Study on Carbon Emission Measurement Effects and Factors of Trade in Agricultural Products in China

--An Empirical Analysis Based on the Counterfactual IO-SDA

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Abstract. The carbon emissions derived from production energy consumption have been transferred from country to country through trade segregation, which in turn has changed the spatial and temporal distribution pattern of global carbon emissions. Trade in agricultural products provides an interface for the release of carbon emissions at the production end of the “outer cycle”. The “double-edged sword” effect can not only alleviate the carbon pressure on domestic agriculture but also may exacerbate the problem of international carbon transfer. In this article, the total amount and change trend of carbon emissions in agriculture and forestry sectors were calculated, the IO-SDA model was used to decompose the impact of carbon emissions from the scale effect, structural effect, and technological effect, two types of counterfactual extreme scenarios 1 and 2 were set up, and the demand for trade in intermediate products and the trade structure were introduced to measure the effect of carbon emission reduction. The results showed that, firstly, the total carbon emissions of trade in agricultural products in China basically showed a trend of first rising and then falling; in terms of industries, agriculture and forestry sectors in China showed significant differentiated development trends, and the carbon emissions of the agricultural sector were much higher than those of the forestry sector. Secondly, the technological effect factors promoted the decline of carbon emissions of trade in agriculture and forestry sectors in China, and the structural effect factors and scale effect factors slowed down the decline of carbon emissions; the overall effect of carbon emission reduction in the forestry sector was better than that of the agricultural sector. Thirdly, the counterfactual results showed that the carbon emission reduction effect of intermediate trade in agricultural products in China showed a steady increase trend, the demand for trade in intermediate products showed an overall carbon-increasing effect, and the intermediate trade structure showed an overall carbon-decreasing effect.

Keywords: Trade in agricultural products; Carbon emission measurement; IO-SDA model; Counterfactual scenario.

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1 Introduction

The global industrial division of labor provides the production basis for the effective allocation of products and service resources in the world, but the carbon emissions derived from the production energy consumption have been transferred from country to country through trade segregation, which in turn has changed the spatial and temporal distribution pattern of global carbon emissions. In recent years, a series of problems brought about by global climate change have pushed countries around the world to pay sustained attention to greenhouse gas emissions and ecological and environmental protection, strive to reach a unanimous consensus on realizing the vision of carbon neutrality and carbon peaking, and put forward measures, including a carbon border adjustment tax and an effective carbon pricing scheme, as well as actively propose the realization of the goal of carbon emission reduction. China, as the largest carbon emitting and trading country in the world, urgently needs to make sustained efforts from two dimensions including economic value and green value of trade, and actively explores effective paths for the development of green trade. In October 2022, the Implementation Plan for the Establishment of a Sound Standard and Measurement System for Carbon Peaking and Carbon Neutrality explicitly proposed the improvement of the "carbon market-oriented standard system", "ecological product value realization standards", and the promotion of "carbon trading" and other market instruments. The report of the "two sessions" in 2024 proposed to support the upgrading of processing trade, expand trade in intermediate products, green trade, and other new growth points, and improve the quality and quantity of foreign trade. How to clarify and measure the transfer and change of carbon emissions and carbon trading in international trade has become an important driving force for the country to continue to promote the development of a green and low-carbon economy "going global".

Agriculture, as an important greenhouse gas emission source industry, also hides the crisis of carbon emission surge in the bailout of industrial development in China. Currently, more than one-third of carbon emissions in China come from agricultural production, and traditional smallholder production has increased its independent responsibility for agricultural carbon emissions reduction, constantly exerting pressure on the agricultural "carbon peaking and carbon neutrality" development in China. Trade in agricultural products provides an interface for the release of carbon emissions at the production end of the "outer cycle". The "double-edged sword" effect can not only alleviate the carbon pressure on domestic agriculture but also may exacerbate the problem of international carbon transfer. Therefore, in this article, the total amount and change trend of carbon emissions in the agriculture and forestry sectors were calculated, the IO-SDA model was used to decompose the impact of carbon emissions from the scale effect, structural effect, and technological effect, two types of counterfactual extreme scenarios were set up, and the demand for trade in intermediate products and the trade structure were introduced to measure the carbon emission reduction effect. Combined with the results of the analysis, optimization countermeasures for the development of trade in agricultural products in China were proposed, providing a new solution to the problem of reducing the total carbon emissions of trade in agricultural products and promoting the growth of economic interests.

