Modern Economy, 2026, 17(11), 1457-1465
https://www.scirp.org/journal/me
ISSN Online: 2152-7261
ISSN Print: 2152-7245

Synergistic Pathways for Agricultural Green Innovation and Low-Carbon Transformation in the Minjiang River Basin from the Perspective of Rural Revitalization

Guoning Jiang, Chen Qian, Yanyan Lin*

School of Finance and Accounting, Fuzhou University of International Studies and Trade, Fuzhou, China
Email: *linyanyan0822@163.com

How to cite this paper: Jiang, G. N., Qian, C., & Lin, Y. Y. (2026). Synergistic Pathways for Agricultural Green Innovation and Low-Carbon Transformation in the Minjiang River Basin from the Perspective of Rural Revitalization. *Modern Economy, 17,* 1457-1465.
https://doi.org/10.4236/me.2026.1711072

Received: June 25, 2026
Accepted: November 17, 2026
Published: November 20, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

Against the backdrop of rural revitalization and the "dual carbon" goals, the synergy between agricultural green innovation and low-carbon transformation constitutes a core pathway for high-quality agricultural development. The Minjiang River Basin is a typical agricultural basin in the hilly regions of southern China and a key platform for ecological civilization construction in Fujian Province. However, basin-scale research on the synergistic mechanisms between these two processes remains limited. Using panel data from 34 counties in the basin from 2016 to 2025, this study applies a coupling coordination degree model and a two-way fixed effects model for empirical analysis. The results show that agricultural green innovation significantly promotes agricultural low-carbon transformation, indicating a pattern of coordinated development between the two. Digital agriculture and fiscal support also exert positive moderating effects.

Keywords

Rural Revitalization, Minjiang River Basin, Green Agricultural Innovation, Low-Carbon Agricultural Transition, Coupling Coordination

1. Introduction

As a national ecological civilization pilot zone, Fujian Province issued the Action Plan for Accelerating the Comprehensive Green Transformation of Fujian's Economic and Social Development, designating the Minjiang River Basin as a pilot area for agricultural carbon sinks and a key region for green transformation. The

report to the 20th National Congress of the Communist Party of China set out systematic arrangements for comprehensively advancing rural revitalization and promoting green development, explicitly calling for accelerating the development of China into an agricultural power and promoting a green transformation of the development model. In recent years, agricultural green development in the Minjiang River Basin has achieved initial progress, but problems remain, including extensive production methods, low resource-use efficiency, high pressure from carbon emissions, and insufficient dissemination of green technologies. Most existing studies have examined agricultural green innovation or low-carbon transformation separately, with insufficient systematic analysis of their synergistic evolution and a lack of targeted research at the scale of the Minjiang River Basin. Building on the above research, exploring the mechanisms and pathways of synergy between the two is of important practical significance for enriching theories of agricultural green development in river basins and promoting high-quality agricultural development in hilly areas of southern China.

2. Theoretical Analysis and Research Hypotheses

Agricultural green innovation is a core driver of the low-carbon transformation of agriculture, and the interaction between the two has long been a key research focus in the field of agricultural green development. A review of the existing literature shows that it mainly centers on three issues.

First, green innovation has a positive effect on low-carbon transformation. Scholars represented by Zhan Jintao et al. (2024) argue that green production technologies, such as slow- and controlled-release fertilizers, biological control, and water- and energy-saving irrigation, can directly promote the decarbonization of agricultural production by reducing dependence on fossil energy, mitigating non-point-source pollution, and improving resource-use efficiency. The diffusion of green technologies can also encourage neighboring farmers to adopt low-carbon production practices through a "learning effect".

Second, the relationship between the two is not simply positive. Gao & Zhang (2022) found that some green technologies exhibit a "rebound effect", whereby cost- and labor-saving technologies may lead to an expansion of cultivated area and thereby increase total emissions; meanwhile, smallholders' financial and cognitive constraints may reduce the adoption rate of green technologies and weaken their emission-reduction effects.

Third, the two systems exhibit coupled synergistic characteristics and regional heterogeneity. Existing studies have shown that agricultural green innovation and low-carbon transformation are linked by a bidirectional feedback relationship of coupling coordination, with their synergy shaped by multiple factors, including resource endowments, policy regulation, and the degree of marketization. Research at the watershed scale indicates that, owing to differences in natural conditions and development levels, the degree of synergy varies markedly across geographic units, and the evolutionary pathways of mountainous and hilly areas dif-

fer significantly from those of suburban plains (Qiu et al., 2024). From the perspective of "actors-structure-value", Wu Linping (2026) finds that asymmetric interest linkages, constraints arising from asset specificity, and the weakening of environmental regulation can easily lock business entities into low-level non-synergistic states, thereby constraining the ecological transformation of industries. However, existing research has mainly focused on typical watersheds in northern China, with relatively limited measurement of synergy levels and analysis of mechanisms in the Minjiang River Basin.

