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The Internal Logic and Impact Path of Empowering High-Quality Agricultural Development with Digital New Quality Productivity

——Empirical Verification Based on the Evaluation System of Digital New Quality Productivity

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ABSTRACT

Abstract: Against the backdrop of accelerating the construction of a new development pattern and continuously promoting high-quality agricultural development, the organic integration of digital new quality productivity with agricultural development, rural construction, and farmers' lives can release the inclusive effect, resource allocation effect, and income increasing effect of digital technology innovation, which can promote the optimization and upgrading of agricultural structure and is of great significance for promoting high-quality agricultural development. This article constructs a comprehensive evaluation index system for the development of digital new quality productivity based on the criteria of "laborers, labor objects, and labor materials"; Based on the panel data of the provincial innovation index report from 2011 to 2022, using "scientific and technological innovation" as the mediating variable, a fixed effects model and a reconstructed explanatory and dependent variable system GMM were used to test the robustness of the results. Furthermore, the mediating effects model was further used to explore the internal logic and impact path of digital new productivity empowering high-quality agricultural development. Research has found that in terms of impact, digital new quality productivity improves agricultural production efficiency and achieves high-quality development of agriculture. However, due to differences in economic development and innovation levels in different regions, their impact effects vary. Therefore, it is necessary to continuously leverage the role of digital new quality productivity in promoting high-quality agricultural development, use digital new quality production technology to promote comprehensive transformation of agriculture, promote the integration of agriculture with other industries, and form a new pattern of agricultural development.

KEYWORDS

Digital new quality productivity; High-quality agricultural development; Benchmark regression; System GMM; Mediating effect

1. INTRODUCTION

Digital new quality productivity, as a new form of productivity in the digital economy era. It is reshaping the global economic landscape at an unprecedented speed and breadth. It deeply integrates various cutting-edge technologies and combines them with traditional productivity factors, forming a new type of productivity with intelligent, efficient, and green characteristics. This change in productivity promotes the optimization and upgrading of industrial structure. It also promotes the comprehensive development of the economy and society. The integration of digital new quality productivity technology lies in technological innovation. The increasingly mature technologies are powerful technical support for the development of digital new quality productivity. The widespread application of big data technology provides possibilities for the collection, analysis, and processing of various data, and provides a data foundation for accurate decision-making and efficient operation of digital new quality productivity. The popularization of cloud computing technology has lowered the threshold for enterprise information construction, allowing more enterprises to feel the convenience brought by digital technology transformation. The integration of the Internet of Things and the application of blockchain technology. This further promotes a more intelligent and transparent production process, significantly improving production efficiency and product quality. In the field of agriculture, digital new quality productivity has significantly improved agricultural production efficiency and quality through precision agriculture, intelligent agricultural machinery, digital agriculture platforms, and other means. The application of remote sensing technology and big data analysis has made real-time monitoring of farmland environment a reality, facilitating managers to accurately understand crop growth; The application of intelligent agricultural machinery and IoT technology has achieved automation and intelligence of agricultural machinery operations, greatly reducing the labor intensity of farmers; Through digital agriculture platforms, the sharing and transparency of agricultural information can be achieved, promoting the collaborative development of the agricultural industry chain. These applications are used to improve agricultural production efficiency and sustainability. It also provides new impetus for increasing farmers' income and developing rural economy. Although digital new quality productivity is developing rapidly, it also faces significant challenges in the process of development. The important factor restricting the development of digital new quality productivity is still the technological bottleneck. The independent research and development capabilities of core technologies such as high-end chips, sensors, and intelligent algorithms still need to be improved, and some key technologies are still monopolized by foreign companies. At the same time, the development of digital new quality productivity also faces problems such as talent shortage, data security, and lack of standard specifications. In 2024, at the 11th collective learning conference of the 20th Central Political Bureau, General Secretary Xi Jinping proposed that developing new quality productive forces is an inherent requirement and important focus for promoting high-quality development. Around the goal of building a strong agricultural country, we will increase the application of scientific and technological innovation achievements, such as seed industry and agricultural machinery. With the support of policies, digital new quality productivity will maintain a rapid development trend, continuously improve, play a role in more fields, and promote high-quality economic development.

