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Analysis of the Intermediary Effect of New Quality Productivity: Scientific and Technological Innovation Drives High-quality Agricultural Development

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Abstract

Accelerating the formation of new agricultural productive forces represented by scientific and technological innovation is the inevitable path to achieving high-quality agricultural development, advancing rural revitalization, and building a socialist agricultural power. This paper selects panel data from 30 provinces in China between 2012 and 2022 and explores the impact of scientific and technological innovation on high-quality agricultural development and its underlying driving mechanism by constructing fixed-effects models and mediation effect models. The results indicate that scientific and technological innovation can promote high-quality agricultural development, by conducting robustness checks through the addition of control variables, the results remained significant. The heterogeneity analysis reveals that the driving effect of scientific and technological innovation on the high-quality development of agriculture and rural areas exhibits a heterogeneous impact paradigm across different geographical locations, specifically manifesting as a stronger enabling effect of scientific and technological innovation on the high-quality development of agriculture in major grain-producing areas. The mediation effect indicates that scientific and technological innovation can drive the high-quality development of agriculture by fostering new types of productive forces. Based on this, it is recommended to increase investment in research and development for scientific and technological innovation and create a favorable environment for such innovation, comprehensively tapping into the potential of scientific and technological innovation to empower the high-quality development of agriculture; focus on the integration of scientific and technological innovation achievements with institutional reforms to stimulate the mediating role of new types of productive forces.

Keywords

Scientific and technological innovation; new-type productive forces; high-quality agricultural development

1. Introduction

High-quality agricultural development is not only the cornerstone for ensuring national food security but also a pivotal force driving comprehensive economic and social progress in rural areas. However, issues such as low production efficiency, high resource consumption, and severe environmental pollution are prevalent in current agricultural production, severely hindering the sustainable development of agriculture. Therefore, analyzing the intrinsic relationship between scientific and technological innovation and high-quality rural development, and delving into the role played by new-type

productive forces in this context, is of great significance for enhancing agricultural production efficiency, safeguarding food security, and building a socialist agricultural power.

2. Literature Review

2.1 The effect of digital technology and scientific and technological innovation on the high-quality development of agriculture

Wang Qinmei and Yang Junge argue that, in the field of agriculture, digital technology by combining with the traditional three factors of production, forms a new type of productive force in digital agriculture, thereby driving innovation-driven high-quality agricultural development [1]. Yan and Wang pointed out that, driven by scientific and technological innovation, this new type of productive force can synergize with digital rural development and play a positive enabling role in the process of China's digital rural construction [2].

2.2 Related research on new quality productivity

Zhang Zhenyu argues that new-type productive forces can empower digital rural construction through industrial upgrading, rural development, and farmer progress, thereby achieving high-quality agricultural development [3]. Some scholars have further revealed the internal mechanism through which new-type productive forces promote high-quality economic development from four dimensions: "production factors, organizational forms, industrial systems, and technological innovation" [4].

3. Mechanism Analysis and Research Hypothesis

3.1 The relationship between scientific and technological innovation and high-quality agricultural development

Scientific and technological innovation, represented by technologies such as the Internet of Things, big data, and cloud computing, has promoted the modernization, informatization, and intelligentization of agricultural production. The application of modern agricultural machinery, such as smart agricultural equipment and drones, has significantly enhanced agricultural productivity and resource utilization efficiency. The utilization of technologies such as intelligent sensing, intelligent control, and intelligent decision-making enables precise management of agricultural production. Combined with big data analysis, these technologies can formulate precise plans for fertilization, irrigation, pest control, and other measures, thereby improving the precision of agricultural production. Based on this, the following hypothesis is proposed:

H1: Scientific and technological innovation can promote high-quality agricultural development.

3.2 The relationship between scientific and technological innovation, new-type productive forces, and high-quality agricultural development

Scientific and technological innovation embeds digital technology into agricultural laborers, agricultural production materials, and agricultural labor objects, integrating it into the entire process of agricultural production to form new-type productive forces in agriculture. The influence of new-type productive forces in agriculture, represented by digital agriculture, is not limited to a single industry but spans across the primary, secondary, and tertiary industries, forming a new mode of coordinated development. It also promotes deep integration and balanced development between urban and rural areas, thereby driving high-quality agricultural and rural development. Based on this, the following hypothesis is proposed:

H2: Scientific and technological innovation can promote high-quality agricultural development by cultivating new-type productive forces.

4. Empirical Research Design

4.1 Model specification

4.1.1 Benchmark regression model

To explore the relationship between scientific and technological innovation and high-quality agricultural development, based on the aforementioned hypotheses, the following panel data model is specified:

$$Hqda_{it} = \beta_0 + \beta_1 Sti_{it} + \beta_2 Controls_{it} + \mu_i + \delta_t + \varepsilon_{it}$$

In the above equation, the subscripts i and t represent regions and years, respectively; Hqda denotes the level of high-

quality agricultural development; Sti represents scientific and technological innovation; β_0 is the intercept term; β_1 is the estimated parameter for the core explanatory variable; β_2 are the estimated parameters for the control variables; μ_i represents the fixed effects for provinces; δ_t represents the fixed effects for years; and ε_{it} represents the random disturbance term.

