Research on Embodied Carbon Emission of China's Agricultural Product Import and Export Trade

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Abstract: in the context of global warming and rising trade protectionism, the research on the carbon emissions embodied by agricultural product trade is of great significance for agricultural development. By estimating and analyzing the carbon emissions embodied by china's agricultural import and export trade from 2009 to 2017, this paper finds that china is a net carbon importer in agricultural trade. From the perspective of agricultural carbon emissions, such a trade has saved a part of domestic carbon emissions and also reduced the carbon emission reduction responsibility for the agricultural sector to a certain extent. From the perspective of trade structures, china's forestry and fishery sectors have undertaken additional agricultural carbon emissions for foreign countries due to international trade, and the main sectors saving domestic agricultural carbon emissions due to international trade are the planting and animal husbandry sectors.

1. Introduction

According to the introduction of chapter one of the 2006 IPCC guidelines, carbon emissions are estimated based on the types of emissions. In the process of combustion, most of the carbon is rapidly emitted in the form of co_2, but some carbon is emitted as carbon monoxide (co), methane (ch_4) and the like. Because most carbon emitted as non-co_2 will eventually be oxidized into co_2 in the atmosphere and co_2 accounts for the largest proportion as the most important greenhouse gas, people have been accustomed to calling co_2 the carbon emissions. Therefore, in the estimation of carbon emissions generated by the agricultural sector, it is common to measure co_2 emissions in the process of agricultural production. Calculation of agricultural carbon emissions is to measure and analyze the carbon emissions of various agricultural production sectors (including agriculture, forestry, animal husbandry and fishery) during the production process. Calculation of carbon emissions embodied by agricultural products is to use the input-output analysis method to measure the intermediate consumption, plus the direct carbon emissions, to obtain the total agricultural carbon emissions.

As the global greenhouse gas emissions continue to intensify, the issue of carbon emissions embodied in trade has long been receiving widespread attention at home and abroad. According to statistics data, china's exports accounted for 3.3% of the world's total exports in 1995, and the carbon emissions embodied in exports were 1.01 billion tons, accounting for 21.6% of the world's total carbon emissions. In 2009, china's exports accounted for only 12% of the world's total, and the exports' embodied carbon emissions were 2.88 billion tons, accounting for 8% of the total domestic carbon emissions and 35% of the global ones. In 2009, german exports accounted for 12% of the global share, which is the same as china's, but german export carbon emissions accounted for only 4% of the world's. During the same period, the united states and japan accounted for 13% and 5.9% of the global exports, respectively, but their export carbon emissions accounted for only 8% and 4.2% of the world's, respectively (gao jing and liu guoguang, 2016). The carbon emission embodied

by export trade is an important driving factor of national carbon emissions. However, existing researches on the embodied carbon emissions of international trade are mainly focused on industrial products, and few of them are related to agricultural products, so there still are a lot of rooms for researches on the agricultural product exports. This study selects the years of 2009-2017 as the period of investigation, and through the processing of relevant data, analyzes the embodied carbon emissions of china's agricultural product import and export trade in the past nine years. And then this paper provides an effective reference for the national and even global carbon emission reduction researches from the perspective of agricultural product import and export trade.

2. Literature Review

According to some researches on the carbon emissions in international trade, in early periods, the carbon emissions in the imported products of some developed countries accounted for more than 13% of their domestic total carbon emissions. The impact of trade on carbon emissions depends on the carbon emission density (i.e. Co_2 emitted in producing a unit product) in a nation's production as well as the trade structure [1]. Researches on china's trade embodied carbon finds that the proportion of china's net export co_2 in the total domestic co_2 emissions in the same period had increased from 20.75% in 2004 to 25.27% in 2006 [2]. It can be seen that the developed countries and the developing ones are also two different groups. On the whole, the developed countries are the net importers of carbon, while the developing countries are the net exporters of carbon. That is to say, the developed countries transfer co_2 to the developing countries through trade. At the same time, free international trade has a negative impact on global carbon emissions, and international trade has a clear impact on national and international environmental policies. The consumption choices of one country affect the environmental performance of another country. And if the imported goods use more greenhouse gas-intensive products to replace the domestically produced products, higher global co_2 (and other pollutants) emissions will appear as a result [3]. However, for a certain non-differential product, if it is imported from a country with high energy efficiency and low carbon emission intensity, the carbon emissions equivalent to producing the same product in a city can be saved, so that the interregional trade can reduce the total carbon emissions [4]. Therefore, if there is a clear division of product production areas and a trade direction beneficial to carbon emission reduction, it will be conducive to the achievement of global carbon emission reduction goals to a certain extent.

