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How can rural digital development activate agricultural land mobility? -Based on the dual perspectives of resource mismatch and labor mobility

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Introduction: Agricultural land transfer is crucial for achieving labor mobility and rational allocation of resources. The digital development of rural areas provides a new way to solve the dilemma of low level of agricultural land transfer in China.

Method: This article empirically tests the impact and mechanism of rural digital development on agricultural land transfer using a two-way fixed effects model and a mediation effects model, based on balanced panel data from 30 provinces in China from 2006 to 2023.

Conclusion: Firstly, the digital development of rural areas has significantly improved the transfer of agricultural land, and this impact is sustainable. After endogeneity and robustness tests, the results still hold true. Secondly, heterogeneity analysis found that the digital development of rural areas has a more significant impact on agricultural land transfer in central and western regions, the Yangtze River Economic Belt, provinces with lower levels of economic development and total factor productivity. Thirdly, mechanism analysis reveals that rural digital development improves agricultural land circulation by alleviating labor mismatch, land mismatch, and capital mismatch. At the same time, the digital development of rural areas has accelerated labor mobility and improved agricultural land transfer.

Discussion: The development of digital development in rural areas has a "latecomer advantage" and can balance regional imbalances. This article provides theoretical guidance for the relationship and future development between rural digital development and agricultural land transfer.

KEYWORDS

rural digital development, agricultural land transfer, labor mismatch, land mismatch, capital mismatch, labor flow

1 Introduction

China's rural areas have long been characterized by structural features such as small-scale land management and spatial distribution fragmentation. More than 90 per cent of the country's farming households operate on less than 10 acres of arable land, indicating that the current rural production pattern of small-scale farmers is still dominant (Zhu et al., 2025), leading to greater constraints on agricultural operations in terms of the efficiency of resource allocation, economies of scale and market responsiveness. Especially in the context

of agricultural modernization and high-quality development, the structural contradiction between "small farmers" and "big market" is becoming more and more prominent, which is not conducive to the realization of the core objectives of agricultural science and technology promotion, standardized production of agricultural products and the extension of the industrial chain (Aker, 2010; Aker, 2010). To address challenges in rural land use, the state has steadily advanced reforms to the rural land system. These efforts include reinforcing land ownership rights, improving the land transfer market, and encouraging the consolidation of land into the hands of agricultural operators with stronger managerial capabilities and technical expertise. According to the National Bureau of Statistics, agricultural land transfers in China increased substantially from 0.58 billion mu in 2004 to 532 million mu by 2020, indicating early progress in the market-oriented reform of land use rights. Nevertheless, the pace of growth in land transfers has slowed in recent years, suggesting ongoing issues within the rural land transfer market. These include weak alignment with labor migration across regions, the growing variety of agricultural business models, and broader development demands—factors that continue to hinder effective resource allocation and exacerbate the problem of land-use inefficiencies caused by the separation of people from land. In this context, the rapid development of digital technology to crack the inefficient allocation of agricultural land factors provides a new opportunity. Specifically, big data technology integrates land resources, farmer information, and market supply and demand data to achieve precise matching and price prediction of land supply and demand, significantly improving the efficiency and transparency of land transfer; Blockchain technology, with its decentralized and tamper proof characteristics, provides security guarantees for land ownership information registration, contract execution, and transaction traceability, enhancing the credibility of transactions; The Internet of Things technology utilizes sensors, remote sensing equipment, and other means to achieve real-time monitoring and dynamic management of land use status, ensuring the effective utilization of land resources; Artificial intelligence and intelligent algorithms can achieve intelligent matching, credit evaluation, and risk prediction between land supply and demand in the land information platform, improving transaction efficiency and reducing transfer risks; At the same time, the land transfer service platform and digital government system based on mobile Internet have widened the participation channels of farmers, lowered the transfer threshold, and stimulated the vitality of the rural land market. The comprehensive application of these digital technologies, from information symmetry, transaction matching to contract supervision, runs through the entire process of land transfer, providing solid support for building an efficient, transparent, and fair rural land transfer system. Along with the new round of scientific and technological revolution and industrial change, the digital economy has gradually become a key force to reshape the agricultural development model and enhance the efficiency of resource allocation. The 20th CPC National Congress clearly proposed to "accelerate the development of the digital economy and promote the deep integration of the digital economy with the real economy," pointing out the direction for the wide application of digital technology in the field of agriculture and rural areas. Given the obvious shortcomings in information infrastructure, digital talent and technology application in rural areas, especially in central and western and remote provinces, rural digital development has been elevated to a national strategic priority. Since 2018, when "vigorously developing digital agriculture" was first explicitly proposed, the central government has included digital rural areas as a key task in the "No. 1 Document" for five consecutive years, and has successively issued the "Outline of the Digital Rural Development Strategy," the "Plan for the Development of Digital Agriculture and Rural Areas (The Outline of Digital Rural Development Strategy, the Plan for Digital Agriculture and Rural Development (2019–2025), and the Key Points for Digital Rural Development in 2022 have been issued successively, forming a more systematic top-level design and strategic deployment. The digital development of rural areas can not only reshape the production organization and factor allocation logic of agriculture, but will also improve the relationship between supply and demand of agricultural land and stimulate the internal vitality of the land market by optimizing the flow of information, shortening the transaction chain, and improving the matching efficiency (Pirannejad and Janssen, 2019). While promoting the flow and efficient allocation of agricultural land, it also injects a lasting impetus for the realization of rural revitalization and the integrated flow of urban and rural factors, and provides institutional support and technical paths for the realization of the goal of common prosperity.

In recent years, with the rise of a new wave of digitalization, advanced information technologies such as big data, blockchain, and the Internet of Things have accelerated their penetration in the agricultural and rural fields, providing a practical path and technical support for solving the long-standing problems of information asymmetry, unclear property rights, and low transaction efficiency in agricultural land transfer. Among them, big data technology constructs an intelligent supply-demand matching platform through real-time integration and analysis of multidimensional data such as massive land resources, farmer attributes, market prices, and climate conditions. For example, some areas in Shandong rely on the "rural property rights trading platform + data center" model to achieve dynamic tracking and visual scheduling of village level land transfer information, significantly improving the efficiency of land supply and demand matching and market transparency. Blockchain technology, with its "decentralized" and "traceable" characteristics, has demonstrated unique advantages in land ownership confirmation, contract signing, and transfer transaction record management. Taking Deqing, Zhejiang Province as an example, the local pilot project of "blockchain + rural land ownership confirmation" embeds key data such as land ownership information, transfer contracts, and payment records into the chain, achieving verifiability and immutability of the entire transfer process, greatly enhancing the transaction trust between farmers and lessees. In addition, IoT technology has also played a key role in the management and utilization of land transfer. By deploying soil sensors, unmanned aerial vehicle monitoring systems, and agricultural meteorological stations, the cultivation status, input-output, irrigation and fertilization information of the transferred land can be collected in real time and fed back to land operators and regulatory agencies, achieving precise control and intelligent supervision of land use. In Jiangsu, Guangdong and other places, farmers rely on IoT systems for "remote agricultural management,"

greatly improving the efficiency of land use and the level of intensive agricultural management. The deep integration of these technologies not only optimizes the allocation of land elements, but also reshapes the operational logic of agricultural land transfer, providing solid digital support for China's agricultural modernization and rural revitalization.

At present, there are still fewer studies on the relationship between rural digital development and agricultural land transfer. Existing literature mostly focuses on the significance of the construction of digital villages, implementation paths and promotion strategies, as well as the construction of relevant indicator systems (Peng, 2019; Wang et al., 2021; Wen, 2022), and explores its association with digital divide (Cui and Feng, 2020), farmers' income (Qi et al., 2021), and high-quality development of rural areas (Xianli et al., 2019). Meanwhile, scholars have also focused on specific dimensions such as digital governance (Shen and Chen, 2021) and digital literacy (Chang Ling amidships, 2021). However, studies focusing on the direct relationship between rural digital development and agricultural land transfer are still relatively limited, mainly focusing on the specific application of digital technology in land transfer. In addition, some studies have explored the role of digital inclusive finance in land transfer transactions, pointing out that it helps to promote land transfer by alleviating information asymmetry and improving financial literacy (Zhang, 2022). The popularization of the Internet has also received widespread attention, and studies have shown that farmers' access to the Internet can significantly increase the likelihood of land transfer (Wenquan et al., 2022; Zhang and Zhang, 2020; Zhang et al., 2022; Cai et al., 2022). In addition, emerging technologies such as big data and artificial intelligence have also been shown to have a positive effect in enhancing the efficiency of land transfer (Liu et al., 2021). Despite the gradual increase in research on digital countryside and land transfer, the literature that systematically explores the relationship between the two is still insufficient, especially lacking in empirical analysis from a holistic perspective. Therefore, the purpose of this paper is to empirically examine the direct impact of rural digital development on agricultural land transfer and its functioning mechanism, so as to provide theoretical support and policy reference for promoting the development of digital countryside and land transfer practice.

The three innovations of this article are mainly reflected in the following aspects: firstly, based on balanced panel data from 30 provinces in China from 2006 to 2023, the direct impact of rural digital development on agricultural land transfer is empirically tested, and the reliability and sustainability of the results are ensured through endogeneity and robustness tests. Secondly, through heterogeneity analysis, the differential impact of rural digital development on agricultural land transfer under different regions, economic development levels, and productivity conditions has been revealed, enriching the existing theoretical research on regional differences in the effects of rural digital development. Thirdly, from the perspective of the mismatch of labor, land, and capital, a deep analysis was conducted on how rural digital development can improve the efficiency of agricultural land transfer by optimizing resource allocation and promoting factor flow. A theoretical innovation was proposed that rural digital development has a "latecomer advantage."

The other structural arrangements of the article are as follows: the second part is theoretical analysis and research hypotheses; Part Three: Data Sources and Empirical Design; Part Four: Empirical Results Analysis; Further analysis in the fifth part; Part Six Research Conclusions and Policy Recommendations; The seventh part is about research limitations and future research directions.

2 Theoretical analysis and research hypothesis

2.1 Rural digital development and agricultural land transfer

Agricultural land transfer is crucial for advancing agricultural modernization, optimizing rural resource allocation, and improving production efficiency. However, the process is often hindered by factors such as information asymmetry, complex transactions, and a lack of institutional frameworks, which limit its efficiency and scale. In traditional rural societies, the dissemination of land transfer information is restricted, and the transaction process lacks standardized procedures, increasing uncertainty and risk for farmers, thus discouraging participation in land transfer (Gao-Li et al., 2025).

With the in-depth implementation of the national "Digital China" strategy, the digital development of rural areas is an important part of it, and the gradual improvement of digital infrastructure in rural areas, the increasing popularization of digital technology, and the continuous expansion of digital public services provide new opportunities to solve the key bottlenecks restricting the transfer of agricultural land (Zhou et al., 2025). The construction of digital platforms and the promotion of agricultural information systems have enhanced the transparency and availability of rural land supply and demand information, shortened the information transmission chain, and effectively alleviated the information asymmetry between the two parties to the transaction. At the same time, the application of digital technological means such as blockchain and geographic information system in land ownership registration and contract management has improved the degree of standardization and security of land transactions, and reduced the transaction costs in the transfer process (Zhang et al., 2024). In addition, the onlineization of government services, financial resources and legal aid promoted by digital villages has broadened farmers' access to policy support, financing channels, and risk prevention and control tools, and further enhanced their willingness and ability to participate in the land transfer process (Su et al., 2023). This transformation not only optimizes the operating environment of the land market, but also provides institutional support for the construction of a standardized, efficient and transparent rural land transfer system.

2.2 Rural digital development, labor mismatch, and agricultural land transfer

Hypothesis 1: Rural digital development can significantly improve the level of agricultural land transfer.