2 Literature Review

2.1 Trade Carbon Measurement Model

Trade carbon measurement generally refers to the calculation of Embodied Carbon, i.e. the total amount of carbon emissions from all stages of the trade process, such as the acquisition of raw materials, manufacturing and processing, and transportation. Regarding the selection of trade carbon measurement models, the academic community mainly centers on two types of models, namely, Life Cycle Assessment (LCA) and Input-Output Analysis (I-O), for research and application [5]. Compared with the LCA model that focuses on the production cycle, the IO model is based on the measurement of the mutual value of macro-industry production sectors, which is characterized by data availability and quantification and widely used in the fields of energy consumption and bilateral trade carbon emissions [6]. IO models are generally categorized into single-region input-output (SRIO) and multi-region input-output (MRIO) models based on the differences in the number and scope of study regions. The “domestic technology assumption” is an important criterion for distinguishing between the two types of models and reduces the biasing effect of the estimated coefficients [3]. Based on the MRIO model for the measurement of carbon emissions from trade in the United States, the United Kingdom, Germany, and other OECD member countries, scholars have found that through international trade, the developed countries exerted “carbon leakage” pressure on developing countries, weakening the overall impact of the global carbon policies [4].While domestic research on trade carbon measurement is late, most scholars believe that trade carbon transfer is conducive to the realization of energy saving and emission reduction needs in China [7]. In terms of industries, the domestic manufacturing industry consumes a huge amount of traditional energy in the process of development, showing significant energy and heavy chemical industry-driven characteristics [9]. The consumption side of the Kuznets curve for carbon emissions is better than the production side [8]. There is limited research on carbon emissions from agriculture and agricultural products. When Ye Tianyang et al. [10] constructed a spatial Durbin model to measure the impact effect of carbon emissions on RCEP countries. They found that there is a complementary feature between the structure of agricultural exports and carbon emissions, and in particular, the diversification of export trade significantly inhibits the increase of carbon emissions [11].

2.2 Influencing Factors of Trade Carbon Measurement

Regarding the research on the influencing factors of trade carbon measurement, it mainly includes two types, namely index decomposition analysis (IDA) and structural decomposition analysis (SDA), of which the SDA model provides a variety of mathematical methods in decomposing the changes of the influencing factor indicators, including residual improvement, two-stage decomposition, factor ordering variety and weighted average decomposition. Studies have shown that carbon emission intensity, intermediate inputs, and scale structure have an important role in influencing changes in carbon emissions [13], and there is a significant difference in the effect of affecting carbon emissions and transfer, in which the scale of trade and the input structure of the production sector leads to an accelerated rise in carbon emissions [14], while the technological effect, the effect of carbon emission intensity and the effect of value-added play an inhibiting effect [15]. Wang Wenzhi et al. [12] introduced the value-added drive into provincial trade carbon measurement in China, constructed a dual SDA model and a counterfactual method to verify that value-added indirectly realize the carbon emission reduction effect by influencing the scale of trade in intermediate products, trade structure, and other elements. To summarize, SDA is mainly divided into three aspects, namely, scale effect, structural effect, and technological effect in the form of structural decomposition of trade carbon measurement. With the continuous improvement of multi-region and multi-factor input-output models and data, SDA has become the main tool for analyzing the influencing factors of trade carbon emission reduction. A few scholars have also subdivided the types of agricultural products and conducted trade measurements from the perspectives of trade in forest products and trade in aquatic products, respectively, and found that the structure of the forestry industry and the structure of the marine fishery industry also have a strong direct promotion effect on the efficiency of carbon emissions [16].

