Research on the Evolution Relationship between Agricultural Carbon Emissions and Economic Growth in Fujian Province Built on the EKC Model

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Abstract. It is vital to explore the relationship between regional agricultural carbon emissions and economic growth for promoting the research of the agricultural Environmental Kuznets Curve (EKC) in China. Based on this, this research first uses the carbon emissions coefficient method to measure Fujian’s agricultural carbon emissions from 2000 to 2016, and uses the EKC model to explore the evolutionary relationship between regional agricultural carbon emissions and economic growth. Research shows that chemical fertilizers are the main cause of agricultural carbon emissions in Fujian. The agricultural carbon footprints and carbon emission intensity in the research area have not yet met the "inverted U-shape" assumed by EKC. Based on this, the author proposes that Fujian should continue to deepen the adjustment of the agricultural supply-side structure and take the road of green and low-carbon agricultural development. Fujian should implement technology reforms and improve the utilization of fertilizers in agricultural production and other emission reduction measures.

Keywords: Economic Growth, Agricultural Carbon Emissions, Environmental Kuznets Curve, "The Belt And Road Initiatives" Core Areas

1. Introduction
The changing trend of the dependence of agricultural economic growth on resources and the relationship between agricultural development and the resource environment have little by little attracted widespread attention from the academic community [1]. Statistics show that greenhouse gas emissions from agricultural sources is 24% of the total global greenhouse gas emissions. It can be seen that the control of agricultural greenhouse gas emissions is the actual demand for mitigating the overall air pollution sources, and it is also the basis for achieving sustainable agricultural development [2]. Therefore, it is an urgent to realize the importance of developing agricultural carbon emissions and agricultural economic growth as a whole, and is of great significance to the implementation of ecological civilization construction.
Regarding the current agricultural development and carbon emissions, many scholars have conducted extensive research in related research fields. The research mostly concentrates in the fields of industrial wastewater [3] and energy [4], and relatively few research results involving agriculture [5-7]. For example, Bo Li et al. (2019) analyzed the co-integration relationship between agricultural economic growth and agricultural carbon emissions and found that Hubei Province's agricultural economic development, production conditions, and regional development strategies are different, which makes the agricultural carbon emissions gap between regions more and more obvious [8]. Zhang Yafei et al. (2020) analyzed the difference in the relationship between agricultural carbon emissions and economic growth in the two core areas of Xinjiang and Fujian in "the Belt and Road Initiatives" from an agricultural perspective, and the results showed that Xinjiang’s agricultural carbon emissions and agricultural economic growth are less responsive than those of Fujian [9]. In addition, Elina et al., (2016) and Robin et al., (2017) conducted in-depth analysis on agricultural emission reduction measures [10-11]. Mohanad et al., (2018) discussed the factors affecting agricultural carbon emissions [12]. However, studies focusing on the relationship between agricultural carbon emissions and agricultural economic growth in the core area of the “Belt and Road Initiatives” have not yet found. In "One Belt One Road Initiatives", Fujian is identified as the "21st Century Maritime Silk Road core area" and as the first demonstration area of national ecological civilization. Its agricultural production must be combined with its location advantages to develop low-carbon agriculture [13].

At present, the development of agricultural economy has entered a new normal, but the situation of agricultural carbon emission reduction is still severe. The government can neither focus solely on the agricultural economy and destroy the ecological environment, nor can the government blindly emphasize environmental protection and abandon agricultural economic development [8]. Thus, it becomes necessary to coordinate both to ensure the sustainable development of the economic, social-ecological environment system. However, through literature review, it is found that most of the research on agricultural carbon emissions uses national data for analysis. The research scope is large, lacks pertinence, and is limited to simple time series data analysis. In addition, as the country's first ecological civilization experimental zone, Fujian Province is one of the first provinces to implement reform and opening up policies. These years, due to its rapid urbanization and industrialization process, coupled with unreasonable resource consumption, human activities, and excessive short-term economic behaviors, it has caused varying degrees of impact on the ecological environment of some parts of Fujian [14]. Based on this, this investigation discusses the relationship between agricultural carbon emissions and economic growth in Fujian Province, reveals its internal effect mechanism, and verifies whether the two elements in Fujian Province conform to the EKC model. It is expected to provide a reference basis for the formulation of agricultural carbon emission reduction policies in Fujian Province, and have certain guides for accelerating the transformation and upgrading of Fujian Province's agriculture and promoting high-quality agricultural development.