TABLE 1 Construction of indicators for rural digital development

Level 1 indicators	Level 2 indicators	Definition of indicators	Weights
Digital Rural Infrastructure Development	Rural Logistics Coverage	Rural delivery routes/km	0.0337
	Logistics infrastructure investment	Fixed asset investment in transportation, storage and postal industry/billion yuan	0.0430
	Internet infrastructure development	Rural broadband access users/ten thousand	0.0829
	Agro-meteorological Observation Stations	Agricultural meteorological observation station/pc5	0.0242
Digital economization of the countryside	Level of agricultural digitization	Scale of digital agriculture/billion yuan	0.1095
	Rural E-commerce	Taobao village/one	0.1018
	Talent Support for Digital Rural Construction	Total economic enterprises and institutions specialized in agricultural technology professionals and technicians	0.0382
	Digital Technology Service	Employment in Information Transmission, Software and Information Technology Service Industry	0.0856
	E-commerce infrastructure capital investment	Local Financial Transportation Expenditure/billion yuan	0.0272
	Digital Finance Development Level	Digital Inclusive Finance Index	0.0816
Digitizing Rural Governance	Digital Rural Governance Capital Supply	Local Finance Urban and Rural Community Affairs Expenditure	0.0470
	E-government development level	Online government service capacity of provincial governments	0.0930
	TV Penetration Rate	Comprehensive population coverage rate of rural TV programs/%	0.0054
	Radio Penetration Rate	Comprehensive population coverage rate of rural radio programs/%	0.0048
Digitization of Rural Life	Information Service Consumption Level	Rural residents' *per capita* consumption expenditure on transportation and communication/Yuan	0.0312
	Information Technology Services	Total amount of telecommunication services/yuan	0.0925
	Smartphone Penetration Rate	Average number of cell phones per 100 rural households/unit	0.0991

Labor mismatch is a key structural issue that hinders the effective circulation and optimal use of agricultural land resources. This problem is evident in the persistence of a large number of low-efficiency workers in agriculture and rural regions, leading to underutilization of land and dampening both the motivation and scale of land transfer (Wang and Ran, 2022). Traditionally, barriers such as limited information access, inadequate employment services, and uneven urban-rural development restrict rural labor mobility, preventing the efficient reallocation of human capital across regions and industries (Wang and Ran, 2022).

The progress of rural digitalization offers a practical approach to addressing mismatches in rural labor allocation. On one side, digital platforms, online job services, and vocational training programs provide rural workers with more diverse and efficient means of accessing non-agricultural employment opportunities, thereby improving their capacity to seek jobs beyond their hometowns (Zhu et al., 2025). On the other side, the widespread adoption of digital infrastructure has strengthened the digital competence and information accessibility of rural residents, enabling households to respond more swiftly and adaptively to external labor market changes. Moreover, the digitization of public services and the refinement of social security systems have reduced institutional constraints on labor mobility, increasing farmers' willingness to leave agriculture without severing ties with their native communities (Liu, Weijiang and Hao, 2025). As labor outmigration accelerates, some rural residents withdraw from farming, freeing up land and boosting the supply of transferable land parcels. This facilitates the scaling up of land transfers and invigorates land markets. Consequently, the digital transformation of rural areas not only optimizes labor distribution across regions and sectors but also indirectly fosters land circulation through increased population mobility and the restructuring of production factors (Man-Yu and Xiao-Xing, 2022).

Hypothesis 2: Rural digital development promotes the level of agricultural land transfer by alleviating labor mismatch.

2.3 Rural digital development, land mismatch, and agricultural land transfer

Land mismatch is one of the important manifestations of the current low efficiency of agricultural resource allocation in China, which is specifically reflected in the irrational allocation of arable land resources, the rising proportion of abandoned land, and the serious fragmentation of land. TThe root causes lie in multiple factors such as information asymmetry, unclear land ownership, lack of transaction channels, and inconsistent perceptions of land use value among agricultural operators (Sun et al., 2022).

On the one hand, with the help of remote sensing, geographic information system (GIS) and other digital technologies, the precise identification and dynamic monitoring of land resources are realized, so that idle land and inefficiently utilized land can be incorporated into the transfer market in a timely manner; on the other hand, the digital platform enhances the visualization of land resources and the transparency of the transfer of land resources, and reduces the cost of matching between the supply and demand of land and the friction of the transaction (Huang and Ni, 2023). Therefore, rural digital development helps to alleviate the land mismatch problem by improving access to land information, enhancing the efficiency of land allocation, and optimizing the transfer mechanism, thus indirectly promoting the level of agricultural land transfer (Chen and Zhang, 2022).

Hypothesis 3: Rural digital development promotes the improvement of agricultural land transfer by alleviating land factor mismatch and thus promoting the improvement of agricultural land transfer.

2.4 Rural digital development, capital mismatch, and agricultural land transfer

Capital mismatch is one of the important factors restricting the efficient operation of the rural factor market, which is mainly manifested in the problems of insufficient supply of capital in the agricultural sector, restricted financing channels and the disconnection between the distribution of capital and actual demand. In the process of agricultural land transfer, operating entities often find it difficult to undertake new land due to insufficient capital, and potential land suppliers are reluctant to transfer land due to concerns about the lessee's lack of management ability, which in turn inhibits the activity of the land market and the scale of transfer (Chen et al., 2024).

The development of rural digital infrastructure has become a pivotal driver in mitigating capital mismatches within the agricultural sector by accelerating the digital transformation of rural financial systems. On the supply side, the widespread application of digital technology has significantly expanded the coverage of inclusive financial services, enabling agricultural entities to obtain more diversified and efficient financing channels *via* online platforms, thus easing capital constraints. Simultaneously, the integration of big data, artificial intelligence, and blockchain empowers financial institutions to conduct more precise assessments of farmers' credit profiles, land asset values, and operational capacities. This advancement enhances decision-making in credit allocation, optimizes risk management frameworks, and improves the efficiency of rural financial resource distribution. Moreover, the digital convergence of governmental and financial services further promotes the effective allocation and accessibility of agriculture-related funds, strengthening farmers' financial resilience and risk-bearing capacities in land transfer processes (Guo, 2024). Therefore, rural digitalization not only enhances financial accessibility and allocative efficiency but also fundamentally alleviates financing bottlenecks in agricultural production, thereby fostering the viability and sustainability of farmland transfer practices (Shen and Chen, 2021).

Hypothesis 4: Rural digital development contributes to the level of agricultural land mobility by mitigating capital mismatch and thus promoting agricultural land mobility.

2.5 Rural digital development, labor mobility, and agricultural land transfer

Labor mobility is one of the key drivers of agricultural land transfer. As the rural population transfers from agriculture to non-agricultural industries, the original farmers are no longer directly

TABLE 2 Variable definition table.

Symbol	Variable	Variable definition
fd	Agricultural land transfer	The ratio of the transferred area of household contracted farmland to the total area of household contracted farmland
dig	Rural digitalization	The entropy method is used to calculate the four dimensions of digital rural infrastructure, digitalization of rural economy, digitalization of rural governance, and digitalization of rural life
lre	Mismatch of land resources	$lre = (\frac{lre_i}{lre})/(\frac{s_i\beta_{ai}}{\beta_a})$
kre	Mismatch of capital resources	$kre = (\frac{kre_i}{kre})/(\frac{s_i\beta_{ai}}{\beta_k})$
bre	Mismatch of labor resources	$bre = (\frac{bre_i}{bre})/(\frac{s_i\beta_{ai}}{\beta_l})$
lab	migration	The proportion of employees in the secondary and tertiary industries to the total employed population in society
gdp	Per capita GDP	The regional GDP of each province divided by the number of permanent residents in the local area
rpo	Proportion of rural population	The proportion of rural population to the total number of permanent residents at the end of the year
wag	Proportion of agricultural water use	The proportion of total agricultural water consumption in the total social water consumption
dag	Degree of agriculturalization	The ratio of agricultural added value to regional gross domestic product
med	Agricultural machinery density	The ratio of total power of agricultural machinery to agricultural added value
psi	Proportion of primary industry	The ratio of added value of the primary industry to that of the secondary and tertiary industries

engaged in agricultural production, and their land resources holdings are gradually idled or inefficiently utilized, turning into the transfer market. This process not only releases the land supply, but also provides opportunities for specialized and large-scale agricultural management subjects to expand production, thus promoting the concentration and efficient use of agricultural land.

In this context, the advancement of rural digitalization has greatly facilitated labor mobility in rural areas by accelerating the establishment of information networks and expanding access to digital services (Cui and Feng, 2025). On the one hand, digital technologies have expanded rural laborers' access to non-farm employment information and improved their docking efficiency with the urban job market; on the other hand, digital platforms have lowered the cost of job matching and enhanced diversified forms of employment such as skills training, remote employment, and flexible employment (Liang et al., 2024). In addition, the digitization of government affairs and the improvement of the social security system have lowered the institutional barriers for migrant laborers in inter-regional migration, helping to increase their stability and willingness to go out for employment. As the rural labor force continues to move to the urban or non-farm sector, the separation of agricultural producers and land users has intensified, thus promoting farmers to transfer idle land to agricultural management bodies and realize the intensive use of land (Wang and Sun, 2023).

Hypothesis 5: Digital rural development indirectly enhances the level of agricultural land transfer by promoting rural labor mobility.

3 Research design

3.1 Variable selection

3.1.1 Explained variable

Agricultural land transfer (fd). This paper uses the ratio of the area transferred out of family-contracted cropland to the total area of family-contracted cropland area to measure agricultural land transfer. The use of this measure has strong scientific and rationality. This is because: first of all, the ratio can reflect the proportion of farmland owned by farmers for transfer, which can more accurately reflect the actual degree of land transfer, avoiding the scale bias brought about by the absolute area measurement. Secondly, measuring in the form of ratio can eliminate the interference caused by the differences in the total amount of contracted arable land among farmers, and make different farmers comparable to each other, which is convenient for horizontal comparison. Finally, this indicator can reveal the behavioral choices of farmers in the allocation of their own land resources, which helps to deeply understand the economic motivation and institutional influence behind their transfer behaviors. Therefore, the choice of this ratio indicator is both representative and practical, and also helps to improve the accuracy of land transfer research.

3.1.2 Explanatory variables

Current research lacks consensus on the evaluation system for rural digital development, with both single and composite indicators being employed. Single-index measurements often rely on variables such as the number of mobile devices used by farmers, while composite indices are typically constructed using methods like the entropy value approach or principal component analysis. Drawing on the methodologies of Lin et al. (2023) and Lei et al. (2023), this study establishes a multidimensional framework for assessing rural digital development across four aspects: digital infrastructure, digitalization of the rural economy, digital governance, and digital lifestyle. Based on data accessibility, 17 secondary indicators were selected and quantified using the entropy method. The construction of digital rural indicators is shown in Table 1.

3.1.3 Intermediary variable

3.1.3.1 Resource mismatch

From the perspective of resource factor allocation in the agricultural field, this paper focuses on the mediating role that agricultural resource factor mismatch may play between rural digital development and agricultural land transfer. Considering the diversity and structural characteristics of resource inputs in the agricultural production process, this paper classifies resource mismatches in three dimensions: i.e., land resource mismatch (lre), capital resource mismatch (kre) and labor resource mismatch (bre). This categorization aims to reveal more comprehensively the possible structural distortions in agricultural resource allocation and their potential impact on agricultural efficiency. In order to improve the scientificity and operability of the index, the construction of the resource mismatch index draws on the calculation method proposed by Chen et al. (2022), on the basis of which appropriate adjustments are made to better fit the data structure and analytical framework of the current study. The specific calculation methods for the indices are shown in Equations 1–3:

$$\mathrm{lre} = \left(\frac{\mathrm{lre_i}}{\mathrm{lre}}\right) \Big\backslash \left(\frac{\mathrm{s_i}\beta_{\mathrm{ni}}}{\beta_{\mathrm{n}}}\right) \tag{1}$$

$$\mathrm{kre} = \left(\frac{\mathrm{kre_i}}{\mathrm{kre}}\right) \Big\backslash \left(\frac{\mathrm{s_i}\beta_{\mathrm{ki}}}{\beta_{\mathrm{k}}}\right) \tag{2}$$

$$\mathrm{bre} = \left(\frac{\mathrm{bre_i}}{\mathrm{bre}}\right) \Big\backslash \left(\frac{\mathrm{s_i}\beta_{\mathrm{li}}}{\beta_{\mathrm{l}}}\right) \tag{3}$$

In this study, $\mathrm{s_i}\beta_{\mathrm{ni}}$, $\mathrm{s_i}\beta_{\mathrm{ki}}$, $\mathrm{s_i}\beta_{\mathrm{li}}$ are used to measure the input proportion of agricultural resource factors under optimal allocation, corresponding to the three categories of land, capital and labor, respectively. These parameters reflect the reasonable proportion that each resource should occupy under the condition of efficiency maximization. Meanwhile, the proportion of province i's agricultural output in the national agricultural output is also introduced into the model to reflect its relative importance in the national agricultural production. All the agricultural output data involved have been substantively adjusted by the GDP deflator to eliminate the interference of price changes and ensure the comparability of the data. In addition, $\beta_{\mathrm{ni}}, \beta_{\mathrm{ki}}, \beta_{\mathrm{li}}$ denote the output elasticities of land, capital, and labor, respectively, and these elasticity parameters are obtained through the estimation of the Cobb-Douglas production function, reflecting the marginal contribution of each factor to agricultural output. In order to measure the actual allocation of resources in each province, $\frac{\mathrm{lre_i}}{\mathrm{lre}}, \frac{\mathrm{kre_i}}{\mathrm{kre}}, \frac{\mathrm{bre_i}}{\mathrm{bre}}$ are also used to indicate the share of the province's land, capital, and labor inputs in the national total of the

TABLE 3 Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
fd	360	32.706	16.883	3.353	91.111
dig	360	0.123	0.094	0.015	0.659
gdp	360	5.868	3.063	1.602	18.999
rpo	360	0.399	0.121	0.104	0.65
wag	360	0.596	0.182	0.065	0.952
dag	360	0.032	0.041	0.003	0.159
med	360	0.652	0.235	0.252	1.387
psi	360	0.112	0.068	0.002	0.348

corresponding factor inputs. Specifically, land resources are measured by the sown area of crops, capital is measured by the agricultural capital stock, which is estimated by the Perpetual Inventory Method (PIM), and labor resources are represented by the number of people employed in agriculture, which reflects the actual level of manpower inputs in each province. This method helps to systematically analyze the spatial distribution of agricultural resource mismatch and its impact mechanism.

