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Analysis of the Driving Effect of Integrated Agricultural Industry Development on Rural Economic Growth

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Abstract Agricultural industrial integration, as a key component of the rural revitalization strategy, plays a crucial role in driving rural economic growth. The mechanisms and pathways through which it contributes to rural development are currently a major focus of rural development research. This paper examines the impact of agricultural industrial integration on rural economic growth, summarizes its underlying mechanisms and pathways, and constructs a research framework. Using the development status of 20 prefecture-level cities in Province K from 2016 to 2024 as the research sample, the paper employs the entropy weight method to establish an agricultural industrial integration indicator system, summarizing the status of agricultural industrial integration and rural economic growth. With agricultural industrial integration level as the independent variable and rural economic growth as the dependent variable, a regression model is established for empirical analysis. In addition to the coefficient for the level of agricultural industrial integration being consistently significantly positive at the 1% statistical level, in the more developed northern regions, the regression coefficient for the integration of agriculture and services on rural economic growth reached 0.738. Therefore, rural economic development planning should clearly identify the integration of agriculture and tourism as the primary but not the only pathway, while also taking into account regional characteristics and adapting strategies accordingly.

Index Terms agricultural industrial integration, regression model, rural economic growth, entropy weight method

I. Introduction

As China's reform and opening-up and socialist modernisation have steadily progressed, the country has not only achieved rapid economic development but also ensured long-term social stability, making historic achievements in poverty alleviation. However, given China's national conditions, the reform and development of rural areas still face a severe and complex situation. Issues such as rural depopulation, slow growth in farmers' incomes, and unbalanced urban-rural development—collectively referred to as the ‘three rural issues’—severely impact the overall quality of national economic development [1]-[5].

The change in the primary social contradiction has been the main catalyst for the emergence of these issues. As the pace of modern agricultural development in China continues to accelerate, rural areas remain lagging behind, and the extreme imbalance between urban and rural development has further exacerbated the ‘three rural issues’ [6]-[8]. ‘Rural economy’ is not synonymous with ‘agricultural economy,’ and the two should not be equated. If agricultural development remains overly reliant on a single sector, it will be difficult to alter the current state of the rural economy, and promoting farmers' income growth will become even more challenging [9], [10]. Promoting industrial integration has become a new direction for economic development, offering fresh opportunities to form new industrial structures and expand development space. The prosperity of industries is the key to implementing the rural revitalisation strategy, and continuously advancing rural industrial integration is an important lever for rural revitalisation [11]-[14]. The State Council's Office issued the ‘Guiding Opinions on Promoting the Integration of Rural Industries’ in 2015, clearly outlining the significance of advancing rural industrial integration. In 2021, the 14th Five-Year Plan once again emphasised the need to prioritise agricultural and rural development, comprehensively advance rural revitalisation, promote the integration of rural industries, extend the agricultural industrial chain, and develop distinctive modern rural industries that enrich the people. Promoting the integrated development of rural industries is a new approach adopted by the state in the new era to address the ‘three rural issues.’ It takes promoting agricultural development, increasing farmers' income, and improving the rural environment as its fundamental starting point and ultimate goal, thereby reducing agricultural risks and promoting the development of agriculture and rural areas [15]-[18]. Industrial integration is a new trend in modern economic development. Currently, under the guidance of national policies, the integrated development of rural industries has become a key direction for local governments in planning rural economic development [19], [20].

Zhou et al. [21] reported that rural industrial integration helps enhance the resilience of the rural economy (adaptability, transformation and innovation capacity, and recovery capacity), but there are dimensional and regional differences. Wang, R. et al. [22] analysed the level of rural industrial integration in China from 2008 to 2020, finding that the growth in economic benefits was second only to the growth rate of agricultural-service integration. Wang, J et al. [23] reported that rural industrial integration promotes increased product value-added, short-term agricultural output growth, and reduced transaction costs, thereby boosting farmers' incomes, with regional differences emerging under different forms of industrial integration. Jin et al. [24] analysed China's rural industrial integration data from 2011 to 2022 and found that industrial integration can directly narrow the urban-rural consumption gap, with a higher proportion of developmental and enjoyment-oriented consumption. This may be due to increased consumption related to rural cultural tourism, healthcare, and e-commerce industries, leading to gradual growth in rural residents' income and consumption, narrowing the urban-rural consumption gap, and thereby contributing to economic growth.

