Research on the Impact of Green Credit on the Resilience of Agricultural Industry Chain Based on Panel Data

Jiayi Kong*

School of Economics, Qufu Normal University, Rizhao, China, 276826

*Corresponding author: kong_jiayi2004@163.com

Abstract. Based on panel data from 30 Chinese provinces spanning 2010-2021, this paper constructs a resilience index system for the agricultural industry chain, encompassing three dimensions: resistance, recovery and innovation, using the entropy weight method. A fixed-effects panel model is employed to investigate the direct impact, mediating pathways, and moderating mechanisms of green credit on agricultural industry chain resilience. The empirical findings reveal that green credit significantly enhances resilience, particularly in non-major grain-producing regions. Technological innovation and industrial integration serve as important mediators, while agricultural digitalization plays a significant moderating role. These results suggest that optimizing green credit policies by improving financial support systems, strengthening the synergy between technological innovation and industrial integration, and accelerating digital transformation that can effectively foster a greener and more resilient agricultural industry chain.

Keywords: Green Credit, Agricultural Industry Chain Resilience, Panel Data.

1. Introduction

Under the double constraints of global climate change and the dual-carbon target, the agricultural industry chain is facing multiple challenges such as natural risks and market fluctuations, and its resilience level is directly related to national food security and sustainable rural development. Green credit, as a core component of green finance, not only provides financing support for the green transformation of agriculture, but also optimizes the allocation of resources, to reduce the environmental risks of agricultural industry development, thus enhancing the resilience of the agricultural industry chain by guiding the flow of funds to low-carbon and environmental protection areas.

Existing studies have explored the influencing factors of agricultural chain resilience from the aspects of external environment and internal mechanism. In the external environment, climate change, economic fluctuations and policy finance are widely concerned, such as Maohua Xu pointed out that agricultural carbon emissions will exacerbate the negative impact of climate change on the resilience[1]; Weiying Ping et al. studied that policy finance is effective to enhance the resilience of agriculture under the subdimensional and subregional models[2]. In terms of internal mechanisms, technological innovation, resource allocation and industrial agglomeration are the key paths affecting agricultural resilience, Yanfeng Guo et al. pointed that green technological innovation plays the intermediary role between industrial digitization and the resilience of the agricultural industry chain[3]. Research on green credit is more abundant, such as Liu Songqi et al., whose study indicates that green credit can significantly promote green agricultural technological innovation, thereby reducing agricultural carbon emissions [4]. On the whole, there is still a lack of substantial research on the direct association between green credit and the resilience of agricultural industry chain and the mechanism of its action, especially lack of exploration of regional heterogeneity and moderating effects.

The paper starts from the perspective of green credit, assesses its impact mechanism on the resilience of the agricultural industry chain, and makes the following research hypotheses through theoretical analysis. H1: Green credit significantly enhances the resilience of agricultural industry chain. H2: Green credit indirectly enhances the resilience of agricultural chain by promoting technological innovation and agricultural industry integration. H3: Industrial digitization has a significant moderating role. The marginal contributions of the article are mainly reflected in the following three aspects: Firstly, construct the resilience index system of the agricultural industry chain including "resistance, resilience and innovation", empirically examine the direct impact of green credit, and expanding the research paradigm of green finance for the promotion of high-quality development of agriculture. Carry out heterogeneity analysis by grouping the main food-producing areas and non-main producing areas to identify the differences in policy effects, and provide policy recommendations for the differentiated allocation of green credit. Secondly, a dual-mediation path analysis model is introduced to identify the mechanism by which green credit indirectly improves the resilience of the agricultural chain through two paths: technological innovation and industrial integration, so as to enrich the micro-research perspective on the mechanism of green finance. Thirdly, the moderating effect model is used to test the role of industrial digitization as a boundary condition between green credit and the resilience of the agricultural chain, so as to expand the research on the adaptability and effect of green finance in the context of digital transformation.

2. Description of data sources and research design

2.1. Data acquisition and preprocessing

The data used in this paper come from the panel data of 30 provinces (excluding Tibet, Hong Kong, Macao and Taiwan) from 2010-2021 in the China Agricultural Statistical Yearbook, China Rural Statistical Yearbook, China Industrial Statistical Yearbook, and China Economic Census Yearbook of the National Bureau of Statistics. Missing values for some variables and outliers for individual years are filled in by linear interpolation, and logarithms are taken for non-comparative indicators with large values.