3.1.3.2 Labor mobility (lab)

Labor force mobility is measured using the ratio of employees in secondary and tertiary industries to the total employed population of the society in the statistical yearbooks of each province and city. There is a strong rationality in using this ratio for measurement. In the process of China's economic structural transformation, the transfer of labor from the primary industry to the secondary and tertiary industries is the main manifestation of the flow of agricultural labor, and is also an important symbol for measuring the degree of non-agriculturalization of the rural labor force, urban-rural integration, and industrial upgrading. Compared with other measurement methods, this indicator can reflect more intuitively the trend of labor transfer from traditional agricultural sector to non-agricultural industry in each region, which in turn reflects the optimization degree of labor resources allocation.

Labor force mobility is assessed through the proportion of workers engaged in secondary and tertiary sectors relative to the total employed population, based on data from provincial and municipal statistical yearbooks. This metric is highly appropriate, as during China's economic restructuring, a key indicator of agricultural labor migration is the shift from primary to secondary and tertiary industries. It also serves as a crucial measure of rural labor non-agriculturalization, urban-rural integration, and industrial advancement. Compared with alternative metrics, this ratio offers a clearer depiction of regional labor movement away from agriculture toward non-agricultural sectors, thereby highlighting the efficiency of labor resource allocation. The variable definition table is shown in Table 2.

Table 3 presents the descriptive statistical results of the variables, reflecting significant differences in rural digital development and agricultural land transfer between provinces. The average agricultural land transfer rate (fd) is 32.71%, but the maximum value is as high as 91.11% and the minimum is only 3.35%, indicating that there is a significant difference in the level of land transfer activity among different regions; The average value of the Digital Development Index (Digi) for rural areas is 0.123, with a standard deviation of 0.094, indicating a relatively low overall development level and significant regional imbalances in development. The average *per capita* regional gross domestic product (GDP) is 5.868, indicating uneven levels of economic development across different regions. The average proportion of rural population (rpo) is 39.9%, and agriculture still has a large population base. The average proportion of agricultural water use (wag) is 59.6%, indicating a strong dependence on water resources in agriculture; The degree of agriculturalization (dag) is relatively low, averaging only 3.2%; The density of agricultural machinery (med) and the proportion of the primary industry (psi) also show significant fluctuations. Overall, there is strong regional heterogeneity among variables, providing a solid mathematical foundation for subsequent analysis of how rural digital development affects agricultural land transfer.

3.2 Model building

3.2.1 Baseline regression model

In order to empirically analyze the actual effects of rural digital development on agricultural land transfer, this paper constructs and adopts a fixed-effects regression model that includes both time and individual dimensions. The model helps to accurately identify the effects brought about by rural digital development on the basis of controlling time-invariant individual characteristics and cross-individual invariant time factors. The specific measurement model setting is shown in Equation 4:

$$fd_{i,t} = \beta_1 dig_{i,t} + \beta_2 gdp_{i,t} + \beta_3 rpo_{i,t} + \beta_4 wag_{i,t} + \beta_5 dag_{i,t} + \beta_5 med_{i,t} + \beta_6 psi_{i,t} + u_i + \varrho_t + \alpha + \varepsilon_{i,t} \quad (4)$$

Where $fd_{i,t}$ is the explanatory variable of this paper, i.e., agricultural land transfer, $dig_{i,t}$ is the explanatory variable of this paper, i.e., denotes digital rural construction, and the other variables are the selected control variables, u_i denotes the individual fixed effect, which is used to eliminate the effect of heterogeneity that is invariant across the research objects in the dimension of time, and ϱ_t denotes the time fixed effect, which controls for the macro temporal factors that do not change with the region and affect all the observed objects such as policies, economic cycles, *etc.*, α denotes a constant term, and $\varepsilon_{i,t}$ denotes a random perturbation term to reflect other random influences that cannot be explained by the model and is used to describe the error component.

3.2.2 Mediation effects model

In order to deeply study how rural digital development affects the internal mechanism of agricultural land transfer, this paper further introduces a mediated effects model to analyze the possible intermediate transmission paths. This paper draws on Wen (2014) view that the traditional single mediation effect test method has certain limitations and is prone to biased estimation or insufficient significance. Therefore, this paper introduces a more advanced mediation effect test strategy based on the classic mediation test method of Baron and Sobel. This method has

TABLE 4 Benchmark regression results of digital rural construction on agricultural land transfer.

Variables	(1)	(2)
	fd	fd
dig	29.66***	23.90**
	(2.806)	(2.194)
gdp		−1.585*
		(−1.796)
rpo		119.6***
		(3.242)
wag		−13.71
		(−0.995)
dag		21.63
		(0.671)
med		−0.0397
		(−0.00697)
psi		−16.57
		(−0.343)
Individual fixed effects	Yes	Yes
time fixed effect	Yes	Yes
Constant	17.64***	−23.27
	(17.60)	(−1.257)
Observations	360	360
R-squared	0.677	0.725

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

significant advantages in statistical performance: on the one hand, it can improve the statistical efficacy (power) of the estimation results, thus enhancing the model identification ability; on the other hand, it can effectively control the first type of error rate (i.e., misjudging the existence of the mediation effect) and the second type of error rate (i.e., failing to find the real mediation effect), so as to improve the accuracy and reliability of the test. Based on the above considerations, this paper constructs the following regression modeling system, which is used to investigate the mechanism of rural digital development affecting agricultural land transfer. The specific econometric model settings are shown in Equations 5, 6:

$$lre_{i,t}/kre_{i,t}/bre_{i,t}/lab_{i,t} = \beta_1 dig_{i,t} + \beta_2 Z_{i,t} + u_i + \varrho_t + \alpha + \varepsilon_{i,t} \quad (5)$$

$$fd_{i,t} = \beta_1 dig_{i,t} + \sigma_1 lre_{i,t}/kre_{i,t}/bre_{i,t}/lab_{i,t} + \beta_2 Z_{i,t} + u_i + \varrho_t + \alpha + \varepsilon_{i,t} \quad (6)$$

where $lre_{i,t}, kre_{i,t}, bre_{i,t}, lab_{i,t}$ denote land resource mismatch, capital resource mismatch, labor resource mismatch, and labor mobility, respectively. The remaining variables are consistent with the benchmark regression.

In the above model setting, variables $lre_{i,t}$、$kre_{i,t}$、$bre_{i,t}, lab_{i,t}$ represent different dimensions of resource mismatch and labor force mobility, respectively: where $lre_{i,t}$ is used to measure land resource mismatch, $kre_{i,t}$ reflects capital factor mismatch, $bre_{i,t}$ indicates labor force resource mismatch, and $lab_{i,t}$ depicts the volume co-composition of labor force between urban and rural representations of the domain, and the rest of the control variables in the model are set to remain consistent with the baseline regression model for controlling the individual fixed effects, time trends and other key factors that may affect rural land use efficiency to ensure the robustness and explanatory power of the results.

3.3 Data sources

In order to ensure the availability and integrity of data, this paper selects the panel data of 30 provinces in Chinese Mainland (excluding Hong Kong, Macao, Taiwan and Xizang Autonomous Region) from 2006 to 2023, and constructs a research sample with a long time span and wide regional distribution. The collected data covers the output and input in the agricultural field, resource allocation status, and multiple control variables. Among them, the total output value of agriculture, forestry, animal husbandry, and fishery mainly comes from the "Statistical Yearbook of the Third Industry," while the input-output data and control variables related to agricultural production are respectively taken from the "China Statistical Yearbook" and the "China Rural Statistical Yearbook." To compensate for the lack of indicator data for some years and provinces, this article further consulted the statistical yearbooks of various provinces and the statistical bulletins publicly released by the government for supplementation and verification, in order to improve the coverage and consistency of the data. In terms of data processing, considering that price changes may affect the comparability of data between different years, this article uniformly uses 2010 as the base year to adjust the GDP deflator index for all variables related to prices or output values, converting them into actual values measured at constant prices in 2010, in order to more accurately reflect the actual fluctuation trend and economic structural characteristics of variables. This series of processing measures has laid a solid data foundation for subsequent empirical analysis.

4 Empirical result analysis

4.1 Baseline regression resultse

This section conducts an empirical analysis of how rural digital development influences agricultural land transfer, employing a two-way fixed effects model. Table 4 presents the regression outcomes. In column (1), without control variables, rural digital development shows a significantly positive effect on land transfer at the 1% significance level. Column (2), which includes control variables, still demonstrates a positive and significant coefficient at the 5% level, confirming that digitalization in rural areas contributes meaningfully to promoting land transfer. This effect

TABLE 5 Regression results of the impact of digital countryside construction on the sustainability of agricultural land transfer.

Variables	(1)	(2)	(3)	(4)	(5)
	fd	fd	fd	fd	fd
L.dig	31.89***				
	(2.929)				
L2.dig		44.14***			
		(3.483)			
L3.dig			59.63***		
			(3.924)		
L4.dig				83.10***	
				(4.390)	
L5.dig					124.4***
					(5.448)
gdp	−1.780**	−1.923**	−1.801*	−1.642	−0.967
	(−2.058)	(−2.083)	(−1.884)	(−1.603)	(−1.163)
rpo	126.0***	123.7***	110.4**	104.4*	41.96
	(3.388)	(2.994)	(2.300)	(1.775)	(0.668)
wag	−15.00	−21.33*	−20.29	−15.16	−9.571
	(−1.127)	(−1.763)	(−−1.675)	(−1.232)	(−0.817)
dag	25.88	29.58	28.75	20.35	10.25
	(0.792)	(0.901)	(0.917)	(0.615)	(0.343)
med	1.672	5.285	6.530	7.297*	14.54***
	(0.330)	(1.085)	(1.601)	(2.032)	(3.170)
psi	−28.68	−41.34	−34.70	−14.54	9.580
	(−0.591)	(−0.865)	(−0.693)	(−0.254)	(0.166)
Constant	−20.35	−10.83	−2.927	−3.904	9.873
	(−1.099)	(−0.574)	(−0.151)	(−0.179)	(0.452)
Individual fixed effects	Yes	Yes	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	330	300	270	240	210
R-squared	0.680	0.606	0.498	0.409	0.366

can be largely attributed to the enhanced transparency and efficiency brought by increased informatization. firstly, digital technology promotes the accurate management of agricultural land information. Through big data, cloud computing, Internet of Things and remote sensing technology, rapid monitoring, assessment and recording of land resources can be realized, providing reliable data support for agricultural land transfer. Second, the digital platform breaks down information barriers and shortens the information docking cycle between supply and demand. Farmers and investors can quickly release and obtain land transfer information on the digital platform to enhance the efficiency of land transfer. In addition, the application of blockchain and other technologies increases the transparency and security of land transactions and reduces the conflicts that may arise in the process of land transfer. Finally, rural digital development optimizes the rural financial service system and provides financial support for agricultural land transfer, such as land management right mortgage, which further stimulates the vitality of land transfer. In summary, digital rural construction has realized the standardization, scale and market-oriented development of land transfer through technological empowerment, and significantly promoted the process of agricultural modernization. Prove that hypothesis 1 of this article holds true.

