefficient of -0.004. In contrast, the regression results for the eastern and central regions are not significant although the coefficients of the core explanatory variables are negative. It can be seen that the pollutant emission intensity of enterprises in the western region has a strong inhibitory effect on their export value-added rate, while in the eastern and central regions the effect of pollutant emission intensity of enterprises on their export domestic value-added rate is not significant. The reason may be that the eastern region is mostly coastal cities with good geographical location and policy support, and the economy has been in the leading level in China. At the same time, the industry in the eastern region has transformed and upgraded from highly polluting and energy-intensive processing and manufacturing industries to low-polluting industries that are mainly service, knowledge- and technology-intensive, so the impact is not significant. The economic development of the central region has also progressed significantly due to the regional spillover effect, so its impact effect is also not significant. In contrast, the western region has a lower position of enterprises embedded in the global value chain than the eastern region due to the transfer of high-pollution manufacturing industries from the eastern and central regions (Pan et al., 2022). Therefore, the inhibitory effect of SO_2 emission intensity of enterprises in the western region on their export domestic value-added rate is more significant.

Table 5: Analysis of regional heterogeneity

	(1)	(2)	(3)
	eastern part	Central Region	Western Region
so_2pfqd	-0.002	-0.002	-0.004**
	(-1.22)	(-1.26)	(-2.23)
age	0.018***	0.006**	0.007**
	(13.84)	(2.17)	(2.42)
scale	-0.004***	0.007***	-0.000
	(-5.33)	(4.14)	(-0.10)
exprint	-0.115***	-0.037***	-0.041***
	(-43.26)	(-3.94)	(-2.98)
capital_intensity	-0.010***	-0.003	-0.008***
	(-13.22)	(-1.42)	(-3.58)
fdi	-0.007***	-0.003***	-0.005***
	(-41.55)	(-7.67)	(-8.51)
dqtfp	0.015***	0.011	0.010
	(4.33)	(1.26)	(0.89)
Constant	0.916***	0.900***	0.936***
	(84.86)	(34.58)	(27.04)
province effect	Yes	Yes	Yes
vintage effect	Yes	Yes	Yes
N	40853	2960	1563
R^2	0.176	0.067	0.124

*** p<0.01. ** p<0.05. * p<0.1.

5.4.2 Analysis of Ownership Heterogeneity

In this paper, the enterprises included in the selected sample data are classified into three categories, namely, state-owned enterprises, foreign-funded enterprises and private enterprises, according to different types of enterprises, and the effect of the pollution emission intensity of enterprises on the domestic value-added rate of exports of different types of enterprises is explored. Table 6 embodies the regression results of the three subsamples. From the results, it can be seen that the regression results of state-owned enterprises are significant at 10 % confidence level, with the coefficient of the explanatory variable of -0.002. This indicates that the inhibitory effect of the pollution emission intensity under the type of state-owned enterprises on the rate of domestic value-added of their exports is more significant. The reason may be that the political attributes of state-owned enterprises are stronger than their profit attributes, which makes the inhibitory effect of sulfur dioxide emission intensity on the DVAR of state-owned enterprises more significant. At the same time, according to the typical fact analysis mentioned above, the pollution emission intensity of state-owned enterprises is at a relatively high level, which means that the higher the enterprise's investment in pollution prevention and control, the less investment it will make in production and profitability. This will lead to lower efficiency and hindered development of the enterprises, and make it difficult to enhance the domestic value-added rate of their exports. On the other hand, the brand, technology and capital advantages of foreign-funded enterprises as well as the strong competitiveness of private enterprises make them all have stronger incentives for green development. As a result, the export domestic value-added rate of such enterprises is less affected by the intensity of pollution emissions. Private enterprises have strong market competitiveness after the fierce market economy test, facing high energy consumption, high pollution business projects can be improved through their market experience and technology, so the impact is not significant.

Table 6: Analysis of ownership heterogeneity

	(1)	(2)	(3)
	state-owned business	foreign enterprise	private business
so_2pfqd	-0.002*	0.001	-0.003
	(-1.76)	(0.58)	(-1.34)
age	-0.001	0.023***	0.005**
	(-0.74)	(7.69)	(2.26)
scale	0.005***	-0.010***	0.013***
	(2.69)	(-6.51)	(6.48)
exprint	-0.036***	-0.150***	0.001
	(-5.25)	(-32.85)	(0.15)
capital_intensity	-0.011***	-0.012***	-0.002
	(-5.48)	(-8.30)	(-0.82)
fdi	0.001**	-0.008***	-0.001*
	(2.10)	(-11.55)	(-1.68)
dqtfp	0.008	0.006	-0.000
	(1.25)	(1.09)	(-0.02)
Constant	0.931***	0.993***	0.863***
	(45.06)	(54.18)	(35.46)
province effect	Yes	Yes	Yes
vintage effect	Yes	Yes	Yes
N	3778	16950	3668
R^2	0.072	0.157	0.044