As a large developing trading country, china is a net exporter of embodied carbon emissions and bears a large quantity of foreign carbon emissions [5-8]. However, there are still divergent views on the embodied carbon emissions in the field of agricultural trade, some researchers' investigations show that the embodied carbon emissions of agricultural net exports are steadily decreasing, so china has gradually become a net importer of agricultural co_2 emissions [9]. But others have calculated to find that china is a net exporter of embodied carbon emissions of agricultural products [10]. From the perspective of the international division of labor in transferring of polluting industries, the developed countries have the incentive to invest sufficient capital in r&d of low-carbon agriculture, while leaving the pollution-intensive agricultural production processes to countries such as china with labor endowment advantages[11]. Now the co_2 embodied by china's net export of agricultural products is continuously decreasing, and china has become a net importer of co_2 emissions from agricultural products, so the international trade in agricultural products has contributed to energy conservation and emission reduction [9]. The existing researches are mainly focused on the transfer of trade embodied carbon emissions between china and other countries, but few on accurate calculations and in-depth analyses of co_2 emission sources and structural characteristics of export products. At present, the means of carbon emission reduction mainly include structure emission reduction, management emission reduction and technology emission reduction [12]. A detailed study on the commodity source, energy distribution and carbon emission technical coefficient of the embodied carbon emission of agricultural product export trade will provide a targeted decision-making basis for optimizing the export structure of agricultural products [13] and promoting the low-carbon transformation of agricultural structures [14]. In a word, so far,

there are insufficient researches on the embodied carbon emission of international agricultural product trade of china, and further efforts shall be made in this field. This study selects the time period of 2009-2017 to demonstrate the embodied carbon emissions of china's agricultural product import and export trade in the nine years, so as to provide a basis for national and global carbon emission reduction from the perspective of agricultural product trade.

3. Calculation of the Complete Carbon Emission Intensity C in the Agricultural Sector

$$C = R_i \times (\mathrm{I} - \mathrm{A})^{-1} = \frac{EN_{ik} \times \theta_k}{x_i} \times (\mathrm{I} - \mathrm{A})^{-1} \tag{1}$$

Where, R^i is the direct carbon emission coefficient of each industrial sector; $(I-A)^{-1}$ is the Leontief inverse matrix, which indicates the indirect consumption of other industrial sectors by production of a unit of agricultural product as well as the consumption of the agricultural sector itself. EN_{ik} is the consumption of energy k by sector i. θ_k is the carbon emission coefficient of energy k. And x_i is the total output of sector i.

4. Calculation of Embodied Carbon of Agricultural Product Import and Export Trade

The embodied carbon of China's export of agricultural products is:

$$EXCO_2 = C \times Y^{ex} \tag{2}$$

The embodied carbon of China's import of agricultural products is:

$$IMCO_2 = C \times Y^{im} \tag{3}$$

In the above two formulas, C indicates China's total carbon emission intensity, Y^{ex} indicates the agricultural product trade value of China's exports, and Y^{im} indicates the agricultural product trade value of China's imports.