4.2 Sustained impact of rural digital development on agricultural land transfer

The previous section found that the digital development of rural areas has a significant improvement effect on agricultural land transfer. As is well known, the digital development of rural areas is a long-term construction process, and there may be lag effects in this process, which may have a sustained impact on the transfer of agricultural land. Therefore, this section empirically tests whether the digital development of rural areas has a sustained impact on the transfer of agricultural land. Table 5 presents the empirical results. From the empirical results in Table 5, it can be seen that the coefficients for the lag period of rural digital development from one to five are significant at the 1% level, indicating that rural digital development does have a sustained impact on agricultural land transfer. From the regression results of the lag period, it can be seen that the impact of rural digital development on agricultural land circulation shows a significant and continuous strengthening trend, reflecting the lag and cumulative effects of digital construction in activating the flow of land factors. This result reflects in terms of economic connotation that empowering agricultural land transfer with digital technology is not achieved overnight, but rather a gradual process from infrastructure construction to institutional reform and then to market behavior evolution. Firstly, in the short term, although the improvement of digital infrastructure and the initial establishment of platforms have increased the accessibility of land resource information, their impact on the decision-making of land supply and demand behavior still needs time to gradually manifest. Secondly, with the passage of time, the promotion of digitalization on the transfer of agricultural labor, improvement of resource mismatch, and standardization of transfer systems has gradually accumulated, thus releasing stronger promotional effects in the second, third, and even longer periods. For example, as farmers obtain more non-agricultural employment opportunities, their willingness to withdraw from land increases, and new business entities also have stronger land absorption capabilities supported by digital finance and platform matching, thereby promoting the steady expansion of transfer scale. In addition, the government's supervision and standardization of land transfer behavior through digital government systems also have obvious institutional lag characteristics, and it will take some time to translate into sustained improvement in transfer efficiency and farmer trust. Therefore, the digital development of rural areas, through multiple paths of information integration, institutional support, and behavioral incentives, has a sustained impact on the gradient enhancement of agricultural land circulation in multiple lag periods, demonstrating its strategic significance as an institutional infrastructure in the construction of rural land markets.

The main reason is that it has restructured the allocation of rural land resources. Firstly, the vigorous development of digitalization in rural areas, such as big data, blockchain, cloud computing, *etc.*, has made land resource information transparent, real-time, and accurate, providing a solid foundation for predicting the true value of agricultural land and more scientific circulation. Secondly, digital platforms have effectively broken down the information barriers between land supply and demand, achieving efficient integration and significantly improving the matching efficiency and market vitality of land transfer. At the same time, the government relies on digital government platforms to strengthen the supervision of land transfer behavior, promote process standardization and information traceability, and enhance the safety of land transfer and the trust of farmers. In addition, the embedding of digital finance, such as land management rights mortgage loans and other services, provides farmers with new financing channels, reduces economic pressure, and promotes the transformation of land circulation from passive to active. Finally, the digital development of rural areas has attracted new types of agricultural management entities to flow to rural areas, promoting the development of agriculture towards scale and intensification, and further stimulating the long-term stable demand for land transfer. In summary, the digital countryside has built a new ecology for the sustainable development of agricultural land circulation through multi-dimensional construction.

TABLE 6 Endogeneity test regression results.

Variables	(1)	(2)
	dig	fd
internet	0.0534***	
	(11.80)	
dig		61.54***
		(5.644)
gdp	0.0209***	1.090**
	(10.54)	(2.186)
rpo	−0.1120**	−45.36***
	(−2.34)	(−4.497)
wag	0.0737***	−20.27***
	(3.30)	(−5.994)
dag	0.339***	10.40
	(5.61)	(0.572)
med	0.0306**	−10.18***
	(2.64)	(−4.452)
psi	−0.2708***	13.67
	(−4.36)	(0.761)
Constant	−0.384	53.65***
	(−9.91)	(9.088)
Individual fixed effects	Yes	Yes
time fixed effect	Yes	Yes
Kleibergen Paaprk LM	139.212 [0.000]	
Cragg-Donald Wald F	247.505 [16.38]	
Observations	360	360
R-squared		0.657

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

TABLE 7 Indicator construction of rural digital development.

Primary indicators	Secondary indicators	Tertiary indicators	Definitions
Digital Rural Development	Rural Digital Infrastructure Development	Rural Internet Penetration	Rural broadband access subscribers/number of rural households
		Rural Smartphone Penetration Rate	Cell phone ownership per 100 rural households per year
		Agricultural Meteorological Observation Operations	Number of agricultural meteorological observation stations
	Digitalization of Rural Industries	Scale of Agricultural Digitization	Value added of digital economy in primary industry
		Agricultural digitalization transaction	Rural e-commerce sales and purchases
		Agricultural Production Investment Effort	Investment in fixed assets in agriculture, forestry, animal husbandry and fishery/total investment in social fixed assets
	Rural Digital Industrialization	Rural network payment level	Rural digital financial inclusion index
		Rural Information Technology Application	Average population served per business outlet
		Rural digital industry base	Number of Taobao villages

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

4.3 Endogeneity test

Although this paper can alleviate the possible endogeneity problem to a certain extent by selecting regional gdp *per capita*, rural population, and agricultural machinery density as control variables to be added into the model, the reverse causality between rural digital development and agricultural land transfer may also lead to endogeneity. On the one hand, there may be an endogeneity problem between rural digital development and agricultural land transfer (Shan et al., 2022). Agricultural land circulation may be affected by local digital infrastructure, digital village governance, and so on, and also affects the level of regional digitization, and there may be an interaction between the two. The rapid improvement of agricultural land transfer can easily obtain the economic effect of rural digital development, which can further promote agricultural land transfer. On the other hand, from the perspective of government governance, provinces with slower agricultural land flow receive more attention from the government and may receive more resources and digital governance information. Therefore, there may be an endogeneity problem between rural digital development and agricultural land transfer.

To address potential endogeneity, this study adopts the approach of Lin et al. (2023), using the average rural digital development level of neighboring provinces as an instrumental variable. Neighboring regions often share similar geographic, policy, and economic contexts, making their digital development levels correlated with that of the target province, thus satisfying the relevance condition. At the same time, their digital progress is unlikely to have a direct impact on the province's rural economic or social outcomes, fulfilling the exogeneity requirement. Therefore, this variable serves as a valid instrument for rural digital development.

Table 6 presents the regression outcomes of the endogeneity test. Column (1) reports the first-stage results, where the coefficient of the instrumental variable is significantly positive at the 1% level, confirming a strong association. Column (2) displays the second-stage regression, showing that both the null hypothesis of under-identification and the presence of weak instruments are rejected. Even after accounting for endogeneity, rural digital development continues to exhibit a significantly positive effect, aligning with the findings of the baseline regression.

4.4 Robustness tests

4.4.1 Replacement of explanatory variables

In the previous paper, we constructed the indicators of rural digital development from four dimensions, in order to have a more reasonable measurement, we refer to the research methods of Wang and Bai (2022) and Fan et al. (2025), and re-measure the rural digital development from three dimensions and measure it using the entropy value method. The specific construction indicators are shown in Table 7.

Column (1) of Table 8 presents the regression results using an alternative explanatory variable. The coefficient of rural digital development remains significantly positive at the 5% level, confirming the robustness of the findings. This consistency arises because, despite variations in measurement methods, different indicators of rural digital development commonly reflect key aspects such as infrastructure, information services, and digital applications. As a result, they offer a coherent and reliable representation of the true level of rural digital advancement.

4.4.2 Shrinking tail

In order to demonstrate again the robustness of the conclusions of this paper, the indentation process is carried out in this section, with the main purpose of reducing the impact of extreme values on the regression results. In the data counted, there are inevitably individual observations that may appear abnormal due to

TABLE 8 Robustness test.

Variables	(1)	(2)	(3)	(4)
	fd	fd	fd	fd
dig1	40.59**			
	(2.481)			
L.fd				
dig		24.44*	32.70**	9.735***
		(1.971)	(2.735)	(8.691)
gdp	−1.755*	−1.719*	−1.545	−1.154
	(−2.018)	(−2.037)	(−1.542)	(−0.947)
rpo	113.0***	115.9***	84.50	98.83**
	(3.002)	(3.232)	(1.402)	(2.521)
wag	−14.99	−14.71	−14.64	−16.41
	(−1.070)	(−1.101)	(−0.793)	(−0.980)
dag	23.12	23.67	8.194	29.91
	(0.718)	(0.737)	(0.226)	(1.225)
med	−0.454	0.177	3.208	−2.165
	(−0.0834)	(0.0311)	(0.458)	(−0.371)
psi	−17.05	−15.82	−14.85	−0.663
	(−0.358)	(−0.326)	(−0.287)	(−0.0171)
Constant	−19.02	−20.83	−14.67	−13.17
	(−0.989)	(−1.183)	(−0.490)	(−0.640)
Individual fixed effects	Yes	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes	Yes
Observations	360	360	312	270
R-squared	0.727	0.723	0.698	0.787

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

TABLE 9 Heterogeneity in East, Central and West regions.

Variables	(1)	(2)	(3)
	East	Central section	West
dig	16.46	169.8*	95.09***
	(1.714)	(2.120)	(4.026)
gdp	−1.467	3.695**	1.488**
	(−1.615)	(2.527)	(2.292)
rpo	67.41	−167.3	192.9**
	(1.445)	(−1.183)	(2.267)
wag	−21.71	82.88	−74.66***
	(−1.278)	(1.851)	(−3.302)
dag	21.51	21.95	−85.11
	(0.416)	(0.537)	(−1.571)
med	−8.629	19.82***	24.49
	(−1.582)	(4.091)	(1.686)
psi	135.3	−31.87	141.8
	(1.774)	(−0.775)	(1.702)
Constant	13.32	48.00	−75.03
	(0.558)	(0.730)	(−1.364)
Individual fixed effects	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes
Observations	132	96	120
R-squared	0.844	0.870	0.708
Number of cnty	11	8	10

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

statistical errors, and these extreme values may cause bias in the overall estimation results and affect the robustness of the conclusions. Therefore, by shrinking the upper and lower 1% for rural digital development and agricultural land transfer, the interference of outliers can be effectively reduced to ensure that the estimation results are more representative and reliable. Column (3) of Table 8 shows the regression results after shrinking the tails. From the results, the coefficient of rural digital development on agricultural land transfer is significantly positive at the 10% level, indicating that the conclusions of this paper are robust.

4.4.3 Exclude municipalities directly under the central government

Given that China's four centrally administered municipalities differ markedly from other provinces in administrative status, economic structure, fiscal capacity, and digital development level, their inclusion may introduce sample heterogeneity. As highly urbanized entities, these municipalities often benefit from concentrated resources and stronger policy backing in advancing rural digitalization, potentially skewing the overall estimation. To test the robustness of the findings, this section excludes the four municipalities and re-estimates the model. The results, presented in column (4) of Table 8, indicate that rural digital development continues to have a significantly positive effect on agricultural land transfer at the 5% level, further validating the reliability of the paper's conclusions.

4.4.4 Exclude abnormal years

Since 2020, the COVID-19 pandemic has had a profound impact on various aspects of China's socio-economic landscape, particularly in rural areas. It disrupted digital infrastructure development, limited information accessibility, altered industrial structures, and placed additional pressure on public finances. In response, governments at all levels implemented a range of extraordinary

measures, including substantial fiscal investments and the rapid establishment of digital emergency management systems. These interventions may have temporarily altered the trajectory and spatial characteristics of rural digitalization. Furthermore, heightened data volatility and reduced availability during the later stages of the pandemic could compromise the accuracy of empirical analysis. To mitigate such distortions, this study confines the robustness test to the pre-pandemic period of 2006–2019, a phase of relative stability. As shown in column (5) of Table 8, the coefficient for rural digital development remains significantly positive at the 1% level, further confirming the robustness of the results.

4.5 Heterogeneity analysis

4.5.1 Regional heterogeneity

To explore potential regional differences in the effect of rural digital development on agricultural land transfer, China is divided into eastern, central, and western regions. This classification reflects notable disparities in economic status, social structure, infrastructure, and the extent of digitalization. The eastern region typically features more advanced economies, higher urbanization rates, and stronger digital and information infrastructure, with notable progress in rural digital initiatives. In contrast, the central and western areas, where agriculture remains a key sector, lag in economic and technological development, and face more obstacles in advancing digital transformation. The central region has received more policy support in recent years and has greater development potential, but the overall level is still lower than that of the east; while the western region is affected by geographic conditions and historical development differences, and has a weaker foundation for digital construction. Therefore, it is divided into east, center and west.

The detailed regression outcomes are presented in Table 9. According to the findings, rural digital development has a statistically significant impact on agricultural land transfer in the central and western regions—at the 10% and 1% levels, respectively—but shows no notable effect in the eastern region. This disparity may stem from the eastern region's already advanced economic development and high informatization level, where digital infrastructure is long-established and mature. Consequently, the scope for further improvement through digital development is limited, reducing its influence on land transfer activities.