In recent years, the high-quality development of agriculture in China has shown a steady and significant overall trend, with important progress made in multiple dimensions such as policy support, technological innovation, industrial integration, and green development, laying a solid foundation for rural revitalization and development. At the level of policy support and strategic planning, the country continues to strengthen top-level design and has issued a series of important documents such as the "Plan for Accelerating the Construction of an Agricultural Power (2024-2035)". The goal and path of building a strong agricultural country are clear and concise. With the continuous progress of agricultural mechanization, the number of agricultural machinery in China has exceeded 200 million, and the planting and harvesting of crops have been fully mechanized, accounting for as much as 74%. Meanwhile, over 100000 agricultural machinery and equipment are also equipped with the autonomous driving function of the Beidou Navigation System, greatly improving the accuracy and quality of agricultural operations. In addition, the development of intelligent agriculture is also accelerating, and information technology is deeply integrated into various stages of agricultural production. All of these are driving agricultural production towards greater precision and intelligence. The trend of integrated development of agricultural industry is good. The typical high-quality development of rural industries continues to emerge, covering various formats such as characteristic planting, agricultural product processing, rural e-commerce, and rural tourism. The transformation and upgrading of the agricultural product processing industry has continuously increased the ratio to the total agricultural output value, and the conversion rate of agricultural product processing has steadily improved. Various regions are actively cultivating leading enterprises in agricultural industrialization. Promote the advancement of agricultural product processing. Extending the industrial chain and enhancing the value chain have opened up new channels for increasing farmers' income. Positive progress has been made in the green development of agriculture. The prevention and control of agricultural non-point source pollution has achieved significant results, and the use of fertilizers and pesticides has been in a negative growth state for many years. Soil testing formula fertilization, green prevention and control technologies have been widely applied. The comprehensive utilization rate of livestock and poultry manure, straw, and agricultural film recycling continues to improve. The agricultural ecological environment continues to improve. The supply of high-quality green agricultural products has increased, with a total of 81000 certifications and registrations for green, organic, and geographical indication agricultural products. The routine qualification rate of major agricultural products monitoring has reached 98% for the first time. It effectively meets the demand of consumers for high-quality agricultural products. However, the high-quality development of Chinese agriculture still faces some challenges. The constraints of agricultural resources and environment are becoming tighter, the quality of arable land needs to be improved, and the problem of water scarcity is becoming more prominent; Compared with developed countries, there is still a gap in agricultural technology innovation capability and level. The bottleneck problem of key core technologies urgently needs to be solved; There are weak links in the agricultural industry chain and supply chain, insufficient deep processing of agricultural products, and lagging brand building; There are still many shortcomings in rural infrastructure and public services, and the problems of imbalanced urban-rural development and insufficient momentum for rural development are still prominent. In the future, China will continue to focus on the theme of high-quality development. Adhering to the fundamental principle of strengthening the national food security defense line, using technological innovation as a strong engine, and deepening reform as a key breakthrough, we will make every effort to accelerate the process of agricultural modernization. Continuously strengthening the construction of agricultural infrastructure, achieving multidimensional improvement in cultivated land quality, and optimizing agricultural production conditions in all aspects. Establish a solid foundation for high-quality agricultural development. Strengthen agricultural technological innovation, break through key core technological bottlenecks, and promote the self-reliance and self-improvement of agricultural technology; Actively promote the integrated development of agricultural industries, comprehensively cultivate and strengthen rural industries, and deeply promote the integrated development of the primary, secondary, and tertiary industries in rural areas; Vigorously promote the green development of agriculture, strengthen the prevention and control of agricultural non-point source pollution, and significantly improve the efficiency of agricultural resource utilization; Continuously advancing the process of rural reform, implementing the strategy of rural revitalization to strengthen guarantees, and consolidating and optimizing the basic rural management system. Actively cultivating and strengthening new types of agriculture, and comprehensively improving the socialized agricultural service system; Focusing on promoting farmers' income growth and prosperity, expanding their income channels through multiple channels, improving the quality of rural public services, enhancing the living environment in rural areas, and providing farmers with more sense of gain, happiness, and security.

2. LITERATURE REVIEW AND RESEARCH HYPOTHESES

2.1. Research on Digital New Quality Productivity

As the core economic paradigm of the digital economy era, "digital new quality productivity" is essentially a productivity leap formed by the recombination of digital technology and traditional production factors. According to Brynjolfsson&McAfee's (2014) theory of technology capital complementarity, digital technologies such as artificial intelligence, blockchain, and cloud computing reconstruct the production function through the "penetration effect" to form a new output model (D represents data elements). This process is in line with Schumpeter's "creative destruction" path of achieving structural improvement in total factor productivity (TFP) through marginal cost zeroing.