*** p<0.01. ** p<0.05. * p<0.1.

5.4.3 Analysis of Trade Patterns Heterogeneity

In this paper, according to different trade modes, the enterprises in the selected sample data are divided into general trade enterprises and processing trade and other enterprises to be analyzed separately. As shown in Table 7, it can be found that the effect of enterprise sulfur dioxide emission intensity on the export domestic value-added rate of enterprises under the processing trade and other trade modes is significant at the 10% confidence level, with an impact coefficient of -0.003, which suggests that the inhibitory effect of enterprise pollution emission intensity on the export domestic value-added rate of enterprises under the processing trade and other trade modes is more significant. While the effect of pollution emission intensity of enterprises in general trade mode on their export domestic value-added rate is not significant.

Table 7: Analysis of trade patterns heterogeneity

	(1)	(2)
	general trade	Processing trade and others
so_2pfqd	-0.002	-0.003*
	(-1.21)	(-1.94)
age	0.012***	0.022***
	(10.49)	(9.02)
scale	-0.005***	-0.002
	(-5.76)	(-1.08)
exprint	-0.048***	-0.147***
	(-16.34)	(-32.54)
capital_intensity	-0.014***	-0.010***
	(-17.71)	(-7.83)
fdi	-0.005***	-0.007***
	(-34.34)	(-20.49)
dqtfp	0.006*	0.017***
	(1.69)	(2.69)
Constant	0.988***	0.866***
	(93.69)	(46.58)
province effect	Yes	Yes
vintage effect	Yes	Yes
N	27668	17763
R^2	0.114	0.171

*** p<0.01. ** p<0.05. * p<0.1.

5.5 Mechanism Verification

After the previous analyses, it can be seen that the pollution emission intensity has a significant inhibitory effect on the domestic export value added rate of enterprises. In this paper, in order to further explore its intrinsic influence mechanism, the Levinsohn-Petrin (LP) method is chosen to calculate the total factor productivity (*lpTFP*) of enterprises and incorporate it into the regression model. And multiply it with the core explanatory variables as a mechanism variable for testing, mechanism testing model as shown in equation (9).

$$DVAR_{it} = \alpha_0 + \alpha_1 so_2pfqd_{it} + \alpha_2 lpTFP + \alpha_3 so_2pfqd_{it} \times lpTFP + \alpha_4 Z_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (9)$$

Total factor productivity of an enterprise is a comprehensive indicator of the production efficiency and economic efficiency of an enterprise, and it is also one of the core indicators of economic growth. Enterprises can improve the total factor productivity of enterprises through improving production efficiency and technological progress (Solow, 1957). The improvement of the total factor productivity of export enterprises through technological progress can enhance the enterprise's own competitiveness and profitability in the market, thereby promoting the increase of the enterprise's export domestic value-added rate. Therefore, the total factor productivity of enterprises can reduce the decline in the domestic value-added rate of exports due to environmental pollution by improving the resource use efficiency of enterprises and optimizing the production process; at the same time, it can also mitigate the inhibitory effect of the intensity of corporate pollution emissions on the domestic value-added rate of exports through the introduction of cleaner production equipment and innovative technologies. In this paper, in order to ensure the completeness of the data sample test, according to Levinsohn and Petrin (2003). The method in the article uses firms' main business revenue to approximate the value added of output. At the same time, according to the LP method, the logarithmic values of all employment, intermediate inputs, total fixed assets and other variables are used to calculate the total factor productivity of the enterprise, and the mechanism test is conducted.

The regression results of the mechanism test are shown in Table 8, with (1) listed as the regression results of the original model, (2) listed as the regression results after the inclusion of the variable of enterprise total factor productivity (*lpTFP*), and (3) listed as the regression results after the inclusion of the cross term between the core explanatory variables and enterprise total factor productivity (so_2pfqd_{it}_*lpTFP*). The empirical results show that the regression results after adding the cross term between the core explanatory variables and firms' total factor productivity are significantly negative at the 1% confidence interval. Meanwhile, the cross term is significantly positive at the 1% confidence level with an impact coefficient of 0.001. This indicates that the enhancement of firms' total factor productivity can reduce the inhibitory effect of firms' pollution emission intensity on their export domestic value-added rate. Therefore, enterprises need to improve total factor productivity and break through the bottleneck of "green production" at the technological level, so as to slow down the negative impact of the pollution emission intensity of enterprises on the rate of domestic value-added in exports, and to achieve a new situation of win-win situation between the environment and benefits.