2. Investigation Methods and Data Sources

2.1. Agricultural Carbon Emissions and the Calculation Method of Carbon Emissions Intensity

Agricultural carbon emissions refer to the greenhouse gas emissions directly or indirectly caused by chemical fertilizers, pesticides, energy consumption and agricultural waste resource processing in agricultural production [15]. Taking into account the comprehensiveness and availability of data, analyzing the agricultural land use process and calculating the total agricultural carbon emissions generated by carbon sources such as fertilizers, agricultural plastic films, agricultural diesel and pesticides [16]. Here is the calculation formula:

\[ CE = \sum C_i = \sum T_i \times \delta_i \] (1)

In it, \( CE \) is the total agricultural carbon emissions, \( i \) is the type of carbon source, \( C_i \) is the carbon emissions of the type \( i \) carbon source, \( T_i \) is the input of the \( i \) type carbon source, and \( \delta_i \) is the carbon emission coefficient of the \( i \) type carbon source (Table 1).
Table 1. Carbon emission coefficients of various carbon source factors

| Carbon Source          | Carbon Emission Coefficients | Reference Source |
|------------------------|------------------------------|-------------------|
| Fertilizers            | 0.8956 kg C/kg              | [16]              |
| Agricultural plastic films | 5.1800 kg C/kg            | IREEA             |
| Agricultural diesel    | 0.5927 kg C/kg              | IPCC              |
| Pesticides             | 4.9341 kg C/kg              | [16]              |

The agricultural carbon emission intensity refers to the carbon emissions produced by agricultural economic benefits per unit. Here is the calculation formula:

$$ACEI = CE / AGDP$$

In it: $ACEI$ is the intensity of agricultural carbon emissions; $CE$ is the total agricultural carbon emissions; $AGDP$ is the total agricultural output value.

2.2. EKC Model

In 1991, American environmentalists Grossman and Krueger introduced the Kuznets curve to the study of environment and economic growth. The theory believes that with the development of economy, the environment first shows a state of continuous deterioration, but when the economy development reaches a certain level, the environment shows a situation of continuous improvement, that is, the change curve shows an "inverted U-shaped" [17], namely Environmental Kuznets Curve (hereinafter referred to as EKC).

2.3. Data Sources

All the data in this study are derived from the Fujian Statistical Yearbook over the years. Taking into account the availability, continuity and feasibility of the data, the sample of this study is the 16-year panel data of Fujian Province from 2000 to 2016.

3. Investigation Results and Analysis

3.1. The Characteristics and the Trend Analysis of the Total Agricultural Carbon Emissions

According to formula (1-2), the agricultural carbon footprints and its intensity in Fujian Province from 2000 to 2016 can be obtained (Figure 1). It is clear the Figure that agricultural carbon emissions in Fujian Province increased from $175.38 \times 10^4$ t in 2000 to $221.73 \times 10^4$ t in 2016, an increase of 26.43%, with an average annual increase of 1.48%. However, from the perspective of trend, during this period, the agricultural carbon emissions of Fujian province showed a slow rising trend, with a rapid growth before 2008 and a slow growth after 2008. From 2000 to 2007, it increased by 21.8%, with an average annual growth rate of 2.86%. From 2007 to 2016, it increased by 3.80%, with an average annual growth rate of 0.42%. In terms of the agricultural carbon emission intensity of Fujian Province, it can be found that the agricultural carbon emission intensity of Fujian increased from $1.865 \ t/10^4$ CNY in 2000 to $2.101 \ t/10^4$ CNY in 2016, an increase of 12.63%, an average annual increase of 0.75%. However, from the perspective of trend, during this period, the agricultural carbon emission intensity of Fujian Province showed a trend of first rising, then falling, and then slowly rising, rising from 2000 to 2011, falling in 2012, and rising slightly in 2013-2016. Among them, there was an increase of 20.46% between 2000 and 2011, and an increase of 8.12% between 2012 and 2016.
The composition of agricultural carbon emissions in Fujian is shown in Figure 2. It can be seen that agricultural carbon emissions in Fujian Province is mainly from chemical fertilizers. The period of 2000-2016 showed a trend of phase change. From 2001 to 2008, it rose first and then fell, 2009-2013 first rose and then fell, and 2014-2016 showed an upward trend. During the sample period, the carbon emissions of chemical fertilizers increased by 0.03%, indicating that the carbon emissions of chemical fertilizers changed slightly. The carbon emissions of chemical fertilizers in 2016 were $110.91 \times 10^4$ t, accounting for 50.02%. The second is agricultural diesel, which rose first and then fell from 2000 to 2005, and began to slowly rise in 2006. In addition, agricultural diesel carbon emissions increased by 3.74%. In 2016, agricultural diesel carbon emissions were $51.15 \times 10^4$ t, accounting for 23.07%. The lowest are pesticides and agricultural films. In 2000-2006, the carbon emissions of pesticides surpassed that of agricultural plastic films. Since 2007, the carbon emissions of agricultural plastic films have exceeded that of pesticides. The carbon emissions of pesticides were relatively stable during the sample period, increasing by 0.42% from 2000 to 2016. In 2016, the carbon emissions of pesticides were $27.33 \times 10^4$ t, accounting for 12.33%. The carbon emissions of agricultural film increased rapidly before 2008, but changed little after 2008. From 2000 to 2016, it increased by 7.00%, which is the fastest growing. In 2016, the carbon emission of agricultural film was $32.34 \times 10^4$ t, Accounting for 14.58%. It can be seen that from 2000 to 2016, the carbon emissions of chemical fertilizers in Fujian were the highest, but the growth rate was the slowest; while the carbon emissions of agricultural film were relatively low, but the growth rate was the fastest. This shows that Fujian Province has upgraded and transformed its agricultural structure during this period. Adjustments have changed carbon emissions.
3.2. Evolution Analysis on the Agricultural Carbon Emissions and Economic Growth in Fujian Province

