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Digital economy, consumption structure and rural economic transformation: a case study of China

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Introduction: Promoting rural economic transformation is an important foundation for achieving agricultural modernization. Under the background of rural revitalization strategy, digital technology is increasingly being applied in the agricultural sector, and the digital economy is becoming a new driving force for China's rural economic transformation.

Methods: Based on China's provincial panel data from 2013 to 2020, this paper uses the two-way fixed effect model, intermediary effect model, and panel threshold model to deeply analyze the impact and internal mechanism of the digital economy development on rural economic transformation.

Results and discussion: The research shows that the digital economy significantly promotes China's rural economic transformation, and this conclusion is still valid after robustness tests such as selecting historical data as instrumental variables. The mechanism test confirms that the digital economy promotes rural economic transformation by optimizing residents' consumption structure. In addition, the digital economy has a single threshold effect on the rural economic transformation based on the level of consumption structure. After crossing the threshold value, its promotion effect on the rural economic transformation is more prominent, indicating that the impact of the digital economy on the rural economic transformation will show the non-linear characteristics of increasing 'marginal effect' due to the different levels of consumption structure; Heterogeneity analysis found that compared to southern regions, the digital economy in northern regions has a more significant promoting effect on rural economic transformation. This study deepens the understanding of the motivation for rural economic transformation and the effects, mechanisms, and regional differences of the digital economy empowering rural economic transformation. Based on this, this paper proposes that the government fully realize the digital economy's important role in rural economic transformation, actively innovate and promote digital technology, continue to expand and strengthen the consumer Internet, adjust measures to local conditions, and try to achieve coordinated development.

KEYWORDS

digital economy, upgrading consumption structure, rural economic transformation, mediating effect, threshold effect

1 Introduction

Since the reform and opening up, China's rural economy has rapidly transformed and become one of the fastest developing countries in the global rural economic transformation (Huang and Shi, 2021). The International Fund for Agricultural Development points out that there is a close relationship between rural economic transformation and production structure, non-agricultural employment and entrepreneurship, agricultural labor productivity, infrastructure and so on. China has maintained rapid growth in the output value of high-value agricultural products, agricultural labor productivity, and non-agricultural employment of the rural labor force. However, in recent years, rural economic transformation has faced many problems. For example, due to the conflict between high-value agricultural development and new policies, the growth rate of non-agricultural employment in the rural labor force has declined. In the long run, the improvement of agricultural labor productivity needs the strong support of rural talent revitalization. Accelerating the transformation of a rural economy can promote farmers' income and rural development and help solve the food security problem. Therefore, to ensure the steady progress of China's agricultural and rural modernization process, it is necessary to accelerate the transformation of the rural economy.

With the acceleration of the global informatization process, the digital economy has developed rapidly, and the digital dividend has been continuously spread to rural areas. Digital technology is reorganizing the allocation of rural elements such as "people, land, and money," bringing new opportunities for reconstructing the rural economic development model and organizational form and becoming an important driving force for China's rural economic transformation. In recent years, China has successively issued documents such as "Digital Rural Development Strategy Outline" and "Digital Agriculture Rural Development Plan (2019–2025)." It emphasizes accelerating the development of the digital economy and adhering to the priority development of agriculture and rural areas. China's No. 1 Central Document in 2023 makes a vital deployment, which points the way for comprehensively driving the modernization of agriculture and rural areas with the help of digital technology. It emphasizes the significance of digital-enabled development, aiming to leverage digital technology to enhance agricultural production efficiency, optimize the consumption structure in rural areas, and accelerate the transformation of the rural economy. In this context, integrating the digital economy and the consumption structure, realizing the upgrading of the residents' consumption structure, and enhancing the synergy between the digital economy and the rural economic transformation have become a significant practical problem.

China has a super large market with a population of 1.4 billion, which nurtures a large demand for upgrading consumer structure. Adapting to the trend of upgrading residents' consumption structure is not only an inherent requirement for accelerating the cultivation of a complete domestic demand system, but also an important measure to promote rural economic transformation and sustainable and healthy development. Therefore, how to effectively boost consumption has become a key focus of rural economic work. Currently, the rapid development of digital technology has injected new vitality into the development of rural economy, giving birth to a series of new agricultural formats and models with digital economy as the core, providing strong support for the transformation of China's rural economy. At the same time, the consumption concept of the general public is gradually changing, and these emerging technologies also provide important opportunities to stimulate residents' consumption potential (Zhang and Qu, 2024). Utilizing the platform foundation of the digital economy to tap into the potential of social consumption, promote the adjustment and upgrading of consumption structure, and drive changes in supply structure and status driven by demand, thereby enhancing the flow of agricultural production factors and the activity of agricultural product market transactions. From the perspective of adjusting the consumption structure, the iterative updates of digital technology may have a positive impact on the transformation of China's rural economy.

The research on rural economic transformation mainly focuses on qualitative research, such as path, effect, driving force, and comparison of international experiences. In the past 40 years, China's rural economic transformation has undergone three stages and moved toward the fourth stage, sustainable development. Compared with developed and developing countries, China's rural economy has maintained a rapid transformation speed (Zhang et al., 2018), significantly promoting rural poverty reduction and farmers' income increase. Scholars generally believe that investment orientation and government policies are essential driving forces for rural economic transformation (Ma et al., 2019; Fan et al., 2018; Jin et al., 2010). Looking back on the achievements of rural development in China, Huang (2018) summarized the driving forces of rural economic transformation as three aspects: system, policy, and investment. China's rural economy has become a relatively competitive economic system. Increasing capital investment is still the primary way to promote rural economic transformation in a stable institutional and policy environment. There is room for expansion in the research on the relationship between the digital economy and rural economic transformation. The existing research pays more attention to the impact of the digital economy on rural revitalization (He et al., 2023), farmers' income growth (Wang Y. et al., 2023), rural economic development (Li et al., 2022), alleviating rural poverty (Liu and Jiang, 2023), improving rural modernization (Li et al., 2024), promoting high-quality agricultural development (Jiang et al., 2022) and rural industrial integration (Zhang et al., 2023). The research covers China's provinces, regions, prefecture-level cities, districts, and counties. In contrast, there is little literature to study the transformation of the rural economy from the digital economy perspective, especially quantitative research. Does the digital economy drive China's rural economic transformation? What is the transmission mechanism behind it? In this regard, this paper chooses to study the impact of the digital economy on residents' consumption structure. Promoting residents' consumption is the basis of rural economic growth, which plays a vital role in promoting the transformation of old and new kinetic energy, optimizing the structure of agricultural production, expanding employment, and increasing the income of rural residents, thus providing strong support for promoting rural economic transformation. Based on this perspective, this paper attempts to study how the digital economy promotes rural economic transformation through a complete framework. In addition, this paper selects the provincial level as the regional object and can study the digital economy, consumption structure upgrading, and rural economic transformation at the macro scale.