Zhang and Wu [25] pointed out that farmers' participation in contracts during rural industrial integration can reduce production costs and enhance agricultural green productivity. Green production efficiency contributes to economic growth [26]. Li and Wu et al. [27] explored the impact of agricultural capital subsidies in developing countries on rural industrial integration. Such subsidies can reduce the urban-rural economic gap, and subsidies for the secondary industry have a more significant effect on promoting rural industrial integration and reducing the urban-rural economic gap. Yang et al. [28] mentioned that industrial integration can promote rural innovation under labour mobility, and industrial integration is also an important basis for China's economic transformation and innovation. Rural industrial integration effectively breaks through the inherent limitations of agriculture by extending the industrial chain, enhancing the added value of agricultural products, and enabling farmers to share more benefits, thereby attracting rural residents with entrepreneurial aspirations to return to their hometowns to start businesses and drive rural economic development. Research on the economic effects of rural industrial integration will help clarify the direction of rural industrial integration and effectively address the ‘three rural issues’ from the root.

This paper examines the mechanisms and pathways through which agricultural industrial integration influences rural economic growth from both internal and external perspectives, laying the foundation for the study. Using 20 prefecture-level cities in Province K as the research sample, the paper introduces the entropy weight method to construct an agricultural industrial integration indicator system. Based on this, the paper calculates and analyzes the comprehensive score for agricultural industrial integration in Province K and summarizes the current status of rural economic growth in the 20 prefecture-level cities of Province K. Next, dependent variables, independent variables, and control variables are set, and descriptive analysis is conducted on the variables to construct a regression analysis model. Based on the development status of Province K, benchmark regression analysis, regional impact regression analysis, boundary cointegration tests, and spatiotemporal feature analysis are conducted sequentially.

II. The Impact of Agricultural Industry Integration on Rural Economic Growth

By integrating different industries, rural areas can leverage existing resources and infrastructure to reduce the costs of rural development and avoid resource waste. This enables rural areas to make more rational and efficient use of resources when facing development decisions, thereby enhancing economic efficiency. Secondly, agricultural industry integration can transfer surplus labor by extending the industrial chain, thereby promoting farmers' income growth. Through industry integration, rural areas can engage in more industrial activities, thereby expanding employment opportunities and absorbing more surplus labor into employment. This not only reduces income losses for farmers caused by a lack of employment opportunities, further increasing farmers' incomes, but also improves farmers' skills and overall quality. Additionally, agricultural industrial integration enhances the positive externalities of agricultural production. Through industrial integration, rural areas can transform traditional agricultural production methods into diversified agricultural business models and develop new industries such as agricultural product processing and leisure tourism. This not only increases the value-added of agricultural products and boosts farmers' incomes but also promotes rural economic growth. Finally, industrial integration can reduce transaction costs for agricultural products and derivatives. By adopting new integration methods, such as combining agriculture with tourism or internet agriculture, advancements in technology and information technology can be leveraged to reduce transaction costs and improve market efficiency. This enables agricultural products to enter the market more efficiently, expand sales channels and volumes, and elevate farmers' income levels. The specific mechanisms through which agricultural industrial integration influences rural economic growth are illustrated in Figure 1, achieved through the following pathways.

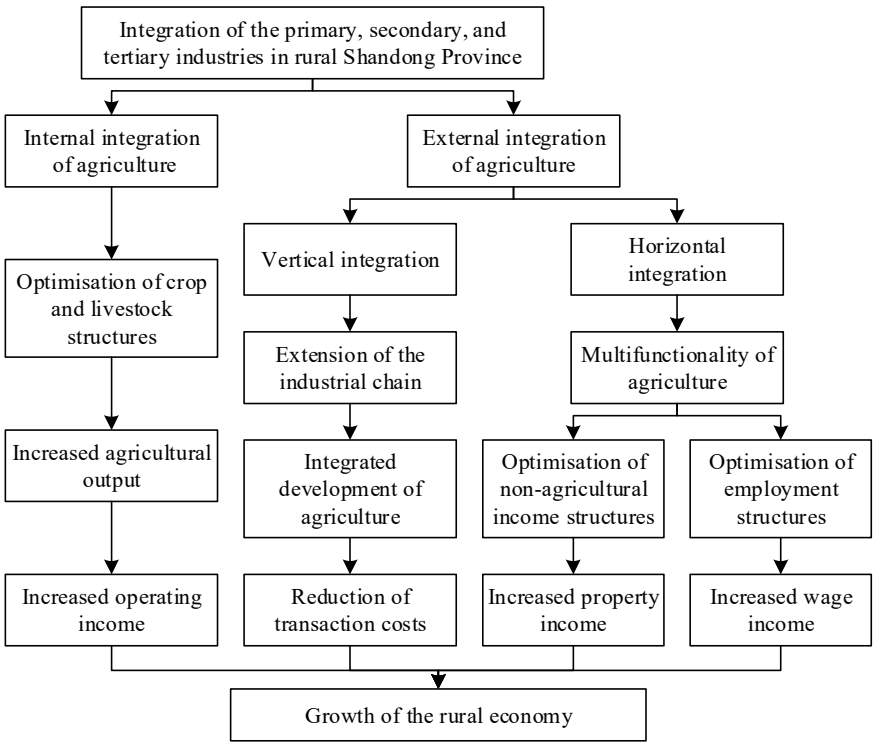

Figure 1: The path by which rural industrial integration affects rural economic growth

III. Measuring Agricultural Industry Integration and Rural Economic Growth

III. A. Comprehensive score analysis of agricultural industry integration

This paper employs the entropy weight method to measure the level of agricultural industrial integration and its internal indicators for the 20 prefecture-level cities in Province K from 2016 to 2024. The calculation method of the entropy weight method is as follows:

First, data preprocessing.