2.2. Definition of variables

Following the evaluation framework developed by Shanshan Wang et al.[5], this paper establishes a comprehensive index system to assess the resilience of the agricultural industry chain. The measurement of green credit draws on the approach adopted by Tingting Xie et al.[6], while the mediating variables, technological innovation and industrial integration, are constructed with reference to the methodologies of Cheng Li et al.[7] and Aimin Hao et al.[8]. Furthermore, informed by the existing literature[9], the level of agricultural digitization is incorporated as a moderating variable to capture its potential influence on the transmission mechanism.Details are as table 1 below.

Table.1 Evaluation System of Variable Indicators

Variables description	Primary indicators	Secondary indicators	Indicators description	weights
Predicted variable (RAC)	Resistance	Percentage of primary sector output	Primary sector output/GDP	0.0486
		Rural population living standards	Engel's coefficient for rural households	0.0187
		Grain production level	Total grain production	0.1085
		Effective irrigation rate	Effective irrigated area/area sown with crops	0.0575
		Agricultural mechanization level	Total power of agricultural machinery/cultivated area	0.0661
		Agricultural mechanization level	Pesticide use/area sown with crops	0.0077
		Agricultural plastic film utilization rate	Agricultural plastic film use/area sown with crops	0.0088
	Resilience	Rural population income level	Per capita disposable income of rural residents	0.0590
		Rural population consumption level	Consumption expenditure of rural residents	0.0523

		Value added in primary sector per capita	Value added of primary sector/number of employees	0.0532
		Value added of primary industry per unit area	Value added of primary sector/area sown with crops	0.0811
		Rural residents average years of schooling	①	0.0155
	Innovation	Rural electricity facilities level	Rural electricity consumption	0.1981
		Agro-industrial innovation capacity	Patent applications granted	0.2249
Explanatory variable	GC	Green credit	②	/
	Urban	Urbanization level	Urban population/year-end resident population	
	Tax	Tax burden level	Tax revenue/GDP	
Control variable	Fiscal	Financial support level	Fiscal general budget expenditure/GDP	/
	Consume	Social consumption level	Consumer goods total retail sale/GDP	
	Gap	Urban-rural income gap	Per capita disposable income of urban/rural residents	
	TI	Technological innovation	R＆D investment/GDP	/
Intermediary variable		Agro-processing	Main agro-processing business income /total value of primary industry	0.4748
	Fusion	Agricultural organization	Rural population (10,000) /specialized agricultural cooperatives number	0.2961
		Agricultural servicization	Gross value of primary sector services/ output	0.2290
		Rural Internet penetration level	Rural broadband access subscribers	0.1705
Moderator variable	Digital	Digital technology applications	E-commerce sales	0.2430
		Circulation service capacity	Express mail volume	0.4025
		Digital Talent	③	0.1840
Replacement indicator of explanatory variable	Resilience	diversification	Agricultural Industry Diversification Index(HHI)	0.4706
		Innovation	Number of agricultural patents granted	0.5294

Note: ①(Number of persons with elementary school education*6+Number of persons with lower secondary school education*9+Number of persons with upper secondary school and middle school education*12+Number of persons with tertiary education and above*16)/Total population over 6 years of age.

②Interest expenses of non-six major energy-consuming industries/total interest expenses of industrial enterprises above designated size.

③Employed in urban units of the information transmission, software and information technology services industry.

RAC-the resilience of the agricultural chain, Fusion-industrial integration level, Digital - agricultural industry digitization level.

2.3. Descriptive statistics

Descriptive statistics are shown in Table 2:

Table.2 Descriptive Statistical Analysis

Type	Variable	Obs	Mean	Std.dev.	Min	Max
Predicted variable	RAC	360	0.223	0.094	0.082	0.555
Explanatory variable	GC		0.473	0.152	0.094	0.808
Control variable	Urb		0.59	0.125	0.338	0.896
	Tax		0.085	0.028	0.045	0.188
	Fiscal		0.259	0.113	0.105	0.758
	Consume		0.394	0.063	0.22	0.61
	Gap		2.591	0.389	1.842	3.735
Intermediary variable	TI		14.76	1.278	12.174	16.742
	Fusion		0.212	0.111	0.031	0.671
Moderator variable	Digital		0.09	0.116	0.001	0.905

Specifically, the mean value of RAC is 0.223 with a standard deviation of 0.094, indicating regional disparities in the resilience of the agricultural industry chain. The average GC is 0.473, suggesting that green financial input in agriculture remains to be enhanced. The mean value of Digital is 0.09, while the maximum reaches 0.905, reflecting significant regional imbalances in digital development. The distribution of control and mediating variables also exhibits notable variation, demonstrating the strong differentiation and explanatory capacity of the constructed variable system.