The marginal contribution of this paper is as follows: First, the existing literature does not consider the factor of the digital economy. This study focuses on the research of the digital economy on rural economic transformation and provides a new perspective for accelerating rural economic transformation. Secondly, from the provincial-level perspective, an index system for the digital economy and rural economic transformation is meticulously constructed. This system serves as a comprehensive framework through which the development levels of both the digital economy and rural economic transformation are comprehensively and in-depth evaluated, providing a solid foundation for subsequent research and policy-making processes. Thirdly, it delves into the influence path of the digital economy on rural economic transformation. By doing so, it not only clearly elucidates the mechanism underlying the upgrading of the residents' consumption structure but also enriches and deepens the existing body of literature in this field. This in-depth exploration contributes to a more comprehensive understanding of the complex relationship between the digital economy and rural economic development, offering fresh insights and perspectives for future research and policy-making initiatives.

2 Theoretical analysis and research hypothesis

2.1 The direct impact of the digital economy on rural economic transformation

The integration of China's rural and digital economy has promoted its economic transformation mainly in the following aspects: The integration of China's rural and digital economy has promoted its economic transformation primarily in the following elements: (1) The digital economy has promoted the development of China's high-value agriculture. According to the firm theory in neoclassical economics, producers are rational economic agents who always pursue the maximization of their own interests. Faced with changes in market prices, farmers will adjust the planting ratio of grain crops and cash crops according to their own endowments to maximize profits. With the deepening development of the digital economy in rural areas, digital technology is gradually being applied to agricultural production. Therefore, the level of development of the digital economy to some extent affects the planting structure of arable land. In theory, the development of the digital economy affects the individual behavior of farmers by affecting the costs and benefits of farmers' behavior. Economic crops have the characteristics of high risk and high income. Developing a digital economy can improve farmers' market acquisition ability, enhance farmers' prevention of market risks, and promote the planting of economic crops (Verdonk, 2019). In addition, the production cost of economic crops is usually high, and the development of the digital economy has realized the coordination and unification of goods, sales, and distribution, which has dramatically reduced the transaction cost of farmers (Zhou et al., 2024) and significantly reduced the production cost of economic crops. The development of a digital economy can also affect the adjustment of farmers' planting structure by improving farmers' planting skills and profitability (Akmarov et al., 2021), enhancing farmers' social capital (Zhong et al., 2022), and reducing farmers' financial acquisition costs (Su et al., 2021). The planting structure of farmers shows a trend of "non-grain." (2) The digital economy is vital in promoting non-agricultural employment of rural labor. In recent years, as a promising and dynamic economic form, the digital economy has achieved innovative development, accelerated the promotion of digital industrialization and industrial digital transformation, created vast employment space and abundant employment opportunities, and enhanced the possibility of non-agricultural employment for the labor force. From a macro perspective, regarding short-term and long-term effects, the digital economy significantly positively affects the non-agricultural employment of the rural labor force (Yan et al., 2018). Sun and Li (2024) believe that the "Broadband China" policy has promoted the development of emerging industries and improved the employment environment, thus providing more non-agricultural employment opportunities for rural women. From the micro level, the digital economy significantly impacts the non-agricultural employment behavior of the rural labor force through the resilience effect (Wang X. et al., 2023). The development of the digital economy has weakened the information occlusion caused by geospatial factors for non-agricultural employment of rural labor, which is conducive to reducing the cost of finding work and increasing the frequency of job search (Mirolyubova et al., 2020). Research shows that the digital economy has increased the probability of the rural labor force working part-time and pure labor (Li and Wen, 2023), narrowed the gender differences in the division of labor in the family, and expanded the intergenerational differences in the division of labor in the family (Lu et al., 2023). (3) Digital economy can improve agricultural labor productivity. With the continuous improvement of rural digital economy, the spatial barriers between urban and rural areas have been broken, and the pattern of rural information resources has been reshaped and improved, providing channels for farmers to obtain market economy information. In this process, the digital economy can integrate new information into every aspect of agricultural production, leveraging the diffusion effect of information (Bratta et al., 2023). This not only reduces the cost of obtaining market information for farmers, but also stimulates the potential of rural market economy, helping to improve agricultural labor productivity through information media. On the one hand, the digital economy helps farmers acquire new knowledge and technologies, promoting the optimization of agricultural human capital. At the same time, the digital economy can also strengthen the social network relationships of farmers (Veselovsky et al., 2018), facilitate the promotion of new agricultural production technologies, and thus reduce agricultural labor costs. In addition, the development of the digital economy can alleviate the problem of idle rural resources caused by non-agricultural employment of rural labor. By reorganizing and allocating existing agricultural resource elements, the utilization rate of resources can be improved, while also promoting the transfer and concentration of land management rights (Deininger and Jin, 2005). The large-scale and intensive business model can not only increase the average output per worker, but also improve land production efficiency by stimulating investment, financing, and technological innovation demand, thereby promoting the achievement of the goal of improving agricultural labor productivity. On the other

hand, the development of the digital economy can lead to the restructuring and redistribution of existing agricultural resources by government departments, improve the efficiency of agricultural resource utilization, and empower the improvement of agricultural labor productivity (Hu et al., 2024). In summary, the following research hypotheses are proposed:

Hypothesis 1 (H1): The digital economy has a promoting effect on rural economic transformation.