To address the limitations of existing research, this study integrates the characteristics of agricultural development in the Minjiang River Basin, examines the patterns of their co-evolution, and proposes the following research hypotheses:

H1: Agricultural green innovation has a positive effect on agricultural low-carbon transformation, and a significant synergistic development relationship exists between the two.

H2: The development of digital agriculture can strengthen the positive effect of agricultural green innovation on the low-carbon transformation of agriculture.

H3: Increased fiscal support for agriculture can strongly promote the coordinated development of agricultural green innovation and low-carbon transformation.

3. Research Design

3.1. Model Specification

3.1.1. Coupling Coordination Degree Model

A coupling coordination degree model for the dual system of agricultural green innovation and agricultural low-carbon transformation is constructed (Liao, 1999; Hou et al., 2024):

$$D = \sqrt{C \times T} \tag{1}$$

$$C = \frac{2\sqrt{U_1 \times U_2}}{U_1 + U_2} \tag{2}$$

$$T = \alpha U_1 + \beta U_2 \tag{3}$$

In Equations (1)-(3), U_1 denotes the composite index of agricultural green innovation, and U_2 denotes the composite index of agricultural low-carbon transition; C represents the degree of coupling between the two systems, T is the comprehensive coordination index ($\alpha = \beta = 0.5$); and D represents the coupling coordination degree between agricultural green innovation and agricultural low-carbon transition, with a value range of [0, 1].

3.1.2. Two-Way Fixed Effects Model

We construct a benchmark regression model for agricultural green innovation and agricultural low-carbon transformation (Ma & Qiu, 2026; Li et al., 2011; Tian & Yin, 2022):

$$LT_{it} = \alpha + \beta GI_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{4}$$

In Equation (4), LT_{it} denotes the level of low-carbon agricultural transfor-

mation in region i during period t; GI_{it} denotes the level of agricultural green innovation; X_{it} denotes the set of control variables, including agricultural industrial structure (IND), the level of digital agricultural development (DIG), fiscal expenditure on agriculture (GOV), per capita income of rural residents (INC), and scale of agricultural operation (SCALE); μ_i denotes region fixed effects; λ_t denotes time fixed effects; and ε_{it} denotes the random error term.

In the baseline regression stage, a model controlling only for county-level individual fixed effects was used to conduct a preliminary test (with the constraint $\lambda_t = 0$) to identify the relationships among the core variables; in the robustness test stage, a time-effects model was further incorporated, and a two-way fixed-effects model was employed to verify the reliability of the conclusions.

3.2. Data Description

The data used in this study are drawn from the Fujian Statistical Yearbook, municipal statistical yearbooks, and county statistical bulletins over the years. The study sample comprises panel data for 34 counties in Fujian Province from 2016 to 2025. Sporadic missing values were imputed using interpolation. Due to limitations in county-level statistical definitions, some sub-indicators are represented by proxy variables, which introduces certain limitations. Descriptive statistics for the variables are reported in Table 1.

Table 1. Descriptive statistics of the main variables.

Variable	Sample size	Mean	Standard deviation	Minimum value	maximum value
Green Innovation Index	340	0.575	0.020	0.461	0.619
Low-Carbon Transition Index	340	0.276	0.165	0.036	0.986
degree of coupling	340	0.695	0.148	0.366	0.999
overall development level	340	0.426	0.089	0.292	0.794
coordination degree	340	0.543	0.110	0.327	0.822

4. Empirical Analysis

4.1. Coupling Coordination Degree Test

As shown in Table 1, the mean coupling degree is 0.695, indicating an overall stage of moderate coupling and suggesting that the two are not mutually independent systems developing in parallel. In terms of coordination degree, the basin-wide mean is 0.543, which falls within the transition range from marginal coordination to primary coordination, thereby confirming their synergistic development characteristics. This indicates that green agricultural innovation and low-carbon transformation in the Min River Basin have formed an interrelated coupled system; however, the overall level of synergy remains low, has not yet entered a stage of good coordination, and still has significant room for improvement.

4.2. Baseline Regression Results

This study employed a baseline regression model that controlled only for county-level fixed effects and the results are presented in Table 2.

Column (1) presents the baseline model controlling only for county fixed effects. The results show that the regression coefficient for the level of agricultural green innovation is 8.307 and significantly positive at the 1% level. After all control variables are included in column (2), the coefficient decreases to 5.434 but remains significantly positive at the 5% level, indicating that agricultural green innovation positively promotes the low-carbon transformation of agriculture. This finding corroborates the results of the coupling coordination degree test, thereby supporting Hypothesis H1. Among the control variables, the coefficients of agricultural industrial structure, the share of animal husbandry, and operational scale do not pass the significance test, suggesting that the emission-reduction effects of industrial restructuring in the basin had not yet fully materialized during the sample period and that scale effects under fragmented operations had not been realized. The reasons for this are that the Min River Basin is predominantly mountainous and hilly, with fragmented agricultural operations prevalent across counties; the implementation cycle for industrial restructuring is relatively long, and the process of transformation and upgrading in the livestock sector has lagged behind. Consequently, the relevant variables have not yet demonstrated significant statistical effects.

