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Environmental Performances of Forest Products Industry Participating in Global Value Chain --Taking the Carbon Emissions of China's Wood Processing and Paper Printing and Publishing Industry as an Example

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Abstract

Compared with the world's major forest products trading countries, China's forest products industry still has relatively high carbon emission intensity. Based on the environment Kuznets curve model of the global value chain, the paper uses the MRIO model to decompose the carbon emissions of China, focusing on the carbon emission intensity of the forest products industry, and calculating the value chain participation index and value chain position indicators of the forest products industry. It is found that both the wood processing industry and the paper printing and publishing industry value chain participation have a significant impact on carbon emission. Because of great significance to the energy conservation and emission reduction of China's forest products industry, policy implications are to improve the status of division of labor in the value chain and to achieve green economic development by absorbing, developing and adopting more green technologies.

Keywords: carbon emission, global value chain, forest products, wood processing, paper printing

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INTRODUCTION

With the development of economic globalization, the international division of labor in manufacturing industry has also changed from the traditional division of labor based on industry to the division of labor based on product, which has resulted in the differences of using resources and environment performances between countries in different position of global value chain. Since the reform and opening-up, China specializes in the labor force intension processing in the global value chain division system by virtue of abundant and cheap labor resources, acts as the role of the world factory and participates in the international division with the primary mode of processing trade. The mode promotes China to rapidly integrate into the global value chain, maintains the long-term trade surplus and accelerates the economic take-off, but it shows the slender processing and assembling fees of trade enterprises and China is kept in the bottom of the global value chain. If a country stays in the low end of the global value chain for a long time and it is short of comparative advantages in innovation, science and capital, it is easy to get caught in the "comparative advantage trap" and it is hard to realize the industrial upgrading. The input structure of China's production factors is irrational, energy consumption is large and additional value of products is low. Low-carbon clean technology and emission reduction pollution control technology have the lagging level. The industry based on the manufacturing industry is kept in the low end of the global value chain for a long time, resulting in the huge carbon emissions. It can be observed that it is necessary to improve Chinese status in the division of the global value chain by reducing economic emissions and realizing economic low-carbon transformation.

At present, the global value chain division of China's manufacturing industry has led to environmental problems, especially large carbon emissions. As an important part of manufacturing industry, wood processing industry has developed rapidly in China, and China has leaped to the position of the largest timber producer and trading country. As resources and environment become more and more constraints for the further development of wood processing industry, it is of great significance to evaluate the environmental effects of China's wood processing industry's participation in the division of global value chains and

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to promote the coordinated development of economy, trade and environment.

LITERATURE REVIEW

Porter (1995), Gereffi (1998) and other scholars have established the concept of GVC and its theoretical framework. They believe that global value chain refers to a cross-enterprise network organization that links the whole process of production and sales to realize the value of a commodity or service (Zhang 2004). Messner and Humphrey (2006) put forward three typical governance modes of GVC, Gereffi (2014), Humphrey (2004) and Garcia (2007), and put forward how developing countries or regions can realize industrial transformation and upgrading through value chain governance.

The theory of value-added accounting of global value chain was put forward by western scholars to analyze the degree of a country's participation in international division of labor and its benefits. Koopman (2011) and others synthesized HIY (Hummels et al. 2001) and DSR (Daudin 2009) and proposed KPWW method of global value chain. Empirically, value-added accounting is mainly based on some measurement indicators and international input-output tables to calculate competitiveness, driving role of upstream and downstream industries, greenhouse gas emissions (Daudin 2011, Koopman et al. 2010, 2012, 2014).