2.2 The indirect impact of the digital economy on rural economic transformation

In the era of the digital economy, new technologies represented by information and communication technology have profoundly impacted residents' consumption structure. The digital economy mainly promotes the optimization of consumption structure by changing consumption patterns and habits, deriving consumer products and services, and narrowing the urban-rural consumption gap. The impact of the digital economy on the optimization of consumption structure is as follows: (1) Change residents' consumption patterns and habits. The digital economy's development has broadened residents' consumption channels, and the consumption mode has gradually changed from the traditional offline consumption mode to the online consumption mode with webcast and online payment as the carrier. Digital technology provides consumers with a variety of rich information resources, improves information symmetry, facilitates the work and life of residents, meets the needs of individual comprehensive and healthy development, and promotes the consumption structure of residents from food, clothing, and other material consumption to material and communication entertainment non-material consumption (He et al., 2022). The use of the Internet has significantly increased the proportion of household entertainment consumption (Hong, 2007), and residents have begun to pay more attention to the pursuit of spiritual wealth. (2) Deriving higher quality, higher cost-effective consumer products and services. New technologies, formats, and industries emerge endlessly in the digital economy era. The platform economy, live broadcast economy, and online celebrity economy provide consumers with more affordable products. At the same time, new consumption models such as online education, online home purchases, and online medical care have greatly improved consumer products and services (Wang and Teo, 2020). It not only enriches consumers' choices but also meets consumers' needs. (3) Narrow the consumption gap between urban and rural residents. The rapid development of communication technologies such as the Internet has broken the spatial distance between rural and urban areas and greatly tapped the consumption potential of rural residents. In addition, the rapid development of e-commerce and express logistics provides rural residents with the same products and services as urban residents, which greatly improves the consumption level of rural residents and further narrows the consumption gap between urban and rural residents.

At the same time, the optimization of consumption structure is an important driving force for rural economic transformation. At the theoretical level, Kuznets proposed that the diversification of non-food consumption demand and the upgrading of consumption structure will bring about changes in production structure, promote the development of production and services in depth, and promote the transformation of rural economy. First of all, consumption upgrading can drive industrial upgrading through the Engel effect (the increase in the proportion of industrial value added in demand income elasticity) and the Baumol effect (the increase in the proportion of industrial value added in high productivity), which is conducive to the industrial structure moving toward the middle and high end (Fan et al., 2023). The ultimate goal of production is to meet the needs of residents' consumption. Residents' consumption has become the key orientation of industrial restructuring. The optimization and upgrading of the consumption structure will force changes in the industrial structure to meet consumers' consumption needs. In addition, to meet the needs of modern consumption of residents' family life, agricultural production methods must be oriented to acceptable, green, organic, high-quality transformation, the development of processing industry projects, centralized breeding communities, planting bases, farm economy, and rural tourism, etc., to promote the development of high-value agriculture. At the same time, to obtain considerable agricultural income to meet consumer demand, farmers are actively engaged in the production and operation of non-grain industries (Zhan et al., 2012). Secondly, the impact of the digital economy on the non-agricultural participation of the rural labor force. The decision of whether the rural labor force enters the non-agricultural industry is affected by many factors at the same time, which is often the result of the overall optimization of rural households based on weighing income and consumption. Chang and Mishra (2008) believed a clear link exists between non-agricultural employment and food consumption in rural households in developing countries. Non-agricultural employment of household heads is positively correlated with food consumption, while non-agricultural employment of spouses is negatively correlated. Finally, the optimization of consumption structure has increased the consumption demand of residents for high-value agricultural products, promoted the optimization of agricultural development and production structure, and increased farmers' income. The non-agricultural employment of the rural labor force has created favorable conditions for the surplus farmers engaged in agricultural production to have more arable land, irrigation water, and other agricultural resources, thus improving agrarian labor productivity and agricultural income.

Hypothesis 2 (H2): The development of the digital economy can promote the transformation of rural economies by optimizing the consumption structure.

2.3 Non-linear effects of the digital economy on rural economic transformation

According to the previous analysis, the digital economy has a positive role in promoting rural economic transformation, but there may be a certain threshold. China's rural economic transformation needs the strong support of residents' consumption. Under the current imbalance of residents' consumption structure, the digital economy has a practical effect on China's rural economic transformation. Due to the limitation of the development

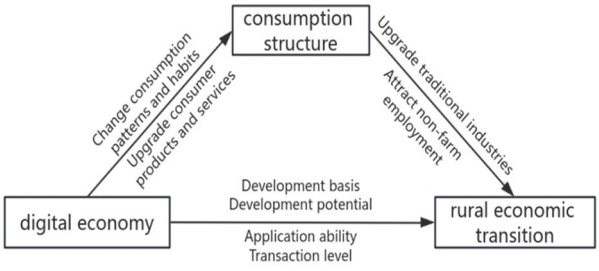

FIGURE 1
Theoretical framework.

foundation of China's real economy and digital technology, there is still a significant gap in the consumption level between urban and rural areas and between different income levels in the early stage of the digital economy development, which leads to the low level of residents' consumption structure and the limited promotion of rural economic transformation. However, with the continuous development of the digital economy, digital technology is effectively embedded in all aspects of residents' consumption. It promotes consumption upgrading by improving consumption levels and reshaping consumption patterns (Zheng and Yang, 2023). At the same time, it effectively improves the selectivity and convenience of consumers' consumption, fully releases the potential of residents' consumption, and increases residents' demand satisfaction significantly. In addition, the optimization of residents' consumption structure increases the demand for a digital economy while stimulating the vitality of residents' consumption. The more urgent the demand for digital technology is, the more pronounced the effect of the digital economy on rural economic transformation will be. In the long run, improving residents' consumption structure will also optimize social labor resources, improve the professional level of agriculture, service industry, and other businesses, and enhance the demand for digital economy. It can be seen that the impact of the digital economy on rural economic transformation is increasing marginally, and its impact increases with the optimization of residents' consumption structure. Therefore, the following research hypotheses are proposed:

Hypothesis 3 (H3): The impact of the digital economy on rural economic transformation will show the non-linear characteristics of increasing "marginal effect" due to the different levels of consumption structure.

Based on the above theoretical analysis, the theoretical framework of this paper is shown in Figure 1.

3 Research design

3.1 Model design

Based on theoretical analysis, in order to test the impact of the digital economy on rural economic transformation, this paper established a two-way fixed effect model:

$$ret_{it} = \beta_0 + \beta_1 digital_{it} + \varphi_k X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In Equation 1, ret represents the level of rural economic transformation in region i in year t, digital means the development level of the digital economy in region i in year t, X represents the control variable, α_i is the provincial fixed effect, λ_t is the time fixed effect, ε_{it} is the random disturbance term.