2.3 Literature Review

In summary, the academic community has conducted extensive and in-depth research on the trade carbon measurement model and influencing factors, which has laid a solid theoretical foundation and technical support for the study of trade in agricultural products herein. However, the literature review revealed some limitations of the existing studies. Firstly, the scope of most trade carbon measurement studies remains at the national or regional level, rarely involving a single industry or a single sector, especially for agricultural products in China, where there is a gap in carbon measurement studies. Secondly, there is a misunderstanding of the classification of trade in agricultural products, and the refinement and selection of product types are not based on the whole agricultural industry chain. Thirdly, there is a lack of effective measurement of the difference between measured and real values of carbon emissions under extreme factual conditions, and in particular, there is a lack of awareness of the difference in carbon emission reductions from trade in intermediate products. Based on this, in this article, firstly, the total amount and change trend of carbon emissions in agriculture and forestry sectors were calculated, enriching the research samples and contents of carbon measurement; secondly, the IO-SDA model was used to decompose the impact of carbon emissions from the scale effect, structural effect, and technological effect; and thirdly, two types of counterfactual extreme scenarios 1 and 2 were set up, and the demand for trade in intermediate products and trade structure were introduced to measure the effect of carbon emission reduction.

3 Study Design

3.1 Trade Carbon Measurement Model

In the trade carbon measurement, firstly, the value of sectoral output in the non-competitive input-output table is measured by constructing an input-output model; second, the sectoral carbon dioxide emissions are calculated according to the carbon emission intensity of different sectors; and third, the sectoral output is multiplied with the sectoral carbon dioxide emissions to get the total trade carbon. The basic input-output model and the extended form are shown in equations (1) and (2):

$$Y = AY + X \tag{1}$$

$$\begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_{\mathrm{m}} \end{pmatrix} = \begin{pmatrix} \alpha_{11} \cdots \alpha_{1m} \\ \alpha_{21} \cdots \alpha_{2m} \\ \vdots \quad \ddots \quad \vdots \\ \alpha_{m1} \cdots \alpha_{mm} \end{pmatrix} \begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_{\mathrm{m}} \end{pmatrix} + \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_{\mathrm{m}} \end{pmatrix} \tag{2}$$

Where Y refers to the output column vector, AY refers to the intermediate use matrix, X refers to the export trade column vector, and A refers to the consumption coefficient matrix. Such input-output models have a row equilibrium relationship, i.e., total output = intermediate demand + final demand.

The sector-based carbon dioxide emissions formula is shown in equation (3):

$$C_i = Q_i Y_i \tag{3}$$

Where C_i is carbon dioxide emissions and Q_i is the carbon emission intensity of sector i. Substituting equation (3) in equation (1) yields a model for the trade carbon measurement of country i as:

$$C_i = Q_i (I - A)^{-1} X \tag{4}$$

3.2 Input-Output Based Structural Decomposition Analysis (SDA) Model

The SDA structural decomposition emphasizes the importance of the number of variables in the process of decomposing the effect of influence; if there are n influence variables, n! forms of structural decomposition exist. Based on the carbon measurement model in the preceding part, in this study, the IO-SDA model was constructed to study the influencing factors of carbon changes in trade in agricultural products with reference to the bipolar decomposition method of Song Hui [1]. Under the condition of considering the initial base period time 0 and suspension period 1, the carbon change $\triangle$Ci between the two periods is shown in equation (5):

$$\Delta C_{it} = \Delta C_{it1} - \Delta C_{it0} = Q_{it1}(I - A_1)^{-1} X_{it1} - Q_{it0}(I - A_0)^{-1} X_{it0} \tag{5}$$