Table 2. Baseline regression results.

Variable	(1) Base model	(2) Full-variable benchmark
	Level of low-carbon agricultural transformation	Level of low-carbon agricultural transformation
Level of green innovation in agriculture	8.307***	5.434**
	(13.311)	(2.332)
agricultural industrial structure		0.033
		(0.963)
Agricultural operating scale		−0.602
		(−1.574)
Share of animal husbandry		0.004
		(0.061)
Control variables	No	Yes
county fixed effects	Yes	Yes
Time fixed effects	No	No
Observed value N	340	340
Adjusted R^2	0.743	0.788

Note: ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively; robust standard errors are reported in parentheses are t-statistics. The same applies below.

4.3. Robustness Checks

To assess the reliability of the baseline regression results, this study conducts robustness tests using three approaches. The results are reported in Table 3. In Column (3), time fixed effects were further controlled, and the analysis was re-estimated using a two-way fixed-effects model. The results show that the regression coefficients for agricultural green innovation remain positive and are significant at least at the 5% level, with no substantial deviations in coefficient values, indicating that the core conclusions of this study are robust. Due to constraints on the availability of county-level data, this study did not employ instrumental variables to address endogeneity issues, which is one of the limitations of this research.

Table 3. Robustness checks.

Variable	(1) Substitute variables	(2) Core variables lagged by one period	(3) Two-way fixed effects
	Coupling coordination degree	Level of low-carbon agricultural transformation	Level of agricultural low-carbon transition
Level of green innovation in agriculture	4.924*** (4.245)	5.128** (2.198)	5.018** (2.207)
agricultural industrial structure	0.007 (0.410)	0.0298 (0.859)	0.036 (0.987)
Scale of agricultural operations	−0.296 (−1.607)	−0.558 (−1.463)	−0.624 (−1.598)
Control variables	Yes.	Yes	Yes
county fixed effects	Yes	Yes.	Yes
time fixed effects	No	No	Yes
Observed value N	340	306	340
Adjusted R^2	0.858	0.762	0.801

4.4. Examination of the Mechanism

To examine the moderating effects of digital agriculture and government support, this study introduces interaction terms and tests the moderating roles of digital agriculture and government support separately; the results are reported in Table 4. In column (1), the coefficient of the interaction term "agricultural green innovation × digital agriculture" is 0.322 and is significantly positive at the 1% level, indicating that digital agriculture can effectively amplify the emission-reduction effect of green innovation, thereby supporting Hypothesis H2. In column (2), the coefficient of the interaction term "agricultural green innovation × fiscal support for agriculture" is 0.215 and is significantly positive at the 5% level, indicating that government fiscal support can effectively lower the threshold for adopting green

technologies and promote the coordinated development of the two systems, thereby supporting Hypothesis H3. A comparison of the coefficients of the two moderating effects shows that the strengthening effect of digital agriculture is greater than that of fiscal support for agriculture.

This implies that, compared to the direct financial support provided by fiscal subsidies, digital tools can unleash multiplier effects across multiple dimensions—including production process optimization, targeted technology dissemination, and information empowerment for farmers—thereby delivering a more pronounced low-carbon impact through green innovation.

Table 4. Results of the mechanism analysis.

Variable	(1) Mechanisms of digital agriculture	(2) Government support mechanisms
	Level of low-carbon agricultural transition	Level of low-carbon agricultural transformation
Agricultural Green Innovation × Digital Agriculture	0.322*** (3.659)	
Agricultural Green Innovation × Fiscal Support for Agriculture		0.215** (2.263)
Control variables	Yes	Yes
county fixed effects	Yes	Yes
Observed value N	340	340
Adjusted R^2	0.802	0.796

5. Conclusions and Recommendations

This paper employs a coupling coordination degree model and a two-way fixed effects model. Based on county-level panel data for 34 counties in the Minjiang River Basin from 2016 to 2025, it examines the synergistic relationship between agricultural green innovation and low-carbon transformation, as well as the underlying mechanisms. The results show that agricultural green innovation has a significant positive effect on promoting the low-carbon transformation of agriculture, and that the two exhibit characteristics of coordinated development; these conclusions remain reliable after robustness tests. Both the development of digital agriculture and government fiscal support positively moderate the synergistic relationship between the two, with the reinforcing effect of digital agriculture being more pronounced. In light of these findings, this paper proposes the following recommendations:

First, the system for promoting green technological innovation should be strengthened. Greater investment should be directed toward the research and development of green and low-carbon technologies, such as controlled-release fertilizers and biological control. The grassroots agricultural technology extension net-

work should be improved, and technical training and demonstration guidance should be provided for smallholders to overcome cognitive and cost barriers to technology adoption. Taking into account the agricultural characteristics of the mountainous and hilly terrain in the Minjiang River Basin, develop low-cost green technologies tailored to small-scale mountainous farming in a context-specific manner to lower the barriers to adoption for smallholder farmers.