For its element reconstruction mechanism, the non competitive data model proves that the non exclusivity and cumulative value-added characteristics of data elements break through the marginal diminishing law of traditional production factors. Domestic scholar Cai Yuezhou (2021) verified through the CES production function that the contribution rate of data elements to GDP growth shows an elasticity coefficient of α=0.12. Refactoring the relationship between workers, labor materials, and labor objects to form a more efficient, intelligent, and green form of productivity. Accelerating the penetration of data elements into various links such as production, consumption, distribution, and circulation, continuously expanding the boundaries of social production possibilities, and breaking through the growth constraints of traditional factor inputs. The Internet Industry Research Institute of Tsinghua University (2025) pointed out that the marginal contribution rate of data elements has exceeded that of traditional capital and labor, becoming the main driving force for growth. On this basis, Acemoglu&Strestrepo's (2019) automation recovery model reveals that the premium of digital skills drives the migration of labor factors to high value-added sectors. The average annual growth rate of human capital return for digital economy practitioners in China from 2015 to 2022 is 7.8% (China Academy of Information and Communications Technology, 2023), which supports Varian's (2019) hypothesis of "expanding the boundaries of human-machine collaborative production". Continuing North's (1990) theory of institutional change has been extended in digital scenarios, where blockchain technology reduces transaction costs through smart contracts, forming the "hybrid governance structure" defined by Williamson (2000). The adaptive regulatory practices represented by the EU's Digital Markets Act have validated Stiglitz's (2019) theory of "non neutrality in digital markets", focusing on the issues of unfair competition and resource misallocation in digital markets. This provides a theoretical basis for governments to formulate relevant policies, such as strengthening anti-monopoly supervision and protecting data privacy. It not only promotes the healthy and fair development of digital markets, but also builds a composite governance system that includes DEPA framework, algorithm auditing, digital taxation, etc.

2.2. Research in Empowering High Quality Agricultural Development with Digital New Quality Productivity

Some scholars have explored the effectiveness of digital technology and new quality productivity in promoting high-quality agricultural development. Through digital technology, agricultural regions can connect with cities and the world, access more information resources, and promote the development of agriculture [6-11]. Digital new quality productivity is driven by digital technology, upgrading the three elements of traditional agricultural productivity into "digital agricultural laborers, digital agricultural labor materials, and digital agricultural labor objects", and promoting agricultural production from experience dependence to data-driven. Therefore, the inherent logic of empowering high-quality agricultural development with digital new quality productivity is to promote the evolution of agriculture towards "high quality, high efficiency, green, and sharing" through three mechanisms: restructuring production factors, optimizing resource allocation, and reducing transaction costs. The application of big data, digital platforms, and IoT technology in agriculture can improve agricultural output, achieve precise monitoring and control of agriculture, and drive the transformation of traditional agriculture to smart agriculture (Zhang Jiao, 2024). There are four major efficiency enhancing mechanisms for digital technology to empower high-quality agricultural development: economies of scale, economies of scope, economies of aggregation, and economies of division of labor (Luo Qianfeng, 2022). The construction of "digital agriculture" based on digital technology has provided new impetus for the high-quality development of agriculture (Xia Xianli, 2019). Some scholars have explored the path and effectiveness of digital agriculture development. Exploring the path of digital agriculture development in China from the perspectives of digital agricultural technology characteristics, model innovation, international experience, and inspiration

(Wang Xuhui, 2024). High quality digital agriculture should be an agricultural development model that integrates digitalization, precision, transparency, and intelligence in agricultural production (Ruan Junhu, 2020). Some scholars have sorted out the mechanism by which digital technology promotes high-quality agricultural development.

2.3. Research Hypothesis Analysis

Digital new quality productivity can improve agricultural productivity and resource utilization through technological penetration and factor upgrading. The core of new quality productivity lies in technological innovation, which is the core driving force for promoting high-quality agricultural development. Its core concept is to enhance human productivity, which requires strengthening economic cooperation between different regions, achieving optimal allocation of resources, scientific layout of industries, and promoting the formation of a social pattern of complementary advantages and win-win cooperation. One of the core elements of new quality productivity is green productivity, which provides clear guidance for firmly pursuing the path of green development.

According to the Romer endogenous growth model, it can be inferred that digital technology, as a non competitive factor of production, can generate positive technological externalities through the "learning by doing" mechanism, while reconstructing the production possibility boundary through factor enhanced technological progress. By infiltrating technology and upgrading factors, digital new quality productivity can reduce input-output loss rates and related transaction costs, narrow the gap between actual and cutting-edge technology, and optimize the Walrasian equilibrium state of the factor market. This will achieve dynamic optimization of configuration and comprehensively improve agricultural quality, empowering high-quality agricultural development with digital new quality productivity.