In addition to the direct effect embodied in Equation 1, to further study the indirect mechanism of the digital economy on rural economic transformation, referring to the research ideas of Wen and Ye (2014), we constructed a model with consumption structure upgrading (csu) as an intermediary variable:

$$csu_{it} = \theta_0 + \theta_1 digital_{it} + \varphi_k X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (2)$$

$$ret_{it} = \sigma_0 + \sigma_1 digital_{it} + \sigma_2 csu_{it} + \varphi_k X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (3)$$

In terms of testing the median effect, testing the coefficients of model (2) and model (3) in sequence is the most commonly used method (Baron and Kenny, 1986). Although some articles have suggested using Bootstrap method to directly test the coefficient product, many application workers still use sequential testing. The reason why sequential testing is popular is that the method is simple, easy to understand and explain. Although the testing power of sequential testing is relatively low among various methods (Hayes, 2009), if researchers have obtained significant results using sequential testing, the problem of low testing power is not a problem for them! At this point, the results of sequential testing are even better than those of Bootstrap method. Wen and Ye (2014) suggest using sequential testing first. If the coefficients of model (2) and model (3) are not significant at the same time, it is recommended to use Bootstrap method for mediating effect testing.

In addition to the mediating effect model, it is also necessary to consider the non-linear effect of consumption structure upgrading on the promotion of rural economic transformation by the digital economy and further construct the panel threshold model:

$$ret_{it} = \gamma_0 + \gamma_1 digital_{it}(csu \le \rho) + \gamma_2 digital_{it}(csu > \rho) + \varphi_k X_{it} + \varepsilon_{it} \quad (4)$$

Among them, ρ represents the threshold value, and Equation (4) considers the single threshold case, which can be expanded to the multi-threshold case according to the econometric test.

3.2 Variable measure and description

3.2.1 Explained variables

Considering the unity of measurement methods for explanatory and dependent variables, this article draws on the research methods of Hong et al. (2023) and Zhang et al. (2023), and uses the entropy method to calculate the comprehensive scores of digital economy and rural economic transformation, respectively. There are two types of assignment methods: subjective and objective. Entropy method is one of the objective assignment methods, and it determines the weight of indicators based on their relative changes in the overall impact. It can reduce the interference of some human factors and make the comprehensive score more reasonable.

This study carefully constructed an index system for rural economic transformation in China, followed by calculating relevant indexes. This is done to quantify the rural economic

TABLE 1 Evaluation index system of rural economic transformation.

Secondary index	Three-level index	Index calculation method	Direction
High-value agricultural development level	Agricultural output value per hectare	Agrarian output value/total sown area	+
	Proportion of grain sown area	Grain sown area/total sown area	−
Agricultural labor productivity	Agricultural labor output value	The output value of the primary industry/the number of primary industry employees	+
Rural labor non-agricultural employment	The proportion of agricultural employment	The number of primary industry employment/the total number of employment	−
	The proportion of wage income in rural households	Wage income/household disposable income	+

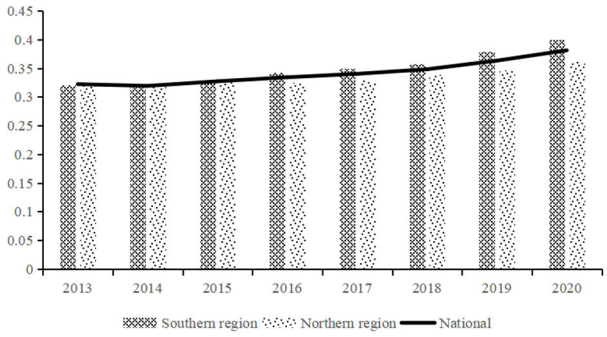

FIGURE 2
The level of rural economic transformation in the whole country and the two major regions.

transformation level across China's provinces (municipalities, autonomous regions). According to the rural economic transformation defined by the rural development report of the International Fund for Agricultural Development, Min et al. (2020) proposed to measure China's rural economic transformation from three indicators: high-value agricultural development level, agrarian labor productivity, and non-agricultural employment of rural labor force. The development level of high-value agriculture adopts two indicators: agricultural output value per hectare and proportion of grain sown area. In areas with better high-value agriculture development, the unit farmland output level is also high. Therefore, the agricultural output value per hectare is selected as a positive indicator (Su et al., 2020). High-value agriculture generally belongs to non-food crops; there are many categories, and there is a certain degree of difficulty in statistics. Therefore, drawing on the research of Zhu et al. (2021), this study uses the proportion of grain sown area to the total area of crops as a negative indicator of the development level of high-value agriculture. In addition, agricultural labor productivity reflects the production value created by the unit agrarian labor force, which is measured by the ratio of the output value of the primary industry to the number of employed people. With the improvement of agricultural production efficiency, many surplus rural laborers have entered non-agricultural sectors, increasing the wage income of rural residents. Based on Timmer's (2009) research, this paper measures the proportion of agricultural employment and household wage income. The assignment description of the above variables are shown in Table 1.

Considering the differences in provincial infrastructure, population mobility and foreign investment, the gap between the north and the south has become a new situation of unbalanced regional development in China. Given this, this paper divides China into two groups of samples, one in the south and one in the north, for statistical analysis and a heterogeneity test. The southern and northern regions of China are delineated by the Qinling Huaihe River, while the northern region includes Beijing, Tianjin, Shanxi, Hebei, Inner Mongolia, Liaoning, Heilongjiang, Jilin, Henan, Shandong, Gansu, Ningxia, Qinghai, Shaanxi, and Xinjiang; The southern region includes: Jiangsu, Anhui, Zhejiang, Shanghai, Hubei, Hunan, Jiangxi, Fujian, Yunnan, Guizhou, Sichuan, Chongqing, Guangxi, Guangdong, Hainan. Figure 2 shows the level of rural economic transformation in the country and the two major regions from 2013 to 2020. Whether at the national level or from a sub-regional perspective, the rural economic transformation has maintained an upward trend of small-scale fluctuations. From 2013 to 2020, the national rural economic transformation level increased from 0.322 in 2013 to 0.381 in 2020, with an average annual growth rate of 2.433%. In addition, the gap between the level of rural economic transformation in the southern and northern regions has gradually widened, from 0.003 in 2013 to 0.038 in 2020, indicating that China's rural economic transformation has noticeable regional differences. On the one hand, the climatic conditions in the southern region enable it to grow various economic crops and has advanced agricultural technology, high-value agricultural development is better, and high agricultural labor productivity. On the other hand, economic structure transformation in the southern region is faster, and the level of industrial structure optimization and rural labor transfer is higher.