Second, the dual support mechanism of digitalization and fiscal policy should be improved. On the one hand, the deployment of digital agricultural infrastructure in the basin should be advanced, enabling the precise implementation of green technologies through digital empowerment. On the other hand, the expenditure structure of fiscal support for agriculture should be optimized, the coverage of subsidies for green production expanded, and complementary instruments such as green credit and carbon-sink finance developed to reduce the costs of green transformation for business entities. By shifting subsidies from a universal approach to a performance-based model—linking subsidies to the outcomes of low-carbon production—we will further enhance the efficiency of fiscal fund utilization.

Finally, moderately scaled agricultural operators should be fostered. Greater support should be provided for the development of new business entities such as family farms and farmers' cooperatives. By standardizing land transfers and promoting shareholding cooperation, appropriately scaled agricultural operations can be advanced, enabling the green technology advantages of large-scale production and improving the overall effectiveness of the low-carbon transition in agriculture. At the same time, address the development needs of smallholder farmers by encouraging cooperatives to facilitate their participation in green and low-carbon production, thereby preventing a rebound in carbon emissions during the process of scaling up operations.

This study still has certain limitations: due to constraints on county-level statistical data, proxy variables were used for some indicators, and no regression analysis by spatial heterogeneity was conducted. In the future, it would be possible to further subdivide the upstream, midstream, and downstream sub-regions to explore differentiated collaborative pathways across different counties, thereby providing more refined empirical evidence for implementing targeted policies in different river basin zones.

Author Contributions

Guoning Jiang: Led the overall research design, model construction and empirical analysis, and was responsible for the full writing, content integration and revision of the manuscript as the primary writer. Chen Qian: Was in charge of data collection, cleaning, sorting and verification, completed descriptive statistics and basic data processing, and provided data support for the empirical analysis. Yanyan Lin: Proposed the core research ideas and overall framework, guided the whole research process and manuscript writing, took charge of the final review and finali-

zation of the manuscript, and undertook correspondence work and project management.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Gao, M., & Zhang, Z. X. (2022). Positioning and Policy Recommendations for China's Agricultural Green Development under the Goals of Carbon Peaking and Carbon Neutrality. *Journal of Huazhong Agricultural University (Social Sciences Edition), 1,* 24-31. (In Chinese)

Hou, Y., Wang, Y., Shi, H. H. et al. (2024). Coupling Coordination Analysis of Low-Carbon Agriculture in Major Grain-Producing Areas: From the Perspective of Agricultural Carbon Emission Efficiency. *Chinese Journal of Eco-Agriculture, 32,* 2022-2033. (In Chinese)

Li, B., Zhang, J. B., & Li, H. P. (2011). Spatiotemporal Characteristics and Decomposition of Influencing Factors of Agricultural Carbon Emissions in China. *China Population, Resources and Environment, 21,* 80-86. (In Chinese)

Liao, C. B. (1999). Quantitative Evaluation and Classification System of Coordinated Development between Environment and Economy: A Case Study of the Pearl River Delta Urban Agglomeration. *Tropical Geography, 19,* 171-177. (In Chinese)

Ma, Z. L., & Qiu, J. Y. (2026). The Impact and Mechanisms of Farmers' Professional Cooperatives on Agricultural Carbon Emission Efficiency. *Research of Agricultural Modernization, 47,* 173-186. (In Chinese)

Qiu, J., Chen, Q. P., Wang, B., & Liu, Z. B. (2024). Coupling Coordination and Influencing Factors of Technological Innovation and High-Quality Green Agricultural Development in the Yellow River Basin. *Journal of Desert Research, 44,* 275-283. (In Chinese)

Tian, Y., & Yin, M. H. (2022). Recalculation of Agricultural Carbon Emissions in China: Current Status, Dynamic Evolution and Spatial Spillover Effects. *Chinese Rural Economy, 3,* 104-127. (In Chinese).

Wu, L. P. (2026). Research on the Micro-Mechanisms of Coordinated Development between Rural Industries and Ecology in the Minjiang River Basin. *Modern Marketing, 12,* 31-33. (In Chinese)

Zhan, J. T., Yang, Y., & Xiong, H. (2024). Environmental Regulation, Green Innovation and Agricultural Carbon Productivity. *Science of Science and Management of S.&T., 45,* 72-90. (In Chinese)