Many scholars have analyzed the environmental effects of international trade or GVCs (Chen et al. 2008). Grossman and Krueger (1991) laid the foundation for later scholars to study the internal relationship between GVCs and carbon emissions. They believed that the expansion of economic scale and the dependence of comparative advantage on high-polluting sectors would increase a country's carbon emissions, while the improvement of environmental-related technologies could reduce a country's carbon emissions. Scholars at home and abroad have discussed the impact of international vertical specialization on environmental pollution. For example, Dean (2002) empirically analyzed the impact of international production segmentation on China's foreign trade pollution intensity; Shui and Harriss (2006) believed that China's production of exports to the United States accounted for more than 10% of China's total emissions. In terms of the impact of foreign trade on carbon emissions, Fan, Su and Cao (2010) analyzed the responsibility of final consumption and carbon emission reduction from an economic point of view; Li (2011) used GMM to analyze the impact mechanism of trade on China's carbon emissions. Global value chain effect has the greatest impact on carbon emissions; Gu (2013) studied the impact mechanism of trade liberalization on carbon emissions from the perspective of global production network using the carbon emission theory model including international division of labor and considering foreign direct investment; Hu (2016) divided the environmental effects of GVCs into scale effect, structural effect, technological effect, vertical FDI effect and chain change effect. Many scholars have studied the impact of GVC's participation on export embodied carbon. Yan and Huang (2015) found that high energy-consuming sectors consumed and exported a large amount of embodied carbon. Meng et al. (2016) based on a fully closed multi-country input-output model, systematically traced the embodied carbon emissions in GVCs according to the direction of trade flows, and found the extent, manner and extent of a country's participation in the value chain. Location is closely related to its carbon emissions.

METHODOLOGY AND DATA

This paper uses MRIO model to decompose and calculate the carbon emissions of China's wood processing industry under the global value chain.

Assuming that there are G countries and N departments, the MRIO model can be expressed as Formula (1):

$$\begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ x_G \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1G} \\ A_{21} & A_{22} & \cdots & A_{2G} \\ \cdots & \cdots & & \cdots \\ A_{G1} & A_{G2} & \cdots & A_{GG} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ x_G \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_G \end{bmatrix} \quad (1)$$

After sorting out, we can get Formula (2):

$$\begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ x_G \end{bmatrix} = \begin{bmatrix} I-A_{11} & -A_{12} & \cdots & -A_{1G} \\ -A_{21} & I-A_{22} & \cdots & -A_{2G} \\ \cdots & \cdots & & \cdots \\ -A_{G1} & -A_{G2} & \cdots & I-A_{GG} \end{bmatrix}^{-1} \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_G \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1G} \\ B_{21} & B_{22} & \cdots & B_{2G} \\ \cdots & \cdots & & \cdots \\ B_{G1} & B_{G2} & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_G \end{bmatrix} \quad (2)$$

Among them, B_{sr} is the Lyontiv inverse matrix, which indicates that the output of S input is needed to increase the final demand per unit of national r, and y_r is the final demand vector of national R. In order to calculate the trade embodied carbon emissions, it is necessary to set the direct carbon emission coefficient vector on the basis of the above model. Set as a direct carbon emission coefficient, which represents the carbon emissions generated by the unit output of a

Table 1. Classification of sectors

No.	Name	No.	Name
c1	Agriculture, forestry, animal husbandry and fishery	c19	Sales, Maintenance and Fuel Retail of Motor Vehicles and Motorcycles
c2	Mining industry	c20	Wholesale business
c3	Food Manufacturing and Tobacco Processing Industry	c21	Retail
c4	textile industry	c22	Catering
c5	Leather and footwear industry	c23	Local Trucking
c6	Wood Processing and Furniture Manufacturing	c24	water transport
c7	Paper Printing and Cultural and Educational Supplies Manufacturing Industry	c25	air transport
c8	Petroleum Processing, Coking and Nuclear Fuel Processing Industry	c26	Other ancillary transport activities, travel agency activities
c9	chemical industry	c27	Postal and Communications Industry
c10	Rubber and Plastics Manufacturing Industry	c28	Financial and Insurance Industry
c11	Non-metallic Mineral Products Industry	c29	Housing industry
c12	Metal Smelting and Calendaring Industry	c30	Leasing and Business Services
c13	Machinery and Equipment Manufacturing Industry	c31	Public administration and social organizations
c14	Manufacturing of Electrical and Optical Equipment	c32	education
c15	Transportation Equipment Manufacturing Industry	c33	Health care and social welfare
c16	Other manufacturing industries	c34	Other groups, individuals and social services
c17	Electricity, Gas and Water Production and Supply Industry	c35	Home Economics Service Industry
c18	Construction business		

sector in a country. Then, global carbon emissions at the national and sectoral levels are as Formula (3):

