Original Research Article

Digital financial inclusion for green agriculture: path to change or bottleneck? --Evidence from China

**Abstract:**

**Aims:** The aim of this study is to explore the role of digital inclusive finance in advancing green agricultural development and investigate the underlying mechanisms, providing references for the government to promote digital infrastructure development and agricultural green development.

**Study design:** This is an empirical research design that examines the relationship between digital inclusive finance and green agricultural development. About digital inclusive finance comes from the Digital Inclusive Finance Index of Peking University. Mediating variables, moderating variables, threshold variables, and control variables are from provincial statistical yearbooks, China Population and Employment Statistical Yearbook, China Statistical Yearbook, National Bureau of Statistics, EPS database, and National Research Network.

**Place and Duration of Study:** The data covers 30 provinces in China, and the study period is from 2011 to 2021.

**Methodology:** The research applies fixed - effect, mediation - effect, moderating - effect, and threshold - effect models to analyze the data. It conducts an overall analysis of the impact of digital inclusive finance on green agricultural development, and also carries out heterogeneity analysis by dividing regions (eastern, western, northern, main production areas, production and marketing balance areas, and high - grade land quality areas).

**Results:** (1) Digital inclusive finance significantly promotes agricultural green development. (2) In the heterogeneity analysis, digital inclusive finance in different regions shows significant positive correlations with green agricultural development. (3) Developing digital rural infrastructure can support the promotion of green agricultural development. (4) The enhancement of green technology innovation in agriculture moderates green agricultural development and accelerates its progress. (5) When digital inclusive finance reaches a certain threshold, its positive impact on green agricultural development becomes more obvious.

**Conclusion:** The research findings reveal the important role of digital inclusive finance in green agricultural development. It is recommended that the government increase funding for digital inclusive finance to promote its rapid development, which can contribute to sustainable agricultural development and reduce the burden on resources and the environment. However, further research may be needed to explore more detailed implementation paths and long - term effects.

*Keywords:digital inclusive finance;agricultural green development;digital village construction;threshold effect;intermediary effect*

1. **Introduction**

Since the reform and opening up, Chinese agriculture has made remarkable progress, with the sown area of crops growing from 150,104 thousand hectares in 1978 to 168,695 thousand hectares in 2021, a growth rate of 12.38%. However, this growth has also been accompanied by increased ecological pollution, and agricultural pollution has become one of the main sources of environmental pollution. The traditional crude agricultural production methods have had a significant negative impact on the ecological environment. Therefore, the green development of agriculture has become a key strategy for realizing sustainable agriculture.

In 2015, the State Council put forward a proposal for the construction of an agroecological civilization and planned a path for the transformation and upgrading of agriculture towards greening. Subsequently, the Ministry of Agriculture issued policies such as the National Plan for Sustainable Agricultural Development (2015-2030) and the Key Points for Agricultural and Rural Ecological Environmental Protection 2023. In recent years, in the face of the severe challenges of global climate change, China has set forth the strategic aim of "carbon peaking and carbon neutrality," which underscores the increased importance of green development. The 2022 No.1 Document from the Central Government reiterated the need to promote green agricultural development, strengthen the control of agricultural surface pollution, optimize agricultural input factors, and hasten the development of carbon-reducing agricultural technologies. Green development has emerged as the principal direction of China's agricultural evolution.

Against this background, digital inclusive finance, as an innovative financial model, focuses on the integration of finance and technology, utilizing network, intelligence and digital elements to enhance services. This model removes time and space barriers in the flow of production factors, enabling financial services to be provided across national borders, which is particularly beneficial to residents in remote areas. By offering accessible and cost-effective financial services, digital inclusive finance alleviates financial constraints on agricultural greening, fosters increased agricultural investment, and bolsters the implementation of the rural revitalization strategy. With the convergence of technologies such as big data, the Internet, and cloud computing, digital inclusive finance broadens its service coverage (Mushtaq et al., 2019). The 53rd China Internet Development Statistics Report indicates that, as of December 2023, there were 326 million rural internet users, and the urban-rural digital gap is closing rapidly. Digital inclusive finance utilizes digital technology to provide farmers with accessible and affordable financial services and products, effectively filling the coverage gaps of traditional financial services and playing a key role in alleviating the financial constraints of green agricultural development. It addresses fragmented demand and inadequate supply in rural financial markets, improves farmers' accessibility to financial services, and facilitates the growth of investment in agriculture. An extensive analysis of the effects and mechanisms of digital inclusive finance in the context of agricultural green development is crucial for optimizing resource distribution, advancing green development transformation, enhancing high-quality agricultural development, and effectively carrying out the rural revitalization strategy.

This study potentially contributes in several significant ways: firstly, while most existing research on digital inclusive finance (DIF) focuses on aspects such as regional economic growth, farmers' employment, and reducing the urban-rural income disparity, there are relatively few studies that analyze the connection between DIF and agricultural green development. This study aims to explore this connection; secondly, it offers a quantitative analysis of the impact of DIF on agricultural green development and its underlying mechanisms, thus filling an existing research gap; thirdly, the study demonstrates that DIF promotes agricultural green development by advancing the level of digital rural development; and lastly, it uncovers a double-threshold effect between DIF and rural residents' per capita income, thereby addressing a previously unexplored area in the literature.

1. **methodology**

The paper is structured as follows: Section 2 reviews the relevant literature, highlighting research gaps and limitations; Section 3 presents the theoretical framework and proposes research hypotheses; Section 4 describes the research methodology, model development, and data collection process; Section 5 discusses the empirical results and their implications; and Section 6 concludes with a summary and provides relevant recommendations.

1. **Literature review**

Currently, Research on agricultural green development is extensive and deep, primarily focusing on indicator system construction, influencing factor analysis, development level evaluation, and characteristic identification. The academic community has designed various indicator frameworks to evaluate agricultural green development from different perspectives. For instance, some scholars have constructed systems encompassing economic and social progress, resource conservation and investment, resource recycling, and environmental compatibility (Zhang et al., 2022). Numerous factors influence agricultural green development, including government subsidies and carbon tax policies (Liu et al., 2020), green finance (van Veelen., 2021), the application of digital information technology, and farmers' green planting and consumption habits (Dai et al., 2023; Luo et al., 2024). Developing green agriculture not only fosters the growth of green natural resources but also helps address climate change and achieve sustainable agricultural development. Additionally, it has positive social welfare impacts, such as enhancing labor education and promoting urbanization (Ji et al., 2022). So far, research has delved into the progress and characteristics of green agricultural development, noting a gradual overall improvement(Guo et al., 2020) but significant regional disparities (Zhang et al., 2021).