The energy consumption data comes from the Energy Consumption Scale by Industry in *China Statistical Yearbook*. Because electricity is converted from other energy sources and is a secondary energy source, this research will not consider the power consumption. Ce_k is calculated based on the reference method provided in Chapter VI of Volume II (Energy) of the United Nations Intergovernmental Panel on Climate Change (2006). The data of international trade in agricultural products come from the UN Comtrade Database. According to the Industry Classification of the National Economy, the import and export of agricultural products are mapped to the agricultural production sector, as shown in Table 1. The total output data of the agricultural sector comes from *China Agricultural Yearbook* and *China Statistical Yearbook*.

Table 1 Corresponding Table of Agricultural Sectors and Primary Agricultural Products

Sector No.	Sector name	Code of customs import and export commodity	Goods name
1	Agricultural products	The seventh chapter	Edible vegetables, roots, and tubers
		The eighth chapter	Edible fruits and nuts; peel of melon or citrus fruits
		The tenth chapter	Grain
		The twelfth chapter	Oilseeds and fruits; miscellaneous seeds and fruits; industrial or medicinal plants; straw, stalk, and feed
		The fourteenth chapter	Plant materials for

			knitting; other plant products
2	Forestry products	The sixth chapter	Living trees and other living plants; bulbs, roots and the like; flower arrangement and decorative foliage
		The thirteenth chapter	Shellac, gum, resin and other plant juices
3	Animal husbandry products	The first chapter	Live animals
		The second chapter	Meat and edible offal
		The fourth chapter	Dairy products; egg products; natural honey; other edible animal products
		The fifth chapter	Other animal products
4	Fishery products	The third chapter	Fish, crustaceans, mollusks and other aquatic invertebrates

Source: Extracting from the 2017 National Economic Industry Classification Notes, revised in 2019

5. Results and Analyses

5.1 The Analysis of the Total Volume

Table 2 China's Agricultural Carbon Emissions, Embodied Carbon Emissions in exports, imports, and net exports from 2005 to 2014. (MtC)

Year	Total carbon emission of agriculture	embodied carbon emissions in exports	embodied carbon emissions in imports	embodied carbon emissions in net exports
2009	17.213	0.701	1.111	-0.410
2010	18.189	0.823	1.343	-0.520
2011	19.291	0.866	1.444	-0.578
2012	19.878	0.781	1.633	-0.852
2013	22.933	0.906	1.956	-1.049
2014	22.868	0.925	2.036	-1.111
2015	23.571	0.927	1.926	-0.999
2016	23.340	0.991	1.906	-0.915
2017	22.059	0.924	1.985	-1.061

Source: computation by this research

By taking into account the intermediate consumption of agricultural production, we use the input-output model to calculate the total carbon emissions of China's agriculture, the embodied carbon emissions of export agricultural product trade, and the embodied carbon emissions of import agricultural product trade. The results are shown in Table 2. From the vertical perspective, from 2009 to 2017, China's total agricultural total carbon emissions increased from 1,721.3 million tons to 2,205.9 million tons, with an increase of 28.16%, showing an overall upward trend. The embodied carbon emissions of export agricultural product trade increased from 70.1 million tons to 92.4 million tons, with an increase of31.7%,. The embodied carbon emissions of imported agricultural product trade increased from 111.1 million tons to 198.5 million tons, with an increase of 18.6%, or an increase of 2.5 times the embodied carbon of exports of agricultural products. The embodied carbon deficit in foreign agricultural trade has increased from 41.0 million tons to 106.1million tons, with an increased of 158.5%, showing the largest increase. From a horizontal perspective, in 2017, the embodied carbon in agricultural export trade accounted for 4.08% of the total domestic agricultural carbon emissions, compared with 4.19% in 2017, showing a growth rate of2.7%. The embodied carbon in agricultural imports in 2009 was 1.58 times that of exports, and in 2017 it was 2.15 times, with a growth rate of 35.67%.