Each indicator has both positive and negative effects on agricultural industrial integration. Therefore, before determining the indicator weights, the original data of each internal indicator is simply processed using the normalization method. Equation (1) is used to process positive indicators, and equation (2) is used to process negative indicators.

$$X_{ij} = \frac{X_{ij} - \min X_j}{\max X_i - \min X_j} + 0.0001 \tag{1}$$

$$X_{ij} = \frac{\max X_j - X_{ij}}{\max X_i - \min X_j} + 0.0001 \tag{2}$$

X_{ij} represents the standard value $(i = 1,2...n, j = 1,2...m)$ for the j rd indicator in the i nd region. $\min X_j$ represents the minimum value in the j th indicator, and $\max X_j$ represents the maximum value in the j th indicator. Adding 0.0001 avoids the problem of the result being 0 after normalization.

Second, the entropy weight method is used to determine the weights.

The weight P_{ij} of the indicator value of the i th region in the j th indicator is calculated as in equation (3):

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \tag{3}$$

Calculate the information entropy value e_j of the j th indicator as shown in Equation (4):

$$e_i = -\ln(n)^{-1} * \sum_{i=1}^{n} P_{ij} * \ln P_{ij} \tag{4}$$

Calculate the redundancy g_j as in equation (5):

$$g_j = 1 - e_j \tag{5}$$

Calculate the weights W_j of each indicator as shown in Equation (6):

$$W_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \tag{6}$$

Calculate the comprehensive score S_j as shown in Equation (7):

$$S_j = \sum_{j=1}^{m} W_j * X_{ij} \tag{7}$$

Based on the analysis above, this paper constructs an entropy-based indicator system for agricultural industrial integration from four dimensions: (A) internal integration within agriculture, (B) extension of the agricultural industrial chain, (C) expansion of agricultural functions, and (D) penetration of high technology, as shown in Table 1.

Table 1: Index system of entropy weight method for rural industrial integration

Primary index	Secondary index
(A) Integrated integration within agriculture	(A1) The level of integration between crop cultivation and animal husbandry and fishery
	(A2) The level of integration between crop cultivation and forestry
	(A3) The level of integration between animal husbandry, fishery and forestry
(B) Extended integration of the agricultural industrial chain	(B1) The per capita comprehensive benefit level of agriculture
	(B2) The level of agricultural servitization
(C) Agricultural functional expansion and integration	(C1) The development level of agricultural production functions
	(C2) The development level of agricultural ecological functions
	(C3) The level of integration between agriculture and tourism
(D) High-tech penetrative fusion	(D1) Level of agricultural mechanization
	(D2) The level of integration between agriculture and informatization

The 20 prefecture-level cities are numbered sequentially from C1 to C20. Based on the geographical location characteristics of Province K, the 20 prefecture-level cities can be roughly divided into the following regions: (N) Northern Region (C13, C4, C9, C7, C16, C15), (M) Central Region (C11, C19, C17, C5, C3, C14, C6, C2), (S) Southern Region (C18, C10, C8, C20, C12, C1). The comprehensive level of agricultural industry integration (RⅡ) for the 20 prefecture-level cities at three time points—2016, 2020, and 2024—is shown in Table 2.

Table 2: The level of rural industrial integration in 20 prefecture-level cities

Prefecture-level city	2016		2020		2024	
	Sort	RⅡ	Sort	RⅡ	Sort	RⅡ
C1	0.03	19	0.14	13	0.2	12
C2	0.08	13	0.16	12	0.21	11
C3	0.13	11	0.1	15	0.15	16
C4	0.21	2	0.26	4	0.32	3
C5	0.13	10	0.13	14	0.22	10
C6	0.08	14	0.17	10	0.19	14
C7	0.19	3	0.27	2	0.3	4
C8	0.06	17	0.07	17	0.05	20
C9	0.19	4	0.4	1	0.37	2
C10	0.06	15	0.04	18	0.1	17
C11	0.17	5	0.26	5	0.29	6
C12	0.03	18	0.17	11	0.2	13
C13	0.34	1	0.26	3	0.43	1
C14	0.1	12	0.04	19	0.1	18
C15	0.17	6	0.18	9	0.27	7
C16	0.17	7	0.24	6	0.26	8
C17	0.16	9	0.22	8	0.29	5
C18	0.06	16	0.04	20	0.05	19
C19	0.16	8	0.24	7	0.25	9
C20	0.03	20	0.1	16	0.19	15
Mean value	0.13		0.17		0.22	
Standard deviation	0.08		0.10		0.10	