Research on DIF effects focuses on its connotation and role. Initially proposed by the UN in 2005, inclusive finance emphasizes building an efficient, convenient, and comprehensive financial system for diverse social groups. Digital technology has evolved inclusive finance into digital finance, overcoming limitations by lowering information costs and credit barriers, thus expanding the scope and penetration of financial services (Munyegera et al., 2016). The rapid development of DIF has broadened financial service coverage, enhanced affordability, and reintegrated marginalized groups into economic activities (Ahmad et al., 2021). It also promotes consumption by widening investment channels and increasing disposable income (Li et al., 2020; Corrado et al., 2017). These positive effects are validated both theoretically and empirically, with studies showing that DIF significantly fosters regional economic growth (Yan, 2022; Ozturk et al., 2022). Additionally, research indicates a positive correlation between DIF development and increases in energy consumption and CO2 emissions (Mukalayi et al., 2023). Further studies reveal that in regions with well-established traditional financial systems or concentrated agricultural industries, DIF can promote agricultural green development (Zhang et al., 2023).

Existing studies show that the research on the impact of digital inclusive finance (DIF) on the green development of agriculture is still at an early stage, and there are fewer related studies, especially those that explore the mechanisms behind it through fixed-effects modeling. Hence, this study uses empirical methods to analyze the effect of digital inclusive finance (DIF) on agricultural green development, drawing on panel data collected from 30 Chinese provinces between 2011 and 2021. From the perspective of DIF, the study aims to elucidate its core mechanism of action and apply mediation and moderating effect analysis to explore the factors affecting agricultural green development in order to supplement the gaps in existing research.

However, this study has some limitations. First, data availability is limited to the provincial level due to missing data from many prefecture-level cities. Second, in measuring green development in agriculture, studies have focused on five dimensions: efficient use, resource conservation, environmental quality, ecological protection, and green living. Nonetheless, the influence of other dimensions such as social benefits and economic effects on agricultural green development also deserves the attention of future research.

1. **Theoretical analysis and hypothesis**

**4.1 Direct effects of DIF on greening agriculture**

Digital Inclusive Finance (DIF) plays a key role in supporting the greening of agriculture. Empowered by digital technology, it enables the asynchronous nature of financial services and the convenience and standardization of transactions. At the same time, digital inclusive finance promotes universal agricultural insurance through mobile platforms, expands coverage, decentralizes and transfers financial risks of agricultural green enterprises, and compensates for their operational losses. In addition, its green attributes effectively reduce pollution and energy consumption in its operation (Wen et al., 2022) and promote environmental pollution control (Zhang et al., 2023).

In promoting the green development of agriculture, digital inclusive finance works through several ways. First, it promotes the rational allocation of agricultural production resources, including land transfer, labor enhancement, marketization, and green technology adoption to conserve resources and improve efficiency (Adnan et al., 2019). Second, it utilizes digital technology to establish farmers' credit files, reduce information asymmetry and moral hazard, improve information dissemination speed and transaction security, and reduce farmers' information and trust constraints, thus enhancing the level of green agricultural production and motivation (Beck et al., 2018).

Through these means, digital inclusive finance plays a crucial role in advancing agricultural green development and encouraging sustainable and green transitions. Therefore, this study proposes hypothesis 1:

H1:Digital inclusive finance can enhance the level of agricultural green development.

**4.2 The mediating effect of digital rural development**

Theoretically, digital financial inclusion originated to address financial exclusion and gradually evolved into the pursuit of financial inclusion and financial equity.In the 1980s and 1990s, the rise of New Keynesianism and endogenous growth theory (Romer, 2012) revealed that bank access and direct financing restrictions could lead to financial service exclusion, suggesting that financial inclusion is constrained by policy orientation. Entering the 21st century, neoliberalism and new institutional economics revisited financial inclusion. Neoliberalism advocates market liberalization and reduced government intervention, which is believed to enhance the universality and efficiency of financial services (McKinnon, 1993). New institutional economics emphasizes the central role of institutions and rules and advocates the promotion of universal access to financial services through effective institutional design, especially the establishment of appropriate financial infrastructure and regulatory frameworks (Hellmann, 2000). Nonetheless, financial exclusion still exists in poor countries or communities due to their inability to bear the cost of building financial systems. Therefore, government subsidies are seen as an effective means to reduce the cost of financial inclusion and protect vulnerable groups.

In practice, digital technology is at the core of the development of digital inclusive finance, promoting the expansion of innovative service tools in the financial industry and, as a complement to traditional finance, expanding the coverage of financial services to benefit more residents and enterprises. The rise of digital inclusive finance has not only accelerated the financialization of the technology industry, but also reshaped the development model of the traditional financial industry. At the same time, it has opened up new paths for financial services to agriculture, rural areas and farmers, helping farmers to increase their income while promoting enterprise development and rural construction (Zhang et al., 2023). Digital inclusive finance has invigorated rural financial services, made farmers' financing processes more efficient, and improved the precision and efficacy of financial services. It promotes the integration and innovative development of rural sectors, such as the implementation of smart agriculture technology, thus boosting the development of niche agriculture and rural tourism. Furthermore, digital inclusive finance has enhanced the rural social service infrastructure, uplifted the living standards of residents, and aided in the rural revitalization strategy. This financial service model has comprehensively promoted the progress of rural areas by optimizing economic structure, promoting industrial integration and improving social services.

The construction of digital villages has achieved remarkable results in rural areas of China, with administrative villages fully covered by “village-to-village broadband”, and the level of informationization in agriculture and rural areas has been greatly improved. This process has deepened the application of modern information technology in the whole agricultural industry chain (Mei et al., 2022), optimizing the purchase of agricultural production materials, information intermediary services and sales of agricultural products through technical rationality. Smart agriculture applying big data technology provides farmers with efficient access to information, while optimizing the agricultural information service system, making the service more convenient and inclusive. Informatization in agriculture and rural areas effectively minimizes resource input costs for agricultural producers, improves production efficiency and productivity, drives the transformation of agricultural production towards resource efficiency and environmental sustainability, and promotes green agricultural development through precise information platform management and the deployment of smart equipment. Thus, this study introduces hypothesis 2:

H2: Digital rural development plays a partial mediating role in the impact of digital inclusive finance for green development of agriculture.

**4.3 Analysis of the moderating effect**

Agricultural green development is intricately connected to the advancement of green technologies (Sun et al., 2020). Digital inclusive finance facilitates the infusion of R&D capital into agriculture by alleviating the financial pressures on agricultural entities and elevating the level of regional agricultural tech innovation. Utilizing digital technology, digital inclusive finance creates a robust credit reporting system (Du et al., 2021), which effectively diminishes the credit risk in offering inclusive financial services to farmers. This support enables agricultural entities to invest in green technology research and development and application, such as water-saving irrigation, organic fertilizers, and biocontrol, to promote the development of agriculture in an environmentally friendly and sustainable direction (Zhang et al., 2018). In addition, digital inclusive finance enhances the confidence of financial institutions in agricultural projects by establishing an efficient credit assessment and risk management system, prompting more capital to flow to green technology projects. This capital inflow accelerates the technology research and development process and promotes rapid commercialization and large-scale application of the technology. Green technology innovations in agriculture enhance the efficiency and quality of agricultural production and significantly reduce the negative impact of agricultural activities on the environment. The adoption of these innovations makes agricultural production more environmentally friendly and helps reduce greenhouse gas emissions, water consumption and soil degradation. This is consistent with the worldwide movement towards green development and establishes a robust basis for the sustainable development of the agricultural industry.