3.2.2 Core explanatory variables

At present, some scholars have carried out calculations on the digital economy, but their measurement indicators and accounting methods have not formed a unified standard. Based on Lin et al. (2023) and the Peking University Digital Inclusive Finance Index (Yu et al., 2022), this paper measures the development level of the digital economy from four dimensions: development foundation, development potential, application ability, and transaction level. Among them, the digital economy development foundation uses mobile phone penetration rate, per capita domain name number, and cable density for accounting. The development potential of the digital economy mainly reflects the level of digital technology

TABLE 2 Index system of the digital economy.

Secondary index	Three-level index	Index calculation method
Development foundation	Mobile phone base station density	The ratio of the number of mobile phone base stations in the provincial area
	Internet broadband port density	The ratio of the number of Internet broadband access ports in the provincial area
	Mobile subscription	Number of mobile phones per 100 people
	Number of domain names per capita	The ratio of domain name number to total population
	Optical cable density	The ratio of cable length to provincial area
Development potential	R&D funding intensity	The ratio of R&D expenditure to GDP
	Higher education level	The ratio of the number of junior college and undergraduate graduates to the total population
	Internet-related practitioners	Proportion of software and information technology practitioners
Application ability	Websites quantity	Number of websites per 100 enterprises
	Number of computers	The number of computers per 100 people
	Proportion of e-commerce enterprises	The proportion of enterprises with e-commerce activities in the total number of enterprises
Transaction level	The average sales of e-commerce enterprises	The ratio of e-commerce sales to the number of e-commerce enterprises
	Proportion of software business income	The ratio of software business income to GDP
	Per capita telecommunications business volume	The ratio of the total telecommunications business volume to the total population
	Inclusive development of digital finance	Digital inclusive financial index

innovation, including the intensity of R&D investment, the degree of higher education, and the Internet-related practitioners. The application ability of the digital economy is measured by the number of websites owned by every 100 enterprises, the number of computers used by every 100 people, and the proportion of e-commerce enterprises. The level of digital transaction development measures the level of digital economic income and mobile payment, including the sales volume of e-commerce enterprises, the proportion of software business income, the per capita telecom business volume, and the inclusive development of digital finance. The assignment description of the above variables is shown in Table 2.

In terms of the development level of the digital economy and its changing trend (Figure 3), the development level of China's digital economy has increased rapidly. In 2013, the development level of

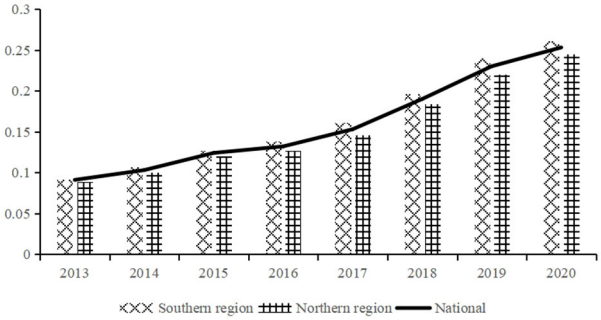

FIGURE 3
The level of the digital economy in the whole country and the two major regions.

the national digital economy was 0.091. By the end of 2020, the development level of the digital economy has risen to 0.253. In terms of regions, the development level of the digital economy in the southern and northern regions in 2013 was 0.092 and 0.089, respectively. By the end of 2020, the development level of the digital economy rose to 0.261 and 0.245, with an average annual growth rate of 16.063% and 15.565%, respectively. It can be seen that there is still a big gap between the development level of the digital economy in the south and that in the north, and the gap between the development level of the regional digital economy is expanding.

3.2.3 Intermediary variables, threshold variables

The analysis of the mediating effect and threshold effect involves the variable of consumption structure upgrading. China's Bureau of Statistics divides the consumption types of residents into food, clothing, housing, household equipment, and supplies, family health care, culture, education, entertainment, transportation, and communication consumption expenditure, etc., reflecting the residents' essential life consumption from food, clothing, housing, and transportation to health care, entertainment, transportation and communication and other major consumption types to improve the quality of life. In quantitative research, the consumption upgrade rate is expressed by the decrease in the proportion of low-end consumption expenditure or the increase in the proportion of high-end consumption expenditure. Dong et al. (2022) believes that consumption upgrading results from the comprehensive improvement of quantity and quality, which embodies the extensive change of consumption structure at different levels. The proportion of low-end or high-end consumption in total expenditure cannot fully reflect this comprehensive change result. This paper refers to the consumption upgrading coefficient used by Wang and Wang (2018) to quantitatively calculate the upgrading of residents' consumption structure, and divides residents' consumption into three levels: primary, intermediate, and advanced. Then, food consumption, residential consumption, transportation, and communication consumption are selected as the representatives of consumption at all levels, and their proportion of total consumption expenditure is calculated. After weighting, the consumption upgrade rate of

residents in the region is obtained. Taking food consumption and residential consumption as the representatives of primary consumption and intermediate consumption, respectively, is more in line with the characteristics of Chinese residents' consumption and is also the common practice of previous research. For advanced consumption, all of us choose traffic communication because traffic communication expenditure reflects residents' high-level consumption and new consumption conditions such as tourism and communication, reflects the improvement level of residents' living and consumption quality, and is more in line with the reality that China's consumption upgrade in recent years is mainly reflected in traffic communication expenditure.