(1) Digital new quality productivity significantly improves agricultural production efficiency and resource utilization through technological innovation and factor upgrading.The new generation of information technology, biotechnology, and new material technology can promote the refinement of agricultural production, optimize the layout of agricultural industries, drive the deep integration of primary, secondary, and tertiary industries, and improve the high-quality development level of agriculture and rural areas. At the same time, the development of new quality productive forces can reduce the cost of information dissemination and sharing in agricultural production, improve the level of large-scale agricultural operation, promote the widespread circulation of agricultural products, to some extent break down the spatial and temporal boundaries between urban and rural areas, promote coordinated development between urban and rural areas, and thus consolidate the foundation for high-quality development of agriculture and rural areas. On this basis, e-commerce live streaming, smart logistics and other models are used to shorten the production and sales chain, increase farmers' income, and promote the generation of network effects through platform economy, thus forming a multilateral market structure under the general equilibrium framework. New quality productivity is a technological revolutionary breakthrough, innovative allocation of production factors, and deep transformation and upgrading of industries, which is an inevitable trend in the development of advanced productivity. The development of this productivity, especially in agriculture, plays a crucial role in expanding markets. In summary, empowering high-quality agricultural development with new quality productivity will have a mediating effect.

(2) Policy support (such as investment in digital infrastructure) positively regulates the empowering effect of digital new quality productivity. Policy support has a positive moderating effect on the empowering effect of digital new quality productivity. The central government has actively responded to and taken measures, emphasizing that the comprehensive coverage of 5G and the Internet of Things in rural areas provides a solid foundation for their technological implementation. Digital infrastructure has non exclusivity and positive externalities, and government investment corrects market failures, breaking through the "critical minimum effort" in Rostov's takeoff theory.

3. EMPIRICAL ANALYSIS

3.1. Model Setting

Given the theoretical analysis mentioned above, with the goal of exploring how digital new quality productivity empowers high-quality agricultural development,

This article constructs a benchmark regression model as follows:

$$AGRI_{n,t} = \alpha_0 + \alpha_1 NQP_{n,t} + \alpha_c Z_{n,t} + \delta_n + \varphi_t + \varepsilon_{n,t} \tag{1}$$

In model (1), AGRIn,t is the dependent variable, which is the level of high-quality agricultural development in n provinces in year t; NQPn,t is the explanatory variable, which is the digital new quality productivity of year t in province n; Zn,t represent a series of control variables that may affect the high-quality development of agriculture; δn and φt represent province and time fixed effects, respectively; εn, t is the random error term; The subscripts n and t represent the province and year, respectively.

Secondly, the article introduces technological innovation as a mediating variable to further examine the relationship between digital new quality productivity and high-quality agricultural development, and constructs the following mediating effect model:

$$techinnov_{n,t} = \beta_0 + \beta_1 NQP_{n,t} + \beta_c Z_{n,t} + \delta_n + \varphi_t + \varepsilon_{n,t} \tag{2}$$

$$AGRI_{n,t} = \theta_0 + \theta_1 NQP_{n,t} + \theta_2 techinnov_{n,t} + \theta_c Z_{n,t} + \delta_n + \varphi_t + \varepsilon_{n,t} \tag{3}$$

Among them, technovn,t represents technological innovation, and model (2) mainly examines the impact of digital new quality productivity on technological innovation. Model (3) mainly examines the impact of digital new quality productivity and technological innovation on high-quality agricultural development. Combined with model (1), it can be used to test the mediating effect of technological innovation. If the coefficient β1 of NQPn,t for digital new quality productivity in model (2) is significant, and the coefficient θ2 for technological innovation in model (3) is significant, then there exists a mediating effect.

3.2. Variable Selection

(1) Explained variable. This study selected the level of high-quality agricultural development (Hqda) as the dependent variable. Specifically drawing on the research results of scholars such as Xinling (2019), Gao Xue (2023), Liu Yicheng (2023), Gao D. (2023), and Li Ruxiao (2023), we have comprehensively selected scientifically reasonable, targeted, and easily obtainable indicators for high-quality agricultural development [12]. The criterion layer in the evaluation index system reflects three aspects: economic vitality, agricultural resources, and harmonious sharing. We have established a measurement index system for the level of high-quality agricultural development and used the entropy method to measure it.