Overall, the level of agricultural industrial integration in Province K in 2016 ranged from 0.03 to 0.34. The highest score was achieved by City C13 (0.36), while the lowest scores were recorded in Cities C1, C12, and C20 (0.03). The average level was 0.13, with nine prefecture-level cities scoring below the overall average. In 2020, the agricultural industrial integration level in Province K ranged from 0.04 to 0.40, with the highest score in City C9 (0.49) and the lowest scores in Cities C10, C18, and C14 (0.04). The average level was 0.17, with a standard deviation of 0.10, and nine regions were below the overall average. Overall, the agricultural industrial integration level in Province K has slightly improved over the past decade.

Further breaking down the agricultural industrial integration indicators for the nine-year period from 2016 to 2024 and calculating the comprehensive scores reveals that: (A) The level of internal integration within rural areas ranged from 0.06 to 1.14, with an average of 0.38 and a standard deviation of 0.09, with eight regions below the overall average. (B) The level of agricultural industrial chain extension-type integration ranged from 0.04 to 0.58, with an average of 0.27 and a standard deviation of 0.07, with 10 regions below the overall average. (C) The level of agricultural functional expansion-type integration ranged from 0.04 to 0.76, with an average of 0.15 and a standard deviation of 0.22, with 13 regions below the overall average. (D) The integration level of high-tech penetration ranges from 0.02 to 0.30, with an average of 0.08 and a standard deviation of 0.06. Twelve regions are below the overall average. As can be seen, the four internal indicators are ranked from highest to lowest as follows: (A) rural internal integration-type integration, (B) agricultural industrial chain extension-type integration, (C) agricultural functional expansion-type integration, and (D) high-tech penetration-type integration.

III. B. Current Status of Rural Economic Growth

III. B. 1) Total Rural Economy

Over the past decade, K Province's agricultural economy has achieved significant growth and improvement with the strong support of national policies and market conditions. As an important agricultural province, its economic structure has been continuously optimized and upgraded, and investment in education in rural areas has gradually increased, promoting the rapid development of the local socio-economy. From 2016 to 2024, K Province's agricultural gross domestic product (GDP) rose from 1115.689 billion yuan to 1751.752 billion yuan, with an average annual growth rate of 5.90%. The agricultural GDP of various prefecture-level cities in K Province from 2016 to 2024 is shown in Table 3. It can be seen that the agricultural GDP of various prefecture-level cities in K Province showed a steady growth trend from 2016 to 2024.

Table 3: The status of agricultural gross product in K Province from 2016 to 2024

Area	2016	2017	2018	2019	2020	2021	2022	2023	2024
C1	509.61	520.49	583.81	626.60	637.82	668.78	703.61	749.01	860.11
C2	534.34	542.26	604.46	644.90	649.01	679.23	713.28	757.93	867.28
C3	559.08	556.11	607.72	635.75	615.44	644.40	677.01	719.71	824.27
C4	598.66	603.61	668.60	708.93	704.96	738.44	776.15	825.44	946.12
C5	559.08	559.08	614.25	646.04	632.23	666.46	704.82	754.10	874.44
C6	534.34	543.25	606.64	648.33	654.61	681.55	712.07	752.83	852.94
C7	588.77	596.68	664.26	707.79	710.56	740.77	774.94	820.34	931.78
C8	524.45	525.44	578.37	609.45	598.66	618.85	641.95	673.85	752.59
C9	588.77	609.55	692.52	752.38	783.29	809.27	839.01	880.21	981.96
C10	524.45	522.47	571.85	599.16	581.87	610.73	643.16	685.32	788.43
C11	578.87	587.78	655.56	699.78	704.96	734.96	768.89	813.97	924.62

C12	509.61	523.46	590.33	636.89	654.61	682.71	714.49	756.65	860.11
C13	662.98	655.07	711.00	738.66	704.96	751.22	802.74	867.47	1024.96
C14	544.24	538.30	584.89	608.31	581.87	610.73	643.16	685.32	788.43
C15	578.87	579.86	638.16	672.34	660.20	695.48	735.04	785.95	910.28
C16	578.87	585.80	651.21	692.92	693.77	722.19	754.38	797.41	903.11
C17	573.92	579.86	643.60	683.78	682.58	716.38	754.38	803.78	924.62
C18	524.45	522.47	571.85	599.16	581.87	604.92	631.07	666.21	752.59
C19	573.92	581.84	647.95	690.64	693.77	721.03	751.97	793.59	895.95
C20	509.61	516.53	575.11	612.88	615.44	649.04	686.68	735.00	852.94
Total	11156.89	11249.91	12462.14	13214.71	13142.51	13747.13	14428.82	15324.11	17517.52