Qi can be further decomposed by equations (3), (4), and (5) into the technological effect ΔV_t^d on carbon emissions from changes in consumption coefficients, the structural effect ΔV_{st}^d on carbon emissions from changes in the structure of consumption, and the scale effect ΔV_{sc}^d on carbon emissions from changes in the scale of consumption. The corresponding change contributions of the three effects are ΔE_t^d , ΔE_{st}^d and ΔE_{sc}^d . The arithmetic mean of the two periods of data is calculated to get the carbon change impact model after the double decomposition as in equation (6):

$$\begin{aligned} \Delta C_{it} &= \Delta E_t^d + \Delta E_{st}^d + \Delta E_{sc}^d \\ &= \frac{[\Delta v_t^d (I - A_0)^{-1} X_{it0} + \Delta v_t^d (I - A_1)^{-1} X_{it1}] + [\Delta v_{st}^d (I - A_0)^{-1} X_{it0} + \Delta v_{st}^d (I - A_1)^{-1} X_{it1}]}{2} \\ &+ \frac{+[\Delta v_{sc}^d (I - A_0)^{-1} X_{it0} + \Delta v_{sc}^d (I - A_1)^{-1} X_{it1}]}{2} \end{aligned} \tag{6}$$

3.3 Counterfactual Scenario Setting

Considering the possible carbon emission reduction effects of changes in intermediate products in trade in agricultural products, in this article, by controlling the value added of trade, import-export cooperation, and carbon emission intensity unchanged, and drawing on the study of Dietzenbacher [2], the impact of the scale of demand for intermediate trade in agricultural products and the structure of demand on carbon emissions was analyzed using counterfactual scenarios. The following two extreme scenarios were set up:

Scenario 1:
$$\begin{aligned} \Delta C_{it}^{'} &= \Delta E_{t,0}^d + \Delta E_{st,0}^d + \Delta E_{sc,0}^d \\ &= \frac{[\Delta v_t^d (I - A_0)^{-1} X_{it0}] + [\Delta v_{st}^d (I - A_0)^{-1} X_{it0}] + [\Delta v_{sc}^d (I - A_0)^{-1} X_{it0}]}{2} \end{aligned} \tag{7}$$

Scenario 2:
$$\begin{aligned} \Delta C_{it}^{''} &= \Delta E_{t,1}^d + \Delta E_{st,1}^d + \Delta E_{sc,1}^d \\ &= \frac{[\Delta v_t^d (I - A_1)^{-1} X_{it1}] + [\Delta v_{st}^d (I - A_1)^{-1} X_{it1}] + [\Delta v_{sc}^d (I - A_1)^{-1} X_{it1}]}{2} \end{aligned} \tag{8}$$

Equation (7) assumes total carbon emissions from intermediate trade demand for agricultural products at time point t in period 0, and equation (8) assumes total carbon emissions from intermediate trade demand for agricultural products at time point t in period 1.The difference between △C and $\Delta C_{it}^{'}$ & $\Delta C_{it}^{''}$ under the counterfactual condition reflects the difference between the real carbon emissions and those of the hypothetical scenario. If the difference is negative, it means that the optimization of the scale of the intermediate demand for agricultural products and the demand structure can reduce carbon emissions, and vice versa.

3.4 Data Description

In this study, data on trade in agricultural products came from the database of the Organization for Economic Cooperation and Development (OECD) and the website of the National Bureau of Statistics, in which the analysis was based on the input-output table of agricultural-related industries of OECD as non-competitive input-output data, and the scope of the data was selected from the categories of "Agriculture, Hunting, Forestry, and Fisheries" and "Timber, Wood, and Cork Products" in the period of 1995-2020 to make measurements. Moreover, agricultural trade products were redistributed between intermediate inputs and final consumption, considering data from the statistical yearbook on the website of the National Bureau of Statistics in the sectors of "Agricultural, Forestry, Animal Husbandry and Fishery Products and Services" and "Timber Processing, Furniture, Papermaking and Printing, and Educational, Industrial and Aesthetic Products". To exclude the effect of the price factor, the year 1990 was taken as the base period for the price index (1990 = 100), and the price index for each year of the agricultural sector was extrapolated step by step. The calculation of carbon emission intensity of agricultural products was based on the IPCC Guidelines for National Greenhouse Gas Inventories 2019. The measurement was based on the carbon emission factors and consumption of raw coal, coke, gasoline, natural gas, etc. The average low-level heat generation of energy sources was determined by reference to the description of relevant energy sources in the 2020 China Energy Statistical Yearbook. The classification standard for agricultural products was derived from the BEC classification of the United Nations Statistical Division. Matlab software was used for modeling in this study.