Therefore, with the aid of digital inclusive finance, green technological innovations in agriculture spur agricultural technological advancement and support the green transformation and sustainable growth of the agricultural industry. This model that combines financial and technological innovations creates a new direction for the future development of agriculture. Accordingly, this study introduces Hypothesis 3:

H3: The moderate effect of agricultural green technological innovation and the enhancement of agricultural green technological innovation promote the green development of agriculture.

**4.4 Threshold effect analysis**

When exploring the impact of digital inclusive finance (DIF) on agricultural green development, we should recognize that this impact is complex and multidimensional. As the level of DIF continues to rise, its facilitating effect on agricultural green development may experience a shift from slow growth to significant acceleration. Before a certain threshold is reached, although DIF has begun to play a role, its effect may not be as pronounced as it is after the threshold, which may be due to the fact that the construction of digital infrastructure is still in its early stages or that agricultural producers are less receptive to new technologies. Once the threshold is crossed, the advantages of DIF in empowering the greening of agriculture will become more apparent. By providing farmers with appropriate financial services, DIF can help farmers better manage their money and invest in sustainable agricultural technologies and applications, such as water-saving irrigation projects, the use of organic fertilizers, and biological control such as pests and diseases. In addition, DIF can help farmers optimize their cropping structure through big data analytics to improve the efficiency of crop cultivation and reduce environmental pollution. However, this threshold effect also suggests that if the promotion and application of DIF fails to reach a certain level, its enhancement of agricultural green development may be small. For this reason, policymakers and relevant institutions need to take some measures to ensure that digital infrastructure can be steadily built, while improving farmers' knowledge and ability to use digital inclusive finance, in order to maximize the release of DIF's potential in promoting green development in agriculture. Accordingly, Hypothesis 4a is formulated in this study:

H4a: The impact of DIF on agricultural green development has a threshold effect, and different development stages of DIF determine the threshold.

Income effect and technology adoption lifecycle theory in economics suggest that as income increases, both consumer and producer behaviors shift, especially in adopting new technologies and sustainable practices. In agriculture, this is evident as rising rural incomes enhance the capacity and willingness of rural residents to adopt Digital Inclusive Finance (DIF) services, thus promoting agricultural greening. Empirical analyses have revealed the time-varying characteristics of rural financial development and rural economic progress from the perspective of rural economic development and farmers' incomes (Xia et al., 2019). Other studies have detailed the threshold effect of financial development in promoting sustainable agriculture, emphasizing its close correlation with increases in rural residents' per capita disposable income (Yiting, 2022). Using a threshold effect model, researchers examined the impact of DIF on improving China's agricultural productivity and protecting rural ecosystems (Chang, 2022). The comprehensive results of these studies indicate a significant threshold effect of DIF on high-quality agricultural development. Accordingly, we propose Hypothesis 4b:

H4b: DIF impacts the green development of agriculture in a stage-wise manner, with the enhancement effect becoming evident over time. This effect's emergence is determined by the different per capita disposable income levels of rural populations.



**Figure 1.Logical framework for theoretical analysis**

1. **Research design**

**5.1 Baseline regression model**

A fixed effects model was used in this study to test hypothesis 1 as shown in equation (1):

$ GAD\_{it}=β\_{0}+β\_{l}DIF\_{it}+β\_{k} Control \_{it}+μ\_{i}+γ\_{t}+ε\_{it}$$(1)$

Equation (1) defines GADit as the green development of agriculture for province i in year t. DIFit is the index of digital inclusive finance for province i during the same period. Control refers to the control variables that might affect the results. μi and γt are the fixed effects for province and year, respectively, while εit is the error term.

**5.2 Mediation model**

In order to test the impact mechanism, the mediation model is as follows:

$\begin{matrix} DIR\_{it}=α\_{0}+α\_{1}DIF\_{it}+α\_{k} Control \_{it}+μ\_{i}+γ\_{t}+ε\_{it} (2)\\ GAD\_{it}=θ\_{0}+θ\_{l}DIF\_{it}+θ\_{2}DIR\_{it}+θ\_{k} Control \_{it}+μ\_{i}+γ\_{t}+ε\_{it} (3)\end{matrix}$

The development level of the digital village is represented by DIRit, which acts as the mediating variable. α and θ are the respective coefficients, with μi and γt denoting the fixed effects for province and year. εit stands for the random error term.

**5.3 Moderating effect model**

This study constructs a moderating effects model to investigate the moderating role of agricultural green technology innovation (AGTI).

$$GAD\_{it}=β\_{0}+β\_{1}DIF\_{it}+β\_{2}AGTI\_{it}+β\_{3}AGTI\_{it}×DIF\_{it}+β\_{k}Control\_{it}+μ\_{i}+γ\_{t}+ε\_{it} (4)$$

The presence of a moderating effect depends on the significance level of the interaction term.

**5.4 Threshold effect model**

In order to explore the diversity of the impact of digital inclusive finance (DIF) on green agricultural development (GAD), this study skillfully introduces two threshold variables - the development level of digital inclusive finance (DIF) and rural disposable income per capita (RDPI). This study seeks to uncover whether the effects of DIF on GAD differ at various developmental stages of digital inclusive finance and different income levels among rural residents. Based on this, this study constructs the following threshold model in order to accurately capture these potential nonlinear relationships:

$$GAD\_{it}=λ\_{0}+λ\_{1}DIF\_{it}×I(DIF\_{it}\leq η\_{1})+λ\_{2}DIF\_{it}×I(η\_{1}<DIF\_{it}<η\_{2})+λ\_{3}DIF\_{it}×I(DIF\_{it}>η\_{3})+λ\_{k}Control\_{it}+μ\_{i}+γ\_{t}+ε\_{it } (5)$$

$GAD\_{it}=ρ\_{0}+ρ\_{1}DIF\_{it}×I(RDPI\_{it}\leq ω\_{1})+ρ\_{2}DIF\_{it}×I(η\_{1}<RDPI\_{it}<ω\_{2})+ ρ\_{3}DIF\_{it}×I(RDPI\_{it}>ω\_{3})+ρ\_{k}Control\_{it}+ε\_{it } (6)$

DIF and RDPI denote two threshold variables: the level of digital financial inclusion development and the disposable income per capita of rural residents, respectively; I (\*) denotes the indicator function of the threshold model, and I is 1 if the condition in parentheses is true, and 0 otherwise.