4.1.2 Mediating effect model

To investigate whether new-type productive forces mediate the impact of scientific and technological innovation on high-quality agricultural development, the following mediating effect model is constructed:

$$Hqda_{it} = \beta_0 + \beta_1 Sti_{it} + \beta_2 Controls_{it} + \mu_i + \delta_t + \varepsilon_{it}$$

$$Nqf_{it} = \alpha_0 + \alpha_1 Sti_{it} + \alpha_2 Controls_{it} + \mu_i + \delta_t + \varepsilon_{it}$$

$$Hqda_{it} = \varphi_0 + \varphi_1 Sti_{it} + \varphi_2 Nqf_{it} + \varphi_3 Controls_{it} + \mu_i + \delta_t + \varepsilon_{it}$$

In which, α_1、α_2、φ_1、φ_2、φ_3 respectively represents the coefficient of each variable, and Nqf_{it} denotes new-type productive forces.

4.2 Variable measurement

4.2.1 Explanatory variable: Level of high-quality agricultural development

The explanatory variable in this paper is the level of high-quality agricultural development (Hqda). Therefore, this paper will construct an evaluation system for high-quality agricultural development indicators that includes five primary indicators and 21 secondary indicators across five dimensions: agricultural innovation development, agricultural coordinated development, agricultural green development, agricultural exploration development, and agricultural shared development. The comprehensive index of high-quality agricultural development will be calculated using the entropy method.

4.2.2 Core explanatory variable: Scientific and technological innovation

The core explanatory variable in this paper is scientific and technological innovation (Sti). This paper comprehensively measures the level of scientific and technological innovation using the entropy method, considering four aspects: the number of authorized patents, the revenue of high-tech industries, the industrial innovation funding of industrial enterprises above a certain size, and the full-time equivalent of R&D personnel in industrial enterprises above a certain size.

4.2.3 Mediating variable: New-type productive forces

This paper selects new-type productive forces (Npf) as the mediating variable. New-type productive forces refer to the advanced productive force quality driven by scientific and technological innovation, characterized by leapfrogging improvements in laborers, means of production, and objects of labor, as well as their optimized combinations. Based on the above definition, an evaluation system for new-type productive forces indicators is constructed that includes seven primary indicators and 14 secondary indicators across three levels: laborers, means of production, and objects of labor. On this basis, the entropy method is used to measure the development level of new-type productive forces in agriculture.

4.2.4 Control variables

To comprehensively analyze the impact of scientific and technological innovation on high-quality agricultural development, it is necessary to identify control variables that may affect high-quality agricultural development. This paper controls for two aspects: government support for agriculture (Gsa) and Engel's coefficient (Rec).

5. Empirical Analysis

5.1 Benchmark regression analysis

Using the mentioned earlier, relevant control variables were included, and a two-way fixed effects model was employed for regression analysis. Cluster-robust standard errors were used to address potential intra-group correlation. Table 1 presents the baseline regression results of scientific and technological innovation empowering high-quality agricultural development. Columns (1) to (3) show the fitting results with control variables added sequentially. In column (3), the regression coefficient of scientific and technological innovation is 0.218 and passes the 1% significance level test, indicating that scientific and technological innovation can still promote high-quality agricultural development when considering fixed effects and control variables. In summary, hypothesis H1 holds, namely, scientific and technological innovation can significantly promote high-quality agricultural development.

Table 1. Results of benchmark regression analysis

Variables	Hqda (1)	Hqda (2)	Hqda (3)
Sti	0.304*** (0.0285)	0.174*** (0.0365)	0.218*** (0.0397)
Gsa		0.186 (0.142)	0.152 (0.125)
Rec			0.0954 (0.220)
Province fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Constant term	0.151*** (0.00528)	0.144*** (0.0174)	0.115** (0.0436)
R^2	0.258	0.921	0.921
Samples	330	330	330

Note: *, ** and *** indicate significance at the levels of 10%, 5% and 1%, respectively, with robust standard errors in parentheses.

5.2 Heterogeneity test

Table 2. Regression Results of the Heterogeneity Test

Variables	Hqda in major grain-producing areas (1)	Hqda in major grain-consuming areas (2)	Hqda in areas with balanced production and consumption (3)
Sti	0.124**(0.0505)	0.186(0.0988)	0.441(0.145)
Variable of control	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Constant term	0.149*(0.0679)	-0.721***(0.143)	0.0812**(0.0308)
R^2	143	77	110
Samples	0.974	0.974	0.983

Note: *, ** and *** indicate significance at the levels of 10%, 5% and 1%, respectively, with robust standard errors in parentheses.