2.4. Research Methodology Design

(1) Fixed panel model setup

Based on the theoretical analysis of H1, the following econometric model is constructed to measure the direct impact of green credit on the resilience of agricultural industry chain:

$$RAC_{i,t} = \alpha_0 + \alpha_1 GC_{i,t} + \beta con_{i,t} + u_i + \varepsilon_{i,t} \quad (1)$$

where i denotes province, t denotes year, α is a constant term, con is control variable (Urban Tax Fiscal Consume Gap), u_i is an individual fixed effect, and ε is random perturbation term.

(2) Mediating effects analysis

Based on the two-step test proposed by Ting Jiang, the following two mediation effect models were developed.

The impact of green credit on mediating variable 1: technological innovation:

$$TI_{i.t} = \gamma_0 + \gamma_1 GC_{i,t} + \gamma_2 con_{i,t} + u_i + \varepsilon_{i,t} \quad (2)$$

The effect of green credit on the mediating variable 2: industrial integration level:

$$Fusion_{i.t} = \delta_0 + \delta_1 GC_{i,t} + \delta_2 con_{i,t} + u_i + \varepsilon_{i,t} \quad (3)$$

Green credit affects the resilience of the agricultural chain:

$$RAC_{i,t} = \rho_0 + \rho_1 GC_{i,t} + \rho_2 con_{i,t} + u_i + \varepsilon_{i,t} \quad (4)$$

(3) Moderating effects analysis

$$RAC_{i,t} = \sigma_0 + \sigma_1 GC_{i,t} + \sigma_2 Digital_{i,t} + \sigma_3 (GC_{i,t} \times Digital_{i,t}) + \sigma_4 con_{i,t} + u_i + \varepsilon_{i,t} \quad (5)$$

where $GC_{i,t} \times Digital_{i,t}$ is the interaction term that portrays the moderating effect.

3. Empirical results and analysis

3.1. Benchmarking Green Credit on the Resilience of the Agricultural Chain

The results of the benchmark test are shown in Table 3. In column (1) where no control variables are introduced, green credit has a significant positive impact on the resilience of the agricultural industry chain at the 1% level, indicating that green credit contributes to strengthening the agricultural industry chain's capacity to withstand external shocks.

In column (2), where control variables are added, the coefficient of GC remains significantly positive at the 5% level, confirming the robustness of the baseline findings in Table 3. Among the control variables, tax exerts a negative effect on resilience, likely due to increased tax burdens reducing the financial flexibility of agricultural actors. Fiscal expenditure has a significantly positive effect at the 5% level, suggesting that government investment in agriculture enhances systemic risk resistance. Conversely, the urban-rural development gap shows a significant negative correlation at the 1% level, indicating that structural imbalances may hinder the coordination capacity of the agricultural system. The high model fit supports the explanatory validity of the constructed framework. All variables have VIF values below 5, indicating no severe multicollinearity and confirming the model's robustness.

To further investigate regional heterogeneity, the paper conducts group regressions based on the national classification of major and non-major grain-producing areas, as defined by the Ministry of Finance's 2003 policy document. The 13 major grain-producing provinces include Anhui, Hebei, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangsu, Jiangxi, Liaoning, Inner Mongolia, Shandong, and Sichuan. The remaining 17 provinces, such as Beijing, Guangdong, and Yunnan, are categorized as non-major producing areas. The regression results by region are presented in Table 3.

Table.3 Benchmark regression results of green credit on agricultural chain resilience

	(1)RAC	(2)RAC	VIF	(3)RAC	(4)RAC
GC	0.169***	0.056**	2.79	0.067*	-0.024
	(0.038)	(0.026)		(0.035)	(0.038)
Tax		-0.484**	2.07	-0.803***	-0.172
		(0.206)		(0.301)	(0.254)
Fiscal		0.173**	2.03	0.290***	-0.032
		(0.073)		(0.103)	(0.105)
Consume		0.004	1.13	-0.056	0.033
		(0.034)		(0.065)	(0.038)
Urban		0.362***	2.98	0.220	0.561***
		(0.076)		(0.136)	(0.078)
Gap		-0.100***	2.49	-0.131***	-0.066**
		(0.024)		(0.038)	(0.027)
cons	0.142***	0.235**	2.25	0.406**	0.112
	(0.018)	(0.101)		(0.180)	(0.101)
N	360	360		204	156
R^2	0.809	0.922		0.894	0.958

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, corrected standard errors in parentheses.