The upgrading rate of consumption structure in urban and rural areas is calculated. Finally, the overall consumption structure upgrading (csu) is calculated according to the proportion of urban and rural populations. The specific calculation formula is as follows:

$$csu = \sum_{m=1}^{2} \frac{P_m}{P} \left(food\% \times 1 + house\% \times 2 + commu\% \times 3 \right) \quad (5)$$

In the formula, P represents the total population. food%, house%, and commu%, respectively, representing the proportion of primary consumption in total consumption, intermediate consumption in total consumption, and advanced consumption in total consumption. m is used to distinguish rural and urban areas. csu is a positive index, the greater the value, the more obvious the consumption structure optimization.

3.2.4 Control variables

To analyze the impact of the digital economy on rural economic transformation more comprehensively, based on relevant studies, the following control variables are selected: Urbanization rate (lnurb), the percentage of urban population in the total population; The level of education (lnedu), with the number of people at all levels of education as the weight of the weighted average; The level of agricultural mechanization (lnmac) is expressed by the total power of agricultural machinery in each region; According to the research of Xu et al. (2022), the proportion of the added value of the primary industry to GDP (lnpri) and the proportion of the added value of the tertiary industry to GDP (lnter) are selected to measure the level of industrial structure.

3.3 Data sources and descriptive evidence

This study used data from 30 provinces in Mainland China from 2013 to 2020 as the research sample. Due to the lack of statistical data in some provinces and municipalities in some years, the data of Hong Kong, Macao, Taiwan, and Tibet of China were excluded. The original data are mainly derived from the "China Statistical Yearbook," "China Science and Technology Statistics Yearbook," "China Population and Employment Statistics Yearbook." In addition, the monetary indicators have been adjusted for inflation based on unchanged prices in 2013. Descriptive statistics of variables are shown in Table 3. It can be seen that each variable has a large range of changes, which accurately reflects the differences in regional development, indicating that the basic data for analyzing the relationship between the digital economy and rural economic transformation is good.

TABLE 3 Descriptive statistics.

Variables	Obs	Mean	S.D.	Min	Max
ret	240	0.342	0.0747	0.210	0.600
digital	240	0.160	0.120	0.0324	0.732
csu	240	1.125	0.073	0.926	1.316
lnurb	240	4.080	0.183	3.635	4.495
lnedu	240	2.215	0.093	1.969	2.540
lnmac	240	7.685	1.128	4.543	9.499
lnpri	240	2.000	0.944	−1.360	3.230
lnter	240	3.911	0.151	3.546	4.428

TABLE 4 Unit root inspection results.

Variables	LLC	*P* value	Hadri	*P* value	Conclusion
ret	−28.0757***	0.0000	10.8210	0.0000	Stable
digital	−12.9326***	0.0000	11.4820	0.0000	Stable
csu	−22.1915***	0.0000	8.5949	0.0000	Stable
lnurb	−11.6872***	0.0000	12.0683	0.0000	Stable
lnedu	−10.2918***	0.0000	3.6247	0.0001	Stable
lnmac	−6.1512***	0.0000	8.5576	0.0000	Stable
lnpri	−20.8833***	0.0000	9.6319	0.0000	Stable
lnter	−13.8193***	0.0000	10.7155	0.0000	Stable

***Significant at the 1% statistical levels.

4 Results of investigation

4.1 Unit root test

To avoid spurious regression, perform unit root tests on panel data before conducting empirical analysis. The LLC test and Hadri test used in this paper showed that all variables passed the significance test and there were no unit roots. The results are shown in Table 4. On this basis, empirical testing can be conducted.

4.2 Results of baseline regression

Table 5 reports the benchmark regression results. This paper uses multiple models for comparative analysis. Model (1) and Model (4) are two-way fixed effect models. Model (2) and Model (3) are random effect models and fixed effect models, respectively. The four models' regression coefficients of the digital economy development are significantly positive. In Model (1), the regression coefficient of the digital economy to rural economic transformation is 0.149, which passes the 5% significance test. In the case of adding control variables, the regression coefficient of the digital economy in Model (4) is 0.341 and passes the 1% significance test. This shows

TABLE 5 Results of baseline regression analysis.

Variables	Model (1): fixed effects	Model (2): random effects	Model (3): fixed effects	Model (4): fixed effects
digital	0.149** (0.068)	0.340*** (0.039)	0.412*** (0.043)	0.341*** (0.101)
lnurb		0.047 (0.039)	−0.046 (0.045)	−0.130* (0.066)
lnedu		0.037 (0.054)	0.062 (0.055)	−0.077 (0.090)
lnmac		0.007 (0.009)	0.023* (0.012)	0.028** (0.013)
lnpri		0.034*** (0.012)	0.081*** (0.018)	0.087*** (0.023)
lnter		0.009 (0.033)	0.063* (0.035)	0.010 (0.046)
cons	0.252*** (0.028)	−0.145 (0.181)	−0.257 (0.193)	0.834* (0.464)
Province FE	Yes		Yes	Yes
Year FE	Yes			Yes
R-squared	0.930	0.518	0.543	0.938
Sample size	240	240	240	240

Robust standard errors are in parentheses; *p < 0.1, **p < 0.05, ***p < 0.01.

that the digital economy can significantly promote rural economic transformation, which aligns with Hypothesis 1 of this paper.

Further analysis model (4) shows that the coefficient of urbanization level is significantly negative at the level of 10%, indicating that urbanization development is not conducive to rural economic transformation. The coefficient of education level is negative but not significant, indicating that education level does not significantly affect the rural economic transformation in the region; The coefficient of agricultural mechanization level is significantly positive at the level of 5%, indicating that the higher the level of agricultural mechanization in the region, the more conducive to rural economic transformation; In terms of industrial structure, the coefficient of the first industrial structure is positive and significant at the level of 1%, the coefficient of the tertiary industry structure is positive but not significant, indicating that the development of the tertiary industry has not significantly promoted the rural economic transformation in the region.

4.3 Results of the mediation effect test

From the perspective of consumption structure optimization, this paper theoretically analyzes the transmission mechanism of the digital economy to rural economic transformation. Table 6 is the empirical test results. Model (1) shows that the coefficient of the digital economy development is 0.341 and passes the 1% significance test, which is consistent with the previous results. In Model (2), the influence coefficient of the digital economy is significantly positive, and digital economy optimizes the consumption structure of residents at the provincial level. The test results of Model (3) show that the consumption structure has a positive effect on rural economic transformation. The influence coefficient of the digital economy on rural economic transformation is lower than that of Model (1), indicating that the optimization of consumption structure is the mechanism of the digital economy promoting rural economic transformation, that is, the consumption structure has a mediating effect in the process of the digital economy promoting rural economic transformation. Observing the specific effect, for every unit increase

TABLE 6 Test results of mediation effect.