$$\hat{F}B\hat{Y} = \begin{bmatrix} \hat{F}_1 & 0 & \cdots & 0 \\ 0 & \hat{F}_2 & \cdots & 0 \\ \cdots & \cdots & & \cdots \\ 0 & 0 & \cdots & \hat{F}_G \end{bmatrix} \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1G} \\ B_{21} & B_{22} & \cdots & B_{2G} \\ \cdots & \cdots & & \cdots \\ B_{G1} & B_{G2} & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} \hat{Y}_1 & 0 & \cdots & 0 \\ 0 & \hat{Y}_2 & \cdots & 0 \\ \cdots & \cdots & & \cdots \\ 0 & 0 & \cdots & \hat{Y}_G \end{bmatrix} = \begin{bmatrix} \hat{F}_1 B_{11} \hat{Y}_1 & \hat{F}_1 B_{12} \hat{Y}_2 & \cdots & \hat{F}_1 B_{1G} \hat{Y}_G \\ \hat{F}_2 B_{21} \hat{Y}_1 & \hat{F}_2 B_{22} \hat{Y}_2 & \cdots & \hat{F}_2 B_{2G} \hat{Y}_G \\ \cdots & \cdots & & \cdots \\ \hat{F}_G B_{G1} \hat{Y}_1 & \hat{F}_G B_{G2} \hat{Y}_2 & \cdots & \hat{F}_G B_{GG} \hat{Y}_G \end{bmatrix} \quad (3)$$

Any horizontal sum in the Formula (3) denotes the production carbon emissions of a certain sector of a country, that is, which countries and sectors consume the domestic production carbon emissions; and the vertical sum denotes the consumption carbon emissions of a certain sector of a country, that is, which countries and sectors produce the domestic consumption carbon emissions. In this way, the diagonal elements represent the carbon emissions produced and consumed by the domestic sector, that is, domestic carbon emissions.

Input-output tables and specific carbon emissions data are from the World Input-Output Database (WIOD), referring to environmental data of 43 major countries and regions and 35 industries in the world from 1997 to 2011. The per capita carbon emission data and value chain participation index used in this paper are all from the WIOT database. The per capita income data comes from the World Bank database, and the import and export volume of forest products comes from the UN Comtrade database.

The departments representing forest products industry in WIOD database are mainly wood processing industry, paper-making printing and publishing industry, namely the 6th and 7th departments in **Table 1**.

COMPUTATION AND DECOMPOSITION OF CARBON EMISSION FROM WOOD PROCESSING INDUSTRY IN CHINA

Total Amount of Carbon Emissions from Wood Processing Industry in China

In terms of specific accounting methods, because Wang's method (2013) is comprehensive and inclusive in global value chain and value-added trade accounting, this paper mainly refers to WWYZ (2013) forward correlation based on producer's perspective, that is, a country or industry GDP decomposition accounting method. Thus, total amount of carbon emissions in 2009 is taken as an example and shown in **Fig. 1**.

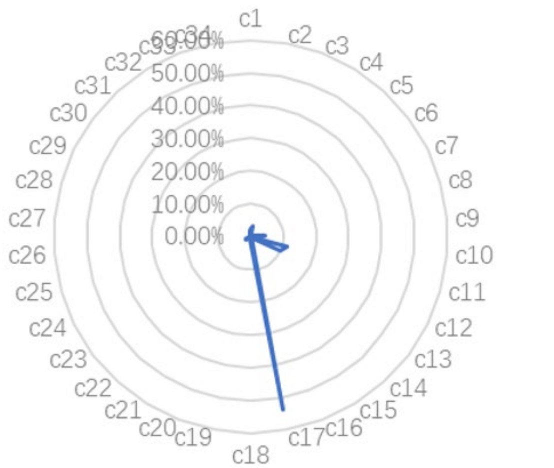

Fig. 1. China's share of carbon emissions in 35 sectors in 2009 (%)

Taking 2009 as an example, China's 35 sectors emitted 6213.55 million tons of carbon, of which 64 million tons were produced by forest products industry, and 0.19% and 0.84% were produced by wood

Table 2. Direct Carbon Emission Coefficients (kg/US$) at all ministries from 1995 to 2009