4 Carbon Measurement and Factor Analysis of Trade in Agricultural Products in China

4.1 Trends in Change

The trend of carbon measurement of trade in agricultural products in China from 1995 to 2020 is shown in Figure 1. In terms of the overall trend, the total carbon emissions from trade in agricultural products in China showed a trend of first rising and then falling during the study interval. During the period 2001-2008, after it acceded to the WTO, China actively participated in the international division of labor in production and the exchange of agricultural products in the market, and the scale of production in the agricultural and forestry products industry expanded, accelerating the rise of carbon emissions. In 2008-2009, carbon emissions from agricultural export trade in China peaked at about 1.4 million tons. Along with the deepening impact of the global financial crisis and the intensification of ecological environmental protection, carbon emissions from 2009 to 2020 steadily declined year by year to 1,099,400 tons, with an average annual growth rate of -1.79%. In terms of industries, agriculture, hunting, forestry, and fisheries sector (hereinafter referred to as the agriculture sector) and the timber, wood, and cork products sector (hereinafter referred to as the forestry sector) in China showed significantly differentiated development trends. In comparison, carbon emissions from trade in the agricultural sector in China showed a “V” pattern of first falling and then rising, and subsequently dropping to a low of 0.34 in 2000, then rising rapidly to 0.84 in 2009, and continuing to stabilize at around 0.8. Carbon emissions from trade in the forestry sector, on the other hand, showed the opposite trend to that of the agricultural sector, showing an “A” pattern of first rising and then falling, reaching a peak of 0.66 in 2000, and then rapidly dropping and remaining at around 0.2. In addition, except for the year 2000, carbon emissions from the agricultural sector were much higher than those from the forestry sector, indicating that the main sources of carbon emissions from trade in agricultural and forestry sectors in China are still productive agricultural behaviors such as planting and transportation. Future carbon measurement should focus on optimizing the structure of the agricultural industry and green innovation in technology.

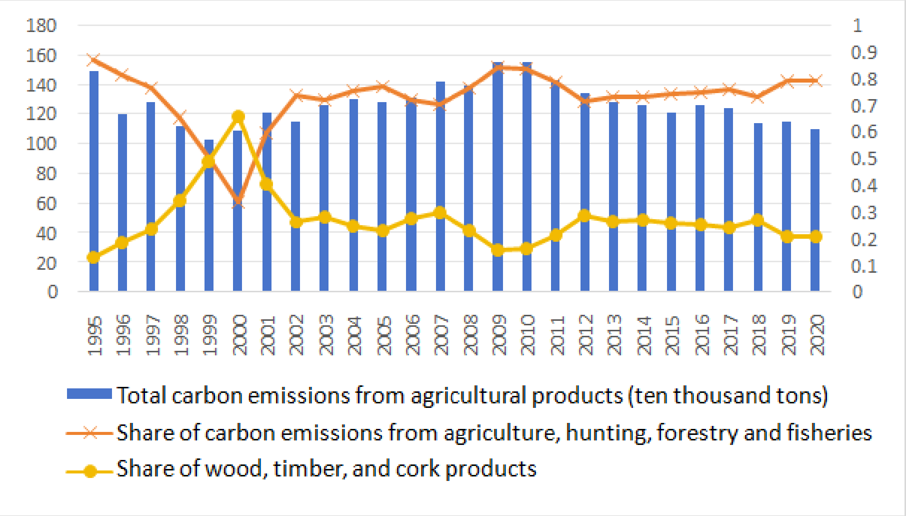

Fig. 1. Total Carbon Emissions from Trade in Agricultural Products in China, 1995-2020

4.2 Overall Structural Decomposition

According to the IO-SDA model, and combined with the stage-specific characteristics of carbon changes in trade in agricultural products in China, the 1995-2020 period was divided into three periods, namely, 1995-2000, 2001-2009, and 2010-2020, and structurally decomposed according to the three types of factors, namely, technological effect, structural effect, and scale effect. The results are shown in Tables 1 and 2.