III. B. 2) Income disparities among rural areas in various prefecture-level cities

The per capita disposable income of rural residents in the 20 prefecture-level cities of Province K from 2016 to 2024 is shown in Table 4. It can be seen that over the nine-year period, the per capita disposable income of rural residents in all 20 prefecture-level cities has been steadily increasing. However, due to differences in the development rates of agricultural science and technology, farmers' educational levels, and information technology adoption across regions, there are also variations in the sophistication of market mechanisms and the intensity of policy support. Consequently, there are significant disparities in rural per capita disposable income across regions. Overall, the per capita disposable income levels of each prefecture-level city align with their comprehensive levels of agricultural industry integration.

Table 4: Per capita disposable income of rural areas in the city from 2016 to 2024

Area	2016	2017	2018	2019	2020	2021	2022	2023	2024
C1	8367.22	8630.83	8978.23	9371.25	10169.22	10544.25	10998.30	11489.38	12273.96
C2	8979.26	9164.61	9480.57	9828.34	10479.11	10845.55	11290.82	11766.94	12487.66
C3	9591.29	9504.28	9559.89	9599.79	9549.44	9841.24	10193.88	10577.38	11205.47
C4	10570.54	10668.89	11040.46	11428.13	12028.55	12552.87	13192.18	13868.50	14838.34
C5	9591.29	9577.07	9718.52	9856.90	10014.28	10477.30	11034.86	11647.98	12701.36
C6	8979.26	9188.87	9533.45	9914.04	10634.05	10912.50	11254.25	11608.33	12060.26
C7	10325.73	10499.05	10934.70	11399.56	12183.50	12619.83	13155.61	13709.89	14410.94
C8	8734.44	8752.14	8846.04	8942.74	9084.61	9104.74	9133.50	9149.91	9068.49
C9	10325.73	10814.46	11622.11	12513.70	14197.78	14594.97	15093.54	15573.53	15906.83
C10	8734.44	8679.35	8687.41	8685.63	8619.78	8870.40	9170.07	9506.78	10136.98
C11	10080.92	10280.69	10723.19	11199.59	12028.55	12452.44	12972.79	13511.63	14197.25
C12	8367.22	8703.62	9136.87	9628.36	10634.05	10945.98	11327.38	11727.29	12273.96
C13	12161.83	11930.55	12071.57	12170.89	12028.55	12921.12	13996.60	15177.01	17189.02
C14	9224.07	9067.56	9004.67	8914.17	8619.78	8870.40	9170.07	9506.78	10136.98
C15	10080.92	10086.59	10300.17	10513.96	10789.00	11314.22	11948.98	12639.28	13769.85
C16	10080.92	10232.16	10617.44	11028.18	11718.67	12084.19	12534.01	12996.15	13556.15

C17	9958.51	10086.59	10432.37	10799.64	11408.78	11916.81	12534.01	13194.41	14197.25
C18	8734.44	8679.35	8687.41	8685.63	8619.78	8703.02	8804.42	8912.00	9068.49
C19	9958.51	10135.11	10538.12	10971.05	11718.67	12050.72	12460.88	12877.20	13342.45
C20	8367.22	8533.78	8766.72	9028.44	9549.44	9975.14	10486.39	11053.20	12060.26

IV. Empirical Research on the Integration of Agricultural Industries and Rural Economic Growth

IV. A. Variable descriptions and descriptive statistics

The dependent variable in this study is rural economic growth (ECO), and the independent variable is the level of agricultural industrial integration (CON). Since the implementation of agricultural industrial integration has been relatively short-term, to ensure the significance of the regression results, additional control variables are included: urbanization level (URB), rural human capital (EDU), rural transportation infrastructure (FRA), and internet development level (INT). The specific variable contents are as follows:

(1) Rural Economic Growth (ECO)

Given the lack of accurate and reliable direct data and related indicators for rural economic growth, this study uses the rural GDP indicator to reflect the rural economic growth variable.

(2) Agricultural industrial integration level (CON)

This variable is represented by the agricultural industrial integration level calculated based on the evaluation indicator system and the determined comprehensive weights.

(3) Urbanization level (URB)

Urbanization is a multidimensional concept encompassing economic, demographic, spatial, and social dimensions. In this study, population urbanization is used as the independent variable, measured by the ratio of urban population to rural population. The phenomenon of rural population continuously migrating to cities has a dual effect. On one hand, it can enhance agricultural mechanization levels and promote the formation of family farms and farmers' cooperatives. On the other hand, population outflow leads to a decline in grain production, so advanced agricultural production technologies are needed to improve agricultural production efficiency. Therefore, this variable is included in the regression model.

