Study on the Carbon Emission Reduction Effect of Green Consumption Development in Rural Areas

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Abstract. Rural green consumption development is an important part of rural green development and plays an important role in rural consumption carbon emission reduction. This paper measured the rural green consumption development index by the TOPSIS entropy weighting method with a sample of 30 provinces, cities, and autonomous regions from 2002 to 2021 to explore the impact of rural green consumption development on carbon emission reduction.It is found that rural green consumption development has a significant inhibitory effect on both rural direct carbon emissions and rural Embodied carbon emissions. Therefore, the government needs to take measures to raise rural residents' awareness of green consumption and increase rural residents' disposable income to improve rural residents' green consumption level. The findings of this paper provide new perspectives and evidence for understanding how rural green consumption development can effectively mitigate carbon emissions and can be used as a reference for the formulation of " dual-carbon" policies.

Keywords : rural green consumption; carbon emission reduction ;TOPSIS ; carbon emission accounting

1 Introduction

At the 75th United Nations General Assembly in September 2020, General Secretary Xi Jinping earnestly stated that "China's carbon dioxide emissions strive to peak by 2030, and work hard to achieve carbon neutrality by 2060." Rural consumption, as an important source of carbon emissions, is one of the main starting points for realizing the goal of carbon neutrality. The scale of China's rural consumption market is quite large, and the proportion of rural residents' consumption expenditure in urban and rural residents' consumption expenditure will reach 35.37% in 2022. Reducing carbon emissions from the growing rural consumption and realizing green and low-carbon development is a powerful support for China to realize the "dual-carbon target".

China's Ministry of Commerce's Implementation Program for Promoting Green Consumption anticipates a significant increase in the market share of green products by 2025, which is of great significance to the high-quality development of China's economy and environmental governance. Can the development of rural green consumption

Y. Jiao et al. (eds.), *Proceedings of the 3rd International Conference on Internet Finance and Digital Economy (ICIFDE 2023)*, Atlantis Highlights in Economics, Business and Management 1,
https://doi.org/10.2991/978-94-6463-270-5_38

bring new momentum for agricultural carbon emission reduction? Thinking and exploring this issue is of great practical significance to the development of rural green consumption and the promotion of rural carbon emission reduction.

2 Literature review

The development of green consumption, as a major inhibitor of carbon emissions, has also attracted extensive academic attention and discussion in recent years. On the one hand, there is research on the definition of green consumption. Elkington and Hailes(1988)[1] defined the connotation of green consumption from the three levels of production, life, and consumption, based on which, Akenji (2014)[2] considered green consumption as the consumption of production, propaganda, goods, and services based on the protection of the environment. On the other hand, there is research on measuring the development level of green consumption, Cui Q(2022)[3] argues that the green consumption indicator system needs to reflect the environmental impact of consumption behavior and the intensity of consumption of energy resources. Cao Y(2023)[4] utilized green economy efficiency to measure green economy development and used the non-radial directional distance function (NDDF) to calculate green economy efficiency.

In conclusion, there is little research on the connection between rural green consumption growth and carbon dioxide emissions. Compared with existing studies, the marginal contribution of this paper focuses on the relationship between rural green consumption growth and carbon emissions.

3 Construction of a rural green consumption indicator system

To empirically test the carbon emission reduction effect of rural green consumption development, it is first necessary to construct a rural green consumption indicator system to evaluate the current situation of rural green consumption development. Rural green consumption indicator system design. Referring to the research of Xie Chi (2020)[5] which divides the green consumption indicator system into three dimensions: production, life, and ecology, the rural green consumption indicator system in this paper will also be constructed from the above three dimensions.

3.1 Data processing methods

As illustrated by the indicator system in Table 1, the indicators of green consumption in rural China encompass three dimensions. Some of these indicators align with a positive direction, while others lean towards a negative direction. Given the extensive scope and wide timeframe of these indicators, the entropy weighting method of TOPSIS proves to be an ideal approach.TOPSIS entropy weight method is not limited by the number of samples and indicators, and can be calculated by setting the ideal solution and measuring the distance between the evaluation object and it, so as to get the good

and bad solutions[6]. Therefore, this paper will use the above TOPSIS entropy weight method to evaluate the development of green consumption in rural China.

Table 1. Rural Green Consumption Indicator System

overall index	Tertiary indicators	orientations
Rural Green Consumption Index	Fertilizer use per unit of irrigated cropland	negative
	Rural solar water heater area	forward
	Rural residents per unit of disposable income living consumption sector coal consumption	negative
	Consumption of liquefied petroleum gas (LPG) by rural residents per disposable income living consumption sector	negative
	Per capita education, culture, and recreation expenditures of rural residents as a percentage	forward
	Number of rural performances by performing arts organizations	forward
	Rural cable radio and television penetration rate	forward
	Area of State-level nature reserves	forward
	Rural latrine penetration rate	forward
	Soil erosion control area	forward

4 Model construction and empirical analysis

4.1 Modeling

1) Accounting for direct carbon emissions.

