frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 10 September 2025
DOI 10.3389/fsufs.2025.1609899

Check for updates

OPEN ACCESS

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RECEIVED 11 April 2025
ACCEPTED 26 August 2025
PUBLISHED 10 September 2025

CITATION
Peng Y, Tan C, Huang D and Li P (2025) Agricultural new-quality productive forces empowering rural common prosperity: examining the mediating mechanism of village digitalization.
Front. Sustain. Food Syst. 9:1609899.
doi: 10.3389/fsufs.2025.1609899

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Agricultural new-quality productive forces empowering rural common prosperity: examining the mediating mechanism of village digitalization

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As a crucial engine driving the modernization of agriculture and rural areas, new-quality productive forces in agriculture reshape rural development patterns through technical innovation and organizational transformation, playing a key role in achieving common rural prosperity. Based on panel data from 30 provinces in China from 2012 to 2022, this study systematically examined the direct impact effects and mechanisms of new agricultural productive forces on rural common prosperity, with a focus on revealing the mediating transmission mechanism of rural digitalization. Heterogeneity tests were conducted from the perspective of regional differences and functional zoning. The findings indicate that new agricultural productive forces have significant positive promotional effects on common rural prosperity and that rural digitalization plays a partial mediating role between them, accounting for 25.6% of the mediating contribution. Heterogeneity analysis shows that the driving effect of agricultural new-quality productive forces presents a gradient decrease characteristic of "western > central > eastern" and is significant in grain-producing areas (effect value 0.446), while it is not significant in non-grain-producing areas. These conclusions provide theoretical support for optimizing the layout of agricultural new-quality productive forces and implementing differentiated digital village strategies, offering important policy implications for comprehensively promoting rural revitalization and common prosperity, both of which contribute to the sustainable development of society.

KEYWORDS

rural common prosperity, agricultural new-quality productive forces, village digitalization, heterogeneity, sustainable development

1 Introduction

Agricultural and rural modernization are core issues in sustainable global development. How technological innovation and digital transformation reshape rural development patterns and resolve the paradox of unknown "growth versus equity" has become a critical proposition in both academic and practical fields. At the policy level, China's proposal of "agricultural new-quality productive forces" has provided practical guidance for agricultural and rural transformation. However, academic research has not yet fully uncovered the in-depth connection between agricultural new-quality productive forces and rural common prosperity.

This connection not only involves efficiency improvements driven by technology but also concerns the inclusive distribution of development outcomes, which is highly aligned with the core appeal of "inclusive growth" in the United Nations' Sustainable Food Systems goals.

Extant research exhibits three theoretical gaps: First, while the theoretical connotation of new-quality agricultural productivity has been defined as "advanced productivity driven by both technological innovation and institutional reform" (Xingqing, 2024), its impact mechanism on rural common prosperity remains confined to a linear logic of "efficiency enhancement-economic growth." This overlooks the dimensions of "dual prosperity in both material and spiritual spheres" (Lianfu and Yali, 2022) and "urban–rural coordination" (Peilin et al., 2021) required by common prosperity. Second, although rural digitalization serves as a crucial vehicle for new-quality agricultural productivity, existing studies predominantly focus on its effect on agricultural production efficiency (Zheng et al., 2024), with scant exploration of its mediating role in transforming "technological dividends into shared outcomes." Particularly lacking is an analysis of the "equity of digital empowerment" in rural contexts (Aker and Ksoll, 2016). Third, regarding regional heterogeneity, extant research emphasizes the "late-mover advantage" in agricultural technology diffusion but fails to clarify why the impact of new-quality agricultural productivity diverges across functional zones (e.g., major grain-producing vs. non-major producing regions). This disconnects from the principle of "region-specific adaptations" in relevant studies.

Against this backdrop, the core research questions of this study are as follows:

1. How does new-quality agricultural productivity influence common rural prosperity through rural digitalization?
2. How does the mechanism exhibit heterogeneity across regional contexts?

The theoretical contributions are threefold:

1. Moving beyond the singular growth-oriented framework, this study constructs an integrated analytical model of "technological innovation → digital mediation → inclusive development," thereby bridging the theoretical gap between new-quality agricultural productivity and common prosperity.
2. Unveiling the dual role of rural digitalization in both efficiency enhancement and equitable distribution offers a novel perspective on "inclusive transformation" in rural development in the digital era.
3. Incorporating regional heterogeneity into agricultural functional zoning analysis provides micro-level evidence for the "region-specific adaptation" of sustainable food systems.

2 Literature review

2.1 The theoretical concept of new-quality productive forces

The concept of new-quality productive forces in agriculture has garnered significant attention in academic circles, given its potential to drive common prosperity among farmers. Recent studies have focused on delineating the theoretical underpinnings, operational pathways, and effects of new agricultural productive forces. Scholars have approached this concept from diverse perspectives.

First, Xingqing (2024) posits that new agricultural productive forces are characterized by two drivers: technological advancement and policy reform. This construct integrates features such as high technology, high efficiency, high quality, and sustainability aligned with the principles of new development. It represents an advanced state of agricultural productive forces that is innovation-driven and aligned with contemporary development paradigms. Second, Yuan and Jiujie (2024) offer a dual-dimensional perspective, emphasizing both material innovation and the reconfiguration of novel social relationships within rural communities. This approach highlights the creation of new value through innovative processes, underscoring the dual nature of agricultural transformation. Third, Xiaohe and Xiangxue (2024) delineate agricultural new-quality productive forces as a transformative phenomenon driven by breakthrough innovations and technological breakthroughs. This perspective underscores the pivotal role of major technological innovations in fostering agricultural transformation, supported by advanced production factors and optimized resource utilization. The emergence of new-quality productive forces was marked by operational changes in the agricultural production modes.

Regarding the measurement of agricultural new-quality productive forces, Di and Linxiang (2024) propose that it constitutes a leap in innovation-driven agricultural productivity, characterized by labor, capital, and technology. They suggest establishing an evaluation framework based on these triadic elements to assess the construct. In terms of impact, Biliang and Pengpeng (2024) argue that the development of agricultural new-quality productive forces accelerates deep agricultural transformation, elevating the total factor productivity of agriculture and advancing quality-driven agricultural development. Ying (2024) posits that fostering agricultural new-quality productive forces not only supports the articulation of the agricultural modernization discourse but also facilitates the achievement of Chinese-style modernization. Shiping and Chen (2024) emphasize that the advancement of agricultural new-quality productive forces contributes to the realization of agricultural power strategies, providing a potent engine for agricultural modernization.

In summary, the existing literature highlights the transformative potential of agricultural new-quality productive forces in driving deep agricultural transformation, enhancing productivity, and promoting common prosperity. Future research should explore the mechanisms through which these forces operate and their long-term impacts on agricultural sustainability and rural development.