5.2 Sector Analysis

(1) Based on Table 2, the exported agricultural products are related to four major agricultural sectors: agriculture, forestry, animal husbandry, and fishery. As seen in Figure 1, the embodied carbon of agricultural products exported by China's four major agricultural sectors from 2009 to 2017 shows the additional agricultural carbon emissions generated by the four major agricultural sectors to meet foreign consumption. Among them, the forestry sector has the smallest proportion, but the proportion is increasing year by year, with an average annual growth rate of 7.97%. The animal husbandry sector is ranked the third, showing an increase first and then a decrease, with an average annual growth rate of1.06%. The fishery sector is ranked the second, showing a large fluctuation and a downward trend after 2014, with an average annual growth rate of 3.21%. The agricultural plantation sector takes the largest proportion of as high as over 45% and has the largest increase, with an annual growth rate of 5.02%.

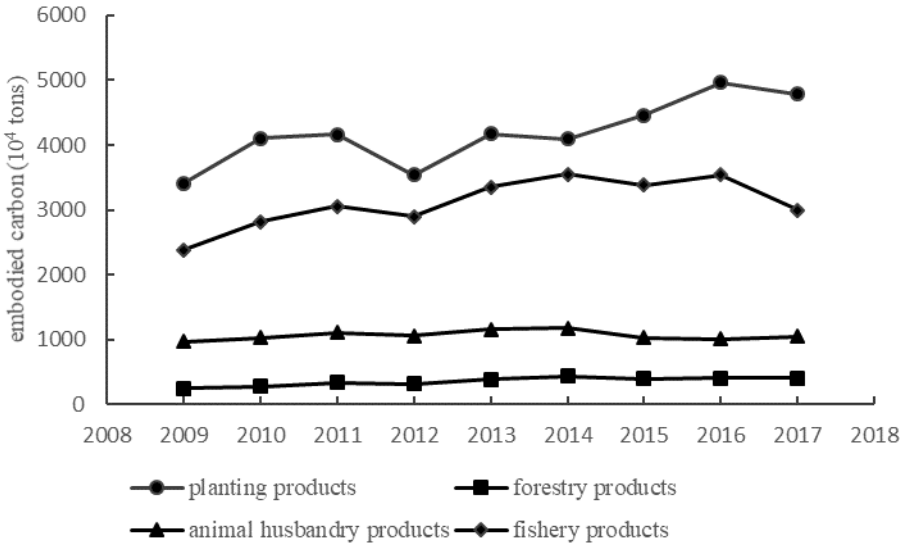

Fig.1 Co_2 Emissions Embodied in Exports of China's Four Agricultural Sectors from 2009 to 2017

(2) As shown in Figure 2, the embodied carbon of agricultural products imported by China's four major agricultural sectors from 2009 to 2017 shows the agricultural carbon emissions saved by the four major agricultural sectors due to the import trade of agricultural products. The proportion of the forestry sector is the smallest, but it is increasing year by year, with an average annual growth rate of 9.32%. The fishery sector is ranked the third, with relatively slow growth by an average annual growth rate of 4.57%. The animal husbandry sector is ranked the second, with a large fluctuation range, showing an average annual growth rate of 29.54%. And the agricultural plantation sector takes the largest proportion of up to more than 70%, with an annual growth rate of 8.08%.