(4) Rural Human Capital (EDU)

As one of the key production factors in agricultural production, the accumulation of human capital plays an irreplaceable role in increasing total agricultural output value, with its root cause being the increase in the average years of education among rural laborers. The promotional effect of rural human capital on rural GDP primarily manifests in agricultural service sector employment, including improving agricultural production management efficiency and upgrading production machinery and equipment. There are significant differences in the promotional effects on total agricultural output value across different educational levels. Therefore, this paper selects the average years of education per capita of the rural labor force as the indicator for this metric.

(5) Rural Transportation Infrastructure (FRA)

The difficulty in achieving market integration for agricultural products stems from two main factors: first, the perishability of agricultural products, and second, the significant segmentation of agricultural product distribution markets, which makes cross-regional distribution challenging and limits the expansion of farmers' income sources. The improvement of rural roads has a significant positive effect on the integration of agricultural product circulation markets, effectively addressing challenges such as cross-regional logistics and distribution. The convenience of transportation infrastructure contributes to the spatial spillover effects on regional economic growth by reducing trade costs between regions, thereby breaking down the segmentation of agricultural product circulation markets. Therefore, this paper uses road density (the ratio of road mileage to provincial/municipal area) to measure rural transportation infrastructure.

(6) Internet Development Level (INT)

The widespread adoption of the internet reflects the level of information technology development. As a public infrastructure, it possesses significant positive externalities and spatial spillover effects, making the modernization of agriculture inseparable from the development of the internet. These positive impacts include enhancing farmers' ability to access information and expanding their income-generating opportunities. The improvement in information technology levels can, on the one hand, help farmers increase agricultural productivity and the profit margin of agricultural products in the planting, selection, and sales processes. On the other hand, the internet can significantly increase the proportion of the tertiary industry, further enhancing its role in driving agricultural

development. Therefore, this paper uses internet penetration rate (the ratio of internet users to the permanent resident population) to measure the level of internet development.

Combining the development situation of 20 prefecture-level cities in Province K from 2016 to 2024, the descriptive statistics of the selected variables are shown in Table 5.

Table 5: Descriptive statistics based on the development situation of Province K

Variable properties	Variable	Sample capacity	Mean value	SD
Dependent variable	ECO	20	0.17	0.749
Independent variable	CON	20	0.45	0.24
Control variable	URB	20	0.34	0.113
	EDU	20	2243	0.609
	FRA	20	3.46	0.245
	INT	20	0.21	0.122
	ECO	20	0.17	0.749

IV. B. Model Construction

Panel data analysis methods address the issue of multicollinearity in time series data while also increasing the sample size to some extent, thereby improving the precision and efficiency of estimates. Due to significant differences in the level of agricultural industrial integration across regions, the impact on rural economic growth also varies significantly. Before establishing the regression equation, the data is first processed using a logarithmic method to eliminate multicollinearity in the series. This paper is based on the Cobb-Douglas production function. Since the variables have been log-transformed, the model LNECOit is constructed as shown in Equation (8):

$$LNECO_{it} = \beta_0 + \beta_1 LNCON_{it} + \beta_2 LNURB_{it} + \beta_3 LNEDU_{it} + \beta_4 LNFRA_{it} + \beta_5 LNINT_{it} + \varepsilon_{it} \quad (8)$$

In this model, i represents the region, t represents the year, β_0 represents the constant term, ECO_{it} represents rural economic growth, CON_{it} represents the level of agricultural industrial integration, URB_{it} represents the level of urbanization, and EDU_{it} represents the stock of rural human capital. FRA_{it} denotes the condition of rural transportation infrastructure, INT_{it} denotes the level of internet development, β_1, β_2, β_3, β_4, and β_5 are the elasticity coefficients of each variable's impact on the dependent variable, and ε_{it} is the residual term.

IV. C. Empirical Results and Analysis

IV. C. 1) Benchmark estimation results

Based on the LNECOit model, this paper estimates the comprehensive impact of agricultural industrial integration on rural economic growth and verifies the robustness of the estimation results by gradually adding control variables. The estimation results are shown in Table 6. Column (1) shows the estimation results without control variables, while columns (2) to (5) show the estimation results with control variables gradually added. It can be seen that, after controlling for prefecture-level city fixed effects and year fixed effects, the coefficient of the level of agricultural industrial integration remains significantly positive at the 1% statistical level when control variables are gradually added. This indicates that an increase in the level of agricultural industrial integration promotes rural economic growth. In terms of the magnitude of the effect, the level of agricultural industrial integration contributes 6.80% to the growth of the rural economy. This indicates that the improvement in the level of agricultural industrial integration has promoted the transformation and upgrading of the local rural industrial economic structure, optimized the rural industrial structure by fostering the development of new industries, new business models, and new patterns, and ultimately achieved rural industrial economic growth.