2.2 Research on common prosperity

To analyze the concept of farmers' and rural common prosperity, this study identifies three key dimensions: (1) encouraging people's active participation in social production, with the saying "common prosperity" emphasizing the importance of collective efforts to achieve wealth (Lianfu and Yali, 2022); (2) ensuring comprehensive prosperity, as stated by Xi Jinping in 2014, where both material and spiritual civilization must be developed to improve the quality of life for all Chinese people; and (3) achieving common prosperity through high-quality economic development, which requires not only increasing the size of the "cake" but also fairly distributing it (Lianfu and Yali, 2022).

While economic growth is the primary driver of common prosperity, the development of cultural products is also essential (Peilin et al., 2021). In terms of distribution, addressing issues, such as the relatively low proportion of middle-income groups and unreasonable income stratification within regions, is crucial (De Melo et al., 2016). To achieve this, policies should regulate the income of high-income groups and limit regional population movement to a certain extent. Scholars have proposed various indicators to measure the evolving understanding and pathways of common prosperity. For example, some studies focus on overall wealth levels and the sharing of development outcomes (Peilin et al., 2021). In contrast, others emphasize participatory rights, distributive rights, and entitlements (Lei et al., 2023). At the provincial level, Yanzhi et al. (2022) developed a comprehensive evaluation system for farmers' and rural common prosperity based on four dimensions: wealth level, commonness, sharing, and sustainability. They found that common prosperity levels in rural areas across provinces generally trend upward. From a horizontal perspective, Lin (2023) assessed common prosperity in rural areas in three dimensions–overall wealth, income fairness, and bottom-line security–revealing that coastal regions have the highest levels of common prosperity. In terms of influencing factors, Pengjie et al. (2023) found that industrial upgrading and the establishment of a modern industrial system are key drivers of common rural prosperity.

2.3 The relationship between agricultural new-quality productive forces and common prosperity

Current scholarship exhibits limited direct investigation into the impact of emerging agricultural new-quality productive forces on common rural prosperity, with existing literature predominantly focusing on the general influence of emerging productive forces on shared affluence. Recent studies demonstrate divergent yet complementary perspectives, and Keqi (2024) identifies emerging productive forces as critical pathways in digital-real integration for advancing urban–rural common prosperity through technological mediation. Huaiyue (2024) proposed these forces as the central driving forces in market economy transformation, arguing for their capacity to generate synergistic effects between productivity enhancement and equitable distribution. Zheng et al. (2024) emphasized their strategic role in constructing new development paradigms, particularly through the dual mechanisms of economic growth acceleration and environmental sustainability improvement. Qiuju and Wenfu (2024) reveal their multi-dimensional contributions to common prosperity, including innovation-driven economic restructuring and human capital optimization. This evolving research landscape underscores the need for specialized investigations into the agricultural applications of emerging productive forces and their distinct pathways for rural wealth creation.

2.3.1 Direct impact mechanism

The endogenous growth theory (Romer, 1990) provides a classical framework for understanding technology-driven economic growth. However, the mechanisms through which the agricultural new-quality productive forces operate are distinct. At the micro level, the application of smart agricultural machinery substitutes for low-skilled labor, generating skill premium effects (Jingming and Huanguang, 2023). At the meso level, digital platforms integrate farmers into new "platform + household" business models (Peng, 2022). At the macro level, green technological innovations redefine distribution patterns through ecological product value realization mechanisms (Xiangbo and Liuxiu, 2024). Existing research tends toward technological determinism, overlooking the regulatory role of institutional environments in distributing technological benefits (Fang, 2024).

2.3.2 Indirect mechanisms

Recently, the mediating role of digital technology has emerged as a focal point of research. Stiglitz et al. (2019) theory of information asymmetry reveals that rural digitalization reduces transaction costs and enhances factor mobility. Chinese practices have demonstrated that county-level e-commerce platforms can lower agricultural product circulation losses by 18% (Alibaba Research Institute, 2023). However, the distributive effects of green technologies are dual-edged: ecological compensation mechanisms can enhance the welfare of low-income groups (Food and Agriculture Organization of the United Nations, 2022). Notably, technology diffusion is subject to "institutional threshold effects": in regions with digital governance levels below 0.4 (standardized values), technological benefits may be captured by elites (World Bank, 2024).

Heterogeneity analysis has become a popular topic in the research on common prosperity. Economic geography highlights that spatial disparities in location advantages (e.g., transport accessibility) and digital infrastructure may lead to spatial variations in technological benefits (Krugman, 1991). Institutional theory emphasizes that local governments' policy responsiveness (e.g., digital village pilot policies) can modulate the intensity of the release of technological efficiency (North, 1990).

2.4 The relationship between rural digitalization and common prosperity

Existing studies have extensively explored the connotations, mechanisms, and socioeconomic impacts of rural digitalization, offering multifaceted perspectives on its linkage with common rural prosperity. At its core, rural digitalization entails the penetration and integration of modern digital information technologies into rural areas, which restructures the socioeconomic fabric of rural societies through deep convergence with agricultural and rural development (Xianli and Zhe, 2019). Fundamentally, this represents a process of "technological empowerment" driven by digital innovations (Yiwu et al., 2021), wherein advancements in digital technologies and their application scenarios activate the endogenous drivers of rural development. As a transformative force and emerging opportunity for agricultural and rural advancement (Kapoor, 2014), rural digitalization exerts multi-dimensional influences spanning economic growth, governance modernization, and livelihood improvement, thereby providing systemic support for achieving rural common prosperity.

From the perspectives of economic growth and industrial development, rural digitalization injects robust vitality into rural economies by expanding productive spaces for labor and enhancing resource allocation efficiency. On the one hand, the application of digital technologies facilitates the optimization and upgrading of rural industrial structures while expanding and upgrading consumer markets, thereby directly contributing to

macroeconomic growth in rural areas (Haodong et al., 2020). On the other hand, digitalization revitalizes underutilized rural resources, such as land and cultural assets, while stimulating entrepreneurial dynamism (Jiajia et al., 2023). This process enables diversified rural industrial development, and the subsequent prosperity of industries generates substantial employment opportunities (Zhichao et al., 2023). Consequently, a virtuous cycle emerges: "economic growth-employment expansion-income elevation," which collectively fosters income growth among rural residents at both macro and micro levels (Feiwei, 2021).

From the perspective of specific empowerment pathways, digital technologies demonstrate transformative impacts across both agricultural production and rural livelihoods. In agricultural production, the application of technologies such as big data analytics and the Internet of Things (IoT) has significantly enhanced production efficiency and output quality, directly contributing to increased agricultural yields and laying a solid industrial foundation for rural economic development. Concurrently, in the sphere of rural livelihoods, digital technologies have substantially improved information service accessibility (Wei and Xian, 2019). These advancements not only facilitate farmers' access to real-time market intelligence and employment opportunities but also augment human capital through online education and skills training (Aker and Ksoll, 2016). Such capacity-building mechanisms provide sustained support for income growth and the reduction of income disparities, embodying the core principles of "capability equality" and "opportunity equality," which are essential for achieving common prosperity.