Variables	(1) ret	(2) csu	(3) ret
digital	0.341*** (0.101)	0.501*** (0.128)	0.294*** (0.104)
csu			0.094* (0.056)
lnurban	−0.130* (0.066)	0.022 (0.084)	−0.132** (0.066)
lnedu	−0.077 (0.090)	−0.061 (0.114)	−0.071 (0.089)
lnmac	0.028** (0.013)	−0.010 (0.016)	0.029** (0.013)
lnpri	0.087*** (0.023)	−0.022 (0.029)	0.089*** (0.023)
lnter	0.010 (0.046)	−0.036 (0.058)	0.014 (0.046)
cons	0.834* (0.464)	1.176*** (0.590)	0.723 (0.467)
Provincial effects	Yes	Yes	Yes
Year effect	Yes	Yes	Yes
R-squared	0.938	0.894	0.939
Sample size	240	240	240

Robust standard errors are in parentheses; *p < 0.1, **p < 0.05, ***p < 0.01.

TABLE 7 Threshold effect test results.

Threshold variable	Model	*P* value	*F* value	10% threshold	5% threshold	1% threshold	BS times
csu	Single threshold	0.050	19.79	17.339	19.742	24.000	300
	Double threshold	0.110	15.12	15.783	19.016	24.755	300

TABLE 8 Threshold value results.

Threshold variable	Threshold	Estimated value	Lower bound of 95% confidence interval	95% confidence interval upper bound
csu	Threshold value ρ	1.216	1.202	1.221

in the digital economy, the consumption structure can increase by 0.501 units, while for every unit increase in the consumption structure, the rural economic transformation will increase by 0.094 units, that is, for every unit increase in the digital economy, the consumption structure path can promote the rural economic transformation by 0.047 units, and the mediating effect accounts for 13.783%.

4.4 Results of the threshold effect test

In the above analysis, the digital economy can significantly improve the level of rural economic transformation. Then, what are the differences in the impact of the digital economy on rural economic transformation in different consumption structure levels? This paper continues to conduct a threshold regression analysis of the data to explore further. First, test whether the threshold variable has a threshold effect, the results are shown in Table 7. The results show that the single threshold test is passed, but the double threshold test is not passed. Therefore, the single threshold model analysis is selected, and the threshold value is 1.216 (Table 8). Then, whether the threshold value selection of the consumption structure level is appropriate is tested. Figure 4 shows that the original hypothesis is accepted and the threshold value is selected appropriately.

Table 9 shows that when the residents' consumption structure level is lower than the threshold value of 1.216, the coefficient is 0.304, which is significant at the statistical level of 1%. When the level of residents' consumption structure is higher than the threshold value of 1.216, the coefficient is 0.416, and it is significant at the level of 1%. The significance of the impact of the digital economy on rural economic transformation is enhanced and the coefficient is more substantial. The two stages of the digital economy play an increasingly important role in promoting rural economic transformation, which verifies Hypothesis 3 of this paper. It shows that under the condition of optimizing the consumption structure level, the digital economy has a more positive role in promoting the transformation of the rural economy. The wide application of digital technology helps to optimize the consumption structure, promote the adjustment of agricultural production structure and industrial structure, promote the transfer of rural surplus labor force, and then change the inefficient production mode in rural areas and promote the transformation of rural economy.

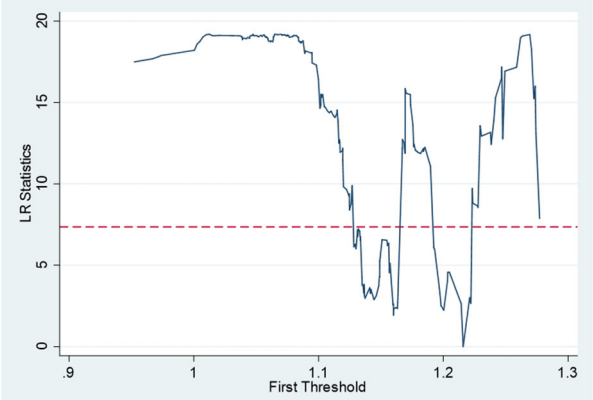

FIGURE 4
Single threshold estimation of consumption structure level.

4.5 Heterogeneity tests

Location heterogeneity. Based on the previous analysis, it is found that the level of rural economic transformation in China shows the regional characteristics of strong in the south and weak in the north. At the same time, the development of the digital economy varies greatly among provinces in China. There may be regional heterogeneity in the impact of the digital economy on rural economic transformation. The results are shown in Table 10 models (1) and (2). It can be seen that the coefficient of the digital economy in the northern region is significantly positive, while the coefficient of the digital economy in the southern region is positive but not significant, indicating that the digital economy has promoted the rural economic transformation in the northern region. The possible reason for this phenomenon is that the development level of rural economy in northern regions is relatively weak, and the introduction of digital economy has brought stronger marginal effects and development elasticity, accelerating the transformation of rural economy. At the same time, agriculture has a relatively large proportion in the economic structure of northern regions, and the impact of digital economy on rural economy is broader. Moreover, rural development in northern regions has greater elasticity, stronger absorption capacity for technology and capital, and can fully unleash the incremental effects brought by digital economy. The level of rural economic transformation in southern regions

is relatively high, and the incremental effect of digital economy is relatively small. Moreover, the diversification of economic structure has dispersed the effectiveness of digital economy in rural areas. This phenomenon indicates that the northern region should fully leverage the "latecomer advantage" of the digital economy and accelerate the transformation of rural economy.

5 Further test

5.1 Robustness test

The robustness test of the explanatory variable lag 1. There may be a time lag in the impact of the digital economy on rural economic transformation, so the digital economy lags by one period for regression. The results are shown in Table 11, and the regression coefficients and significance are consistent with the original results, which verifies the robustness and credibility of the empirical results.

Tobit model regression. The Tobit model is used for regression. Since the comprehensive index of rural economic transformation is between 0 and 1, which meets the Tobit setting conditions, Model (2) shows that the coefficient of the digital economy is significantly positive.