(2) Explanatory variable: Digital Quality Productivity (NQP). The current academic community generally believes that digital new quality productivity is a new type of productivity that relies on technological innovation to achieve the transition and upgrading of traditional productivity. Based on this and the research of relevant scholars, the article constructs an evaluation index system for digital new quality productivity, and uses entropy weight method to calculate the status of digital new quality productivity, as shown in the table.

Table 1. Comprehensive Evaluation Index System for High Quality Agricultural Development

Target layer	The criteria level	Indicator layer	unit	attribute	weight
High-quality development Of agriculture	Economic vigor, economic vitality, economic vitality	The ratio of added value of agriculture, forestry, animal husbandry and fishery to GDP	%	Positive indicators	0.0576
		per capita output of grain	yuan	Positive indicators	0.1310
		Per capita disposable income of rural residents	yuan	Positive indicators	0.0784
	agricultural resource	Rural television programmes	%	Positive indicators	0.0134
		Rural broadband access users	Ten thousand households	Positive indicators	0.2144
		Investment in scientific research activities in rural areas	yuan	Positive indicators	0.2102
	Harmonious and shared development	Area of soil erosion control	hectare	Positive indicators	0.1294
		Number of rural doctors and health workers per 1,000 agricultural population	people	Positive indicators	0.1656

This article uses the entropy method to calculate the weight of indicators for high-quality agricultural development in China. The entropy method is an objective evaluation method that can determine weights based on the amount of information and dispersion provided between various indicators. The calculation steps of this method are:

(1) Standardization: $X_{ij}=\frac{\max(x_{ij})-x_{ij}}{(\max(x_i)-\min(x_i))}$ (positive indicators),

$X_{ij}=\frac{x_{ij}-\min(x_{ij})}{(\max(x_i)-\min(x_i))}$(negative indicators);

(2) $P_{ij}=\frac{ij}{\sum_{i=1}^{n} x_{ij}}$ (3) Information entropy value: $e_i=-(\frac{1}{\ln n})\sum_{j=1}^{n} p_{ij}\ln(p_{ij})$ (4) Weight: $W_j=\frac{d_j}{\sum_{j=1}^{n} d_j}$ (5)

Composite index: $S_i=\sum_{j=1}^{n} w_j \cdot x_{ij}$

Table 2. Evaluation Index System for Digital New Quality Productivity

Target layer	The criteria level	Indicator layer	unit	attribute	weight
New quality of digital productivity	Digital workers	Employment in other units of information transmission, computer services and software industries	people	Positive indicators	0.1219
		Internetbroadband access users	household	Positive indicators	0.0715
	Digital labor materials	Optical cable line length	kilometre	Positive indicators	0.0705
		highway mileage	kilometre	Positive indicators	0.0378
		length of railroad lines in service, railroad lines opened to traffic	kilometre	Positive indicators	0.0 425
		Number of invention patent applications granted	piece	Positive indicators	0.1681
		Technology market transactions	Ten thousand yuan	Positive indicators	0.2177
	Digital objects of labor	Software revenue	yuan	Positive indicators	0.2016
		Internet broadband access port	Ten thousand	Positive indicators	0.0684

(3) Mediating variable: technological innovation. Based on data availability, three primary indicators of technological innovation environment, technological activity input, and technological activity output are selected to measure technological innovation, and the index method is used to measure the level of technological innovation. Among them, the proportion of financial funds used for scientific research activities in the environment of technological innovation is represented; The investment in scientific and technological activities is measured by the funding and personnel investment in scientific research activities; Measurement of the proportion of sales revenue from the use of new products in technology activities to the total sales revenue of products.

(4) Control variables. To avoid the impact of omitted variables on the regression results, the following control variables were selected based on existing literature: agricultural fiscal expenditure (fiscal), which reflects the government's support for agriculture and is represented by national fiscal expenditure on agriculture, forestry, and water affairs; The level of agricultural mechanization reflects the level of agricultural mechanization and directly affects production efficiency. Represented by the total power of agricultural machinery; Effective irrigation area (irrigation) measures the level of agricultural infrastructure, affects disaster resistance and output stability, and is measured using the agricultural effective irrigation rate. The above variables reflect the impact on the high-quality development of agriculture.