Although these studies have advanced our understanding of the relationship between agricultural new-quality productive forces and common rural prosperity, several limitations remain. First, the theoretical integration of agricultural new-quality productive forces is insufficient, and definitions and conceptual frameworks lack consensus. Second, empirical evidence on the mediating role of rural digitalization in the agricultural context remains fragmented, with most studies focusing on industrial-or enterprise-level analyses rather than agricultural settings. Third, the heterogeneity of the regional effects has not been adequately explored, particularly in terms of how policy responsiveness and institutional environments mediate the distribution of technological benefits.

To address these gaps, this study makes three key contributions. First, it constructs a theoretical framework linking "agricultural new-quality productive forces," "rural digitalization," and "rural common prosperity," thereby elucidating the multi-dimensional pathways through which rural digitalization empowers common prosperity. Second, it employs fixed effects and bootstrap mediation effect models to systematically test the direct effects, mediating mechanisms, and heterogeneity of the agricultural new-quality productive forces. Third, by aligning with national policy directives, this study offers differentiated policy recommendations to facilitate the transformation of technological benefits into inclusive outcomes, thereby supporting the realization of common rural prosperity.

By addressing these gaps, this study not only enriches the theoretical discourse on agricultural new-quality productive forces, but also provides actionable insights for policymakers seeking to harness the potential of digitalization and technological innovation in achieving rural common prosperity.

3 Theoretical analysis and research hypotheses

3.1 Direct impact of agricultural new-quality productive forces on rural common prosperity

As an advanced manifestation of agricultural productivity, representing a higher stage of agricultural modernization, agricultural new-quality productive forces (ANPF) directly contribute to common rural prosperity. This study identified the pathways through which ANPF facilitated this objective.

First, ANPF optimize the rural development environment, creating conditions for building livable and economically vibrant communities. By enabling value reconstruction and reassessment of ecological endowments (e.g., mountains, waters, forests, farmlands, lakes, and grasslands), ANPF transform environmental assets into economic drivers. Its environment-friendly and resource-intensive characteristics signify a qualitative leap from traditional agriculture, fostering emerging sectors such as organic and eco-agriculture. This promotes the deep exploitation and efficient utilization of agricultural natural resources. For instance, the application of soilless cultivation technology addresses the high-cost issues associated with traditional segregated planting and breeding systems, while simultaneously reducing waste pollution and decreasing rural dependence on conventional energy sources. These advancements have enhanced the value realization of ecological agricultural products, consolidated competitive advantages for sustainable rural development, and activated new dynamic drivers to achieve common prosperity.

Secondly, ANPF facilitate the transformation of agricultural production modes, enabling high-quality and efficient agricultural development. Driven by digital and intelligent technologies as its core components, ANQPF enhance the effective integration and synergistic development of agricultural, industrial, and innovation chains. This promotes the evolution of agricultural resource allocation toward Pareto optimality, thereby expanding the production possibility frontier of agriculture (Qinmei and Junge, 2023). In this process, the primary, secondary, and tertiary industries in rural areas achieve deep integration and coordinated development. Such integration not only overcomes the limitations of traditional agricultural production models and optimizes the agricultural industrial structure but also shifts the agricultural development paradigm from extensive to intensive. These transformations have significantly improved agricultural productivity, laying a solid foundation for common rural prosperity.

Thirdly, ANPF contribute to enhancing farmers' welfare, providing robust support for achieving rural prosperity. The development of internet-based public service innovations, such as online education and telemedicine, facilitated by ANPF, enables the widespread distribution of high-quality public service resources to rural populations. This significantly improves both the quantity and quality of rural public service provision. By expanding the economic "pie" while ensuring its more equitable distribution, these advancements serve as a critical safety net in promoting rural common prosperity. This dual mechanism fosters wealth creation and addresses distributional equity, establishing a solid foundation for inclusive rural development.

> *H1*: Agricultural new-quality productive forces significantly promote rural common prosperity.

3.2 Mediating role of rural digitalization

The development of new agricultural production forces is inseparable from the in-depth penetration of digital technologies. As the core carrier for the extension of digital technologies to agricultural and rural fields, rural digitalization plays a crucial intermediary role between agricultural new-quality productive forces and common rural prosperity. This intermediary role is not a one-dimensional transmission; instead, it constructs a transmission chain of "agricultural new-quality productive forces - rural digitalization - rural common prosperity" through the systematic transformation of agricultural production factors, industrial forms, governance models, and public services by digital technologies. Specifically, the intermediary effect of rural digitalization can be realized through the following four mechanisms.

First, it accelerates the digital and intelligent reconstruction of agricultural production factors, thereby amplifying the factor allocation efficiency of the new agricultural production forces. The core of the agricultural new-quality productive forces lies in breaking through the constraints of traditional production factors through technological innovation. Moreover, rural digitalization provides crucial support for this breakthrough. Digital technologies such as the Internet of Things and big data enable the precise management and control of traditional factors such as land. For example, smart irrigation and unmanned aerial vehicle-based plant protection enhance efficiency and reduce environmental dependence, consistent with the characteristics of new agricultural production forces. In addition, they give rise to data elements. Through agricultural data sharing platforms, data from the entire industrial chain is integrated, helping business entities accurately connect with the market, increasing the added value of agricultural products, and driving farmers' income growth.

Second, it promotes the upgrading of agricultural industrial forms, expands value, and creates space for new agricultural production forces. Digitalization facilitates the integration of agriculture with secondary and tertiary industries, giving rise to new business forms, such as smart agriculture. E-commerce directly connects production and marketing and reduces losses, and the integration of agriculture, culture, and tourism enhances the value of resources. Digital twins and blockchain promote large-scale and standardized production, contributing to brand formation. This upgrading of industrial forms not only reflects the "high-quality and high-efficiency" characteristics of agricultural new-quality productive forces but also directly promotes rural common prosperity by broadening the channels for farmers to increase their income and creating non-agricultural employment opportunities.

Third, it optimizes rural governance and public services and strengthens the inclusive characteristics of agricultural new-quality productive forces. Digital technologies simplify rural administrative procedures through the "Internet and government services" models, and digital public opinion monitoring improves governance precision. Online education and telemedicine break through the constraints of time and space, promote the sinking of resources, and strengthen the inclusiveness of agricultural new-quality productive forces.

Fourth, it promotes regionally coordinated development and reduces the spatial spillover effect of new agricultural production forces. The interconnection of digital infrastructure enables the rapid radiation of technological achievements of agricultural new-quality productive forces, narrowing the gaps; cross-regional digital platforms help small farmers integrate into large markets, and this spatial spillover effect further expands the scope of rural common prosperity benefited by agricultural new-quality productive forces.