Within the study interval, the technological effect factor was still the primary factor contributing to the decline of carbon emissions from trade in the agricultural sector in China, with a contribution value of -13,770,919 tons, which manifests itself as a direct inhibition of carbon emissions by changes in carbon emission intensity. Both the structural effect factor and scale effect factor slowed down the declining efficiency of carbon emissions from trade in the agricultural sector in China, of which the structural effect factor slowed down the effect most obviously, contributing 14,987,788 tons, and the scale effect factor contributing 4,211,422 tons. It can be seen that, although the Chinese government continues to promote the development of ecological environmental protection and energy-saving emission reduction technologies, the role of technological effects is relatively limited, and the structural effects have offset the carbon emission reduction capacity brought about by technological advances, so the task of controlling and reducing carbon emission in the agricultural sector is still arduous.

Table 1. Structural Decomposition of Factors Affecting Carbon Emissions from Trade in the Agricultural Sector in China, 1995-2020

Decomposing	Change in carbon emissions from trade in the agricultural sector (ten thousand tons)			
factor	1995-2000	2001-2009	2010-2020	1995-2020
Technological effect	-112.6490	-152.7799	-472.6930	-1377.0919
Structural effect	33.9965	-6.2123	-172.6595	1498.7788
Scale effect	136.9704	311.0192	878.0132	421.1422
Total	58.3179	152.027	232.6607	542.8291

Table 2. Structural Decomposition of Factors Affecting Carbon Emissions from Trade in the Forestry Sector in China, 1995-2020

Decomposing	Change in carbon emissions from trade in the forestry sector (ten thousand tons)			
factor	1995-2000	2001-2009	2010-2020	1995-2020
Technological effect	-299.4253	-352.2721	-993.1124	-3708.1142
Structural effect	63.2643	123.0922	34.2312	1898.7788
Scale effect	778.9078	1692.3323	883.2334	1121.3523
Total	542.7468	1463.1524	-75.6478	-687.9831

Within the study interval, similar to the agricultural sector, the technological effect factor was the primary factor contributing to the decline of carbon emissions from trade in the forestry sector in China, with a contribution value of -37,081,142 tons, which manifests itself as a direct inhibition of carbon emissions by changes in carbon intensity. Both the structural effect factor and scale effect factor slowed down the declining efficiency of carbon emissions from trade in the forestry sector in China, of which the structural effect factor slowed down the effect relatively obviously, contributing 18,987,788 tons, and the scale effect factor contributed 11,213,523 tons. It is worth noting that the contribution of the forestry sector to the total effect of carbon emission reduction was -6,879,831 tons, and the overall control effect of the “carbon peaking and carbon neutrality policy” was realized. Compared with the agricultural sector, products of the forestry sector are characterized by high pollution and high energy consumption, and technological transformation and upgrading are earlier. Although the structural effect has offset to a certain extent the carbon emission reduction capacity brought about by technological advancement, on the whole, the overall carbon emission reduction effect of the forestry sector has been obvious.

There is variability in the extent of the role of various types of decomposition factors over time. From 1995 to 2000, carbon emissions from the agriculture and forestry sectors grew positively, with the scale effect playing a dominant role. From 2001 to 2009, the scale effect increased, and carbon emissions rose rapidly in the agriculture and forestry sectors, with the scale effect particularly strong in the forestry sector. Since 2010, the positive role of technological effects increased dramatically, with a stronger impact on the forestry sector than on the agricultural sector.

4.3 Counterfactual Results

Two types of extreme scenarios 1 and 2 were set based on the counterfactual model. Years 1995, 2001, and 2010 were taken as period 0 to measure the contribution of the demand for intermediate trade in agricultural products and the structure of intermediate trade to trade carbon emissions in different periods, as shown in Figures 2 and 3. Considering that intermediate product inputs in the agriculture and forestry sectors were not split in the original data, in this section, counterfactual scenarios were analyzed only for the broad category of agricultural products.