Table 3. Descriptive statistical results of variables

Variable	observed value	sd	min	maximum	mean
AGRI	360	0.089	0.085	0.621	0.312
NQP	360	0.123	0.008	0.678	0.190
technov	360	0.0439	0.000	0.272	0.117
Fiscal	360	2912.986	120.220	13353.020	3460.606
machinery	360	1694.004	109.240	6666.390	2215.095
irrigation	360	2.86e+10	9.18e+09	1.36e+11	5.73e+10

3.3. Data Sources and Sample Selection

It is crucial to choose appropriate data sources when studying the empowerment of digital new quality productivity for high-quality agricultural development. In recent years, due to the impact of the epidemic and other factors, some indicators have changed abnormally. In order to ensure the reliability of the research results, this study selected the panel data of the provincial innovation index report from 2011 to 2022 as the analysis sample. The raw data mainly comes from the National Bureau of Statistics, statistical yearbooks of various provinces (regions), China Statistical Yearbook, China Environmental Statistical Yearbook, and China Rural Statistical Yearbook

4. EMPIRICAL TESTING

4.1. Benchmark Regression

4.1.1. Analysis of benchmark regression results

Table 4 shows the benchmark regression results of the impact of digital new quality productivity on the high-quality development of agriculture and rural areas. It can be observed that column (1) only shows the regression results of digital new quality productivity on the high-quality development of agriculture and rural areas, while columns (2) to (4) show the regression results with control variables added sequentially. The results show that regardless of whether control variables are included, digital new quality productivity significantly promotes high-quality agricultural development at the 1% level, preliminarily verifying hypothesis H1. This is because digital new quality productivity takes digital economy and technological innovation as important engines, can deeply tap into the advantageous industrial resources of rural areas, create emerging industries in the agricultural field, encourage and guide leading agricultural industrialization enterprises and new agricultural management entities such as farmer professional cooperatives to closely cooperate and demonstrate, in order to improve agricultural production level and agricultural product quality, and promote high-quality development of agriculture and rural areas.

Table 4. Benchmark Regression Results

	(1)	(2)	(3)	(4)
	AGRI	AGRI	AGRI	AGRI
NQP	0.0596	.0433***	0.0473***	.0448***
	(2.51)	(1.78)	(2.13)	(2.05)
fiscal		3.12e-06***	2.15e-06***	1.52e-06***
		(2.70)	(2.02)	(1.42)
machinery			1.32e-06***	1.16e-06**
			(7.93)	(6.74)
irrigation				0.0000113***
				(3,14)
_cons	0.357***	0.347***	0.304***	0.274***
	(45.28)	(40.10)	(31.82)	(20.28)
N	360	360	360	360

4.1.2. Robustness test results

To verify the robustness of the benchmark regression results, namely the promotion effect of digital new quality productivity on high-quality agricultural development, the article adopts the following method for robustness testing. On the one hand, Beijing, Tianjin, Shanghai, and Chongqing, the four municipalities directly under the central government, are the cities with the highest urban level, the best economic foundation, and the most benefits from national policies in China. Including them in the model may lead to biased regression results. Therefore, this article excluded the four municipalities directly under the central government and conducted regression analysis again. The results are shown in column (3) of Table 5. The results of column (3) indicate that digital new quality productivity can still significantly promote high-quality agricultural development at the 1% level, once again proving the robustness of the benchmark regression results.

On the other hand, in order to minimize the interference of outliers on the research conclusions, this paper re estimated the sample data of each variable after bilateral 1% truncation processing. The results are shown in column (1) of Table 5. The estimation results show that after bilateral tail reduction treatment, the regression coefficient of digital new quality productivity is 0.042 and passes the significance test at the 1% level, indicating the robustness of the benchmark regression results.

A key factor in conducting robustness analysis of fixed effects models is that static panel data models may not fully capture the dynamic changes in data and potential lag relationships between variables. To address the above challenges, a two-step GMM method with individual effects was introduced to enhance the model's ability to capture data dynamics and the accuracy of parameter estimation.

Secondly, the two-step GMM method used utilizes the estimated residuals from the first step to construct a more effective weight matrix, which helps to address potential endogeneity issues. When there is a time lag relationship between variables, using this lag relationship can serve as an instrumental variable to help solve endogeneity problems.

Secondly, considering the existence of individual effects can effectively control the unobservable heterogeneity of each cross-sectional unit. The model constructed in this article includes fixed individual effects to more accurately manage unobserved individual specific factors that may remain constant over time but have an impact on the explained variable. Through this setting, the model can accurately capture individual differences and their impact on the dependent variable.

In this study, we used the Generalized Method of Moments (GMM) model to analyze the data and explore the relationship between high-quality agricultural development and digital productivity. The generalized moment estimation method was used to analyze the relationship between the independent and dependent variables.