From this analysis, it is evident that rural digitalization is the "technical carrier" and "transformer" of agricultural new-quality productive forces. Factor optimization, industrial upgrading, governance improvement, and regional coordination promote common rural prosperity.

> *H2*: Rural digitalization partially mediates the relationship between agricultural new-quality productive forces and common rural prosperity.

3.3 Regional heterogeneity effects

The impact of ANPF on common rural prosperity is inherently heterogeneous across regions owing to spatial disparities in resource endowments, institutional environments, and developmental pathways. Drawing on the New Economic Geography (Krugman, 1991), which emphasizes the role of agglomeration economies and transportation costs in shaping regional disparities, and Institutional Theory (North, 1990), which highlights how formal and informal institutions mediate economic outcomes, we posit that the efficacy of ANPF is contingent on the two dimensions of regional heterogeneity.

3.3.1 Geographical gradient effects

Rooted in Core-Periphery Dynamics (Friedmann, 1966), western China—characterized by lower baseline agricultural productivity and weaker path dependence on traditional practices—exhibits greater marginal returns to ANPF adoption. Empirical studies show that mechanization adoption rates in western provinces increased by 12–18% per annum post-ANPF intervention compared to 4–7% in the eastern regions (National Bureau of Statistics of China, 2023). This gradient aligns with Myrdal's (1957) cumulative causation theory, wherein lagging regions experience amplified growth responses to technological shocks due to the lower opportunity costs of institutional inertia.

3.3.2 Policy-moderated threshold effects

Institutional heterogeneity, as conceptualized in the Varieties of Capitalism (Hall and Soskice, 2001), explains why regions with digital infrastructure investment exceeding 3% of the GDP amplify the ANPF's impact by 21–33% ($p < 0.05$). This aligns with evidence from the European Union's Smart Villages initiative, where policy coherence between digitalization and agricultural innovation accounts for 40% of regional variance in rural income growth (European Commission, 2021).

> *H3*: The impact of agricultural new-quality productive forces on common rural prosperity demonstrates significant heterogeneity across regions and functional zones.

TABLE 1 Rural common prosperity index system.

Level 1 indicator	Level 2 indicator	Level 3 indicator	Property
Wealth Dimension	Material Wealth	Rural Resident Disposable Income (in Yuan)	Positive
		Rural Resident Household Expenditure per Household (in Yuan)	Positive
		Rural *Per Capita* Fixed Asset Investment (in Ten Thousand Yuan)	Positive
		Rural *Per Capita* Agricultural Output Value (in Yuan)	Positive
	Spiritual Wealth	Rural Household Engel Coefficient (%)	Negative
		Rural Resident *Per Capita* Educational and Cultural Entertainment Expenditure Ratio (%)	Positive
		Rural Households with Cable Broadcast Television as a Percentage of Total Households (%)	Positive
Shared Prosperity	Social Security	Rural Health Centers per 10,000 People	Positive
		Rural Nursing Institutions per 10,000 People	Positive
		Rural Doctors per 10,000 People	Positive
		Rural Lowest Living Security Expenditure (in Billion Yuan)	Positive
	Urban–Rural Coordination	Urban–Rural Income Gap	Negative
		Urban–Rural Consumption Gap	Negative

4 Research design

4.1 Model building

4.1.1 Baseline regression model

To examine the impact of the development of new agricultural production forces on farmers' common prosperity, a baseline regression model was constructed.

$$\mathrm{CWM}_{it} = \alpha_0 + \alpha_1 ANPF_{it} + \alpha_3 X_{it} + \sigma_i + \upsilon_t + \varepsilon_{it} \quad (1)$$

In Equation 1, CWM_{it} represents farmers' common prosperity, $ANPF_{it}$ represents the new agricultural production forces, X_{it} represents control variables, α represents estimation coefficients, σ_i, υ_t represents provincial and temporal fixed effects, and ε_{it} represents random disturbance terms.

4.1.2 Mediation effect model

To further investigate whether a mediating effect exists in rural digitalization, a stepwise regression model was constructed based on Equation 1. This model verifies the transmission mechanism of rural digitalization in the relationship between the new agricultural production forces and farmers' common prosperity. Additionally, a bias-corrected non-parametric percentage bootstrap estimation was performed on this model, with 500 bootstrap resampling iterations conducted to estimate the 95% confidence interval. A mediating effect was considered if the confidence interval did not contain zero.

$$DIG_{it} = \beta_0 + \beta_1 ANPF_{it} + \beta_2 Z_{it} + \sigma_i + \upsilon_t + \varepsilon_{it} \quad (2)$$

$$CWM_{it} = \gamma_0 + \gamma_1 ANPF_{it} + \gamma_2 DIG_{it} + \sigma_i + \upsilon_t + \varepsilon_{it} \quad (3)$$

In Equation 2, DIG_{it} is the mediating variable that represents rural digitalization and is estimated to show the impact of the new agricultural production forces on rural digitalization. A constant term is included in the model. In Equation 3, the combined effect of the new agricultural production forces and rural digitalization on farmers' common prosperity is tested while controlling for the mediating variable.

4.2 Variable selection

4.2.1 Explanatory variable: rural common prosperity

To ensure a comprehensive understanding of rural common prosperity (CWM), this study adopted the multi-dimensional evaluation framework developed by Huiai et al. (2022). Building on their work, this study constructs a composite index for the CWM by considering both wealth and shared prosperity dimensions. Specifically, a two-level and thirteen-level indicator system was established (Table 1). The wealth dimension comprises four sub-indicators, whereas the shared prosperity dimension encompasses thirteen sub-indicators. To ensure scientific and objective measurements, the entropy method was used to calculate the CWM index for each province. This approach allows for a nuanced assessment of rural regions' progress toward achieving CWM, providing valuable insights into the distribution of prosperity across different rural areas.

4.2.2 Core explanatory variable: agricultural new-quality production force (ANPF)

Agricultural New-quality Production Force are driven by technological advancements and reforms, which create new production factors and relationships through technological progress, managerial innovation, and changes in production methods. Based on the Marxist theory of the three productive forces, the agricultural new-quality productive forces exhibit three significant characteristics compared with the traditional production force: an ample supply of labor, high skills and quality among laborers, and higher individual productivity per laborer. Additionally, the new productive force's labor objects refer to the specific tasks that people work on. With the penetration of modern technology, new crop varieties and agricultural

products have emerged, leading to the transformation and upgradation of the agricultural industry. This led to the development of multifunctional, ecological, and other new forms of agriculture. Furthermore, new productive materials encompass all material facilities with which laborers interact, including production tools, facilities, and infrastructure. Key factors include the development of information technology, mechanization, and digitalization. Drawing on Di and Linxiang (2024), this study evaluates the new agricultural production forces from three dimensions: laborers, labor objects, and labor materials. A composite evaluation index system was constructed, and the entropy method was employed for measurement (see Table 2).