Table 6: Benchmark estimation result

Variable	(1)	(2)	(3)	(4)	(5)
CON	0.088**	0.079***	0.078***	0.079***	0.068***
	(0.025)	(0.019)	(0.023)	(0.022)	(0.022)
URB		0.341***	0.341***	0.319***	0.298***
		(0.051)	(0.049)	(0.045)	(0.041)
EDU			0.035	0.039	0.026
			(0.038)	(0.039)	(0.037)

FRA				-3.921***	-3.699***
				(0.987)	(0.991)
INT					0.996***
					(0.042)
Constant term	15.254***	9.603***	9.197***	9.631***	8.876***
	(0.014)	(0.790)	(0.935)	(0.927)	(0.958)
Fixed effect of prefecture-level cities	Controlled	Controlled	Controlled	Controlled	Controlled
Annual fixed effect	Controlled	Controlled	Controlled	Controlled	Controlled
N	20	20	20	20	20
F Value	258.507	261.458	237.67	225.535	211.329
R2	0.806	0.822	0.823	0.827	0.830

Note: ***, ** and * represent significance levels of 1%, 5% and 10% respectively. The figures in parentheses are robust standard errors, the same below

IV. C. 2) Impact of sub-regions on regression results

For the three study regions—the (N) northern region, (M) central region, and (S) southern region—this paper constructs three autoregressive distributed lag models (ARDL) and performs regression analysis using group regression. The independent variable “agricultural industry integration level (CON)” is decomposed into two subsystems: (CON1) agriculture-industry and (CON2) agriculture-services. Three additional distributed autoregressive models are constructed to explore the specific relationships between each subsystem and the dependent variable “rural economic growth” in the three study regions. The regression results for the impact of improvements in the level of agricultural industrial integration on rural economic growth in the three different regions of Province K over the nine-year period from 2016 to 2024 are presented in Table 7.

Table 7: The regression results of the impact of CON on regional economic growth

Variable	N		M		S	
	(1)	(2)	(3)	(4)	(5)	(6)
CON	0.798***		0.501***		0.361***	
	(6.532)		(17.097)		(9.897)	
URB	0.346*	0.328*	0.297*	0.319**	0.302*	0.292**
	(0.244)	(0.279)	(0.583)	(0.817)	(0.748)	(0.889)
EDU	0.372**	0.391**	0.039**	0.0019***	0.088*	0.025**
	(1.955)	(1.852)	(0.271)	(0.044)	(0.657)	(0.152)
FRA	-0.327	-0.332	-0.048	-0.032	-0.039	-0.049
	(-3.141)	(-3.001)	(-1.326)	(-0.921)	(-1.616)	(-1.869)
INT	0.029***	0.027***	0.036***	0.035***	0.028***	0.033***
	(2.859)	(2.724)	(9.669)	(8.856)	(6.091)	(6.247)
CON1		0.039		0.302**		0.559***
		(1.598)		(1.575)		(1.133)
CON2		0.738***		0.318*		0.089
		(1.373)		(5.468)		(0.491)
Constant term	0.379	0.402	-0.051	-0.086	-0.159	-0.040
	(1.998)	(1.811)	(0.349)	(0.627)	(-1.039)	(-0.209)
N	6	6	8	8	6	6
R2	0.931	0.931	0.837	0.839	0.955	0.958

From the regression results of the sub-regions, models (1), (3), and (5) show that the regression coefficients for all three regions are positive and pass the 1% significance level test. Among these, the northern region (N) has the strongest promotional effect on rural economic growth in the region, with a coefficient of 0.798, followed by the central region (M) at 0.501, and the southern region (S) at 0.361. From the regression models (2), (4), and (6) of the two subsystems, the coefficients of both subsystems passed the statistical significance level test, indicating that the primary factors driving the growth of the rural economy in Region K are the deep integration and development of agriculture with industry and agriculture with services. For the northern region (N), the key driver is the agriculture-services integration (CON2) with a coefficient of 0.738. Although the central region (M) lags behind the northern region (N) in overall development, its levels of integration between agriculture and industry (0.302) and agriculture and services (0.318) are relatively balanced. Due to geographical location and overall regional

development conditions, the primary driving force for rural economic growth in the southern region (S) is agriculture-industry integration (0.559).

Overall, the improvement in the level of agricultural industry integration can effectively and significantly promote rural economic growth in prefecture-level cities in Province K. However, in terms of specific driving forces, the primary drivers of rural economic growth vary across regions due to their geographical location and overall development status.