Table 5. Results of robustness test

variable	(1)Tail retraction treatment	(2) Replace it with GMM estimation method	(3) Exclude the sample data of municipalities directly under the Central Government
NQP	0.042***(1.95)	0.067***(0.53)	0.046***(2.05)
AGRI		0.874***(4.43)	
control variable	true	true	true
Provincial fixed effects	true	true	true
Time fixed effects	true	true	true
R^2	0.977	0.974	0.973
sample number	360	360	360

5. HETEROGENEITY ANALYSIS

The infrastructure in regions with faster economic development is more complete, and the digital economy has stronger competitiveness. It can stimulate new industries and formats in the field through disruptive innovation and cutting-edge technology, and promote the modernization of agriculture and rural areas. Therefore, the impact of digital new quality productivity on the modernization development of agriculture and rural areas may have heterogeneity based on the level of economic development. In view of this, based on the four major economic regions, this article divides the research sample into the eastern, central, western, and northeastern regions. The regression analysis results are shown in columns (1), (2), (3), and (4) of Table 6. It can be seen that:

(1) Eastern technology dominant type. The highly coordinated development of agricultural mechanization and irrigation area in the eastern region, with agricultural technology playing a core role, and technological innovation being the core factor driving agricultural development, indicates that new quality productivity significantly improves the high-quality development of agriculture through technological innovation, and also confirms that agricultural technological innovation is the most effective lever to enhance output. However, due to the fact that the eastern region has reached a relatively high level, the marginal benefits are decreasing; Technology has replaced some of the scale investment, resulting in inefficient material investment.

(2) Dual drive of irrigation and technology in the central region. The excessive development of non-agricultural industries has squeezed agricultural resources. The total power of agricultural machinery is highly correlated with the effective irrigation area. Similar to the results in the eastern region, agricultural technology innovation is the biggest driving force, and expanding the effective irrigation area can significantly promote high-quality agricultural development. Therefore, we need to adopt a "technology investment+water conservancy construction" approach for optimization. The development of non-agricultural industries has a crowding out effect on agriculture. At this time, there are issues with the efficiency of fund allocation, such as large expenditure but low utilization efficiency (such as misappropriation, high management costs, and inaccurate investment); Agricultural investment has slow returns, and there is no time lag effect in the current expenditure effect; The paradox of fiscal expenditure arises due to issues such as higher efficiency in other inputs (such as technology and machinery), masking the independent contribution of fiscal expenditure and generating substitution effects to some extent. The reasons for this are also related to the mediating effect discussed earlier. To address this issue, we need to coordinate the pace of non-agricultural industries, prevent excessive transfer of resources, and on this basis, accurately allocate fiscal

expenditures. Prioritize increasing investment in agricultural technology. On this basis, we will strengthen the construction of agricultural water conservancy, maintain the growth of irrigation area, coordinate the development of non-agricultural industries, avoid excessive resource crowding out of agriculture, optimize the structure of fiscal support for agriculture, and focus on the efficiency of fund utilization rather than simply increasing the quota.

(3) Western technology is dominated by inclusiveness. The western region explains 85.34% of the variation and F=146.69, which is overall significant. All coefficients are significantly positively correlated. Technological innovation is the core driving force in the western region, and it is also significantly positively correlated with digital new quality productivity, reflecting the complementary potential of industry and agriculture. In terms of material capital contribution, there should be a strong correlation with mechanical investment, and attention should be paid to the possibility of duplicate investment or crowding out effects. Therefore, it is necessary to avoid overlapping investment between machinery and irrigation facilities. At the same time, similar to the central region, the infrastructure (irrigation) of both may be nearing saturation or have bottlenecks; Mechanical input may not be efficient due to terrain and land size limitations. Priority should be given to technology investment in the western region, as agricultural technology innovation has the highest return on investment. Therefore, strengthening the promotion of agricultural science and technology is the optimal way. On this basis, we will improve the level of agricultural mechanization, optimize fiscal expenditure and structure, and avoid overlapping investment with machinery investment. At the same time, pay attention to the coordinated development of industries and promote the integration of industry and agriculture.