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
c1	0.44	0.39	0.38	0.38	0.37	0.30	0.29	0.29	0.29	0.28	0.29	0.27	0.21	0.14	0.13
c2	1.65	1.53	1.24	1.43	1.15	0.91	0.95	0.93	0.87	0.74	0.62	0.51	0.46	0.45	0.42
c3	0.65	0.47	0.38	0.42	0.36	0.28	0.27	0.24	0.20	0.20	0.17	0.13	0.10	0.10	0.09
c4	0.53	0.38	0.35	0.35	0.27	0.22	0.20	0.18	0.17	0.19	0.15	0.12	0.10	0.09	0.08
c5	0.16	0.11	0.10	0.10	0.09	0.07	0.06	0.06	0.06	0.07	0.05	0.04	0.03	0.03	0.03
c6	0.45	0.30	0.25	0.28	0.21	0.16	0.15	0.13	0.14	0.16	0.13	0.10	0.08	0.07	0.07
c7	1.13	0.79	0.66	0.68	0.52	0.50	0.46	0.45	0.38	0.40	0.31	0.28	0.22	0.23	0.22
c8	1.54	1.45	1.47	1.52	1.23	1.00	0.88	0.79	0.83	0.68	0.57	0.60	0.47	0.38	0.39
c9	2.71	2.25	1.82	1.93	1.47	1.26	1.05	0.98	0.86	0.68	0.60	0.52	0.41	0.37	0.33
c10	0.66	0.50	0.35	0.36	0.29	0.21	0.19	0.16	0.15	0.18	0.14	0.10	0.08	0.08	0.07
c11	4.55	3.71	3.23	3.51	3.15	2.89	2.65	2.69	2.79	3.31	2.80	2.44	1.98	1.89	1.77
c12	1.99	1.69	1.54	1.54	1.41	1.28	1.22	1.27	1.15	1.04	0.99	0.72	0.58	0.46	0.48
c13	0.55	0.50	0.39	0.36	0.27	0.19	0.17	0.15	0.13	0.12	0.10	0.08	0.06	0.06	0.06
c14	0.17	0.15	0.11	0.10	0.07	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01
c15	0.34	0.30	0.25	0.24	0.21	0.16	0.14	0.11	0.08	0.10	0.08	0.07	0.05	0.05	0.05
c16	0.96	0.70	0.48	0.51	0.40	0.29	0.25	0.21	0.18	0.21	0.15	0.10	0.08	0.07	0.07
c17	29.92	29.41	23.60	21.92	19.83	19.65	18.09	17.88	16.28	11.82	9.97	11.13	8.61	6.87	6.90
c18	0.11	0.09	0.09	0.10	0.09	0.09	0.08	0.08	0.07	0.12	0.11	0.09	0.08	0.05	0.05
c19	0.10	0.09	0.08	0.10	0.11	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05
c20	0.17	0.16	0.12	0.11	0.12	0.09	0.09	0.08	0.05	0.04	0.03	0.03	0.02	0.01	0.01
c21	0.26	0.25	0.21	0.19	0.20	0.17	0.16	0.15	0.13	0.12	0.06	0.05	0.08	0.06	0.06
c22	0.21	0.17	0.10	0.10	0.10	0.09	0.08	0.08	0.06	0.09	0.08	0.08	0.07	0.07	0.08
c23	0.96	0.77	0.85	0.94	0.89	0.80	0.72	0.70	0.72	0.65	0.62	0.54	0.45	0.39	0.36
c24	3.64	2.96	3.11	2.10	1.82	1.67	1.47	1.34	1.43	1.29	1.25	1.18	1.14	0.93	0.92
c25	2.45	1.84	2.04	2.78	2.26	1.66	1.97	2.03	2.39	2.33	1.84	1.51	1.43	1.11	1.79
c26	0.25	0.24	0.21	0.21	0.25	0.32	0.33	0.37	0.54	0.57	0.46	0.43	0.35	0.29	0.28
c27	0.11	0.10	0.08	0.08	0.07	0.09	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.03	0.03
c28	0.06	0.05	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
c29	0.25	0.19	0.09	0.08	0.08	0.06	0.06	0.05	0.05	0.05	0.04	0.03	0.02	0.01	0.01
c30	0.24	0.21	0.13	0.13	0.14	0.11	0.10	0.10	0.09	0.09	0.08	0.07	0.06	0.06	0.06
c31	0.30	0.26	0.17	0.14	0.14	0.11	0.09	0.08	0.08	0.10	0.09	0.08	0.07	0.08	0.08
c32	0.72	0.63	0.33	0.30	0.26	0.21	0.18	0.16	0.14	0.12	0.10	0.08	0.06	0.07	0.07
c33	0.30	0.26	0.15	0.14	0.12	0.09	0.08	0.07	0.07	0.07	0.08	0.08	0.07	0.09	0.09
c34	0.88	0.81	0.63	0.49	0.44	0.35	0.29	0.26	0.25	0.24	0.22	0.20	0.15	0.15	0.15
c35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

processing industry, paper printing and publishing industry (**Fig. 2**).