Column (3) of Table 1 shows the regression results of green credit for agricultural chain resilience in food non-main producing areas, which has a significant enhancement effect at the 10% level; whereas the regression of green credit for agricultural chain resilience in food main producing areas in column (4) is not significant. The effect of green credit to promote agricultural resilience is stronger in food non-dominant production areas.

This difference may stem from the heterogeneity of factor endowment and financial structure of agricultural development in different regions. In non-main producing areas, green credit as a policy financial instrument takes on more of a guiding role, and its complementary effect on the weak links of the agricultural industry chain is more prominent, thus the effect on resilience is more significant.

In the main production areas, agricultural infrastructure is more perfect, financial resources are more sufficient, the marginal effect of green credit tends to diminish, and it is difficult to form a significant gain in the overall resilience of the agricultural industry chain in the region. The performance of control variables also confirms the above judgment.

3.2. Test for the mediating effect of green credit on the resilience of agricultural industry chain

As shown in Table 4, column (1) confirms the direct effect of green credit on agricultural industry chain resilience, with results significant at the 5% level.

In column (2), green credit significantly promotes technological innovation at the 1% level, indicating its key role in enhancing resilience indirectly by advancing agricultural science and technology. This suggests that technological innovation acts as an important mediating channel in the relationship between green credit and industry chain toughness.

Column (3) presents the regression of green credit on the integration level of the agricultural industry, which also shows a significant positive association with resilience. This supports the notion that industrial integration partially mediates the impact of green credit on system adaptability and risk resistance. Additionally, the significance and direction of control variables further confirm the validity of the proposed transmission mechanisms.

Table.4 Mechanism test of green credit on the resilience of agricultural industry chain

	(1)RAC	(2)TI	(3)Fusion	(4)RAC
GC	0.056^{**}	0.547^{***}	0.090^{**}	-0.045^{*}
	(0.026)	(0.194)	(0.038)	(0.022)
Tax	-0.484^{**}	-1.257	-0.086	-0.279^{*}
	(0.206)	(1.545)	(0.303)	(0.148)
Fiscal	0.173^{**}	0.797	0.497^{***}	0.069
	(0.073)	(0.547)	(0.107)	(0.052)
Consume	0.004	1.071^{***}	0.007	0.007
	(0.034)	(0.256)	(0.050)	(0.024)
Urban	0.362^{***}	2.553^{***}	0.398^{***}	0.209^{***}
	(0.076)	(0.572)	(0.112)	(0.058)
Gap	-0.100^{***}	-0.040	-0.142^{***}	-0.112^{***}
	(0.024)	(0.177)	(0.035)	(0.017)
cons	0.235^{**}	-0.442	0.177	0.393^{***}
	(0.101)	(0.760)	(0.149)	(0.073)
Digital				-0.176
				(0.097)
GC*Digital				0.695^{***}
				(0.142)
N	360	360	360	360
R^2	0.922	0.969	0.877	0.960

Note: * p < 0.1, ** p < 0.05, *** p < 0.01, corrected standard errors in parentheses.

3.3. Test for the moderating effect of green credit on the resilience of agricultural chain

Column (4) of Table 4 presents the results of the moderating effect of green credit on the resilience of the agricultural chain. The coefficient of green credit is significantly negative when the moderating factors are not taken into account, indicating that it has a negative impact on the resilience of the industrial chain, which may be interfered with by real factors such as the threshold of credit access and structural mismatch. The level of agricultural digitization does not pass the significance test, and its direction reveals that digitization is not yet able to fully empower the industry chain stability before an inclusive digital infrastructure pattern is formed. It is noteworthy that the interaction term is highly significant, indicating that agricultural digitization plays a reinforcing moderating effect in it. That is, as the level of agricultural digitization increases, the facilitating effect of green credit on the resilience of the agricultural industry chain increases significantly. This may be attributed to the role of digital technology in resource allocation, credit risk identification and integration of agricultural production chain, which provides effective support for green credit tools to release potential.

3.4. Robustness Tests and Endogeneity Tests

For the robustness test, the article adopts the indicator construction method of changing the predicted variables to conduct the alternative test. Referring to the research idea of Yanqi Wei [10],

agricultural industry chain resilience is remeasured from the dimensions of industrial diversification and innovation. These two indicators are synthesized using the entropy weight method to form a composite resilience index (Resilience), as detailed in Table 1.