(4) Large scale mechanical applications in the northeast. The weak contribution of fiscal expenditure in the Northeast region indicates the possibility of inefficient allocation of funds. Digital new quality productivity and technological innovation have a significant positive impact on the high-quality development of agriculture and are core variables for improving agricultural performance. The effect of technological innovation is greater. Combining the geographical environment of Northeast China, agricultural technology research and development can be upgraded, cold resistant varieties can be cultivated, and smart agriculture can be promoted. This places higher demands on quality, and large-scale investment in machinery may face the need for upgrading (old machinery with low efficiency) or a mismatch with agricultural technology, requiring more than just quantity expansion for mechanical updates and iterations. Reform the performance of fiscal expenditure and introduce third-party evaluation to comprehensively optimize resource allocation.

Table 6. Heterogeneity test results

Variable	Ease (1)	Central section (2)	West (3)	Northeast (4)
AGRI	0.138 (22.37)	0.163(25.19)	0.77(8.54)	0.144(2.56)
NQP	0.134(5.33)	0.203(10.09)	0.311(9.38)	0.228(1.65)
techinnovi	0.521(5.29)	1.178(0.137)	0.862(7.24)	0.55(1.1)
machinery	0.000014(8.57)	1.51(0.84)	0.0000393(9.1)	0.0000671(8.31)
irrigation	4.15(0.1)	0.000022(5.32)	7.5(2.61)	0.0000124(1.83)
fiscal	0.000012(0.76)	1.83(0.84)	4.3(1.91)	7.44(1.59)
Crowding Out Effect	deny	true	true	true
mesomeric effect	deny	true	deny	deny
R^2	0.95	0.93	0.85	0.96
sample number	120	72	132	36

In summary, agricultural technology is a universal engine, with the elasticity coefficient ranking in the central region (1.28)>western region (0.73)>eastern region (0.52)>northeast region (0.47); As a major grain producing area, the central region may have the highest elasticity due to factors such as great potential for technological application, high marginal benefits, relatively good foundation, and strong technological absorption capacity. The lower level in Northeast China may be due to the relatively saturated technology caused by its large-scale production or the greater difficulty of agricultural technology research and development in cold regions. The material input is generally inefficient and needs to shift towards the strategy of "quality replacing quantity"; The fiscal expenditure was not significant in all four districts, indicating a systemic problem in fund allocation. Adapting agricultural policies to local conditions: focusing on technology transformation and financial efficiency in the eastern region; Balancing non-agricultural industries and water conservancy investment in the central region; Technology popularization and industrial integration in the western region; Mechanical updates and technological iterations in the northeast.

6. CONCLUSION AND IMPLICATIONS

This study analyzes the mechanism and impact path of digital new quality productivity empowering high-quality agricultural development, in order to explore in depth how digital new quality productivity can better integrate with agricultural development, rural construction, and farmers' lives, and how to better promote high-quality agricultural development. Firstly, a comprehensive evaluation index system for the development of digital new quality productivity is constructed. Based on this, through the analysis of multiple models, it is concluded that:

Based on previous theoretical analysis, this article draws the following insights:

In the process of high-quality agricultural development, the addition of digital new productivity has injected new vitality into agricultural development. For workers, the application of digital technology can efficiently complete production tasks and improve work efficiency; In terms of labor materials, the development of new quality productivity can improve agricultural production efficiency, achieve precision in production, and realize intelligent management. By optimizing the agricultural production structure, promoting the deep integration of traditional agriculture with the secondary and tertiary industries, improving the efficiency of agricultural product production, expanding the diversity of sales channels, and helping traditional agriculture move towards modernization, high-quality development of agriculture can be achieved.

Digital new quality productivity also promotes agricultural development and high-quality economic and social development by continuously strengthening technological innovation and advancing technological progress. Strengthening investment in basic research, by enhancing cutting-edge fundamental research such as artificial intelligence, quantum information, and blockchain, encouraging cooperation among diverse innovation entities, can provide theoretical support for breakthroughs in digital technology, and can leverage the advantages of the new national system to gather innovative achievements in key fields such as integrated circuits, high-end chips, and industrial software, concentrate on tackling "bottleneck" technologies, improve independent innovation capabilities, and promote innovation transformation. The development of digital technology has reduced the marginal cost of innovation cooperation, broken through industry boundaries and time and space limitations, promoted collaborative innovation, and propelled the upgrading of the scientific and technological innovation system. Utilizing digital new quality production technology to promote comprehensive transformation of agriculture, improving integrated agricultural data platforms, promoting the integration of agriculture with other industries, and forming a new development pattern for agriculture.

Digital new quality productivity can effectively enhance technological innovation, promote the transformation and upgrading of traditional industries, promote the development of emerging industries, improve factor productivity, and safeguard high-quality economic and social development.

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