4.2.3 Control variables

To minimize the potential bias caused by omitted variables, this study incorporates the following control variables into the empirical analysis: Agricultural Industrial Structure (AIS), represented by the ratio of total agricultural output to the total output of the agriculture, forestry, and fishery sectors; Urbanization Level (UR), represented by the proportion of urban population to the total population in the region; Degree of Openness to the Outside (OPEN), represented by the ratio of foreign direct investment and exports in each province to the regional GDP; and Fiscal Support for Agriculture (GOV), represented by the ratio of agricultural and rural affairs fiscal expenditures to local general budget expenditures. These control variables were included to capture the impact of broader contextual factors on common rural prosperity, ensuring a more robust analysis of the relationship between agricultural new-quality productive forces and common rural area prosperity.

4.2.4 Mediating variable

Given the lack of unified standards in the academic literature for measuring rural digitalization, this study focuses on farmers' use of digital technology in rural areas, specifically examining Internet broadband access, mobile phone ownership, and computer ownership rates at the household level. Following Mingzhong and Binhui (2024), three indicators were selected to reflect rural digitalization: rural broadband Internet subscribers (in thousands of households), rural mobile phone ownership rate per 100 households, and rural computer ownership rate per 100 households. The entropy method was employed to calculate the rural digitalization index, which was then used to assess the digitalization levels across provinces. This approach provides a comprehensive measure of rural digitalization, facilitating a more robust analysis of the relationship between agricultural new-quality productive forces and common rural prosperity.

4.3 Data sources

This study selected panel data from 30 provinces in China (excluding Tibet, Taiwan, Hong Kong, and Macau) for the period 2012–2022. All data were sourced from the official website of the National Bureau of Statistics, various editions of the China Statistical Yearbook, China Rural Statistical Yearbook, China Educational Statistical Yearbook, China Science and Technology Statistical Yearbook, China Population and Employment Statistical Yearbook, local annual statistical yearbooks, EPS database, and Beijing Academy of Digital Finance Research. Table 3 presents the descriptive statistics for all variables. This approach ensured comprehensive and reliable data collection, supporting the empirical analysis of common rural prosperity and the agricultural new-quality productive forces.

5 Empirical result analysis

5.1 Baseline regression analysis

To test Hypothesis 1, we conducted a Hausman test to determine an appropriate regression model. With a p-value of 0.0023, which was significantly less than the conventional significance level of 0.05, the null hypothesis was rejected. Consequently, a fixed effects model was selected as the baseline regression model. A stepwise regression approach was employed for the empirical testing, and Table 4 presents the results. Column (1) shows the regression results without controlling for the variables, while Columns (2)–(5) sequentially introduce the control variables. The coefficients for the ANPF are consistently positive and significant at the 5% level, indicating its positive and significant impact on rural common prosperity. Although the regression coefficients decrease as the control variables are added, they remain positive and significant at the 5% level. These findings provide initial support for Hypothesis 1. Specifically, in Column (5), after controlling for a series of variables, the estimated coefficient of the agricultural new-quality productive force is 0.214, meaning that a 1% increase in the agricultural new-quality productive force leads to a 0.214% increase in rural common prosperity. This demonstrates that the agricultural new-quality productive force facilitated the transition of production forces, thereby promoting the progress of rural prosperity.

5.2 Robustness tests

Three robustness tests were employed to ensure the validity of the regression results. First, outlier trimming was conducted to eliminate the potential influence of extreme values on regression results. A 1% trimming ratio is applied to ANPF, and the results are presented in Table 5, Column (1). The regression coefficient for ANPF remains at 0.506, which is significant at the 1% level, further verifying Hypothesis 1. Second, a Tobit regression model is used. Given that both ANPF and rural common prosperity (CWM) are measured using the entropy method and fall within the range of 0–1, the Tobit model was selected for robustness testing. The regression coefficient for ANPF was 0.489 and significant at the 1% level, confirming the robustness of the baseline regression results. Third, a sample restriction test was conducted, excluding four directly administered cities (Beijing, Shanghai, Tianjin, and Chongqing). Due to the significant differences in digital innovation levels and agricultural development between the four directly administered cities and other provinces, a separate regression analysis was performed on the reduced sample. The regression coefficient for the ANPF was 0.344, which was significant at the 1% level. These findings suggest that for most provinces in China, the agricultural new-quality productive force has a positive and significant impact on rural common prosperity, thereby validating Hypothesis 1 (Table 5).

TABLE 2 Agricultural new-quality production force index system.

Level 1 indicator	Level 2 indicator	Level 3 indicator	Measurement method	Property
Agricultural New-quality Production Force	Laborers	Education Level	Rural labor force average years of education	Positive
		Vocational Training Ratio	The ratio of vocational education school graduates to rural population	Positive
		Labor Force Mobility	Ratio of migrant labor force to rural employment population	Negative
	Production Objects	Environmental Quality	Forest coverage rate	Positive
			Ratio of environmental protection fiscal expenditure to government public fiscal expenditure	Positive
			Ratio of COD(Chemical Oxygen Demand) emissions in agriculture to the value of agricultural output	Negative
			Ratio of ammonia emissions in agriculture to the value of agricultural output	Negative
		New Production Industries	Agricultural, Forestry, and Fishery Services Value	Positive
	Production Materials	Traditional Infrastructure	Ratio of rural road length to rural population	Positive
		Digital Infrastructure	Ratio of rural broadband internet users to rural households	Positive
			Optical Fiber Line Length	Positive
		Energy Consumption	Rural per capita electricity consumption	Positive
		Technological Innovation	Agricultural Technology Workers	Positive
			Agricultural R&D Investment Stock	Positive
		Digitalization Level	Digital Inclusive Finance Investment Index	Positive
			Digital Inclusive Finance Mobile Payment Index	Positive

5.3 Endogeneity tests

Considering the endogeneity problem caused by measurement errors and omitted variables, this study follows the approach proposed by Jiemei and Zeng (2024) and uses lagged one-period agricultural technological progress as an instrumental variable. This study employed the two-stage least squares (2SLS) method for regression analysis. The results of the 2SLS regression, as presented in Table 6, indicate that selecting lagged one-period agricultural technological progress as an instrumental variable is reasonable. The Lagrange multiplier (LM) statistic and–g the Donald Wald F statistics suggest that this instrumental variable is a valid and identifiable instrument. The regression coefficients from the 2SLS estimation are consistent with those from the baseline regression, demonstrating the robustness of the baseline regression results. This finding further supports H1, which asserts that agricultural technological progress can positively promote farmers' collective wealth. Table 6 summarizes the results.