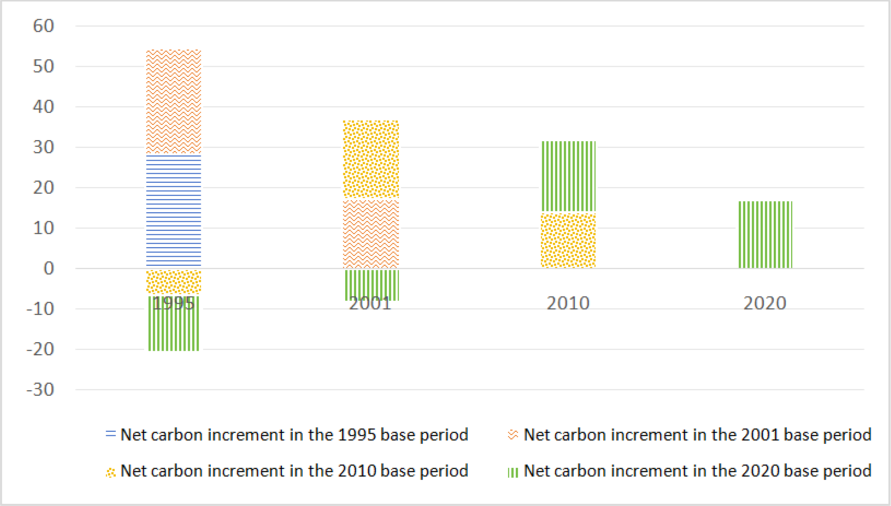

Fig. 2. Carbon Emission Impacts of Demand for Intermediate Trade in Agricultural Products in China, 1995-2020

Within the study interval, the demand for intermediate trade in agricultural products in China showed an overall carbon-increasing effect. In terms of time, when 1995 was taken as period 0, the demand for intermediate trade in agricultural products in 2001 showed a carbon-increasing effect while the demand for intermediate trade in agricultural products in 2010 and 2020 showed a carbon-decreasing effect. When 2001 was taken as period 0, the demand for intermediate trade in agricultural products in 2001 showed a carbon-increasing effect while the demand for intermediate trade in agricultural products in 2020 showed a carbon-decreasing effect. When 2010 was taken as period 0, the demand for intermediate trade in agricultural products in 2020 showed a carbon-increasing effect. Moreover, the structure of intermediate trade in agricultural products in China showed an overall carbon-reducing effect, with the exception of 2001 and 2010 relative to 1995, the structure of intermediate trade in agricultural products in the period t showed a carbon-decreasing effect. In 2020, for example, compared with 1995, 2001, and 2010, the carbon reduction of the structure of intermediate trade in agricultural products was 340,600 tons, 379,900 tons, and 371,200 tons, accounting for 31.22%, 34.74%, and 34.04% of the total carbon emissions in 2020, respectively. It can be seen that by controlling the value added of trade, import-export cooperation, and carbon emission intensity unchanged, the carbon reduction effect of intermediate trade in agricultural products in China has shown a steady increase, in which the continuous optimization of the trade structure of intermediate products has become an important development path for controlling the carbon emission reduction of agricultural products.

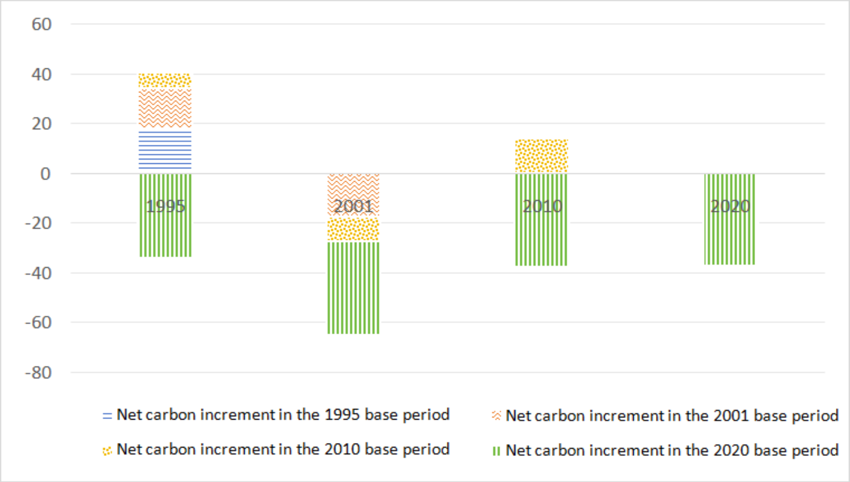

Fig. 3. Carbon Emission Impacts of the Intermediate Trade Structure of Agricultural Products in China, 1995-2020