Specifically, the Hirschman-Herfindahl Index (HHI) is employed to quantify industrial diversification, using the following formula:

$$Indiv = \frac{1}{HHI} = 1/\sum_i^N S_i^2 \tag{6}$$

where HHI is the concentration of the agricultural industry; S_i denotes the share of the output value of the primary sector in regional GDP.

The regression results using the alternative dependent variable are presented in Table 5. In column (1), without control variables, green credit retains a significantly positive effect at the 5% level. Column (2), incorporating control variables, also supports this relationship at the 10% level. Additionally, key controls such as fiscal expenditure and consumption level exhibit expected signs and significance, indicating a well-fitting model and validating the positive effect of green credit on agricultural resilience.

To account for potential distortions from extraordinary events, the data for 2020-2021 are excluded to mitigate the impact of COVID-19 on the agricultural chain. The results in column (3) show that green credit remains significantly positive, confirming that the findings are not driven by pandemic related shocks. The direction and significance of control variables remain consistent, reinforcing the robustness and reliability of the empirical conclusions under alternative sample structures.

Table.5 Test result of green credit on resilience of agricultural chain

	(1)Resilience	(2)Resilience	(3)RAC	(4)RAC	(5)RAC
GC	0.02503**	0.0591*	0.074***		
	(0.0383)	(0.0333)	(0.026)		
L.GC				0.064**	
				(0.025)	
L2.GC					0.094***
					(0.024)
Tax		-0.3825	-0.494**	-0.439**	-0.407**
		(0.2658)	(0.227)	(0.204)	(0.205)
Fiscal		0.1831*	0.272***	0.153**	0.132*
		(0.0940)	(0.084)	(0.071)	(0.069)
Consume		0.1447***	0.041	-0.001	-0.001
		(0.0440)	(0.036)	(0.033)	(0.032)
Urban		-0.7740***	0.268***	0.364***	0.362***
		(0.0981)	(0.081)	(0.077)	(0.077)
Gap		-0.1520***	-0.092***	-0.103***	-0.100***
		(0.0305)	(0.027)	(0.027)	(0.026)
cons	0.1219***	0.8840***	0.221*	0.243**	0.227**
	(0.0183)	(0.1305)	(0.119)	(0.107)	(0.105)
N	360	360	300	330	300
R^2	0.9494	0.9605	0.933	0.933	0.945
LM Test				25.840[0.0000]	12.221[0.0005]
Wald F Test				107.910{16.38}	35.303{16.38}

Note: * p < 0.1, ** p < 0.05, *** p < 0.01, corrected standard errors in parentheses.

p-values in [] and the Cragg-Donald Wald F-test 10% threshold in {}

To address potential endogeneity arising from reverse causality or omitted variable bias between green credit and agricultural industry chain resilience, the paper adopts a lagged variable approach. Following the instrumental variable strategy proposed by Cheng Li et al., the one-period and two-period lags of green credit (L.GC and L2.GC) are introduced as instruments.

Table 5 presents the two-stage least squares (2SLS) estimation results. Column (4) uses L.GC as the instrument, while Column (5) uses L2.GC. In both cases, the coefficients of green credit remain significantly positive, at the 5% and 1% levels respectively, confirming the robustness of the estimated effects.

The underidentification tests for both instruments are significant, indicating strong correlation with the endogenous variable. Moreover, the Cragg-Donald Wald F-statistics exceed the 10% Stock-Yogo critical threshold, ruling out weak instrument concerns. These results affirm the validity of the instrumental variable specification and further strengthen the credibility of the causal interpretation.

4. Conclusions

Based on a fixed-effects panel model, this study examines the impact of green credit on the resilience of the agricultural industry chain, yielding the following key findings:

(1) Green credit significantly enhances agricultural industry chain resilience, with more pronounced effects in non-major grain-producing regions.

(2) Technological innovation and industry integration serve as critical mediating mechanisms, jointly facilitating resilience and long-term sustainability.

(3) Agricultural digitalization plays a significant moderating role, amplifying the effectiveness of green credit in promoting resilience.

In light of the empirical results, the following policy recommendations are proposed:

(1) Strengthen the green credit support system and tailor financial instruments to regional agricultural characteristics.

(2) Foster coordinated development between technological innovation and industry integration to reinforce systemic resilience.

(3) Accelerate digital transformation in agriculture to optimize the allocation and effectiveness of green credit resources.

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