5.4 Mediation effect analysis

Table 7 presents the regression results for the mediating effects of rural digitalization. Column (1) shows that the coefficient of the impact of agricultural technological progress on rural digitalization is 0.848, which is statistically significant at the 1% level. In Column (2), after including the mediator, rural digitalization, the coefficient for the impact of agricultural technological progress on farmers' collective wealth becomes significantly greater than zero, with a value of 0.364. These findings indicate that the "agricultural technological progress - rural digitalization - farmers' collective wealth" pathway exists, thereby validating Hypothesis 2.

The Bootstrap test results indicate that the corrected indirect effects of rural digitalization are significantly different from zero, further confirming its mediating role; the coefficients for both the indirect and direct effects are statistically significant. Specifically, the coefficient for the indirect effect was 0.125, with a standard error of 0.056, yielding a Z-value of 2.23 and a p-value of 0.026. The 95% confidence interval for this coefficient is [0.015, 0.235], which did not include zero, indicating that the indirect effect was significant. Similarly, the coefficient for the direct effect is 0.364 with a standard error of 0.093, resulting in a Z-value of 3.94 and a p-value of 0.000. The 95% confidence interval for this coefficient was [0.183, 0.546], which did not include zero, further confirming that the direct effect was significant. These findings suggest that the mediating variable effectively transmits the influence of the independent variable to the dependent variable. Therefore, the Bootstrap test results support the hypothesis that the independent variable exerts a significant and measurable impact on the dependent variable, both indirectly through the mediator and directly after controlling for it. Table 8 summarizes the results.

5.5 Heterogeneity test

The heterogeneity of agricultural technological progress across Chinese provinces is significant because of vast differences in natural geographical environments and economic development levels. Given the diverse types of agricultural developments across regions, the

TABLE 3 Variable descriptive statistics.

Variable Name	Mean	Standard deviation	Minimum value	Maximum value
Rural Common Prosperity(CMW)	0.377	0.118	0.123	0.704
Agricultural New-quality Productive Force(ANPF)	0.176	0.091	0.047	0.503
Agricultural Industrial Structure (AIS)	0.530	0.089	0.054	0.736
Degree of Openness (OPEN)	0.260	0.274	0.008	1.441
Urbanization Level(UR)	0.607	0.117	0.363	0.896
Fiscal Support for Agriculture(GOV)	0.114	0.034	0.040	0.204

TABLE 4 Baseline regression results.

Variable names	CWM				
	(1)	(2)	(3)	(4)	(5)
ANPF	0.396*** (3.999)	0.397*** (3.997)	0.370*** (3.695)	0.214** (2.368)	0.214** (2.368)
AIS		−0.079 (−0.585)	−0.066 (−0.492)	0.094 (0.780)	0.096 (0.795)
OPEN			−0.130* (−1.774)	−0.080 (−1.230)	−0.079 (−1.211)
UR				1.003*** (9.001)	1.001*** (8.963)
GOV					0.132 (0.335)
_CONS	0.307*** (16.977)	0.349*** (4.733)	0.381*** (5.034)	−0.299*** (−2.958)	−0.315*** (−2.826)
N	330	330	330	330	330

t-statistics in parentheses.
*$p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 5 Robustness tests.

Variable Name	(1)	(2)	(3)
	Winsorized at the 1% level	Tobit model	excluding the four directly administered cities
ANPF	0.506*** (7.096)	0.489*** (7.041)	0.344*** (3.127)
AIS	−0.189*** (−2.881)	−0.190*** (−2.910)	0.104 (0.878)
OPEN	−0.213*** (−5.864)	−0.210*** (−5.831)	−0.142 (−1.350)
UR	0.620*** (8.235)	0.615*** (8.237)	0.965*** (8.685)
GOV	−0.053 (−0.217)	−0.056 (−0.231)	0.144 (0.377)
_CONS	0.073 (1.028)	0.079 (1.113)	−0.288*** (−2.672)
var(e. CWM)		0.009*** (12.845)	
N	330	330	286

t-statistics in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

impact of technological progress on farmers' collective wealth is expected to vary significantly by region. This study employs two methods for heterogeneity testing: one based on geographical divisions, dividing the 30 provinces into three regions (eastern, central, and western), and the other based on agricultural production functions, dividing the 30 provinces into two zones (major and non-grain-producing regions). Table 9 presents the regression results.

From a geographical perspective, the regression coefficients of the agricultural new-quality productive forces in Columns (1)–(3) are all positive, but there are obvious regional differences. The coefficient for the eastern region was 0.139, which was not significant. This is because the eastern region has a developed economy, a high level of agricultural mechanization, a large proportion of farmers' non-agricultural income (operational and property-related), a small gap between urban and rural development, and a good foundation for common prosperity. Therefore, the marginal impact of agricultural new-quality productive forces is "diluted." The regression coefficient of the agricultural new-quality productive forces in the central region was 0.492 ($p < 0.10$), which is significant at 10%. The regression

coefficient of agricultural new-quality productive forces in the western region was 0.466 ($p < 0.01$), which is significant at 1%. This may be because the central and western regions have low economic levels, and farmers rely on agriculture for their livelihoods. New agricultural production forces have become the core driving forces of rural wealth accumulation by improving production efficiency and increasing agricultural output value. Particularly in the western region, which is mainly engaged in traditional planting and breeding, innovation in production management and sales models enabled by digitalization is directly related to the growth of farmers' income.

TABLE 6 Endogeneity tests.

Variable Name	(1)	(2)
	First stage	Second stage
L. ANPF	0.867*** (27.229)	
ANPF		0.658*** (6.258)
AIS		−0.190** (−2.571)
UR		0.782*** (10.000)
GOV		−0.026 (−0.123)
OPEN		−0.325*** (−6.512)
_CONS	0.022*** (3.493)	−0.035 (−0.467)
K-P rk LM statistical measure	69.061 (0.000)	
C-D Wald F statistical measure	442.556 (16.38)	
N	300	300

t-statistics in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 7 Mediation effect analysis.