Table 8: Mechanism verification

	(1)	(2)	(3)
	DVAR	DVAR	DVAR
so_2 pfqd	-0.002**	-0.003***	-0.017***
	(-1.96)	(-3.29)	(-3.70)
lpTFP		-0.014***	-0.014***
		(-12.28)	(-12.46)
so_2 $pfqd_{it}$ _lpTFP			0.001***
			(3.03)
age	0.017***	0.017***	0.017***
	(14.27)	(14.18)	(14.05)
scale	-0.004***	0.007***	0.007***
	(-5.34)	(6.15)	(5.97)
exprint	-0.110***	-0.115***	-0.115***
	(-43.61)	(-44.63)	(-44.60)
capital_intensity	-0.010***	-0.004***	-0.004***
	(-13.91)	(-4.39)	(-4.50)
fdi	-0.007***	-0.006***	-0.006***
	(-42.92)	(-42.22)	(-41.99)
dqtfp	0.013***	0.014***	0.014***
	(4.11)	(4.25)	(4.26)
Constant	0.918***	0.970***	0.974***
	(93.08)	(90.25)	(89.90)
province effect	Yes	Yes	Yes
vintage effect	Yes	Yes	Yes
N	45431	45431	45431
R^2	0.184	0.187	0.187

*** p<0.01. ** p<0.05. * p<0.1.

6. Conclusions and Policy Implications

This paper is based on the microenterprise perspective, using panel data from 2000-2013 for statistical and model regression analyses. It also uses the latest green development database, industrial enterprise database and customs enterprise data to measure the pollution emission intensity of Chinese enterprises and their export domestic value-added rate. The article explores the effect of pollution emission intensity of Chinese enterprises on their export domestic value-added rate. The results of the study show that, firstly, according to the two-way fixed-effects regression model, the pollution emission intensity of Chinese enterprises has a negative impact on the domestic value-added rate of their exports, and the results still hold after a series of robustness tests. Second, the inhibitory effect of the pollution emission intensity of Chinese enterprises on the domestic value-added rate of exports of enterprises in the western region is stronger than that of enterprises in the eastern and central regions, which may depend on factors such as regional differences in factor endowments, policy preferences, and the sequence of industrial transformation and upgrading. Third, the pollution emission intensity of Chinese enterprises has a stronger negative effect on state-owned enterprises, and the effect on foreign-funded enterprises and private enterprises is not significant, mainly due to the political attributes of state-owned enterprises and the characteristics of high pollution and high energy consumption. Fourth, the pollution emission intensity of Chinese enterprises has a significant inhibitory effect on the domestic value-added rate of exports in processing and other modes of trade, while the effect in general trade is not obvious. Finally, the improvement of total factor productivity of enterprises can reduce the inhibitory effect of pollution emission intensity of Chinese enterprises on their export value added rate.

Based on the above conclusions, this paper gains the following insights:

(1) Industrial enterprises should actively implement the national policy and call for the implementation of energy saving, carbon reduction, pollution reduction and emission reduction in the whole process of fine management for coal chemical enterprises. Strengthen green technology innovation and industrial structure transformation, through green technology means to reduce the pollution emission intensity of industrial enterprises, improve the efficiency of resource and energy use. At the same time, the government should be industrial enterprises in green technology research and development and pollution reduction and emission reduction action of financial and policy support. In the context of the global division of labor, industrial enterprises should improve the efficiency of clean energy use through their own reforms and technological innovations, and increase the research and development of green products, so as to improve the construction of China's green value chain, industrial chain and supply chain.

(2) As the industrial pillars of the manufacturing industry, state-owned enterprises (SOEs) bear an important responsibility for the country's economic development. Therefore, the government needs to continue to deepen the governance of pollution emissions from state-owned enterprises, strengthen policy support for innovation

and application of green technology in state-owned enterprises, and cultivate the awareness of emission reduction and the learning of knowledge and management to reduce the intensity of pollution emissions in state-owned enterprises.

(3) Industrial enterprises in the western region need to continue to optimize their energy structure and vigorously develop clean energy. Expand the path of sustainable industrial development from a multi-dimensional perspective, and improve the construction of industrial green manufacturing system. Learn from the East and Central regions of enterprise management and green technology innovation means, strengthen the digital, intelligent enterprise transformation and upgrading. And then realize green, safe and efficient production construction, and promote the extension of China's green value chain, industrial chain and supply chain.

(4) Chinese industrial enterprises urgently need to improve their resource efficiency and optimize their production structures and processes. At the same time, they should enhance the development and application of green innovative technologies, and improve the total factor productivity of enterprises by learning or introducing the green technologies of leading industries at home and abroad to upgrade the level of production technology and promote technological progress, so as to achieve the two-way goal of "green" and "efficiency". Win-win goal. From the perspective of enterprises, we will create a low-pollution and high-efficiency industrial chain and supply chain development model in China, and build a new green global value chain system led by China.

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