**5.5 variable selection**

Dependent variable: green agricultural development (GAD) is the core explanatory variable of this paper. In this study, through the review of the literature related to green agriculture and eco-agriculture (Bhatnagar et al.,2022; Struik et al., 2017), 14 indicators were selected after comprehensive consideration to measure the level of green development of agriculture in terms of efficient use (efu), resource conservation (rec), environmental quality (enq), ecological protection (ecp), and green living (grl), and the positivity and negativity of each indicator are shown in Table 1.

**Table 1.The indicator system for green agricultural development**

|  |  |  |  |
| --- | --- | --- | --- |
| Dimensions | Indicators | Indicator attribute | Unit |
| *efu* | Added value of primary industry | ＋ | Billion |
| agricultural productivity | ＋ | % |
| *rec* | socialization of agricultural production | ＋ | % |
| Agricultural Mechanization | ＋ | Kilowatt hours/hectare |
| Effective irrigation rate | ＋ | % |
| Water consumption per unit of agricultural output value | － | Cubic meter/yuan |
| *enq* | Application intensity of agricultural fertilizers | － | Tons/hectare |
| Pesticide usage intensity | － | Tons/hectare |
| Agricultural film usage intensity | － | Tons/hectare |
| *ecp* | Area of soil erosion control | ＋ | hectares |
| Flood control area | ＋ | hectares |
| forest coverage | ＋ | % |
| *grl* | Number of rural doctors and healthcare workers | ＋ | ten thousand people |
| Popularity rate of sanitary toilets | ＋ | % |

Dependent variable: digital inclusive finance index (DIF). This study uses the Digital Inclusive Finance Index (DIF) calculated by Peking University for the period 2011-2021 to measure the DIF.The index consists of three dimensions: breadth of coverage (coverage\_breadth), depth of use (usage\_depth), and digitization level (digitization\_level).

Mediating variables: (1) Digital village development level (DIR), measured as the ratio of rural broadband access to rural population. The higher the ratio, the better the development of the digital village.

Moderating variable: agricultural green technology innovation level (AGTI). Currently, scholars use different indicators to measure agricultural technology innovation activities, such as revenue from new product sales or patents. Given that this study focuses on agricultural green technology innovation, patent data can more accurately reflect the technological field characteristics of innovation activities compared to new product sales revenue and help attribute innovation activities to the green agricultural field. In order to comprehensively measure the level of agricultural green technology innovation in each region, this study refers to previous scholars' studies (Li., 2023) and selects four key indicators. These include the number of applications for agricultural green invention patents, the number of agricultural green invention patents granted, the number of applications for agricultural green utility model patents, and the number of agricultural green utility model patents granted. Refer to Table 2 for the specific indicators.

**Table 2.Index system for agricultural green technology innovation**

|  |  |  |  |
| --- | --- | --- | --- |
| Dimensions | Indicators | Indicator attribute | Unit |
| Application quantity | Number of agricultural green invention patent applications | ＋ | Piece |
| Number of agricultural green invention patents authorized | ＋ | Piece |
| Authorized quantity | Number of agricultural green utility model patent applications | ＋ | Piece |
| Number of agricultural green utility model patents authorized | ＋ | Piece |

Threshold variables: two indicators, Digital Inclusive Finance Index (DIF) and Rural Disposable Income per Capita (RDPI), are used instead of threshold variables.

Control variables: (1) Agricultural industry agglomeration(LQ), expressed by using the quotient obtained by dividing the ratio of the agricultural output value of a province (city) to the GDP of the province (city) by the ratio of the national agricultural output value to the national GDP. The larger the location entropy index, the higher the degree of agricultural industry agglomeration. The specific formula is as follows:

$$ LQ＝（N\_{ij}/M\_{ij}）/（N\_{j} /M\_{j}） (7) $$

In equation (7), LQ is the industrial industrial agglomeration level of each province and city, Nij is the agricultural output value of province (city) i, Mij is the gross product of province (city) i, Nj represents the national agricultural output value, and Mj represents the national gross domestic product.

1. Calculate the industrialization level (INDL) using the ratio of industrial value added to the gross domestic product of each region. (3) Industrial structure (IS) is expressed using the proportion of value added of the secondary industry in each province to each province's GDP. (4) Urbanization level (URBL), expressed as the proportion of total urban population. (5) Agricultural-related expenditures (ARPO), using the fiscal expenditures consumed by each province to support the development of agriculture, rural areas and farmers.

**5.6 Data Sources**

Given the availability of data and the observability of the findings, this study uses provincial panel data for China from 2011-2021. Data on green agricultural development are from the China Agricultural Yearbook, China Rural Statistics Yearbook, and provincial statistical yearbooks. About digital inclusive finance comes from the Digital Inclusive Finance Index of Peking University. Mediating variables, moderating variables, threshold variables, and control variables are from provincial statistical yearbooks, China Population and Employment Statistical Yearbook, China Statistical Yearbook, National Bureau of Statistics, EPS database, and National Research Network, respectively. Descriptive statistics are given in Table 3 below.

**Table 3.Descriptive Statistics**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  Variable |  Obs |  Mean |  Std. Dev. |  Min |  Max |
|  *GAD* | 330 | 0.25 | 0.104 | 0.077 | 0.628 |
|  *DIF* | 330 | 2.315 | 1.033 | 0.183 | 4.59 |
|  *LQ* | 330 | 1.229 | 0.742 | 0.042 | 4.364 |
| *INDL* | 330 | 0.321 | 0.082 | 0.101 | 0.556 |
|  *IS* | 330 | 0.492 | 0.091 | 0.326 | 0.841 |
|  *URBL* | 330 | 0.597 | 0.116 | 0.429 | 0.868 |
| *ARPO* | 330 | 5.614 | 2.767 | 0.918 | 13.394 |
|  *LANG* | 330 | 0.433 | 0.172 | 0.172 | 1.233 |
|  *INBA* | 330 | 0.106 | 0.089 | 0.004 | 0.428 |
| *usage\_depth* | 330 | 2.268 | 1.058 | 0.068 | 5.107 |
| *digitization\_level* | 330 | 3.01 | 1.174 | 0.076 | 4.622 |
|  *RDPI* | 330 | 1.332 | 0.59 | 0.428 | 3.852 |
|  *AGTI* | 330 | 0.112 | 0.134 | 0 | 0.767 |
|  *DIRi* | 330 | 0.148 | 0.121 | 0.007 | 0.509 |
|  *HUCL* | 330 | 0.02 | 0.006 | 0.008 | 0.042 |

**5.7 Empirical Results**

**5.7.1 Benchmark regression**

The results of the benchmark regression analysis, as shown in Table 4, investigate the impact of digital financial inclusion on agricultural green development. The Hausman test strongly rejects the original hypothesis, indicating that a fixed effect model is appropriate. The empirical results reveal that the coefficient for digital financial inclusion is consistently positive and significant at a 1% significance level, supporting Hypothesis 1. This implies a significant positive relationship between the growth of digital financial inclusion and agricultural green development. On the one hand, digital financial inclusion simplifies farmers' access to loans and other financial products through the provision of convenient financial services, and promotes farmers' investment in green agricultural technologies such as water-saving irrigation, organic fertilizers, and renewable energy systems, thereby increasing the sustainability of agricultural production. On the other hand, digital financial inclusion improves the transparency and efficiency of the agricultural supply chain. Consumers can easily identify and purchase green agricultural products through digital platforms, which motivates farmers to adopt green production methods and raises environmental standards in the supply chain. Additionally, the development in digital inclusive finance has contributed to improving farmers' financial knowledge and hastening the transition to green agriculture.