Variable Name	(1)	(2)
	DIG	CWM
ANPF	0.848*** (8.519)	0.364*** (4.022)
AIS	0.019 (0.320)	−0.193*** (−2.690)
UR	0.790*** (10.283)	0.499*** (5.838)
GOV	−0.782*** (−3.152)	0.059 (0.257)
OPEN	−0.029 (−0.647)	−0.205*** (−3.915)
DIG		0.147** (2.361)
_CONS	−0.255*** (−3.975)	0.116* (1.700)
N	330	330

t-statistics in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

From the perspective of agricultural production functions, the regression coefficient of agricultural new-quality productive forces in non-grain-producing areas (Column 4) is positive but fails to pass the significance test. The regression coefficient of the agricultural new-quality productive forces in grain-producing areas (Column 5) is 0.446 ($p < 0.01$), which is significant at the 1% level. Grain-producing areas are characterized by prominent large-scale and specialized agricultural production, and rural digitalization is more likely to synergize with new agricultural production forces. Cultivated land is concentrated in major producing areas, and the application of digital technologies (such as smart irrigation and precision planting) has low costs and quick results, which can directly increase agricultural benefits by improving efficiency and reducing costs. However, major producing areas assume the role of ensuring food security and policy support. Agricultural subsidies and infrastructure investment are more inclined toward them, creating conditions for the implementation of agricultural new-quality productive forces and strengthening their driving forces for common prosperity. Non-grain-producing areas have diverse but scattered agricultural formats, making it difficult to adapt to digitalization. Moreover, agriculture accounts for a low proportion of the regional economy, and it is difficult for it to contribute to resource agglomeration and the synergistic effects of agricultural new-quality productive forces, resulting in an insignificant impact.

In summary, the impact of agricultural new-quality productive forces on common rural prosperity is essentially the result of the interaction of multiple factors, such as the regional economic foundation, agricultural industry status, and policy resource endowment. Behind the differences in geographical locations lies the divergence between economic development stages and agricultural function positioning. The differences in production function zoning reflect the distinctions in the degree of agricultural scale and intensity of policy support.

These findings validate Hypothesis 3, which demonstrates that the impact of agricultural technological progress on farmers' collective wealth exhibits region-specific heterogeneity. Table 9 summarizes the results.

6 Conclusion and policy recommendations

6.1 Conclusion

Based on the current background of accelerating the formation of new production power and comprehensively promoting farmers' collective wealth, this study examined the impact of agricultural technological progress on farmers' collective wealth using provincial-level data on agricultural technological progress and the farmers'

TABLE 8 Bootstrap results.

Effect Type	Observed Coef	Bootstrap Std. Err.	*Z*	$p > \|z\|$	Normal-based [95% Conf. Interval]	
Indirect effects	0.125	0.056	2.23	0.026	0.015	0.235
Direct effects	0.364	0.093	3.94	0.000	0.183	0.546

TABLE 9 Heterogeneity test.

Variable Name	(1)	(2)	(3)	(4)	(5)
	Eastern	Central	Western	non-grain-producing regions	major grain-producing regions
ANPF	0.139 (1.012)	0.492* (1.876)	0.466*** (3.042)	0.085 (0.596)	0.446*** (3.594)
AIS	−0.124 (−0.307)	0.067 (0.186)	0.162 (1.492)	−0.096 (−0.235)	0.103 (0.926)
UR	0.599 (1.498)	1.534*** (7.514)	0.896*** (7.127)	0.560* (1.707)	1.038*** (9.803)
GOV	−0.064 (−0.050)	0.042 (0.047)	−0.523 (−1.160)	−1.357 (−1.625)	0.837** (2.021)
OPEN	−0.111 (−1.282)	−0.495 (−1.009)	−0.193 (−0.930)	−0.126 (−1.461)	0.086 (0.528)
_CONS	0.087 (0.196)	−0.528* (−1.686)	−0.230** (−2.252)	0.230 (0.634)	−0.468*** (−4.400)
N	121	88	121	110	220

t-statistics in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

collective wealth index for 30 provinces over the period of 2012–2022. The following conclusions were drawn:

1. From a comprehensive perspective, agricultural technological progress significantly promotes collective wealth among farmers, with both variables showing synchronous upward trends.
2. Rural digitalization plays a mediating role in the process by which agricultural technological progress drives farmers' collective wealth. This validates the "agricultural technological progress, rural digitalization, and farmers' collective wealth" mechanism.
3. From the perspective of the heterogeneity analysis, the impact of agricultural technological progress on farmers' collective wealth exhibits regional heterogeneity. Specifically, the driving effect was the most significant in the western region, followed by the central region, whereas the eastern region showed negligible effects. Furthermore, based on agricultural functional zones, the driving effect was significant in grain-producing regions but not in non-grain-producing regions. These findings validate Hypothesis 3, demonstrating that the impact of agricultural technological progress on farmers' collective wealth is regionally specific and varies across regions.

6.2 Policy recommendations based on research conclusions

First, it strengthens the coordinated regional development of agricultural technological progress and promotes collective inter-regional wealth. (1) Optimize regional policy support to narrow regional development gaps. Given that the driving effect of agricultural technological progress on collective wealth is most significant in the western region, followed by the central region, and negligible in the eastern region, the national government should intensify policy support for western and central regions, particularly in terms of infrastructure construction, technological innovation, and talent cultivation related to agricultural technological progress. (2) Promote high-quality development of agricultural technological progress in the eastern region: As an economically developed region, the eastern area should focus on enhancing the quality of agricultural technological progress, fostering deep integration with secondary and tertiary industries, and increasing agricultural added value. (3) Adapt to local conditions, implement differentiated strategies based on the resource endowments and developmental stages of different regions, and formulate tailored strategies for the development of agricultural technological progress. For instance, grain-producing regions should continue to play a core role in food security and agricultural technological progress. In contrast, non-grain-producing regions should explore diverse pathways, such as developing specialty agriculture and rural tourism.

Second, rural digitalization should be promoted to strengthen the mediating role of agricultural technological progress. (1) Accelerate the construction of rural digital infrastructure. To leverage the mediating role of rural digitalization between agricultural technological progress and farmers' collective wealth, the government should increase investments in rural digital infrastructure, promoting the dissemination of 5G, the Internet of Things, and artificial intelligence in rural areas through initiatives like "digital rural development pilot projects." (2) Enhancing farmers' digital literacy to foster deep integration between digital technology and agricultural production: Given that some farmers have relatively low acceptance of digital technology, it is recommended to conduct digital skills training to improve their ability to use digital tools. Programs such as the "Internet+Agriculture" training initiative can help farmers acquire skills in smart agriculture and e-commerce, enabling them to better leverage digital technology to boost agricultural productivity and market competitiveness. (3) Construct digital public service platforms to promote resource sharing in rural areas. Government and enterprise collaboration should establish comprehensive digital public service platforms nationwide, providing farmers with agricultural technology consulting, market information, and financial support. For example, an "agricultural big data platform" can integrate agricultural resource information to assist farmers in optimizing their production decisions.

Third, institutional safeguards must be strengthened to promote technological progress in agriculture. (1) Establishing a robust policy support system for agricultural technological progress through the establishment of dedicated funds, tax incentives, financial support, agricultural technological innovation, and industrial upgrades should be encouraged. (2) Optimize the institutional environment for agricultural technological progress and implement reforms in land

and financial support policies to provide institutional safeguards for agricultural technological progress. (3) Develop a monitoring and evaluation mechanism for agricultural technological progress, regularly monitor and evaluate the development of agricultural technological progress, identify issues in a timely manner, and adjust policies accordingly.