In contrast, the central and western regions have historically lagged in development, with agriculture still playing a major role in the economy. These areas tend to rely on traditional land systems and face more pronounced issues such as information asymmetry and high transaction costs. Strengthening digital infrastructure in these regions can greatly improve transparency and coordination in the land transfer market, cut down transfer costs, and enhance land resource allocation efficiency, thereby more effectively facilitating land transfers.

Moreover, recent policy efforts have prioritized digital rural development in these less developed regions. This policy focus has accelerated the expansion of digital services and infrastructure, further amplifying the positive effects on agricultural land transfer. Therefore, the heterogeneity analysis highlights that digital rural initiatives have a more significant influence in the central and western areas, underscoring the varying policy impacts across regions due to differences in development conditions and policy responsiveness.

4.5.2 Yangtze River economy

To further investigate the regional heterogeneity in the influence of rural digital development on agricultural land transfer, we classify regions based on whether they fall within the Yangtze River Economic Belt. This classification is grounded in the Belt's distinctive role in China's economic and regional development. Stretching across multiple provinces, the Yangtze River Economic Belt encompasses some of the most dynamic and interconnected areas in the country. As a strategically prioritized zone, it generally outpaces other regions in infrastructure, industrialization, policy support, and digitalization—factors that highlight its greater potential in advancing rural digital initiatives.

Accordingly, we perform an empirical analysis using this regional division. The regression results, presented in Table 10, reveal that rural digital development significantly influences agricultural land transfer in provinces along the Yangtze River Economic Belt at the 5% significance level, while such influence is statistically insignificant in provinces outside the Belt. This demonstrates a clear heterogeneity in the impact of rural digital development based on regional classification.

Several factors may account for this variation. Provinces within the Yangtze River Economic Belt typically enjoy more advanced digital infrastructure, higher levels of informatization, and more robust governmental backing for rural digital transformation. The relatively rapid urbanization in this area, along with more developed rural land markets and wider digital applications, facilitates smoother land transfers. Additionally, the region's efficient transportation, logistics networks, and streamlined information flows help lower transaction costs and reduce information asymmetries in land transactions.

Thus, the stronger effect observed in the Yangtze River Economic Belt likely stems from its comprehensive digital readiness, economic maturity, and targeted policy support. These elements together enhance the spillover benefits of digital rural development, accelerating the evolution of the agricultural land transfer market in these areas.

4.5.3 Different levels of rural digital development

In order to comprehensively identify the potential differential impacts of rural digital development on agricultural land transfer, this section introduces panel quantile regression method for empirical testing. Compared with traditional OLS methods, quantile regression can estimate the marginal effects of the dependent variable at different distribution positions of the independent variable, thereby capturing the heterogeneous effects that may exist between variables under different conditions. Specifically, this article divides rural digital development into different levels of development for quantile analysis, aiming to systematically explore the distribution effects of rural digital development on agricultural land transfer and further explore its role characteristics at different stages of development.

The regression results are shown in Table 11. According to the estimation results, when the rural land transfer rate is at the 10%,

TABLE 10 Heterogeneity test whether in the Yangtze River Economic Belt.

Variables	(1)	(2)
	In the Yangtze River Economic Belt	Not in the Yangtze River Economic Belt
	fd	fd
dig	35.25**	−13.28
	(2.675)	(−0.702)
gdp	−1.933*	−1.273
	(−2.093)	(−0.488)
rpo	126.9**	67.51
	(2.534)	(0.749)
wag	−24.91	−11.65
	(−1.646)	(−0.431)
dag	−7.760	192.0*
	(−0.230)	(2.177)
med	−1.283	1.000
	(−0.212)	(0.114)
psi	24.85	−232.1*
	(0.561)	(−2.161)
Constant	−23.71	19.65
	(−0.940)	(0.650)
Individual fixed effects	Yes	Yes
time fixed effect	Yes	Yes
Observations	228	132
R-squared	0.759	0.770
Number of cnty	19	11

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

30%, and 50% percentile, the digital development of rural areas has a significant positive impact on agricultural land transfer, and the regression coefficient is statistically significant; This indicates that in the regions corresponding to these quantiles, rural digital construction can effectively improve land transfer rates and promote the reallocation of land resources. However, when the land transfer rate is at the high percentile of 70% and 90%, the impact of rural digital development on land transfer is no longer significant, and the regression coefficient tends to decrease or even lose statistical significance, indicating that the marginal promotion effect of digital policies in high-level development areas is no longer significant.

The reason for this result may lie in the phased characteristics of the level of digital development in rural areas. In regions where digitalization is in its early stages or development, the introduction of digital technology can greatly improve information asymmetry, reduce land transfer transaction costs, enhance farmers' willingness to participate, and significantly increase land transfer rates due to outdated information infrastructure, closed market information, and poor circulation channels. The policy promotion and infrastructure investment in this stage can quickly take effect, and the activation effect on the land market is particularly evident. However, in areas where the level of digital development in rural areas is already high, such as developed provinces along the eastern coast or pilot demonstration areas, the relevant infrastructure is relatively complete, the degree of institutionalization of land transfer markets is high, and the efficiency of information acquisition and matching among farmers has become mature. In this situation, the marginal contribution of further improving the level of digitization to land transfer becomes limited, exhibiting a typical diminishing marginal effect phenomenon.

From an economic perspective, this quantile regression result reveals that the impact of rural digital development on land circulation has stage and level characteristics. Digital technology plays the most significant role in filling the gap in the initial stage of imperfect market mechanisms, while in an environment where market mechanisms have matured, its "efficiency" space gradually narrows. This discovery has important implications for the formulation of relevant policies: in promoting rural digitization, the government should adhere to differentiated and precise policy guidance, focus on supporting the central and western regions and underdeveloped areas with low land transfer rates and low market activity, accelerate the construction of digital infrastructure and service capabilities, in order to maximize policy effectiveness; At the same time, for regions with higher levels of development, more attention should be paid to the integration of digitalization and institutional innovation, avoiding duplicate investment and resource waste, and promoting the formation of a sustainable and balanced digital rural pattern.

In summary, the empirical results of quantile regression not only verify the heterogeneous impact of rural digital development at different stages of development, but also provide empirical evidence on the trend of marginal effect changes, which helps us to better understand the differential impact paths of digital policies on land system reform and rural revitalization strategy implementation.

4.5.4 Differences in levels of economic development

To examine how varying economic development levels across provinces might influence the outcomes, this section categorizes regions into two groups—high and low economic development—based on the median *per capita* GDP. Given the stark contrasts in resource endowments, institutional settings, market maturity, and agricultural structures across regions, this classification facilitates a more nuanced understanding of the differential impacts of rural digitalization under diverse economic conditions.

The empirical evidence is presented in Table 12. Regression results indicate that rural digital development significantly promotes agricultural land transfer in both groups at the 5% significance level. However, the effect is more pronounced in provinces with lower economic development. This may be attributed to several factors. First, less developed areas tend to suffer from limited access to land

TABLE 11 Heterogeneity of different rural digital development levels.

Variables	(1)	(2)	(3)	(4)	(5)
	10%	25%	50%	75%	90%
	fd	fd	fd	fd	fd
dig	25.91*	25.18**	24.08***	22.49	21.68
	(1.797)	(2.301)	(2.779)	(1.599)	(1.170)
gdp	−1.614	−1.603**	−1.588***	−1.565	−1.554
	(−1.619)	(−2.120)	(−2.651)	(−1.610)	(−1.213)
rpo	124.5***	122.7***	120.0***	116.1***	114.2**
	(3.447)	(4.476)	(5.528)	(3.296)	(2.459)
wag	−18.80	−16.94*	−14.16*	−10.10	−8.069
	(−1.414)	(−1.678)	(−1.770)	(−0.779)	(−0.472)
dag	15.99	18.05	21.12	25.62	27.88
	(0.477)	(0.709)	(1.048)	(0.783)	(0.647)
med	−0.914	−0.595	−0.118	0.579	0.928
	(−0.147)	(−0.126)	(−0.0317)	(0.0957)	(0.116)
psi	−36.13	−29.00	−18.33	−2.728	5.095
	(−0.978)	(−1.032)	(−0.822)	(−0.0756)	(0.107)
Individual fixed effects	Yes	Yes	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

transfer information, high transaction costs, and weak organizational frameworks. The integration of digital platforms in these regions can help dismantle information barriers, reduce costs, and enhance transaction efficiency—thereby yielding greater policy benefits and institutional improvements.

Second, traditional agriculture still dominates these areas, with low land use efficiency and substantial room for reallocating land resources more effectively. Digital technologies can significantly enhance land circulation and optimize resource use. In contrast, economically advanced regions already have well-established land markets, efficient transfer mechanisms, and high levels of informatization and market activity. Thus, the marginal contribution of rural digital development in these areas is limited. As a result, digital infrastructure plays a more transformative role in underdeveloped regions by facilitating the flow of land to more productive entities and significantly boosting land transfer activity.

4.5.5 High and low levels of total factor productivity

To assess how varying levels of total factor productivity (TFP) influence the effect of rural digital development, provinces are classified into two groups—high and low TFP—based on the median TFP value. As an indicator of the efficiency with which inputs such as land, labor, and capital are utilized in agricultural production, TFP reflects both the technological advancement and modernization level of a region's agriculture. This grouping facilitates the identification of heterogeneous effects across regions at different development stages and offers guidance for formulating more tailored policy interventions.

The empirical outcomes are presented in Table 13. According to the regression analysis, rural digital development has a statistically significant effect on agricultural land transfer in both high- and low-TFP areas, with coefficients significant at the 10% and 5% levels, respectively. Notably, the effect is stronger in regions with lower TFP. This heightened impact may be explained by the "bottleneck compensation" mechanism: in low-TFP areas, digital infrastructure can bridge existing gaps by improving information access, lowering transaction costs, and enhancing farmers' capacity to engage with external markets. These improvements help facilitate land mobility and more efficient resource allocation.

Conversely, in high-TFP provinces, where production systems and market mechanisms are already relatively mature, the additional benefits brought by digital tools tend to be marginal. As such, the effect of rural digital development on land transfer is comparatively weaker in these more advanced regions.

4.5.6 Urban-rural differences

In order to analyze whether the digital development of rural areas will have differential impacts on the transfer of urban and rural

TABLE 12 Heterogeneity of differences in the level of economic development.

Variables	(1)	(2)
	High level of economic development	Low level of economic development
	fd	fd
dig	18.92**	141.5**
	(2.363)	(2.651)
gdp	−2.625**	−1.535
	(−2.503)	(−0.363)
rpo	151.6***	191.5***
	(3.781)	(3.938)
wag	−16.72	8.458
	(−1.109)	(0.388)
dag	57.31	29.04
	(1.361)	(0.791)
med	−0.652	3.296
	(−0.198)	(0.477)
psi	−28.90	23.22
	(−0.219)	(0.581)
Constant	−14.57	−105.5***
	(−0.798)	(−3.153)
Individual fixed effects	Yes	Yes
time fixed effect	Yes	Yes
Observations	180	180
R-squared	0.796	0.784
Number of cnty	29	25

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

land from the perspective of urban-rural differences. This article measures the heterogeneity of urban-rural structure based on the provincial panel data used in the paper and the existing variable of rural population proportion, and groups them according to the median rural population proportion. When the proportion of rural population to the total population is higher than the median of the sample, the province is considered a rural area; When the proportion of rural population is lower than the median of the sample, the provinces are urban areas.

The specific regression results are shown in Table 14. From the regression results, the effect of rural digital development on agricultural land transfer in urban areas is not significant, and the coefficient for agricultural land transfer in rural areas is significant at the 5% level. This indicates that the digital development of rural areas has a more significant impact on land circulation in rural areas. Possible reasons are: firstly, rural areas have a stronger dependence on digitalization and a greater marginal effect. In areas with a high proportion of rural population, traditional information dissemination and land transfer matching mainly rely on acquaintance networks or offline administrative means, and the problems of information blockage and high transaction costs are more prominent. The introduction of digital means such as online land trading platforms, digital government services, and remote finance in such areas can significantly improve the efficiency of land transfer and have stronger marginal effects. Therefore, the positive effect of rural digital development on land transfer is more significant in rural areas.