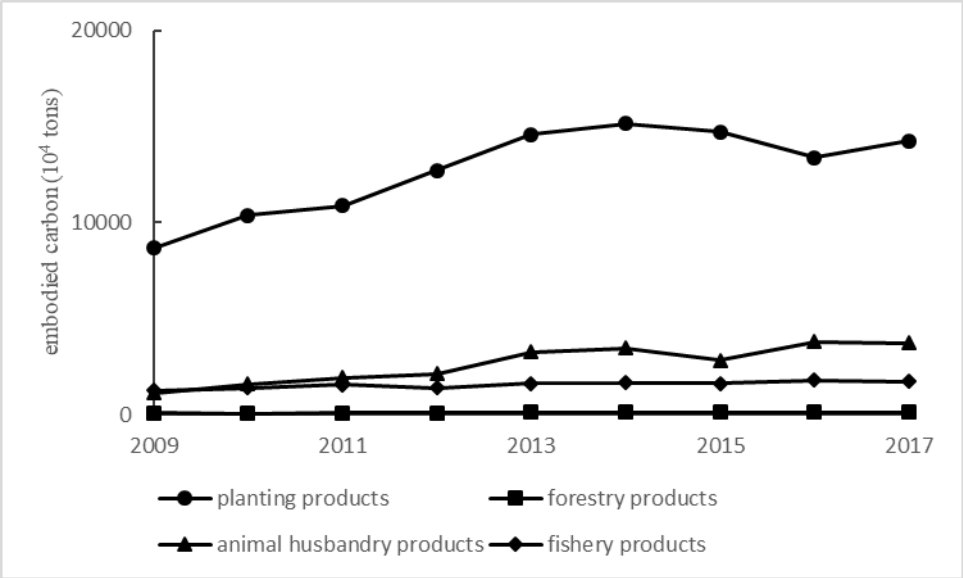

Fig.2 Co_2 Emissions Embodied in Imports of China's Four Agricultural Sectors from 2009 to 2017

(3) The embodied carbon of China's four major agricultural sectors' net export trade is shown in Table 3. The trade of crop products shows a net import of carbon, indicating that China's crop sector has saved domestic carbon emissions due to international trade; and this sector's net import trade has the largest percentage of embodied carbon, indicating that the major agricultural sector which saves carbon emissions due to international trade is the plantation sector. The trade embodied carbon of forest products is in net export, which indicates that China's forestry sector has been increasing additional carbon emissions for foreign consumption. The embodied carbon in the trade of animal husbandry products is in net import, which accounts for a small proportion but grow at the fastest rate. The results show that China has saved the agricultural carbon emissions of the animal husbandry sector while adjusting its trade structure. The embodied trade carbon of fishery products is in net export, which indicates that China's fishery products are more exported than imported, therefore increasing the additional carbon emissions of the fishery sector.

Table 3 the Embodied Co_2 in the Net Export Trade of China's Four Agricultural Sectors from 2009 to 2017 (10^3 tons)

Year	planting products	forest products	livestock products	fishery products	Total
2009	-5253	173	-140	1123	-4097
2010	-6283	201	-545	1423	-5205
2011	-6730	257	-805	1503	-5775
2012	-9178	232	-1061	1491	-8516
2013	-10431	276	-2087	1750	-10493
2014	-11055	326	-2274	1892	-11111
2015	-10256	286	-1801	1778	-9993
2016	-8413	296	-2780	1750	-9148
2017	-9486	276	-2676	1274	-10613

Source: computation by this research

6. Conclusion and Enlightenment

6.1 Conclusion

Although China is changing its traditional mode of agricultural production, the total carbon emission of domestic agriculture is still increasing year by year. In terms of the driving factors, besides the increase of national consumption, the additional agricultural carbon emissions due to meeting the demands of foreign countries grow faster than those of domestic agricultural production, indicating that the agricultural product export trade is also the main factor in the increase of domestic agricultural carbon emissions in china. In fact, however, China's international trade of

agricultural products has long been in deficit, indicating that China has transported agricultural carbon emissions to other countries by international agricultural product trade, thus saving its domestic carbon emissions. In addition, the increase in the proportion of embodied carbon in import and export trade in China's total agricultural carbon emissions shows that the impact of Chinese agricultural products' international trade on CO_2 emissions due to domestic agricultural production and consumption has gradually increased.

China's trade in plantation and animal husbandry products results in net imports of carbon, but the trade in fishery and forestry products results in net exports of carbon. In other words, the former is saving domestic carbon emissions, while the latter increasing. As a result, China's additional domestic carbon emissions from international trade are mainly due to increased foreign demands for Chinese fishery products and forest products; and China's reduction in domestic agricultural carbon emissions from international trade is mainly due to the increased demands for foreign planting products, especially oil crops and animal husbandry products.