As illustrated in column (6) of Table 4, the coefficients for agricultural industry agglomeration, the level of urbanization, and expenditures related to agriculture are significantly positive, indicating that advancements in these aspects favor agricultural green development. On the other hand, the coefficients for the level of industrialization and the industrial structure are -0.117 and -0.279, respectively, both statistically significant, suggesting an inhibitory effect on agricultural green development.

**Table 4.Benchmark Regression**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) | (5) | (6) |
| *DIF* | 0.065\*\*\* | 0.075\*\*\* | 0.054\*\*\* | 0.042\*\* | 0.062\*\*\* | 0.068\*\*\* |
|  | (0.017) | (0.019) | (0.020) | (0.019) | (0.020) | (0.019) |
| *LQ* |  | 0.008\* | 0.008 | 0.007\* | 0.011\*\* | 0.010\*\* |
|  |  | (0.005) | (0.006) | (0.004) | (0.004) | (0.004) |
| *INDL* |  |  | -0.130\*\*\* | -0.200\*\*\* | -0.173\*\*\* | -0.117\*\*\* |
|  |  |  | (0.037) | (0.034) | (0.036) | (0.038) |
| *IS* |  |  |  | -0.314\*\*\* | -0.297\*\*\* | -0.279\*\*\* |
|  |  |  |  | (0.060) | (0.062) | (0.058) |
| *URBL* |  |  |  |  | 0.177\*\* | 0.131\* |
|  |  |  |  |  | (0.082) | (0.079) |
| *ARPO* |  |  |  |  |  | 0.006\*\*\* |
|  |  |  |  |  |  | (0.001) |
| Province FE | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES |
| \_cons | 0.100\*\*\* | 0.067 | 0.157\*\*\* | 0.362\*\*\* | 0.190\* | 0.147 |
|  | (0.038) | (0.046) | (0.057) | (0.063) | (0.101) | (0.097) |
| *N* | 330 | 330 | 330 | 330 | 330 | 330 |
| adj. *R*2 | 0.968 | 0.968 | 0.969 | 0.973 | 0.973 | 0.975 |

Standard errors in parentheses

\* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01(the same below)

**5.72 Heterogeneity Analysis**

*5.721 Regional Heterogeneity Examination*

This research explores the regional heterogeneity in the influence of digital inclusive finance on agricultural green development by dividing the geographic distribution of 30 Chinese provinces and municipalities into Eastern, Central, and Western regions. Table 5 indicates that there are considerable regional differences in how digital inclusive finance affects agricultural green development. Specifically, the impact of digital inclusive finance on agricultural green development in the Central region is not significant, possibly due to the lack of targeted policy support and efficient financial services, which limits its promotion and application. In contrast, in both the Eastern and Western regions, the coefficients for digital inclusive finance are significantly positive. This may be attributed to the geographic advantages and resource endowments of the Eastern region, as well as the benefits the Western region gains from national strategies such as the "Belt and Road" initiative. These factors collectively provide favorable conditions for the development of digital inclusive finance, thereby promoting agricultural green development.

Further, the study divides the 30 provinces and municipalities into Northern and Southern regions based on geographical location. In the Northern region, empirical results indicate that digital inclusive finance significantly promotes agricultural green development. The climate and natural resources of the Northern region may be more suitable for certain green agricultural technologies, such as water-saving irrigation and greenhouse farming, providing abundant application scenarios for digital inclusive finance. However, in the Southern region, due to differences in climate conditions and natural resources, the application of green agricultural technologies may face more challenges, which could affect the promotion and operation of digital inclusive finance.

**Table 5.Test of regional heterogeneity**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (1) | (2) |
|  | Eastern | Central | Western | Northern  | Southern |
| *DIF* | 0.078\* | 0.044 | 0.098\*\*\* | 0.087\*\*\* | -0.004 |
|  | (0.040) | (0.040) | (0.034) | (0.022) | (0.025) |
| Control | YES | YES | YES | YES | YES |
| Province FE | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES |
| \_cons | -0.014 | 0.315 | 0.157 | -0.061 | 0.413\*\*\* |
|  | (0.213) | (0.258) | (0.105) | (0.124) | (0.136) |
| *N* | 121 | 88 | 121 | 165 | 165 |
| adj. *R*2 | 0.976 | 0.973 | 0.964 | 0.987 | 0.965 |

**5.73 Heterogeneity Analysis of Grain Distribution**

Based on the "National Medium- and Long-term Plan for Grain Security (2008-2020)", the sample is classified into three types: major grain-producing regions, major grain-consuming regions, and grain-production-consumption balanced regions. The regression analysis results of these types are detailed in Table 6.

The study of the relationship between digital inclusive finance and agricultural green development in China shows significant differences among different grain distribution regions. Particularly in major grain-producing areas, there is a significant positive correlation between digital inclusive finance and agricultural green development. This indicates that major grain-producing regions often have larger agricultural production scales and higher market concentration, which helps to form economies of scale and market effects. By reducing financing costs for farmers and improving the efficiency of fund usage, digital inclusive finance can drive the standardization and specialization of agricultural production, thereby accelerating the adoption of green agricultural technologies. In major grain-consuming areas, there is a negative correlation between digital inclusive finance and agricultural green development, but it is not significant. This may be because major grain-consuming regions are primarily consumption areas with intense market competition and significant price pressures. Farmers might prioritize short-term profit maximization, opting for traditional agricultural production methods that are cost-effective but potentially more harmful to the environment, rather than investing in more expensive but environmentally friendly green technologies.

Moreover, in areas where grain production and consumption are balanced, digital inclusive finance exerts a significant positive effect on agricultural green development. A plausible explanation is that these regions, typically located between production and consumption areas, enjoy a favorable geographic position. This location allows farmers to better grasp market dynamics and adjust production strategies in a timely manner, providing greater motivation to adopt green agricultural technologies to meet market demands.