Secondly, rural land resources in urban areas are scarce and have limited circulation space. Urban provinces, due to their high level of urbanization and a large proportion of industrial and service industries, often have smaller rural areas and scarce land resources. The boundaries and demand space for agricultural land transfer are relatively limited, and even with the improvement of digitalization, the driving force for land transfer behavior may be constrained by the "land resource bottleneck." Thirdly, agriculture in urban areas is not dominant, and the diversification of land use weakens the motivation for land transfer. In urban dominated areas, agriculture is not the main source of income for non residents, and farmers have a lower willingness to engage in agricultural production, with insufficient incentives for land transfer. At the same time, some rural land is facing pressure to be converted to non-agricultural use, leading to a more non market driven "vacating" configuration of land transfer, and digital mechanisms are difficult to effectively intervene. Fourthly, policy resources should be more inclined towards rural areas. The current national rural digital development strategy (such as digital rural pilot projects, rural e-commerce projects, smart agriculture construction, *etc.*) often focuses on traditional agricultural provinces and rural population concentrated areas. Therefore, digital infrastructure, platform services, and institutional support are more centrally invested in rural areas, and the driving effect of digitalization on land factor flow is stronger in these areas.

4.5.7 Differences in industrial structure

Due to the vast territory of our country, there are significant differences in industries among different regions, and their industrial structures vary. These differences affect the use and value of land, as well as the way digital technology operates. If the industrial structure is not distinguished, it is possible to misjudge the role of digitalization in reforming the land system, leading to the failure or inefficiency of the "digitalization + land" policy. Therefore, in order to further verify the differential impact of industrial structure differences on rural digital development and land transfer, this article divides them into agricultural dominated regions: regions where the proportion of the primary industry is greater than 50%. Industrial dominated regions: regions where the proportion of the secondary industry is greater than 50%. Service oriented areas: areas where the proportion of the tertiary industry is greater than 50%.

The specific regression results are shown in Table 15. From the regression results, the effect of rural digital development on agricultural land transfer in agriculture dominated areas is

TABLE 13 Heterogeneity of total factor productivity differences.

Variables	(1)	(2)
	High total factor productivity	Low total factor productivity
	fd	fd
dig	17.70*	37.23**
	(1.864)	(2.630)
gdp	−1.936**	0.166
	(−2.398)	(0.0849)
rpo	146.0***	31.17
	(3.986)	(0.463)
wag	−23.23*	19.31
	(−1.814)	(0.773)
dag	−20.07	32.59
	(−0.467)	(0.839)
med	−8.704	5.555
	(−1.644)	(0.795)
psi	−12.75	15.03
	(−0.274)	(0.329)
Constant	−22.59	−16.58
	(−0.954)	(−0.635)
Individual fixed effects	Yes	Yes
time fixed effect	Yes	Yes
Observations	181	179
R-squared	0.698	0.774

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

significant at the 5% level, while its effect on industrial dominated areas and service-oriented areas is not significant. This indicates that the digital development of rural areas plays a more significant role in land transfer in agricultural dominated areas. Mainly due to the high dependence of agriculture on land. The application of digital technology in agriculture, such as intelligent agricultural machinery, precision planting, and agricultural technology service platforms, has improved the efficiency of large-scale operations, thereby enhancing the demand for centralized land transfer. Meanwhile, small farmers are more inclined to transfer their land to new agricultural management entities with technological and resource advantages when facing digital barriers. In areas dominated by industry and service-oriented owners, the rural economic structure has partially "de landed," and digital development is more focused on extending the industrial chain, building platforms, and non-agricultural employment. The core position of land in economic activities has weakened, so the driving effect of digitalization on land circulation is not significant.

5 Further analysis

5.1 Mechanism analysis of resource mismatch

5.1.1 Labor mismatch

Labor mismatch refers to the inefficient allocation of labor resources in the industry, region or skill dimension, which is often manifested in the fact that the rural labor force cannot effectively flow or fails to engage in positions that match their abilities. By providing information services, employment platforms, skills training and digital infrastructure, rural digital development can help break down information barriers and improve the efficiency of employment matching, thereby alleviating the labor mismatch problem. Given that labor may be a factor affecting the scale of agricultural land operation and transfer, for this reason, using it as a mediating variable helps to test how rural digital development indirectly affects land transfer through optimizing factor allocation.

Table 16 presents the results of the mediating effect test concerning labor mismatch. According to the regression in column (2), rural digital development has a significantly negative impact on labor mismatch at the 1% level, suggesting its effectiveness in mitigating such mismatches. In column (3), both rural digital development and labor mismatch exhibit statistically significant coefficients in relation to agricultural land transfer—at the 5% and 10% levels, respectively—indicating that labor mismatch functions as a mediating variable in this relationship.

This may be attributed to the role of digital tools in enhancing rural workers' access to employment information and broadening non-agricultural job opportunities, which encourages part of the agricultural labor force to exit farming and transfer land to more capable operators. Furthermore, digitalization strengthens ties between rural laborers and modern agriculture, improves both geographical and occupational mobility, and eases structural labor shortages in the agricultural sector. These improvements foster the conditions necessary for larger-scale land operations. Thus, by optimizing labor distribution, rural digital initiatives also facilitate more efficient land resource allocation. Prove that hypothesis 2 of this article holds true.

5.1.2 Land mismatch

Land mismatch is usually manifested in the fact that land is not allocated to the most capable farmers with the greatest potential for large-scale operation in accordance with the principle of efficiency, resulting in inefficient land utilization and insufficient incentives for agricultural production. By promoting informationization, digital services and the construction of land transfer platforms, the rural digital development effectively improves the information symmetry between land supply and demand sides, reduces transaction costs and optimizes the allocation efficiency of the land market. Therefore, the introduction of land mismatch as a mediating variable helps to test how rural digital development indirectly promotes the intrinsic mechanism of land transfer by improving the allocation of land resources.

Table 17 reports the mediating effect test results related to land mismatch. As shown in column (2), rural digital development exhibits a significantly negative coefficient on land mismatch at the 5% level, suggesting its capacity to reduce mismatches in land

TABLE 14 Heterogeneity test of urban-rural differences.

Variables	(1)	(2)
	城市	农村
	fd	fd
dig	26.01	48.90**
	(1.070)	(2.251)
gdp	−1.976	−0.629
	(−1.310)	(−0.807)
rpo	−52.87	191.2***
	(−0.557)	(4.387)
wag	−24.68	6.318
	(−1.333)	(0.420)
dag	171.9*	3.184
	(1.903)	(0.0775)
med	1.353	−5.112
	(0.206)	(−1.124)
psi	−225.2**	41.09
	(−2.367)	(0.723)
Constant	81.95	−60.23**
	(1.493)	(−2.336)
Individual fixed effects	Yes	Yes
time fixed effect	Yes	Yes
Observations	180	180
R-squared	0.763	0.802
Number of cnty	17	16

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

allocation. Column (3) further reveals that both rural digital development and land mismatch significantly affect agricultural land transfer at the 5% and 10% levels, respectively, implying that land mismatch acts as a mediating channel in this relationship.

This effect is primarily due to digital technologies enhancing the efficiency of land factor allocation. Through the establishment of information-sharing platforms for land transactions, the application of big data, and the use of remote services, digital villages have increased transparency in land markets and streamlined the transfer process. These efforts have contributed to a more market-oriented and precise allocation of land resources.

In addition, digital tools have reinforced oversight of land utilization, curbed underuse and inefficiency, and facilitated the reallocation of land to more productive operators. Thus, by mitigating land mismatch, rural digital initiatives not only improve the circulation of land elements but also enhance their overall allocation efficiency, promoting the orderly transfer of agricultural land. Prove that hypothesis 3 of this article holds true.

5.1.3 Capital mismatch

Capital mismatch primarily refers to the inability of agricultural entities to access financing aligned with their marginal productivity, largely due to information asymmetries, limited financial inclusion, and constrained lending channels. This restricts their capacity for production expansion and, in turn, hampers the efficient flow of land resources. Rural digital development—through the advancement of digital financial services, improved credit accessibility, and the optimization of capital supply—can bridge informational gaps between capital providers and users, thereby enhancing allocation efficiency. Introducing capital mismatch as a mediating factor allows for a more nuanced examination of how digital rural initiatives improve capital distribution and subsequently support land circulation.

Table 18 presents the results of the mediating effect analysis. Column (2) shows that rural digital development significantly reduces capital mismatch at the 5% significance level. In column (3), both rural digital development and capital mismatch exhibit significant coefficients in explaining agricultural land transfer, at the 5% and 10% levels, respectively—confirming the mediating role of capital mismatch.

This relationship may stem from the digital transformation of rural financial systems, which enhances farmers' access to financing—particularly for emerging agricultural enterprises—enabling them to acquire land and engage in scaled operations. Additionally, digital platforms have strengthened financial institutions' capacity to assess rural credit risks, directing credit resources toward more productive and creditworthy actors. This reallocation facilitates the aggregation of land into the hands of capable farmers, thereby raising land-use efficiency. In sum, by optimizing capital flows, rural digitalization not only activates agricultural productivity but also promotes the effective and orderly transfer of farmland. Prove that hypothesis 4 of this article holds true.

5.2 Labor force mobility

As a large number of rural laborers migrate and surplus labor declines, farmers increasingly prefer to lease their land to capable and specialized entities to achieve more efficient land utilization. The advancement of digital village initiatives has notably boosted rural labor mobility by offering more accessible employment information, promoting digital skill development, and expanding channels for working outside local areas. Consequently, using labor mobility as a mediating factor provides a framework to examine how digitalization in rural areas indirectly accelerates land transfer through the activation of population mobility.

Table 19 presents the empirical analysis of this mediating effect. In column (2), the coefficient for rural digital development on labor mobility is significantly positive at the 5% level, suggesting that digitalization fosters the movement of the rural workforce. Column (3) further demonstrates that both rural digital development and labor mobility have statistically significant impacts on land transfer—at the 5% and 1% levels respectively—highlighting labor mobility as a key intermediary. This outcome likely stems from enhanced access to online job platforms, remote employment opportunities, and vocational training, all of which enable rural

TABLE 15 Heterogeneity test of industrial structure differences.

Variables	(1)	(2)	(3)
	Agricultural dominated regions	Industrial dominated regions	Service oriented areas for homeowners
	fd	fd	fd
dig	41.84**	34.97	9.168
	(2.300)	(1.300)	(0.392)
gdp	−1.356	−1.332	−2.619
	(−1.078)	(−0.744)	(−1.560)
rpo	39.85	15.82	146.3*
	(0.315)	(0.102)	(2.099)
wag	−30.13	−35.92	−32.61
	(−1.705)	(−1.642)	(−1.396)
dag	−26.47	7.951	93.50
	(−0.606)	(0.0935)	(1.349)
med	2.913	−1.770	−6.205
	(0.342)	(−0.207)	(−0.581)
psi	−64.14	18.66	−154.5
	(−1.210)	(0.135)	(−0.837)
Constant	27.93	38.40	10.46
	(0.477)	(0.566)	(0.357)
Individual fixed effects	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes
Observations	162	127	124
R-squared	0.762	0.756	0.750
Number of cnty	20	17	18

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

workers to shift away from farming to other sectors. As labor exits the agricultural field, the resulting labor shortage prompts farmers to contract out land to larger, more professional operators, facilitating land consolidation and efficiency. Thus, by reshaping the composition of the agricultural workforce, rural digital transformation indirectly propels the circulation and optimized use of land resources.

The digital development of rural areas has played a positive role in promoting labor mobility in various aspects, indirectly promoting the improvement of agricultural land transfer. Specifically, the improvement of digital infrastructure and the expansion of platform economy have provided more remote employment opportunities and non-agricultural positions for rural labor, such as e-commerce operations, online services, outsourcing processing, *etc.*, effectively expanding farmers' employment channels, reducing dependence on self owned farmland, and releasing more transferable land resources; At the same time, digital technology also provides convenient vocational skills training and information acquisition platforms for rural labor, enhancing farmers' employment ability and migration willingness, accelerating the transfer of rural labor to secondary and tertiary industries and urban areas, and further enhancing the driving force of land outflow. In addition, digital platforms have significantly improved the efficiency of land supply and demand matching by promoting efficient information integration between land resources and management entities; Technologies such as blockchain and big data have reduced transaction costs and risks in land ownership confirmation, contract signing, and credit evaluation, enhancing farmers' willingness and sense of security in land transfer. In summary, rural digitization indirectly promotes the effective circulation of agricultural land from multiple dimensions by promoting labor transfer, improving human capital levels, and optimizing the land market environment, providing strong support for the efficient allocation of rural land resources and the modernization of agriculture. Prove that hypothesis 5 in this article holds true.

TABLE 16 Mediating effect test o000f labor mismatch.