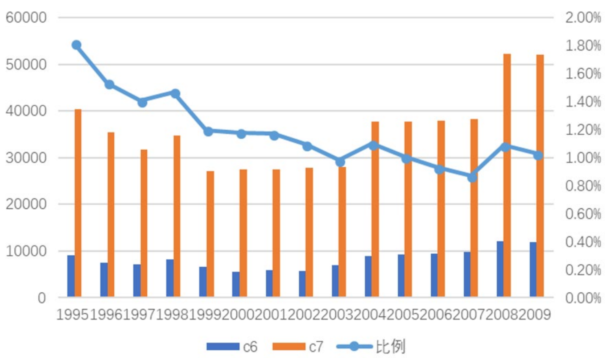

Fig. 2. Carbon Emission (kt) and Its Proportion in Timber Industry 1995-2009

Decomposition of Carbon Emissions

As can be seen from **Table 2**, compared with all sectors, the direct carbon emission coefficient of timber manufacturing industry remains at a low level, while the direct carbon emission coefficient of paper-making, printing and publishing industry is at a medium-to-high level, indicating that the carbon emission intensity of timber manufacturing industry in China's forest products industry is low, belonging to low-energy-consuming sector, while the carbon emission intensity of paper-making, printing and publishing industry is high, belonging to energy consumption.

As shown in **Table 3**, from 1995 to 2009, the carbon emission intensity of forest products industry showed a downward trend, indicating that the forest products industry has changed from extensive economic model to intensive economy, and achieved some results in energy saving and emission reduction. Compared with the major forest products trading countries in the world, the carbon emission intensity of China's forest products industry is still higher.

Table 3. Comparison of Direct Carbon Emission Coefficient in Forest Products Industry (kg/US $)

	1995	2000	2005	2009			1995	2000	2005	2009
Australia	0.09	0.04	0.02	0.02		**Australia**	0.12	0.15	0.08	0.08
Brazil	0.06	0.09	0.06	0.04		**Brazil**	0.16	0.20	0.15	0.10
Canada	0.16	0.17	0.15	0.10		**Canada**	0.33	0.29	0.23	0.09
China	0.45	0.16	0.13	0.07		**China**	1.13	0.50	0.31	0.22
Germany	0.04	0.06	0.04	0.04		**Germany**	0.09	0.10	0.09	0.08
Finland	0.04	0.03	0.02	0.02		**Finland**	0.22	0.23	0.17	0.15
France	0.06	0.06	0.04	0.03		**France**	0.14	0.13	0.09	0.05
Indonesia	0.06	0.27	0.25	0.08		**Indonesia**	0.08	0.58	0.56	0.46
Italy	0.07	0.08	0.05	0.04		**Italy**	0.13	0.16	0.12	0.11
Netherlands	0.08	0.11	0.05	0.06		**Netherlands**	0.07	0.09	0.08	0.05
Russia	0.35	0.63	0.20	0.19		**Russia**	0.19	0.53	0.10	0.08
Sweden	0.03	0.02	0.01	0.01		**Sweden**	0.13	0.12	0.09	0.06
U.S.A	0.20	0.16	0.11	0.18		**U.S.A**	0.19	0.18	0.17	0.14

Table 4. Carbon Emissions from China's Forest Products Industry Trade (kt)

	Wood Processing Industry	Paper Printing and Publishing Industry
1995	29.52%	22.51%
2009	25.07%	25.34%

Table 5. Comparison of Domestic and Foreign Demand of Forest Products Industry from 1995 to 2011