**Table 6.Test of the heterogeneity of food distribution**

|  |  |  |  |
| --- | --- | --- | --- |
|  | (1) | (2) | (3) |
|  | Main production area | Main sales area | Balance of production and sales area |
| *DIF* | 0.078\* | -0.026 | 0.110\*\*\* |
|  | (0.041) | (0.042) | (0.034) |
| Control | YES | YES | YES |
| Province FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| \_cons | 0.451\*\* | 0.211 | 0.236\*\* |
|  | (0.213) | (0.291) | (0.105) |
| *N* | 143 | 77 | 110 |
| adj. *R*2 | 0.965 | 0.970 | 0.965 |

**5.74 Heterogeneity Analysis of Land Quality**

The study divides the sample into high-quality and low-quality land using the median level of land quality to analyze the impact of digital inclusive finance on agricultural green development across different land quality conditions. The empirical analysis in Table 7 shows that in regions with lower land quality, digital inclusive finance has a positive but not significant impact on agricultural green development. This could be because the productivity of low-quality land is limited, and even with financial support from digital inclusive finance, the inherent constraints of the land may hinder the effective application of green agricultural technologies. For example, issues such as poor soil fertility and insufficient water resources may limit the effectiveness of these technologies. Conversely, in regions with higher land quality, the impact of digital inclusive finance on agricultural green development is significantly positive and remains significant at the 1% level. This could be due to better ecological conditions typically associated with high-quality land, such as fertile soil, ample water resources, and favorable climate, all of which are crucial for efficient agricultural production. Under these conditions, green agricultural technologies, such as precision irrigation, the use of organic fertilizers, and eco-friendly crop protection methods, can be more effectively applied, thereby improving crop yield and quality.

**Table 7.Heterogeneity of land quality levels**

|  |  |  |
| --- | --- | --- |
|  | (1) | (2) |
|  | Low land quality  | High land quality |
| *DIF* | 0.023 | 0.092\*\*\* |
|  | (0.024) | (0.033) |
| Control | YES | YES |
| Province FE | YES | YES |
| Year FE | YES | YES |
| \_cons | 0.206\*\* | 0.003 |
|  | (0.085) | (0.172) |
| *N* | 165 | 165 |
| adj. *R*2 | 0.970 | 0.977 |

**5.75 Mechanism Test**

Table 8 displays the results of the mediation effect test. Column (1) shows that the coefficient of digital inclusive finance is 0.068 and is significant at the 1% level, indicating that digital inclusive finance can drive agricultural green development. Column (2) shows that the coefficient of digital inclusive finance is significantly positive, implying that digital inclusive finance has a positive effect on the level of digital village development as well. Column (3) shows that the level of digital village development has a significantly positive effect on agricultural green development. These results suggest that the level of digital village development partially mediates the relationship between digital inclusive finance (DIF) and agricultural green development, supporting hypothesis H2. By improving the level of digital village development, digital inclusive finance enhances the informatization and intelligence of agricultural production. This, indirectly promotes agricultural green development by increasing resource utilization efficiency and reducing environmental pollution.

**Table 8.Influence Mechanism Test**

|  |  |  |  |
| --- | --- | --- | --- |
|  | (1) | (2) | (3) |
|  | *GAD* | *DIR* | *GAD* |
| *DIF* | 0.068\*\*\* | 0.116\*\* | 0.060\*\*\* |
|  | (0.019) | (0.046) | (0.019) |
| *DIR* |  |  | 0.068\*\* |
|  |  |  | (0.026) |
| Control | YES | YES | YES |
| Province FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| \_cons | 0.147 | -1.178\*\*\* | 0.227\*\* |
|  | (0.097) | (0.225) | (0.100) |
| *N* | 330 | 330 | 330 |
| adj. *R*2 | 0.975 | 0.900 | 0.975 |

**5.76 Moderation Effect Test**

According to the results of the moderation effect test in Table 9, column (1) demonstrates that digital inclusive finance significantly drives agricultural green development. In-depth analysis reveals that after introducing agricultural green technology innovation (AGTI) as a moderating variable in column (2), the coefficient of the interaction term (DIF×AGTI) is significantly positive and persists at a significance level of 10%. This indicates that agricultural green technology innovation plays a positive moderating role in the promotion of agricultural green development by digital inclusive finance. Specifically, the higher the level of agricultural green technology innovation, the stronger the promoting effect of digital inclusive finance on agricultural green development. Higher levels of agricultural green technology innovation can more fully leverage the funds, information, and other resources offered by digital inclusive finance, thus advancing agricultural green development more efficiently. This finding supports hypothesis H3 of this study, which posits that agricultural green technology innovation positively moderates the impact of digital inclusive finance on agricultural green development.

**Table 9.Moderation Effect Test**

|  |  |  |
| --- | --- | --- |
|  | (1) | (2) |
| *DIF* | 0.042\*\*\* | 0.029\* |
|  | (0.016) | (0.016) |
| *AGTI* | 0.083\*\*\* | -0.019 |
|  | (0.019) | (0.055) |
| *DIF×AGTI* |  | 0.027\* |
|  |  | (0.015) |
| Control | YES | YES |
| Province FE | YES | YES |
| Year FE | YES | YES |
| \_cons | 0.193\*\* | 0.220\*\* |
|  | (0.087) | (0.088) |
| *N* | 330 | 330 |
| adj. *R*2 | 0.977 | 0.977 |

**5.77 Threshold Effect Test**

This study employs the Bootstrap method with 300 resamples to investigate the threshold effects of digital inclusive finance (DIF) and rural residents' per capita disposable income (RDPI) on agricultural green development. The results in Table 10 show that the p-values for single, double, and triple thresholds of DIF are 0.0000, 0.0067, and 0.3433, respectively. For RDPI, the p-values for single, double, and triple thresholds are 0.0033, 0.0067, and 0.2200, respectively. These results indicate that there is a significant double threshold effect of DIF on agricultural green development when considering both DIF and RDPI.

**Table 10.DIF and the threshold effect of RDPI**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Values | Threshold | RSS | MSE | Fstat | Prob | Crit10 | Crit5 | Crit1 |
| DIF | Single | 0.0786 | 0.0002 | 70.14 | 0.0000 | 19.1537 | 22.9899 | 35.8051 |
| DIF | Double | 0.0737 | 0.0002 | 21.20 | 0.0067 | 10.4384 | 12.8166 | 18.2586 |
| DIF | Triple | 0.0718 | 0.0002 | 8.31 | 0.3433 | 13.8525 | 15.6636 | 21.8264 |
| RDPI | Single | 0.0772 | 0.0002 | 77.16 | 0.0033 | 26.6166 | 33.9961 | 61.4909 |
| RDPI | Double | 0.0697 | 0.0002 | 34.49 | 0.0067 | 17.3325 | 20.7975 | 28.7799 |
| RDPI | Triple | 0.0668 | 0.0002 | 13.61 | 0.2200 | 20.2025 | 25.5116 | 37.8190 |

**5.78 Threshold Effect Regression Analysis**

Table 11 presents the threshold effect regression analysis results for digital inclusive finance (DIF) and rural residents' per capita disposable income (RDPI). Both DIF and RDPI exhibit two thresholds, dividing the effects into three intervals.