Variables	(1)	(2)	(3)
	fd	ler	fd
dig	23.90**	−0.259***	23.39**
	(2.194)	(−3.060)	(2.178)
ler			−1.612*
			(−1.789)
gdp	−1.585*	−0.0134	−1.991
	(−1.796)	(−1.284)	(−0.951)
rpo	119.6***	−0.0331	119.5***
	(3.242)	(−0.0784)	(3.226)
wag	−13.71	0.0603	−13.59
	(−0.995)	(0.394)	(−0.979)
dag	21.63	0.350	22.33
	(0.671)	(0.734)	(0.690)
med	−0.0397	−0.0163	−0.0722
	(−0.00697)	(−0.240)	(−0.0128)
psi	−16.57	−0.366	−17.29
	(−0.343)	(−1.134)	(−0.355)
Constant	−23.27	0.792***	−21.69
	(−1.257)	(3.901)	(−1.177)
Individual fixed effects	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes
Observations	360	360	360
R-squared	0.725	0.230	0.726

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

TABLE 17 Mediating effect test of land mismatch.

Variables	(1)	(2)	(3)
	fd	dgmm	fd
dig	23.90**	−0.470***	24.37**
	(2.194)	(−3.090)	(2.259)
dgmm			−1.565*
			(−1.756)
gdp	−1.585*	−0.0200	0.987
	(−1.796)	(−1.504)	(0.590)
rpo	119.6***	−0.00805	119.6***
	(3.242)	(−0.0175)	(3.252)
wag	−13.71	−0.0202	−13.69
	(−0.995)	(−0.123)	(−0.993)
dag	21.63	0.122	21.51
	(0.671)	(0.318)	(0.667)
med	−0.0397	−0.110	0.0693
	(−0.00697)	(−1.267)	(0.0122)
psi	−16.57	−0.559	−16.01
	(−0.343)	(−1.470)	(−0.331)
Constant	−23.27	0.953***	−24.21
	(−1.257)	(4.718)	(−1.320)
Individual fixed effects	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes
Observations	360	360	360
R-squared	0.725	0.304	0.725

Note: ***, **, * respectively indicate significance at the 1%, 5%, and 10% levels. The heteroscedasticity robust T-values adjusted for national level clustering are shown in parentheses.

6 Conclusions and policy recommendations

6.1 Conclusion

This article uses balanced panel data from 30 provinces in China from 2006 to 2023 to systematically analyze the impact and mechanism of rural digital development on agricultural land transfer. The research results indicate that the overall digital development of rural areas has significantly promoted the transfer of agricultural land and has strong sustainability. This conclusion remains robust after controlling for potential endogeneity issues and conducting various robustness tests. Further heterogeneity analysis shows that this driving effect is more significant in the central and western regions, the Yangtze River Economic Belt, and provinces with lower levels of economic development or total factor productivity, reflecting the potential of rural digitization in promoting regional coordinated development. Mechanism analysis further reveals that the digital development of rural areas has effectively promoted land circulation by alleviating the mismatch of labor, land, capital and other factors in agricultural production, optimizing resource allocation, and so on; At the same time, the construction of digital rural areas has accelerated the rational flow of rural labor and created a favorable environment for factor mobility. In summary, rural digitization is not only an important way to promote the market-oriented allocation of agricultural land factors, but also injects new development momentum into achieving rural revitalization and agricultural modernization.

6.2 Suggestion

6.2.1 Strengthening digital rural construction and strengthening the digital foundation of agricultural land transfer

Digital rural development is emerging as a key strategic approach to advancing agricultural and rural modernization, with

TABLE 18 Mediation effect test of capital mismatch.

Variables	(1)	(2)	(3)
	fd	ols	fd
dig	23.90**	−0.222***	23.14**
	(2.194)	(−3.024)	(2.123)
ols			−1.619*
			(−1.754)
gdp	−1.585*	−0.00970	−3.458
	(−1.796)	(−1.137)	(−0.386)
rpo	119.6***	−0.459	118.0***
	(3.242)	(−1.291)	(3.212)
wag	−13.71	−0.0102	−13.74
	(−0.995)	(−0.0978)	(−0.996)
dag	21.63	0.168	22.21
	(0.671)	(0.582)	(0.671)
med	−0.0397	−0.0603	−0.248
	(−0.00697)	(−1.452)	(−0.0442)
psi	−16.57	−0.465	−18.17
	(−0.343)	(−1.284)	(−0.356)
Constant	−23.27	1.086***	−19.51
	(−1.257)	(7.523)	(−0.986)
Individual fixed effects	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes
Observations	360	360	360
R-squared	0.725	0.692	0.725

TABLE 19 Mediating effect test of labor mobility.

Variables	(1)	(2)	(3)
	fd	htd	fd
dig	23.90**	26.67**	23.71**
	(2.194)	(2.549)	(2.158)
htd			4.595***
			(6.644)
gdp	−1.585*	0.179	−1.586*
	(−1.796)	(0.174)	(−1.789)
rpo	119.6***	−74.18**	120.1***
	(3.242)	(−2.317)	(3.255)
wag	−13.71	54.99***	−14.11
	(−0.995)	(2.783)	(−1.008)
dag	21.63	123.9***	20.73
	(0.671)	(3.171)	(0.636)
med	−0.0397	−6.848	0.0100
	(−0.00697)	(−1.081)	(0.00175)
psi	−16.57	−49.47	−16.21
	(−0.343)	(−1.131)	(−0.337)
Constant	−23.27	63.29***	−23.72
	(−1.257)	(3.894)	(−1.293)
Individual fixed effects	Yes	Yes	Yes
time fixed effect	Yes	Yes	Yes
Observations	360	360	360
R-squared	0.725	0.368	0.725

its role in enhancing resource allocation and agricultural productivity becoming increasingly evident. The study reveals that rural digitalization significantly facilitates agricultural land transfers, underscoring its growing influence in driving more efficient land use. To harness this potential, it is essential to reinforce the top-level design of digital strategies in rural areas, emphasizing strategic alignment and the integration of resources. Efforts should be made to ensure comprehensive deployment and effective use of information infrastructure, data systems, and smart technologies in rural regions. In particular, expanding rural broadband, IoT networks, satellite remote sensing, and other digital infrastructure—especially in central, western, and remote rural areas—will be crucial for improving connectivity and access to information. On the other hand, we should focus on deepening the application of digital functions, embedding digital technology into specific scenarios such as agricultural production, land management and labor mobility, and promoting "Internet + Agricultural Management," "Blockchain + Land Rights Confirmation," "Big Data + Land Monitoring" and other measures. Promote the implementation of "Internet + agricultural management," "blockchain + land rights confirmation," "big data + land monitoring" and other models. In addition, the investment in rural human capital should be strengthened, and farmers' knowledge and application of digital tools should be enhanced through regular training and skill certification, so as to narrow the "digital divide" and avoid the phenomenon of "digital exclusion." Through the construction of a wide-coverage, multi-level, strong synergistic digital rural ecosystem, it can provide a solid institutional foundation and technical support for agricultural land transfer, and improve the operational efficiency and service capacity of the rural land system.

6.2.2 Improve the agricultural land transfer system and promote the construction of a market-oriented allocation mechanism for land elements

This paper finds that the construction of digital countryside significantly improves the level of agricultural land transfer through multiple mechanisms, but the land transfer market itself is still facing constraints such as asymmetric information, unstandardized transactions, and insufficient legal protection. Therefore, it is necessary to take institutional construction as a hand to comprehensively improve the mechanism of agricultural land

transfer. First, the establishment of a unified and standardized land transfer information platform, the use of digital technology to realize the real-time release of land supply and demand information, matching and matching, to enhance the efficiency and transparency of the transaction. The second is to strengthen the registration and electronic management of land ownership, and improve the dynamic updating and cross-sector sharing mechanism of land ownership data, so as to reduce the transaction risks caused by unclear property rights. Third, promoting the standardization of land transfer contracts and the construction of a legal service system, providing both parties to the transfer with convenient and efficient legal consultation, dispute mediation and litigation services, and enhancing institutional trust and market vitality. Fourth, improve the land value assessment system and land financial support policies, and explore innovative modes such as land mortgages and pledge of income rights through financial technology means to enhance the financing function of land transfer. In addition, attention should be paid to the protection of the interests of farmers in the process of land transfer to prevent damage to the rights and interests of farmers caused by "involuntary transfer" or "adverse selection." By building a fair, efficient and safe land transfer market, we can better activate rural land resources and promote the optimal reorganization and efficient use of agricultural resource elements.

6.2.3 Strengthening the Government's role in resource allocation and forming a synergistic promotion mechanism

On the one hand, the evolution of rural digital development and land transfer system depends on the government's leading role in financial input, institutional supply and policy orientation. It is suggested that we should focus on financial support, policy innovation and institutional safeguard to enhance the government's governance capacity and guidance efficiency. Specifically, we should increase financial transfers to central and western regions and areas with weak rural infrastructure, and set up a special fund for the synergistic development of digital villages and land transfer, which can be used for infrastructure construction, technology promotion and talent training. At the policy level, cross-sectoral coordination should be strengthened, and data barriers and policy divisions in agriculture and rural areas, information and communication, natural resources, finance and financial services should be broken down to establish a synergistic mechanism for the policy of linking the construction of digital villages and the development of land circulation. In terms of system, we should promote the formulation and implementation of local laws and regulations to promote agricultural land transfer, clarify the boundaries of the rights and responsibilities of various types of subjects in the land transfer and the protection mechanism, and improve the operability and implementation of the system. At the same time, it is recommended to build a performance evaluation and incentive mechanism, set a quantifiable and traceable index system for digital rural development and land transfer, and incorporate it into the performance evaluation of local governments, so as to guide the local governments to strengthen the coordination and promotion of the integration of land system innovation and digital technology in their development strategies. By enhancing the government's system design capability and public service effectiveness, a multi-dimensional co-management pattern can be built up with government guidance, market-led, farmer participation and social synergy, providing strong support for the integration of the agricultural land system and the digital economy. Specifically, the construction of policy coordination mechanisms should start from the following aspects: firstly, the government should strengthen top-level institutional design, improve land transfer management regulations, promote local governments to formulate detailed measures tailored to local conditions, clarify land ownership confirmation, transfer procedure norms, contract performance supervision, and dispute mediation mechanisms. At the same time, a unified information service platform should be established to integrate land resources, policy information, and market supply and demand, and improve the transparency and service efficiency of the land transfer market. Secondly, fully leverage the role of market mechanisms, encourage the development of specialized intermediary service providers such as rural property rights trading centers and land custody companies, establish standardized price discovery mechanisms, and promote the market-oriented and standardized operation of land transfer; Simultaneously innovate land financial instruments to enhance the capital attributes of land management rights. Thirdly, it is necessary to fully safeguard the dominant position of farmers, promote the registration and certification of rural land rights, strengthen the predictability of farmers' land rights, and improve their awareness and participation in land transfer policies through policy promotion, skill training, and legal assistance. Finally, it is necessary to guide social forces to participate in collaborative governance, encourage social organizations, research institutions, digital platform enterprises, *etc.*, to provide technical support, policy consultation, and data services, and establish sound mechanisms for information disclosure, public opinion supervision, and risk warning. Through the coordination and cooperation of the above-mentioned multiple entities, a long-term mechanism for land transfer can be formed, which integrates interests, shares responsibilities, and jointly builds governance, thereby improving the efficiency of rural land resource allocation and the overall vitality of rural economy.

6.2.4 Promote regional differentiated development path and achieve precise implementation of regional policies

The heterogeneity analysis results of this article indicate that the digital development of rural areas has a more significant impact on agricultural land transfer in central, western, Yangtze River Economic Belt, and provinces with lower levels of economic development and total factor productivity. This discovery reveals the regional imbalance between digital rural development and land system reform, suggesting that policymakers should avoid a "one size fits all" policy expansion when promoting relevant strategies, and instead focus on building differentiated development paths. Firstly, for the central and western regions as well as economically underdeveloped provinces, rural digital development should be given priority deployment as a fundamental project, and efforts should be focused on breaking through key bottlenecks such as weak information infrastructure and shortage of technical services. On this basis, a collaborative mechanism between land transfer and rural factor integration should be explored. Secondly, for ecologically sensitive areas with relatively complete institutional foundations such as the Yangtze River Economic Belt, the integration of digital technology with ecological agriculture and green land use models can be focused on to promote the integrated

development path of "ecology + digital + system." Thirdly, for regions with low total factor productivity, digital means should be used to accelerate the reallocation of resources such as land, labor, and capital, improve agricultural production efficiency, and stimulate market vitality in land transfer. In addition, it is necessary to combine regional development strategies and functional positioning to clarify the functional boundaries and development priorities of digital rural areas and land transfer. For example, national grain producing areas focus on stabilizing the transfer order, while urban suburban areas focus on the development of urban agriculture and the extension of the industrial chain. By implementing precise, regional, and hierarchical policy combinations and mechanism innovations, it can effectively promote the deep integration of land system reform and digital strategies, and promote the efficient allocation of regional land resources and high-quality agricultural development.