5 Conclusions and Recommendations

In this article, the total amount and change trend of carbon emissions in agriculture and forestry sectors were calculated, the IO-SDA model was used to decompose the impact of carbon emissions from the scale effect, structural effect, and technological effect, and two types of counterfactual extreme scenarios 1 and 2 were set up, and the demand for trade in intermediate products and trade structure were introduced to measure the effect of carbon emission reduction. The following conclusions were reached: firstly, the total carbon emissions of trade in agricultural products in China basically showed a trend of first rising and then falling; in terms of industries, agriculture and forestry sectors in China showed significant differentiated development trends, and the carbon emissions of the agricultural sector were much higher than those of the forestry sector. Secondly, the technological effect factors promoted the decline of carbon emissions of trade in agriculture and forestry sectors in China, and the structural effect factors and scale effect factors slowed down the decline of carbon emissions; the overall effect of carbon emission reduction in the forestry sector was better than that of the agricultural sector. Thirdly, the counterfactual results showed that the carbon emission reduction effect of intermediate trade in agricultural products in China showed a steady increase trend, the demand for trade in intermediate products showed an overall carbon-increasing effect, and the intermediate trade structure showed an overall carbon emission reduction effect.

Based on the above conclusions, the following countermeasures were proposed in this study:

Firstly, improve the measurement and monitoring of carbon flows in trade in agricultural products, and open up the “technologically advanced” road. The carbon value of trade in agricultural products should be scientifically quantified, and the international multi-regional input-output model should be used to calculate the carbon transfer value. Relying on the input-output specification table and implementation standards of OECD and the World Bank, the agricultural product trade input-output table in China should be independently formulated, and a five-year normalization mechanism should be formed. In addition, horizontal cooperation between the agricultural sector and the trade sector should be strengthened, and a big data platform for agricultural trade should be constructed based on digital technology and information applications, to share information, reduce carbon barriers to the “going global” trade in agricultural products, and efficiently and scientifically reduce the transfer of carbon emissions and other environmental costs.

Secondly, optimize carbon production patterns for agricultural trade to provide the basis for “green trade”. It is necessary to comply with the increasing trend of international trade, rationalize the scale of agricultural trade and export, enhance the status of agricultural products in China in the global market, and reduce the carbon emissions on the production side of agricultural products in China. The reprocessing capacity of intermediate products in the agricultural industry should be appropriately increased to achieve a “win-win” situation in which resource consumption is reduced and economic benefits are increased. In addition, it is desired to insist on the green concept of agricultural trade exchange, carry out the construction of an international low-carbon cooperation mechanism, drive the worldwide carbon emission management of agricultural products with a green consensus, and construct a global carbon transfer compensation payment network.

Thirdly, use the carbon tax mandates on agricultural trade to promote the realization of a “community of carbon reduction”. It is desired to learn from the carbon tax governance experience of developed countries and explore the integration mechanism of carbon tax and carbon trading. Carbon taxes should be levied in time for industries not covered by the carbon trading market, and dynamic tax rates should be flexibly adjusted to achieve the effect of responding to international carbon tariffs and reducing the impact of agricultural trade. Green carbon tariffs should be formulated according to the types of agricultural products to achieve dynamic carbon compensation for agricultural trade. The management concept of “carbon footprint” should be introduced, the monitoring and management of “carbon footprint” should be strengthened, and carbon transfer service fees should be collected from counterparties, to reduce the pressure of carbon emissions on the production side, realize the sharing of responsibilities between the two sides of the trade, and establish a “community of carbon reduction” for all mankind.

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