In the first interval (DIF ≤ 2.6682), the coefficient is 0.010. In the second interval (2.6682<DIF< 3.3203), the coefficient is 0.015. In the third interval (DIF≥ 3.3203), the coefficient is 0.021. This indicates that as the level of DIF increases, its positive influence on agricultural green development intensifies. After surpassing the first threshold, this influence becomes more pronounced. This phenomenon can be explained by the initial stages where the penetration and depth of digital financial services might be insufficient, and farmers’ adaptation to new financial tools needs improvement. As DIF develops and especially after crossing the first threshold, its positive impact on agricultural green development significantly strengthens. In the second interval (2.6682<DIF<3.3203), the coefficient rises to 0.015, showing the potential of digital inclusive finance in promoting the adoption of green agricultural technologies and sustainable practices begins to be realized. This enhancement could be related to the expansion of geographical coverage of financial services, financial product innovation, and the improvement of farmers' financial literacy. When DIF reaches and exceeds the second threshold (DIF≥3.3203), its impact coefficient further increases to 0.021, indicating that the supporting role of digital inclusive finance in agricultural green development reaches a new height. This significant impact at this stage may be due to the deepening of digital financial services, including broader market access, more efficient resource allocation, and stronger risk management capabilities, collectively accelerating the green transformation in agriculture. Thus, hypothesis H4a is validated.

In the first interval (RDPI≤1.4512), the coefficient is 0.007. In the second interval (1.4512<RDPI<1.9217), the coefficient is 0.013. In the third interval (RDPI> 1.9217), the coefficient is 0.021. This indicates that as the level of rural residents' per capita disposable income increases, the positive effect of DIF on agricultural green development strengthens. After surpassing the first threshold (RDPI≤1.4512), this effect becomes significant. This phenomenon can be explained by the limited role of DIF in agricultural green development at early stages of lower income levels. As income levels rise to the second interval (1.4512<RDPI<1.9217), the coefficient increases to 0.013, indicating that with higher purchasing power, rural residents are better able to utilize digital financial tools, thereby promoting the adoption of green agricultural technologies. When RDPI further increases and exceeds 1.9217, the coefficient rises to 0.021, showing significant growth. This suggests that higher disposable income makes rural residents more likely to invest in green agricultural practices, allowing DIF to play a larger role. This change reflects the economic theory that income growth leads to an upgrade in consumption structure. Therefore, hypothesis H4b is confirmed.

**Table 11.Threshold Model Estimation Results**

|  |  |  |
| --- | --- | --- |
| Variant | GAD | GAD |
| DIF·I （DIF≤2.6682）DIF·I （2.6682＜DIF＜3.3203）DIF·I （DIF≥3.3203） | 0.010\*\* |  |
| (0.005) |  |
| 0.015\*\*\* |  |
| (0.005) |  |
| 0.021\*\*\* |  |
| (0.005) |  |
| DIF·I （RDPI≤1.4512）DIF·I （1.4512＜RDPI＜1.9217）DIF·I （RDPI＞1.9217） |  | 0.007 |
|  | (0.005) |
|  | 0.013\*\*\* |
|  | (0.005) |
|  | 0.021\*\*\* |
|  | (0.005) |
| Control | YES | YES |
| Province FE | YES | YES |
| Year FE | YES | YES |
| -cons | 0.264\*\*\* | 0.176\*\* |
| (0.063) | (0.065) |
| adj. *R*2 | 0.798 | 0.809 |

**5.79 Sensitivity Analysis**

*5.791 Replacement of explanatory variables*

In this study, two variables, usage\_depth as well as digitization\_level, are used to re-measure digital financial inclusion to ensure the accuracy of the results. The results in columns (1) and (2) of Table 12 show that the coefficients of usage\_depth as well as digitization\_level are positive and significant after replacing the measures of digital financial inclusion index. Hypothesis 1 is again confirmed.

Excluding special regional interference

Taking into account that the levels of digital inclusive finance (DIF) and agricultural greening in the four directly governed municipal regions of China might differ from other areas, this study excludes samples from these regions and re-conducts the regression analysis. The results are shown in column (3) of Table 12. The coefficient of DIF is 0.091 and is significant at the 1% level, reaffirming the robustness of the baseline results.

*5.792 Addition of control variables*

In order to ensure the stability and reliability of the results, this study reduces the effects of model bias and confounding variables by introducing an additional control variable, human capital level (HUCL), in order to better control for other factors that may affect the results of the study. The results are shown in column (4) of Table 12.The coefficient of DIF is 0.077 and remains significant, proving the robustness of the baseline regression.

**Table 12.Sensitivity Analysis**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) |
|  | Replacement of core explanatory variables | Replacement of core explanatory variables | Excluding municipalities | Add variable |
| usage\_depth | 0.020\*\* |  |  |  |
|  | (0.010) |  |  |  |
| digitization\_level |  | 0.025\*\*\* |  |  |
|  |  | (0.006) |  |  |
| DIF |  |  | 0.091\*\*\* | 0.077\*\*\* |
|  |  |  | (0.024) | (0.019) |
| HUCL |  |  |  | 2.478\*\* |
|  |  |  |  | (1.004) |
| Control | YES | YES | YES | YES |
| Province FE | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES |
| \_cons | 0.319\*\*\* | 0.263\*\*\* | 0.326\*\*\* | 0.130 |
|  | (0.080) | (0.072) | (0.102) | (0.095) |
| *N* | 330 | 330 | 286 | 330 |
| adj. *R*2 | 0.974 | 0.975 | 0.975 | 0.975 |

*5.793 Quantile regression*

In order to thoroughly investigate the asymmetric effects of digital inclusive finance (DIF), this study performed regression analysis at the 25%, 50%, and 75% quartiles. The regression results are displayed in Table 13. The findings indicate that DIF is significantly positively correlated at all quartiles, which aligns with the baseline results.