	Domestic Demand	Foreign Demand	Ratio		Domestic Demand	Foreign Demand	Ratio
1995	765.7140267	585.5328609	1.307721697	1995	1137.143794	653.4332573	1.740260052
1996	737.1919496	532.2619596	1.385017164	1996	1283.735055	656.4382983	1.955606579
1997	858.9995451	543.6125195	1.580168804	1997	1704.272372	617.9058396	2.758142524
1998	762.9800324	363.6494691	2.098119473	1998	1827.765339	503.3909078	3.630906539
1999	784.8970727	364.0913772	2.155769463	1999	1908.071772	509.948583	3.74169443
2000	972.7786289	405.5796835	2.398489541	2000	2441.196192	494.3928663	4.93776581
2001	1092.073332	343.8834286	3.175707933	2001	2687.108413	473.0089671	5.680882604
2002	1330.562227	341.2138952	3.899496021	2002	3256.91658	504.5054787	6.455661469
2003	1696.028857	404.3949069	4.193991636	2003	3771.72865	502.6821116	7.503208417
2004	2297.435683	507.8539275	4.523811984	2004	4867.970251	690.5814198	7.049089523
2005	2972.838506	554.7198758	5.359170702	2005	6093.246352	629.7383189	9.67583863
2006	4359.284039	622.5541402	7.002256925	2006	6760.256621	653.0297411	10.35214202
2007	5496.992343	799.7463924	6.873419369	2007	8042.310997	571.7499166	14.0661341
2008	6381.907351	866.9080195	7.361689138	2008	9729.461962	707.3257002	13.75527845
2009	5091.509454	651.8094658	7.811346292	2009	8297.092424	559.6397018	14.82577522
2010	6748.517843	925.0147076	7.295578964	2010	10967.95066	779.2803072	14.07446147
2011	8107.374859	1212.939897	6.684069735	2011	13511.07482	1029.198039	13.12776969

As shown in **Table 4**, domestic carbon emissions account for a large part of the carbon emissions in China's forest products industry, and the proportion of carbon emissions from trade is relatively small (about 25%). Compared with 1995, the proportion of carbon emissions from timber industry in forest products industry decreased slightly, while the proportion of carbon emissions from paper printing and publishing industry increased slightly.

Comparison of Domestic and Foreign Demand

Overall, the proportion of domestic demand in China's forest products industry is gradually rising, while the proportion of foreign demand is gradually declining. Among them, the domestic demand and foreign demand of timber industry increased from 1.31 to 6.68, and the domestic demand/foreign demand of paper-making, printing and publishing industry increased from 1.74 to 13.13, with more obvious changes. From this point of view, China's forest products industry in the process of integration into the global value chain to obtain increasing domestic value added, foreign value added declined relatively.

Kuznets Curve of Carbon Emission and Regression Analysis

From **Fig. 3** and **Fig. 4**, we can see the comparison of the carbon emission environment Kuznets curve of the forest products industry in the United States and that of in China, it can be seen that there is a positive correlation between China's per capita income and carbon emissions, and the Kuznets curve of the carbon emission environment is on the rise. In the United States, the Kuznets curve of the carbon emission environment has an inflection point, and then it has a downward trend overall.

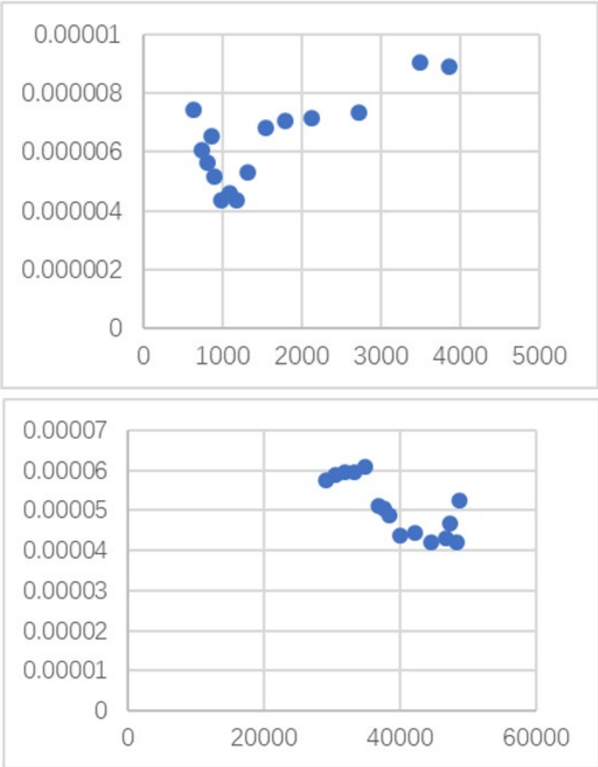

Fig. 3. Comparisons of Carbon Emissions in Wood Processing Industry between China and the United States