7 Discussion

This study investigated the impact of agricultural new-quality productive forces on common rural prosperity, as well as the mediating role of rural digitalization, using panel data from 30 provinces in China spanning 2012 to 2022. It reveals the characteristics of regional heterogeneity. In this section, the implications of the results are critically analyzed by integrating theoretical perspectives and international experience, and the limitations of the study and its implications for sustainable development are discussed.

7.1 Empirical results and theoretical dialogue

The positive impact of agricultural new-quality productive forces on rural common prosperity corroborates the core proposition of the endogenous growth theory that technological innovation drives economic growth (Romer, 1990). However, it further highlights the particularities of the agricultural sector: it not only promotes growth by improving total factor productivity (Biliang and Pengpeng, 2024) but also achieves the synergy of "growth and sharing" through the transformation of ecological values and the optimization of public services. This aligns with the connotation of common prosperity as "dual prosperity in material and spiritual aspects" (Lianfu and Yali, 2022).

The 25.6% mediating contribution rate of rural digitalization verifies the applicability of information asymmetry theory in rural contexts: digital technologies facilitate factor mobility by reducing transaction costs (Stiglitz, 2019), serving as a key link in the transformation of agricultural new-quality productive forces into common prosperity. This finding supplements the limitations of existing research on digitalization in the industrial sector (Zheng et al., 2024) and provides empirical support for the "technology-digitalization-inclusiveness" transmission mechanism in agricultural scenarios.

The gradient characteristic of regional heterogeneity, i.e., "western regions > central regions > eastern regions," resonates with the "latecomer advantage" theory: less developed regions enjoy higher marginal returns from technological applications (World Bank, 2024). The western regions, with their high dependence on agriculture, witnessed a direct increase in income through the digital empowerment of agricultural new-quality productive forces. By contrast, the marginal effect in the eastern regions is diluted because of the high proportion of non-agricultural industries and small urban–rural gaps, which is consistent with Lin's (2023) conclusion that the eastern regions have a better foundation for common prosperity.

7.2 Underlying logic of regional asymmetry

The difference in the effects between major and non-major grain-producing regions stems from the interaction between agricultural scale and policy support. Major grain-producing regions, characterized by concentrated arable land and a high degree of specialization, benefit from lower costs and more significant effects from the application of digital technologies. Moreover, infrastructure investments (such as high-standard farmland) driven by national food security policies have strengthened the conditions for implementing new-quality productive forces (Xiaohe and Xiangxue, 2024). In contrast, non-major grain-producing regions feature fragmented agricultural formats, which increase the difficulty of digital adaptation coupled with weaker policy support, making it difficult to form scale effects.

This phenomenon shares commonalities with international experiences. Studies in countries like Brazil and India have shown that scaled regions are more likely to achieve benefit-sharing through technological innovation, while scattered areas with smallholders often face a "technology gap" (Food and Agriculture Organization of the United Nations, 2022). However, China's particularity lies in the fact that policy inclinations in major grain-producing regions (such as agricultural subsidies) have mitigated the problem of "elite capture" (World Bank, 2024), enabling technological dividends to reach ordinary farmers more easily.

7.3 Concerns about sustainability and digital inequality

The "greening" characteristics of agricultural new-quality productive forces (e.g., ecological agriculture and resource intensification) provide support for sustainable food systems (Zheng et al., 2024). However, there are potential risks: first, the high dependence of western regions and major producing areas on new-quality productive forces may exacerbate ecological pressures. Therefore, there is a need to be vigilant against the damage to sustainability caused by "efficiency first" orientations. Second, rural digitalization relies on the equalization of infrastructure. Yet, the current rural digital divide is significant (e.g., the broadband coverage rate in rural western China is only 60% of that in eastern China, China Statistical Press, 2022), which may lead to the marginalization of "digitally excluded" groups and widen income gaps (Zhichao et al., 2023).

This suggests the need to balance "efficiency" and "equity": coordinating yield increases and environmental protection through green technological innovations (e.g., low-carbon farming), and reducing access barriers through digital skills training (e.g., e-commerce training for farmers), so as to prevent digitalization from becoming a new source of inequality (Aker and Ksoll, 2016).

7.4 Research limitations and future directions

This study has three limitations: First, the measurement of rural digitalization does not include soft indicators such as digital literacy, which may lead to an underestimation of its role. Second, although a one-period lagged instrumental variable was used to address

endogeneity, the influence of omitted variables, such as cultural customs, cannot be completely ruled out. Third, the heterogeneity analysis did not go deep into the county or farmer level, making it difficult to reveal differences in micro-level behaviors.

Future research can be expanded in three ways: constructing an index system for rural digitalization that incorporates digital capabilities, exploring the acceptance mechanism of agricultural new-quality productive forces among small-scale farmers through field surveys, and conducting international comparisons to contrast the differences in technology empowerment paths between China and other developing countries.

7.5 Implications for rural transformation

This study offers Chinese experiences for global rural transformation: agricultural modernization requires a dual-driver mechanism of "technological innovation + institutional guarantee"—not only breaking through factor constraints through agricultural new-quality productive forces but also ensuring the sharing of achievements via digitalization. For developing countries, China's practice demonstrates that less developed regions can achieve "curve overtaking" through differentiated policies (such as preferential support for western regions and major grain-producing areas). However, it is necessary to simultaneously address the shortcomings in digital infrastructure and human capital to avoid the trap of "technological dependence."

In summary, the driving effect of agricultural new-quality productive forces on common rural prosperity is the result of the joint action of technological revolution, institutional innovation, and regional characteristics. Only by embedding technological progress into a sustainable and inclusive framework can the high-quality development of agriculture and rural areas be synergistically advanced with the realization of common prosperity.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Author contributions

YP: Writing – original draft, Data curation, Conceptualization, Writing – review & editing. CT: Data curation, Writing – review & editing. DH: Visualization, Formal analysis, Writing – review & editing. PL: Writing – review & editing, Funding acquisition, Project administration, Validation.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This study received the following grants: Philosophy and Social Science Research Project of Hubei Provincial Department of Education, "Mechanisms and Practical Paths for Red Cultural Resources to Enable Joint Prosperity in Revolutionary Old Areas", grant number (24Y043). National Natural Science Foundation of China, grant number (42201234). Ph.D. Fund Project, "Construction of Support System for Rural Industry: Revitalization and Women's Industry Project Participation" grant number (2042021027). High-Level Cultivation Project of Huanggang Normal University, "Study on the influence mechanism and optimization mechanism of cultural capital on the well-being of rural residents in old revolutionary base areas", grant number (204202422704). School-Level Teaching and Research Project of Huanggang Normal University, "Training of innovation ability of economics and management students based on project drive", grant number (0601202341).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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