6.2 Enlightenment

China's international trade of agricultural products has generally saved domestic carbon emissions. Yet, China has not achieved the goal of reducing domestic agricultural carbon emissions. The government can reduce the domestic carbon emission by taking measures in the following aspects: first, to improve the domestic low-carbon agricultural production's technology level, and fundamentally restrain the increase of agricultural carbon emissions caused by the rapid growth of agricultural product consumption both domestically and abroad. In the process of the transformation and upgrading of Chinese agricultural production from the traditional agriculture to a modern one, the utilization of intermediate products should be improved. It is necessary to reasonably plan and control the resources of the secondary and tertiary industries in the process of agricultural production, so as to suppress the increase of carbon emissions caused by the intermediate consumption of agricultural production. Second, to subdivide industrial sectors to adjust the structure of agricultural industry. The modern agricultural production mode in combination of planting and raising is conducive to reducing intermediate consumption and thus cutting the agricultural carbon emissions at the production end. And third, to subdivide the industrial sectors to adjust the trade structure. By cooperating with other countries, China can achieve a reasonable allocation of resources based on the strengths and weaknesses of each nation's resources. With large-scale production and exportation of agricultural products with local advantages, and with large-scale importation of agricultural products without local advantages, China can reduce international and domestic agricultural carbon emissions from the consumer side.

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References

[1] Wyckoff Andrew W., Roop Joseph M. The embodiment of carbon in imports of manufactured products: Implications for international agreements on greenhouse gas emissions. Energy Policy. 1994. 22(3). 187-194

[2] Wang Zhengpeng, Li Ying, Li Degui. Preliminary analysis of the impact of import and export trade on China's energy carbon dioxide emissions. China energy. 2008. (03). 14-17

[3] Li You, Hewitt C. N. The effect of trade between China and the UK on national and global carbon dioxide emissions. Energy Policy. 2008. 36(6). 1907-1914

[4] Zhong Zhangqi, Wang Zheng, Xia Haibin, Sun Yi, Le Qun. Spatial evolution of China's agricultural production potential under global climate change. Journal of natural resources. 2015.30 (12). 2018-2032

[5] Shui Bin, Harriss Robert C. The role of CO2 embodiment in US–China trade. Energy Policy. 2006. 34(18). 4063-4068

[6] Li You, Hewitt C. N. The effect of trade between China and the UK on national and global carbon dioxide emissions. Energy Policy. 2008. 36(6). 1907-1914

[7] Liu Xianbing, Ishikawa Masanobu, Wang Can, Dong Yanli, Liu Wenling. Analyses of CO_2 emissions embodied in Japan–China trade. Energy Policy. 2010. 38(3). 1510-1518

[8] Qi Ye, Li Huimin, Xu Ming. Estimation of implied carbon in China's import and export trade. China's population, resources and environment. 2008. (03). 8-13

[9] Xu Yuan, Gu Haiying, Wu kaiyao. The implicit Co - 2 evaluation of China's agricultural trade: Based on the non competitive input-output model. Ecological economy. 2013. (08). 82-86

[10] Zhang Di, Wei Benyong, Fang Xiuqi. Research on implicit carbon emissions of China's agricultural trade in 2002 based on input-output analysis. Journal of Beijing Normal University (NATURAL SCIENCE EDITION). 2010. (06). 738-743

[11] Sun Huaping, Chen Lizhen. Empirical Study on the impact of carbon emissions on Sino US agricultural trade. Macroeconomic research. 2014. (02). 137-143

[12] Wang Shaohua, Yu Weiyang, Zhang Wei. Analysis of the impact of technological progress, environmental protection investment and export structure on China's low-carbon industrial structure. Resource science, 2014.36 (12). 2500-2507

[13] Ding Yumei, Liao Chengsheng, Wu Xianrong, Tian Yun. Measurement and spatiotemporal analysis of implied carbon emissions in China's agricultural trade. Journal of Huazhong Agricultural University (SOCIAL SCIENCE EDITION). 2017. (01). 44-54

[14] Dai Yuqin, Feng Zhongchao, Li Gucheng. Measurement and structural analysis of implied carbon emissions in China's agricultural export trade. China Science and Technology Forum, 2016. (01). 137-143.