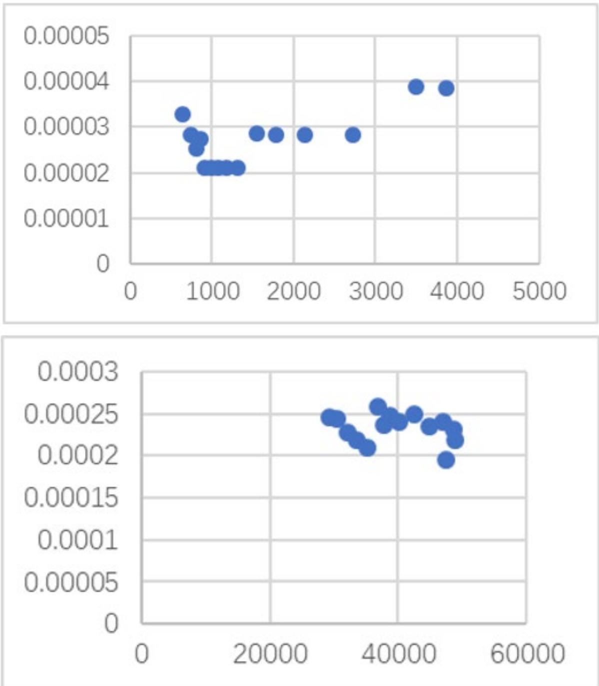

Fig. 4. Comparison of carbon emission EKC between China and the United States in the paper printing and publishing industry

Table 6. Regression results of timber manufacturing industry

Variable	coefficient	standard deviation	T value	probability
C	13.68459	6.373833	2.146996	0.0549
Y	-6.958734	1.708674	-4.072593	0.0018
Y^2	0.481794	0.115401	4.174944	0.0015
GVC	0.515993	0.193819	2.662247	0.0221
Coefficient of determination	0.784672	Means of Interpreted Variables		-11.97220
Modified resolvable coefficient	0.725946	Standard deviation of interpreted variables		0.233574
standard deviation	0.122276	F value		13.36158
Sum of squares of residuals	0.164467	probability		0.000548
Logarithm of likelihood function	12.56416	DW value		1.403961

Combined with the global value chain participation index and the classical environmental Kuznets curve model, a carbon emission environment Kuznets curve model (see Formula 4) that introduces global value chains is established.

$$\ln C = \alpha + \beta_1 \ln Y + \beta_2 \ln Y^2 + \beta_3 \ln GVC + \beta_4 \ln X + \beta_5 \ln M + u \quad (4)$$

Among them, C represents the per capita carbon emissions (unit: thousand tons / person), and Y is the per capita income level (unit: US dollars). Combined with the classical environment Kuznets curve model, the square term of the per capita income level is also introduced to reflect the nonlinear relationship between income and carbon emissions. GVC is the value chain participation index, X is the corresponding forest product export volume, M is the corresponding forest product import volume, and u is the error term.

After deleting the insignificant variables, the final regression results are as follows in **Table 6** and **Table 7**.

Table 7. Regression Results of the Model of Paper Printing and Publishing Industry

Variable	coefficient	standard deviation	T value	probability
C	24.60822	7.676372	3.205709	0.0084
Y	-9.422260	1.964287	-4.796783	0.0006
Y^2	0.642508	0.129576	4.958535	0.0004
GVC	0.640479	0.311872	2.053660	0.0646
Coefficient of determination	0.802324	Means of Interpreted Variables		-10.50461
Modified resolvable coefficient	0.748413	Standard deviation of interpreted variables		0.205666
standard deviation	0.103159	F value		14.88224
Sum of squares of residuals	0.117059	probability		0.000346
Logarithm of likelihood function	15.11436	DW value		1.809425

Based on the above regression results, the impact model of the value chain participation of wood processing and paper printing and publishing industry on carbon emissions is:

$$\ln C = 13.68 - 6.96 \ln Y + 0.48 \ln Y^2 + 0.52 \ln GVC$$
$$\ln C = 24.61 - 6.42 \ln Y + 0.64 \ln Y^2 + 0.64 \ln GVC$$

That is to say, both the wood processing industry and the paper printing and publishing industry value chain increasing participation has a significant impact on carbon emissions, improving the value chain division of labor is of great significance to the energy conservation and emission reduction of China's forest products industry.

Regression results show that forest product value chain participation has a significant positive impact on carbon emissions of. This paper will further analyze the dynamic relationship between value chain participation and carbon emissions of wood processing industry and paper printing and publishing industry by constructing VAR model and using impulse response function.