This paper uses the IPCC inventory accounting method to calculate direct carbon emissions[7]. At present, direct carbon emissions from residents refer to carbon emissions from direct energy consumption in residents' lives, and direct carbon emissions from rural residents' living consumption mainly come from CO2 emissions from 11 types of fossil energy consumption, such as raw coal, coke, coke-oven gas, other gases, gasoline, kerosene, natural gas, and so on.

2) Accounting for Embodied carbon emissions

Embodied carbon emissions refer to the CO2 emissions generated by the consumption of energy in the various stages of production and distribution of various non-energy goods and services needed by residents to meet their basic daily needs[8]. The input-output method is used for Embodied carbon emissions.

In this paper, input-output analysis (IOA)[9] is used to account for Embodied CO_2 emissions caused by Chinese residents' consumption. With the help of input-output tables, IOA can trace the complete upstream industry chain of final consumer goods, to accurately account for the Embodied emissions caused by final consumption. The embodied carbon emissions caused by residents' consumption can be calculated by equation(1).

$$T = t(I - A)\ Y^{-1} \tag{1}$$

where t is the element of the matrix, i.e., the intensity of direct CO2 emissions from each sector; I is the unit matrix; (I-A)−1 is the Leontief inverse matrix, which represents the direct and Embodied induced effects on the sectors of the national economic system when increasing the final demand of one unit of a sector; T is the row vector of Embodied CO2 emissions from consumption of residents in each sector; and Y is the diagonal matrix of residential consumption.

3)Selection and description of variables

(1) Explained variables This paper fully considers the impact of rural residents' green consumption development on both direct and Embodied carbon emissions and chooses the natural logarithmic value of direct carbon emissions (ED) and the natural logarithmic value of Embodied carbon emissions (EI) as the explanatory variables.

(2) Explanatory variables. This paper chooses the rural green consumption development index obtained according to the construction of the rural green consumption indicator system as an explanatory variable.

(3) Control variables. Drawing on the practice of Wan Guanghua (2022)[10] and other studies .The following four control variables that may affect the development of rural green consumption are introduced from the dimensions of economic development and demographic characteristics: ① Per capita disposable income. Measured by the disposable income of rural residents; ②Financial development level. Measured by the ratio of the total deposits and loads of banking financial institutions to the GDP of each province in each year;③The proportion of the secondary industry. Measured by the ratio of the value added of the secondary industry to the GDP of each province in each year;④Elderly dependency ratio. Measured by the ratio of the number of elderly people to the number of people of working age in each province in each year.

4)Benchmark regression modeling

This paper constructs econometric models (2) and (3) with direct carbon emissions (ED) and embodied carbon emissions (EI) as the being explanatory variables and rural green consumption development index (gcd) as the explanatory variables as shown below.

$$EDit=a0+a1\,gcdit+a2\ \text{Control}\ it+rt+ui+\varepsilon it \tag{2}$$

$$EIit=\beta 0+\beta 1\,gcdit+\beta 2\ \text{Control}\ it+rt+ui+\varepsilon it \tag{3}$$

Where $EDit$ denotes direct carbon emissions of rural residents in year t in the province; $EIit$ denotes embodied carbon emissions of rural residents in year t in the province; $gcdit$ denotes rural green consumption development index in year t in the province; Control it denotes control variables in year t in the province; rt denotes time fixed effect ,ui represents province fixed effect and εit represents residual terms.

4.2 Empirical analysis

1)Analysis of the results of the estimation of the baseline model

The impact of rural residents' development of green consumption on rural direct carbon emissions and embodied carbon emissions is shown in Table 2 by the results of the OLS estimation. The estimation results in column (1) of the table show that the coefficients of the explanatory variables of the rural green consumption development index are all significantly negative, which shows that the development of green consumption by rural residents impacts direct carbon emissions, reduces the intensity of energy consumption and optimizes the structure of energy consumption, which makes the consumption of energy more efficient. From the estimation results in column (2) of the table, it can be seen that the coefficient of the explanatory variable rural residents' green development index is also significantly negative, which indicates that the development of rural residents' green consumption also harms rural embodied carbon emissions and that the effect of rural residents' green consumption reduces embodied carbon emissions through the promotion of green consumption upgrading of rural residents and then forcing enterprises to transform their industrial structures into green ones.In conclusion, the growth of rural green consumption has a detrimental impact on both direct and embodied carbon emissions.

Table 2. Estimated results of OLS regression model of rural green consumption development affecting rural carbon emissions

	Direct carbon emissions（OLS estimation）(ED)	Embodied carbon emissions (OLS estimation) (EI)
gcd	-1.2222***	-0.2473*
income	0.0052***	-0.0004
finance	0.2286***	-0.0464***
second industry	0.8372***	0.5765***
elderly	-0.0127***	-0.0033
constant	5.4588***	7.5870***
individual effect	Yes	Yes
time effect	Yes	Yes
N	597	600
adjusted_R^2	0.8755	0.9806

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

5 Conclusions

The theoretical analysis in this paper shows that the development of rural green consumption can reduce carbon emissions. In 2022, rural residents' consumption accounted for 31.24%, which is still growing at a high rate, and the focus of the "dual carbon policy" in the future should focus on how to promote the development of rural residents' green consumption to achieve the "dual carbon goal".

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