Influenced by the functions and orientations of agricultural development, major grain-producing areas possess stronger endowments of agricultural production resources and more complete agricultural production systems compared to non-major producing areas. Furthermore, due to potential disparities in the levels and stages of agricultural scientific and technological innovation and agricultural modernization development between major grain-producing areas, major grain-consuming areas, and areas with balanced production and consumption, their enabling effects on the high-quality development of agriculture may also differ. Therefore, this paper follows the approach of Yuchun Yao and adopts a three-region classification method reflecting grain production and sales conditions—major grain-producing areas, major grain-consuming areas, and areas with balanced production and consumption—to test the heterogeneity of scientific and technological innovation in empowering the high-quality development of agriculture [5]. Among them, major grain-producing areas have natural conditions suitable for growing grain crops, high grain yields, and large planting proportions, ensuring self-sufficiency while also exporting large quantities of commodity grain; major grain-consuming areas are relatively economically developed but have a large population and limited land, resulting in significant gaps between grain production and demand; areas with balanced production and consumption contribute limited to national grain production but can basically maintain self-sufficiency. The test results, as shown in Table 2, indicate that scientific and technological innovation in major grain-producing areas has a positive and significant impact on the high-quality development of agriculture at the 5% level, while the impact of scientific and technological innovation in major grain-consuming areas on the high-quality development of agriculture is positive but not significant. In areas with balanced production and consumption, scientific and technological innovation has a positive and significant impact on the high-quality development of agriculture at the 5% level. Possible reasons include the advantages of scale and intensification in agricultural production in

major grain-producing areas, where the government provides strong support for high-standard farmland, irrigation systems, and smart agriculture, enabling scientific and technological innovation to exert a multiplier effect in promoting agricultural mechanization and improving agricultural productivity, thereby fully demonstrating its positive enabling effect on the high-quality development of agriculture. In contrast, major grain-consuming areas and areas with balanced production and consumption have weaker endowments of agricultural production resources and more dispersed agricultural production, resulting in a relatively weaker impact of scientific and technological innovation on the high-quality development of agriculture.

5.3 Analysis of action mechanism

Previous sections have confirmed that scientific and technological innovation can significantly improve the quality of agricultural development, but how scientific and technological innovation affects high-quality agricultural development remains at the level of theoretical analysis. To further explore the transmission mechanism of "technological innovation - new-type productive forces - high-quality development," the mediation effect model constructed earlier was estimated. The test result (2) in Table 3 shows that scientific and technological innovation (Sti) has a positive and significant impact on new-type productive forces (Npf) at the 1% significance level. The test result (3) in Table 3 shows that new-type productive forces in agriculture have a positive and significant impact on high-quality agricultural development at the 5% significance level, meaning that after controlling for the variable of scientific and technological innovation, new-type productive forces in agriculture significantly promote high-quality agricultural development. The test result (3) in Table 3 also shows that after controlling for the variable of new-type productive forces, the impact of scientific and technological innovation on high-quality agricultural development still has a significant positive effect at the 1% significance level, with a coefficient of 0.179, which is smaller than the estimated coefficient of 0.218 in the benchmark regression model (1) in Table 3. This indicates that after controlling for the variable of new-type productive forces in agriculture, the driving effect of scientific and technological innovation on high-quality agricultural development decreases, suggesting that new-type productive forces in agriculture play a partial mediation role in empowering high-quality agricultural development through scientific and technological innovation. Among them, the mediation effect accounts for 17.889% of the total effect, meaning that 17.889% of the promotion effect of scientific and technological innovation on high-quality agricultural development is achieved through the mediation of new-type productive forces in agriculture. Thus, hypothesis H2 is confirmed.

Table 3. Mediating effect test results

Variables	Hqda Main effect (1)	Nqf Mediating effect (2)	Hqda Mediating effect (3)
Sti	0.218*** (0.0319)	0.416*** (0.0813)	0.179*** (0.0349)
Npf			0.0926** (0.0313)
Variable of control	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Constant term	-0.289 (0.181)	0.156(0.165)	-0.303 (0.180)
R^2	0.965	0.963	0.966
Samples	330	330	330

Note: *, ** and *** indicate significance at the levels of 10%, 5% and 1%, respectively, with robust standard errors in parentheses.

6. Conclusion

This paper analyzes and tests the impact of scientific and technological innovation and new-type productive forces in agriculture on high-quality agricultural development, as well as their mechanisms. Based on model testing results using provincial panel data from 2012 to 2022, the conclusions are as follows: (1) The estimation results with two-way fixed effects in the baseline regression model show that scientific and technological innovation has a significant positive impact on high-quality agricultural development in China; (2) By introducing the variable of new-type productive forces in agriculture into the model for mediation effect testing, it is found that 17.889% of the promotion effect of scientific and technological innovation on high-quality agricultural development is mediated through new-type productive forces in

agriculture.

Based on the above analysis, the following policy recommendations are proposed: On the one hand, it is necessary to increase investment in research and development for scientific and technological innovation, create a favorable environment for scientific and technological innovation, fully tap the potential of scientific and technological innovation, and empower high-quality agricultural development. On the other hand, it is important to focus on the outcomes of scientific and technological innovation and structural reforms and stimulate the mediation role of new-type productive forces.

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