6.2.5 The reference significance for other countries

Although this study uses China as an example for empirical analysis, digital development also has important reference value and practical significance for other countries, especially for developing economies. Firstly, the improvement of digital infrastructure is a key prerequisite for countries to promote economic modernization. There is still a significant digital divide between urban and rural areas, as well as between regions in many countries. It is recommended that governments increase investment in digital infrastructure according to local conditions and improve the penetration rate of digital access. Secondly, domestic enterprises should be encouraged to embrace digital technology, promote the digital transformation and innovation of traditional industries, and enhance overall industrial competitiveness. In addition, the shortage of digital talents is a global issue, and countries should strengthen education system and technical training reforms to cultivate a new type of workforce with digital skills. Finally, countries need to strengthen digital governance and international cooperation, develop unified data standards and cross-border regulatory frameworks to jointly address the opportunities and challenges brought by the digital economy. Through policy coordination and experience sharing, countries can achieve more inclusive and sustainable development in the global digitalization process.

7 Research limitations and future research directions

Firstly, in terms of research limitations, this article points out that due to the fact that the data used is mainly based on panel data at the provincial level, although it has a certain degree of wide representativeness, it is difficult to deeply reveal the specific impact of rural digitization on land transfer behavior at a more micro level (such as county, township, or farmer level), especially in terms of farmers' decision-making motivation, land transfer transaction costs, information acquisition methods, *etc.*, which lack direct observation. Therefore, there is a certain degree of "macro meso disconnect" in explaining the mechanism of the conclusion. Secondly, although the indicators of rural digital development used in the article are as comprehensive as possible, the indicator system constructed based on statistical yearbooks and public data may not fully reflect the true state of rural digital development, especially in measuring the quality and depth of digital use, which is still insufficient. In addition, although the empirical model of the article has undergone various robustness tests and endogeneity controls using instrumental variable methods, it may still be affected by unobserved variables (such as local policy implementation capacity, grassroots organizational efficiency, *etc.*), thereby affecting the external validity of the conclusions.

In terms of future research directions, the article may expand its research from two levels: first, strengthen micro level investigation research, especially using survey data from farmers or villages, to explore how digitalization affects farmers' willingness to transfer land, land pricing ability, and transaction matching efficiency through micro mechanisms, and further reveal the impact path; Secondly, from the perspectives of policy interaction and institutional environment, we will conduct in-depth research on the policy differences, land system arrangements, and the moderating effects of infrastructure investment on the digital effects of promoting digital rural construction by different local governments. In addition, the author also points out that further cross-country comparative research can be conducted to test the applicability and differences of the mechanism of rural digitalization promoting land transfer in different institutional environments and development stages, thereby enriching the theoretical connection and policy implications between digital agriculture and land system reform in developing countries.

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

XW: Funding acquisition, Writing – original draft, Project administration, Conceptualization, Data curation.

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Conflict of interest

The author declares 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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References

Aker, J. C. (2010). Information from markets near and far: mobile phones and agricultural markets in Niger. *Am. Econ. Journal: Applied Econ.* 2 (3), 46–59. doi:10.1257/app.2.3.46

Cai, W. C., Huo, X. X., and Yang, H. Y. (2022). Can internet use promote farmers' farmland transfer? -An examination based on transaction costs. *Rural. Econ.* (07), 28–36. doi:10.13581/j.cnki.rdm.20210684

Chen, E., Cai, H. L., and Wu, C. C. (2024). Production automation, human capital mismatch and firm performance. *Econ. Manag.* 46 (07), 109–128. doi:10.19616/j.cnki.bmj.2024.07.007

Chen, Z., and Zhang, X. (2022). Can the construction of digital villages alleviate the mismatch of agricultural resource elements? *Journal of Agroforestry Economics and Management,* 21 (06), 736–743. doi:10.16195/j.cnki.cn36-1328/f.2022.06.79

Cui, K., and Feng, X. (2020). Research on the design of rural digital economy index system under the perspective of digital village construction. *Res. Agric. Mod.* 41 (06), 899–909. doi:10.13872/j.1000-0275.2020.0079

Cui, L., and Feng, F. (2025). How the digital economy affects labor market segmentation among cities: "deepening the divide" or "ironing out the gullies". *Contemp. Econ. Sci.* 47 (02), 54–65. doi:10.20069/j.cnki.DJKX.202502004

Fan, Z., Guo, F., and Bian, C. (2025). Digital rural construction, resource mismatch, and rural land use efficiency. *Front. Environ. Sci.* 2025, 1546082. doi:10.3389/fenvs.2025.1546082

Gaoli, Z., Fangping, R., Jian, Z., and Fazhi, L. (2025). How digital industry agglomeration drives green total factor productivity enhancement-an empirical study based on the perspective of resource mismatch. *Explor. Econ. Issues* (05), 63–76. doi:10.14067/j.cnki.1673-9272.2025.01.010

Guo, H. H. (2024). Digital village construction, resource factor mismatch and green total factor productivity in agriculture. *J. China Univ. Geosciences Soc. Sci. Ed.* 24 (01), 102–116. doi:10.16493/j.cnki.42-1627/c.20231213.001

Huang, D., and Ni, J. (2023). Digital economy, resource mismatch and high-quality development of the Yangtze River Economic Belt. *J. Chongqing Univ. Soc. Sci. Ed.* 29 (06), 52–68. doi:10.16387/j.cnki.42-1867/c.2023.06.009

Lei, Z., Qi, Q., and Wang, L. (2023). Can digital rural construction drive high-quality growth of agricultural economy? *J. Huazhong Agric. Univ. Sci. Ed.* (03), 54–66. doi:10.13300/j.cnki.hnwkxb.2023.03.006

Liang, G., Zhang, L., and Liu, K. (2024). Digital financial inclusion, labor mobility and county economic development. *West. Forum* 4 (01), 18–31. doi:10.19571/j.cnki.1000-2995.2024.06.010

Lin, H., Zhao, Lu B., and Hu, Y. (2023). Can digital village construction promote common prosperity in old revolutionary areas. *China Rural. Econ.* (05), 81–102. doi:10.20077/j.cnki.11-1262/f.2023.05.005

Liu, Z., Xian, X. I. N., and Lu, Z. (2021). Does internet agricultural information access promote farmers' land transfer. *Agric. Technol. Econ.* (02), 100–111. doi:10.13246/j.cnki.jae.2021.02.009

Man-Yu, HUANG, and Xiao-Xing, WANG (2022). Digital economy, resource mismatch and corporate total factor productivity. *Macroecon. Res.* (12), 43–53. doi:10.16304/j.cnki.11-3952/f.2022.12.001

Peng, C. (2019). The logic of the advancement of digital rural strategy. *People's forum* 33, 72–73. doi:10.19647/j.cnki.37-1462/f.2025.03.008

Pirannejad, A., and Janssen, M. (2019). Internet and political empowerment: towards a taxonomy for online political empowerment. *Information Development* 35 (1), 80–95. doi:10.1177/0266666917730118

Qi, W., Li, M., and Jingbo, L. I. (2021). Digital village empowerment and farmers' income growth: role mechanism and empirical test-A study on the moderating effect based on farmers' entrepreneurial activity. *J. Southeast Univ. (Philosophy Soc. Sci. Ed.)* 23 (02), 116–125+148. doi:10.13916/j.cnki.issn1671-511x.2021.02.014

Shan, D., Zhang, Y., and Wang, Y. (2022). Farmers' digital literacy, property income and common wealth. *J. Central Univ. Natl. (Philosophy Soc. Sci. Ed.)* 49 (03), 143–153. doi:10.15970/j.cnki.1005-8575.2022.03.011

Shen, F., and Chen, X. (2021). *Maintaining rurality: a theoretical elaboration for realizing the characteristics of digital village governance.* E-Government, 39–48. doi:10.16582/j.cnki.dzzw.2021.03.00403

Su, J. Q., Pan, T., and Dong, C. H. (2023). Development of agricultural digitalization and evaluation of regional differences in China. *J. Northwest Agric. For. Univ. Soc. Sci. Ed.* 23 (04), 135–144. doi:10.13968/j.cnki.1009-9107.2023.04.15

Sun, Y., Ge, L., and Wang, X. (2022). The impact of digital finance on labor mismatch and its heterogeneity analysis - based on panel data of prefecture-level cities in China. *Sci. Res.* 40 (01), 47–56+138. doi:10.16192/j.cnki.1003-2053.20210312.005

Wang, D., and Ran, X. (2022). Rural digitization, human capital and rural industrial integration development-empirical evidence based on Chinese provincial Panel data. *J. Chongqing Univ. Soc. Sci. Ed.* 28 (02), 1–14. doi:10.13713/j.cnki.cssci.2022.02.006

Wang, Z., and Bai, Y. (2022). Theoretical construction, empirical analysis and optimization path of coupling digital economy and rural revitalization. *China Soft Sci.* (01), 132–146. doi:10.19456/j.cnki.tjyzx.2022.06.011

Wang, S., and Sun, P. (2023). Digital economy, labor mobility and urban-rural income gap. *J. Harbin Univ. Commerce (Soc. Sci. Ed.)* 05, 108–118. doi:10.20004/j.cnki.ujn.2024.06.009

Wang, S., Yu, N., and Fu, R. (2021). Digital village construction: role mechanism, realistic challenges and implementation strategy. *Reform* (04), 45–59. doi:10.19714/j.cnki.1671-7465.2021.0006

Weijiang, L. I. U., and Hao, Y. (2025). Digital divide and labor reallocation-analysis of dynamic effects and efficiency enhancement. *Contemp. Econ. Sci.* 12 (03), 1-12. Available online at: http://kns.cnki.net/kcms/detail/61.1400.F.20250424.1534.002.html.

Wen, F. (2022). Digital village construction:Importance, practical dilemma and governance path. *Guizhou Soc. Sci.* (06), 147–153. doi:10.13713/j.cnki.cssci.2022.04.011

Wen, Z., and Ye, B. (2014). Mediating effect analysis: method and model development. *Advances in Psychological,* 22 (05), 731–745.

Wenquan, ZHENG, Ang, D. I., and Guo, J. (2022). Research on the impact of internet use on farmland transfer and its optimization path-an examination based on the perspective of non-farm income. *J. Guizhou Univ. Finance Econ.* (03), 27–36. doi:10.14116/j.nkes.2021.11.002

Xianli, X. I. A., Chen, Z., Zhang, H., and Zhao, M. (2019). High-quality development of agriculture: digital empowerment and realization path. *China Rural. Econ.* 12, 2–15. doi:10.13253/j.cnki.ddjjgl.2019.07.007

Zhang, H., Li, S., and Qian, X. (2024). Digital development, rural construction and rural energy conservation and emission reduction. *J. Agric. For. Econ. Manag.* 23 (02), 206–215. doi:10.16195/j.cnki.cn36-1328/f.2024.02.23

Zhang, Y. Q. (2022). Research on the impact and mechanism of digital financial inclusion on rural land transfer - empirical evidence from CFPS and PKU-DFIIC. *Econ. Manag.* 36 (03), 30–40. doi:10.13331/j.cnki.jhau(ss).2022.03.011

Zhang, J., and Zhang, X. (2022). A study on the impact and mechanism of internet use on the decision to transfer agricultural land-micro evidence from CFPS. *China Rural. Econ.* (03), 57–77. doi:10.13331/j.cnki.jhau(ss).2022.03.008

Zhang, P., Wu, M., and Zhang, X. (2022). Internet, agricultural land transfer and sustainable livelihoods. *Res. Dev. Manag.* 34 (02), 41–53. doi:10.13581/j.cnki.rdm.20210684

Zhou, Y., Xiao, X., and Yang, L. (2025). Rural digital transformation, employment opportunity selection and farmers' income increase. *Soc. Sci.* (03), 120–132. doi:10.13644/j.cnki.cn31-1112.2025.03.010

Zhu, J. J., Wang, H. M., and Zhang, F. H. (2025). A study on the impact of digital literacy on the supply of agricultural production services in family farms. *Agricul. Econ. Manag.* 52–63.02. doi:10.13575/j.cnki.319.2025.14.039