IV. C. 3) Boundary cointegration test

Based on the results of the regression model analysis in the previous section, this section conducts a cointegration test to examine the long-term relationship between two types of industrial integration and economic growth. The lag order of variables in the ARDL model was selected based on the AIC criterion. The AIC information criterion results for the 20 relatively optimal equations are shown in Figure 2. Among them, the AIC information criterion of the ARDL(1) model is relatively the smallest (<0.85), indicating that there is a one-period lag between the level of agricultural industrial integration and rural economic growth in the 20 prefecture-level cities of Province K.

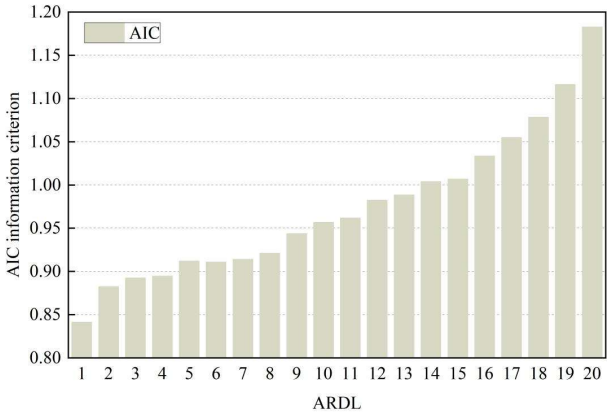

Figure 2: AIC information criterion diagram

IV. C. 4) Spatio-temporal feature analysis

To characterize the time-varying nature of the impact of two types of agricultural industry integration on rural economic growth, this paper further constructs the following state space model, where equation (9) is the measurement equation and equation (10) is the state equation.

$$ECO = \mathrm{svl} * RHD + [\mathrm{var} = \exp(c(1))] \tag{9}$$

$$svl = svl(-1) \tag{10}$$

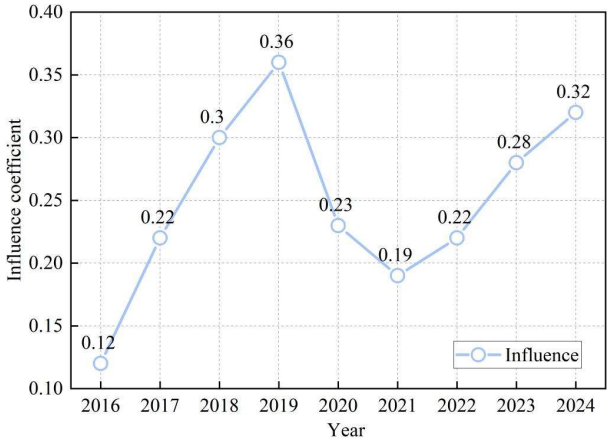

Figure 3: The trajectory of the impact of industrial integration on economic growth

Using a one-step-ahead forecasting method, the dynamic changes in the impact of two levels of agricultural industry integration on rural economic growth in prefecture-level cities in Province K are shown in Figure 3. Prior to

2019, the marginal effect of agricultural industry integration on rural economic growth showed a steady upward trend, with its influence rising from 0.12 to 0.36. Since 2019, the marginal influence of agricultural industrial integration levels on rural economic growth has declined but has stabilized around 0.2. In recent years, the marginal influence of agricultural industrial integration levels on rural economic growth has shown signs of recovery. Although the impact of agricultural industrial integration levels on rural economic growth is time-varying, it has consistently exerted a positive influence (>0.1) on rural economic growth during the sample period. This indicates that promoting deep integration among rural industries is an effective and important means of stimulating rural economic growth.

V. Conclusion

Between 2016 and 2024, the overall level of agricultural industrial integration across the 20 prefecture-level cities in Province K showed a positive trend. The specific development patterns were as follows: internal integration within rural areas (0.38) > extension of the agricultural industrial chain (0.27) > expansion of agricultural functions (0.15) > high-tech penetration (0.08). Over the nine-year period, the total rural economic output of K Province increased annually, but there were significant disparities in per capita rural income within the region.

Using the 20 prefecture-level cities of K Province as the research sample, the level of agricultural industrial integration was set as the independent variable, and rural economic growth as the dependent variable. Based on the specific development status of the prefecture-level cities in K Province, a regression model was constructed for empirical analysis. Overall, the level of agricultural industrial integration contributes 6.80% to the increase in rural GDP, consistently exerting a positive influence (>0.1) during the sample period. There is a one-period lag between the two: the ARDL(1) model <0.85. The regression coefficients for different types of industrial integration across the three regions of Province K are all positive and pass the 1% significance level test. The specific promotional effects vary by region, with the more developed northern region primarily focusing on the integration of agriculture and services (0.738).

The deep integration of the agricultural industry can positively and significantly promote rural economic growth by extending the industrial chain into areas such as tourism, e-commerce, and internet finance, thereby increasing the added value of agricultural products. This, in turn, drives the adjustment and optimization of the rural industrial structure, stimulates agricultural development, and boosts agricultural economic income.

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