The study used comparable per capita GDP (PGDP) based on 2000 as the abscissa, and agricultural carbon emissions (CE) and agricultural carbon emission intensity (ACEI) as the ordinate to determine the EKC between the two. This study was based on SPSS 26.0 as the computing platform for fitting regression. Linear equation, quadratic polynomial equation and third power polynomial equation were under fitting respectively, and the model was selected according to the coefficients of determination and related parameters. Figure 3 shows the scatter Figure of Fujian Province's per capita GDP and agricultural carbon emissions. It is clear that "inverted U-shaped" trend is not obvious between the two. The fitting results of the Linear equation, quadratic polynomial equation and third power polynomial equation are as follows:

Linear equation:
\[ CE = 8.4043 \times PGDP + 183.0159 \times PGDP^2 \times PGDP^3 = 0.6994 \]

Quadratic polynomial equation:
\[ CE = 32.2926 \times PGDP - 3.7330 \times PGDP^2 + 152.9995 \times PGDP^3 = 0.8891 \]

Third power polynomial equation:
\[ CE = 86.6834 \times PGDP - 22.4127 \times PGDP^2 + 1.9001 \times PGDP^3 + 108.0872 \times PGDP^4 = 0.9554 \]

It can be seen that the fitting effect of the third power polynomial equation is the best. However, it can be seen that no matter which equation is used, the relationship between the two in Fujian Province does not conform to the characteristics of EKC, that is, agricultural carbon emissions do not rise first and then fall with the rise of per capita GDP.
Figure 3. Fitting curve of agricultural carbon emissions in Fujian province

Figure 4 demonstrates the scatter Figure of Fujian Province's per capita GDP and agricultural carbon emissions. The Figure says that the "inverted U-shaped" trend is not obvious between the two. The fitting results of the Linear equation, quadratic polynomial equation and third power polynomial equation are as follows:

Linear equation:
\[ ACEI = 0.0041 \times PGDP + 2.0778 \quad R^2 = 0.0022 \]

Quadratic polynomial equation:
\[ ACEI = 0.2830 \times PGDP - 0.0436 \times PGDP^2 + 1.7273 \quad R^2 = 0.3304 \]

Third power polynomial equation:
\[ ACEI = 1.5570 \times PGDP - 0.4811 \times PGDP^2 + 0.0445 \times PGDP^3 + 0.6754 \quad R^2 = 0.7920 \]

It can be seen that the fitting effect of the third power polynomial equation is the best. However, it is also true that no matter which equation is used, the relationship between the two in Fujian Province does not conform to the characteristics of EKC, that is, agricultural carbon emissions do not rise first and then fall with the rise of per capita GDP.
4. Research Conclusion and Suggestions
This paper applies the EKC model and other methods to first measure the agricultural carbon emissions in Fujian, and obtain the evolution relationship with the economy, so as to explore its emission reduction potential. The research shows that Fujian Province has the highest carbon emissions of chemical fertilizers, and the carbon emissions of agricultural films are relatively low. The structure of agricultural carbon emissions has been adjusted to a certain extent in recent years. In addition, this research shows that as the economy progresses, carbon emissions also increase, but this does not meet the trend characteristics of EKC. The empirical test results of the EKC model show that with the continuous improvement of the economy, carbon emissions are on a clear upward trend, and the pressure on energy conservation and emission reduction has further expanded. Compared with other provinces, Fujian Province should conduct a supervision and planning control of agricultural production activities and bring out the emission reduction potential. Therefore, this research suggests:

(1) Fujian Province needs to continue to deepen the adjustment of the agricultural supply-side structure and take the road of green and low-carbon agricultural development. When promoting agricultural modernization, Fujian Province should further optimize the agricultural structure. Meanwhile, it is necessary to transform the traditional agricultural economic growth model, actively explore low-carbon agricultural development models, and take the path that is resource-saving, environmentally friendly, and ecologically safe.

(2) Fujian Province must implement low-carbon agricultural production technology reforms to increase the use of fertilizers in agricultural production. On the one hand, the government should increase the publicity, training and promotion of new low-carbon agricultural production models and technologies, and use scientific and technological fertilization methods to rationally and maximize the use of chemical fertilizers. By controlling the time, quantity demand and water demand in the fertilization process to reduce both the influence of chemical fertilizers and carbon emissions. What’s more, the government should encourage enterprises, scientific research institutes, etc. to develop low-carbon agricultural technology, and further optimize the technology for improving seed quality in
order to essentially boost the utilization rate of various agricultural materials.

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