**Table 13.Quantile Regression**

|  |  |  |  |
| --- | --- | --- | --- |
|  | (1) | (2) | (3) |
|  | Q25 | Q50 | Q75 |
| DIF | 0.047\*\*\* | 0.064\*\* | 0.038\*\* |
|  | (0.013) | (0.031) | (0.018) |
| Control | YES | YES | YES |
| Province FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| \_cons | 0.211\*\*\* | 0.279\* | 0.281\*\*\* |
|  | (0.064) | (0.151) | (0.086) |
| *N* | 330 | 330 | 330 |

**5.8 Endogeneity testing**

The common endogeneity problems are categorized into three main issues: omitted variable bias, data measurement error and reverse causation. Regarding the endogeneity problem that may arise from omitted variable bias, this study has selected as many shocks affecting agricultural carbon emissions as possible, which mitigates the endogeneity problem caused by omitted variable bias to a certain extent. To avoid the endogeneity problem caused by other factors, this study first adopted explanatory variables lagged by one order, because the impact of digital inclusive finance (DIF) on agricultural green development may have a time lag. This study lagged the regression analysis of DIF by one cycle to ensure the accuracy of the regression results. The results in column (1) of Table 14 show that the coefficient of the first-order lag term is significantly positive, confirming Hypothesis 1. Secondly, This paper adopts the instrumental variable method, referring to previous scholars' studies, and selects the number of Internet broadband access subscribers as the instrumental variable (Xie et al., 2021), and applied the two-stage least squares (2SLS) method to test the model. The test results of the instrumental variables are shown in columns (2)-(3) of Table 14. When the number of Internet broadband access subscribers (INBA) is selected as the instrumental variable, the coefficient of DIF remains significantly positive. The Kleibergen-Paap rk LM statistic for the second-stage regression model is 27.575 with a p-value of 0.000 and the Cragg-Donald Wald F statistic is 30.670, which is much greater than 10, indicating that the instrumental variable is valid, so there is no weak instrumental variable and no unidentifiable situation. By excluding the influence of endogeneity problems, the above test results show that the conclusion that digital financial inclusion promotes agricultural green development still holds, which further underscores the robustness of the study's conclusions.

Considering the inertia of changes in agricultural green development, i.e., the historical level of development may affect the current effect, a dynamic panel model is constructed by introducing a lag term of the explanatory variable agricultural green development on the basis of Equation (1). The introduction of this lag term helps to mitigate the effect of potential omitted variables in the baseline model and reduce the model setting error. To address the endogeneity problem of the introduced lag term, the system GMM strategy is applied. The AR(1) and AR(2) results of the system GMM prove that there is no autocorrelation of the perturbation term, while the Hansen test confirms that all instrumental variables are valid, and these results confirm the appropriateness of the model and analytical approach. The positive impact of digital financial inclusion on agricultural green development is significant, which aligns with the results of the benchmark regression, indicating that the benchmark model is less affected by the endogeneity problem, and the results of the benchmark regression are robust. The estimation results of the system GMM test are presented in column (4) of Table 14.

**Table 14.Endogeneity Test**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) |
|  | First order lag | 2SLS(IV1) | 2SLS(IV2) | System GMM |
| *L.DIF* | 0.046\*\* |  |  |  |
|  | (0.021) |  |  |  |
| *DIF* |  |  | 0.459\*\*\* | 0.081\*\* |
|  |  |  | (0.079) | (0.037) |
| *L.GAD* |  |  |  | 0.830\*\*\* |
|  |  |  |  | (0.143) |
| *INBA* |  | 0.707\*\*\* |  |  |
|  |  | (0.116) |  |  |
| AR（1） |  |  |  | 0.054 |
| AR（2） |  |  |  | 0.489 |
| Hansen |  |  |  | 0.761 |
| Cragg-Donald Wald F statistic |  |  | 30.670 |  |
| Kleibergen-Paap rk Wald F statistic |  |  | 37.265 |  |
| Kleibergen-Paap rk LM statistic |  |  | 27.575\*\*\* |  |
| Control | YES | YES | YES | YES |
| Province FE | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES |
| \_cons | 0.235\*\* | 4.280\*\*\* | -1.003\*\*\* | -0.128 |
|  | (0.094) | (0.210) | (0.296) | (0.114) |
| *N* | 300 | 330 | 330 | 300 |
| adj. *R*2 | 0.976 | 0.997 | 0.931 | / |

1. Conclusions and recommendations

**6.1 Conclusions**

Using China's provincial panel data from 2011-2021, this study thoroughly analyzes the mechanism of the impact of digital inclusive finance (DIF) on agricultural green development. The conclusions are as follows: 1. DIF has a significant promoting effect on agricultural green development. In the regional heterogeneity analysis, the eastern, western and northern regions show a significant positive correlation between DIF and agricultural green development. In the food function heterogeneity analysis, DIF in the main production area and the production and marketing balance area are also strongly positively correlated with agricultural green development. In the analysis of land quality heterogeneity, DIF promotes agricultural green development more significantly under high land quality conditions. 2. DIF promotes agricultural green development by accelerating the construction of digital infrastructure in rural areas. 3. The study also identifies a moderating effect; that is, the enhancement of agricultural green technological innovations accelerates the process of agricultural green development. 4. When DIF and per capita disposable income of rural residents are used as threshold variables, both show double threshold effects. 5. Various robustness tests were conducted, confirming the consistency and reliability of the study findings.

**6.2 Recommendations**

1.Increase investment in digital inclusive finance. Governments should establish special funds to support the development of digital inclusive finance projects, especially in the promotion and application of green technologies in agriculture. Additionally, governments should encourage financial institutions to collaborate with agricultural technology companies to develop customized financial products to meet the financial needs of agricultural green transformation. Policymakers should promote the popularization and application of digital technologies, such as through establishing rural informatization service centers, providing technical support and training to help farmers use digital tools for agricultural production management, thereby improving the efficiency and sustainability of agricultural production.

2.Promote agricultural green technology innovation. The government and financial institutions should take advantage of digital financial inclusion and integrate resources through digital platforms to support the research, development and promotion of smart agricultural equipment, precision agricultural technologies and eco-friendly agricultural practices. In addition, incentives, such as R&D subsidies and preferential market access, should be provided to encourage enterprises and research institutions to develop and apply agricultural green technologies. By establishing demonstration bases for agricultural green technologies and showcasing and promoting successful green agricultural practices, farmers' awareness and acceptance of green technologies can be enhanced, accelerating the green transformation of agricultural production methods. By providing a convenient financing channel, digital inclusive finance not only promotes the green transformation of agricultural production methods, but also enhances the resilience and productivity of agricultural ecosystems through information sharing and risk management, achieving harmonious development of the agricultural economy, society, and environment.

3.Strengthen farmers' education on digital financial inclusion. Financial institutions should conduct regular financial education programs for farmers, aiming to improve their awareness and ability to use digital inclusive financial tools, and to ensure that they can safely and effectively use these tools for financing and risk management. At the same time, they should establish farmers' financial service centers to provide advisory and guidance services to help farmers better understand and utilize digital inclusive financial products. In addition, through regular financial literacy trainings and seminars in cooperation with educational institutions and non-governmental organizations, 3. Improve farmers' financial literacy and enhance their financial decision-making capacity.

4.Increase the per capita disposable income of rural residents. Farmers should be empowered to invest in green agricultural practices and further promote green agriculture through measures such as agricultural subsidies, price support and improved rural infrastructure. At the same time, diversified economic development in rural areas, such as the development of rural tourism, handicraft production and agricultural product processing, should be supported in order to increase farmers' non-farm sources of income. In addition, establishing and improving the rural financial service system and providing more financial products and services will help farmers to expand the scale of their production and operations, thereby raising their income levels.

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