Fig. 5 and **Fig. 6** are impulse response analysis of the impact of the value chain participation index on the carbon emission unit in the wood processing and paper printing and publishing industries. When one unit of value chain participation is positively impacted, the carbon emissions of the timber manufacturing industry will increase rapidly, reaching a peak in the fifth period (0.10), and finally stabilized at the positive level of 0.03; when giving the value chain a unit of positive At the time of impact, the carbon emissions of the paper-printing publishing industry increased rapidly, reaching a peak (0.05) in the fifth period, and then fluctuating continuously, eventually stabilizing at a positive level of

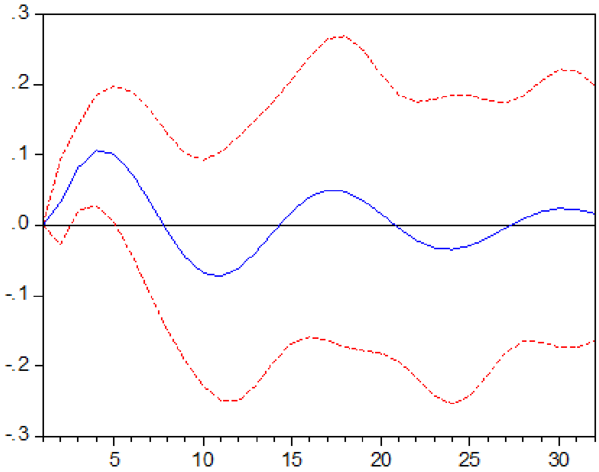

Fig. 5. Response curve of value chain participation to carbon emission unit impact in wood processing industry

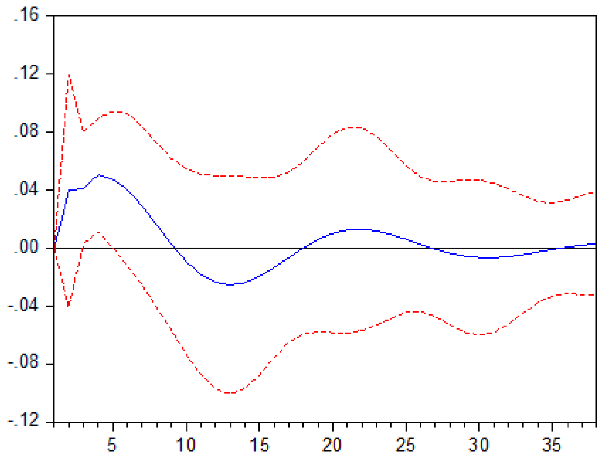

Fig. 6. Response curve of value chain participation to carbon emission unit impact in paper printing and publishing industry

0.01. This shows that increasing participation in the value chain can significantly reduce carbon emissions in the forest products industry in both the short and long term.

CONCLUSION

This paper uses the carbon emissions data of China's 35 sectors from 1995 to 2009 and then calculated 1995-2011 forest product industry value chain participation indicators, value chain position indicators, domestic and foreign demand comparison data, etc. This paper demonstrates and analyses the impact of global value chain participation on carbon emissions, and reached the following conclusions:

From 1995 to 2009, China's forest products industry had a large amount of carbon emissions, mainly in the paper printing and publishing industry. The carbon emission intensity of China's forest products industry generally shows a downward trend, but compared with the world's major forest products trading countries, the carbon emission intensity of forest products industry is still high. At the departmental level, the wood processing industry has a low carbon emission intensity, which is a low-energy-consuming sector, while the paper-printing and publishing industry has a high carbon emission intensity and belongs to a department closely related to energy consumption.

The overall participation of China's forest products industry in the value chain has deepened, but the value chain status indicators of the wood processing industry and the paper printing and publishing industry are generally small, indicating that the position of China's forest products industry in the entire industrial chain has not improved significantly, still in the "downstream" link. Using the environmental Kuznets curve model to study the impact of wood processing and paper printing and publishing industry value chain participation on carbon emissions, it is found that both the wood processing industry and the paper printing and publishing industry value chain participation have significant carbon emissions. Impact and increase the participation of the value chain can significantly reduce the carbon emissions of the forest products industry in both the short-term and the long-term, and improving the value-added status of the value chain is of great significance to the energy-saving and emission reduction of the forest products industry in China.

Based on the above conclusions, in order to promote energy conservation and emission reduction in China, when participating in international division of labor and cooperation as a whole, the paper printing and publishing industry with high emission intensity should strive to enhance the participation of global value chain, improve the international competitiveness of the industry, reduce carbon emissions and achieve green economic development.

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