Tailing treatment. All variables except 1%−99% are set to be winsorized, and Model (3) is its regression result. It can be seen that after the tail reduction, the digital economy still has a significant positive impact on the rural economic transformation.

Delete municipalities. Due to the significant differences in the degree of rural economic transformation between provinces and cities, there are also differences in the level of digital economic development, which may have a certain impact on the final results. Therefore, the model (4) selects the provinces except Beijing, Tianjin, Shanghai and Chongqing as samples and finds that the regression coefficient and significance are consistent with the original results, which verifies the robustness and credibility of the empirical results.

5.2 Endogenous treatment

Starting from the theme of this paper, on the one hand, accelerating the transformation of the rural economy needs to rely on the rapid development of the digital economy, and the development of the digital economy is also inseparable from the improvement of rural economic transformation. Therefore, there is a causal endogenous relationship between the development of the digital economy and the transformation of the rural economy. On the other hand, there are many factors affecting rural economic transformation. Although more comprehensive control variables are selected, it is difficult to prevent the problem of missing variables. Therefore, this paper uses the instrumental variable method to solve the endogenous problem.

This paper adopts the two-stage least squares method (2SLS) to overcome the abovementioned endogeneity problem. From the development history of China's digital economy, the entry of digital technology into the public eye basically began with telephone line dial-up access (PSTN), followed by ISDN and ADSL access to the current fiber broadband access technology. The development of the digital economy should start with the popularization of fixed telephones, so areas with high fixed telephone penetration rates in history are also likely to have better digital economy development. At the same time, compared to the development speed and changes of digital technology, the historical impact of the number of fixed telephones on rural economic transformation is disappearing. Currently, the number of fixed telephones is also difficult to affect rural economic transformation. Based on the

TABLE 9 Panel threshold regression results.

Variables	ret
Digital (csu ≤ 1.216)	0.304*** (0.049)
Digital (csu > 1.216)	0.416*** (0.041)
lnurb	0.013 (0.046)
lnedu	0.091* (0.053)
lnmac	0.025** (0.012)
lnpri	0.112*** (0.019)
lnter	0.082** (0.034)
cons	−0.703*** (0.215)
R-squared	0.579
Sample size	240

Robust standard errors are in parentheses; *p < 0.1, **p < 0.05, ***p < 0.01.

TABLE 10 Heterogeneity regression results.

Variables	(1) Northern area	(2) Southern region
digital	0.316*** (0.085)	0.193 (0.172)
lnurb	−0.091* (0.049)	−0.510*** (0.131)
lnedu	0.061 (0.070)	−0.214 (0.152)
lnmac	0.026*** (0.009)	−0.030 (0.038)
lnpri	0.033* (0.017)	0.243*** (0.050)
lnter	0.076** (0.035)	0.082 (0.105)
cons	−0.121 (0.351)	2.992*** (0.834)
Provincial effects	Yes	Yes
Year effect	Yes	Yes
R-squared	0.978	0.937
Sample size	120	120

Robust standard errors are in parentheses; *p < 0.1, **p < 0.05, ***p < 0.01.

TABLE 11 Robustness test results.

Variables	(1)	(2)	(3)	(4)
L.digital	0.452*** (0.105)			
digital		0.342*** (0.039)	0.366*** (0.095)	0.867*** (0.119)
lnurb	−0.030 (0.071)	0.044 (0.040)	−0.112* (0.066)	−0.218*** (0.062)
lnedu	0.012 (0.084)	0.037 (0.053)	−0.108 (0.089)	−0.065 (0.086)
lnmac	0.029** (0.012)	0.007 (0.009)	0.025** (0.012)	0.029** (0.012)
lnpri	0.117*** (0.023)	0.035*** (0.013)	0.075*** (0.021)	0.046* (0.025)
lnter	0.091* (0.049)	0.011 (0.033)	0.020 (0.045)	0.026 (0.042)
cons	−0.169 (0.464)	−0.146 (0.178)	0.776* (0.439)	0.724* (0.379)
Provincial effects	Yes		Yes	Yes
Year effect	Yes		Yes	Yes
R-squared	0.959		0.941	0.949
Sample size	210	240	240	208

Robust standard errors are in parentheses; *p < 0.1, **p < 0.05, ***p < 0.01.

TABLE 12 2SLS regression results.

Variables	The first stage	The second stage	The first stage	The second stage
digital		0.398*** (0.149)		0.659*** (0.117)
iv1	3.399*** (0.684)			
iv2			1.006*** (0.027)	
lnurb	0.221*** (0.032)	0.146*** (0.048)	0.024** (0.012)	0.135*** (0.046)
lnedu	−0.155** (0.068)	0.059 (0.082)	−0.025 (0.023)	0.032 (0.084)
lnmac	0.017*** (0.004)	0.004 (0.005)	0.001 (0.001)	0.001 (0.006)
lnpri	−0.036*** (0.007)	0.030** (0.012)	−0.002 (0.002)	0.048*** (0.014)
lnter	0.323*** (0.034)	−0.060 (0.074)	0.050*** (0.016)	−0.146** (0.066)
cons	−1.744*** (0.165)	−0.303 (0.411)	−0.217*** (0.072)	0.080 (0.361)
F value	118.96		1783.28	
R-squared	0.854	0.417	0.987	0.435
Sample size	240	240	210	210

Robust standard errors are in parentheses; **p < 0.05, ***p < 0.01.

above logic, this article selects the number of fixed telephones per 100 people in each province in 1984 as the instrumental variable for the digital economy development index. Because the sample of this study is balanced panel data, using only the number of fixed telephones per 100 people at the provincial level in 1984 as an instrumental variable may encounter difficulties in measuring due to the application of fixed effects models. Therefore, based on the setting method of Huang et al. (2019) and Nunn and Qian (2014), the interaction term between the number of fixed telephones per 100 people in 1984 and the proportion of national Internet investment in the previous year was constructed as an instrumental variable. The results are shown in Table 12 models (1) and (2). In addition, in order to ensure the reliability of the method, the lag phase of the digital economy is selected as the instrumental variable to perform 2SLS regression again. The results are shown in Table 11 Models (3) and (4). In this regression, the impact of digital economy development on rural economic transformation is still significantly positive, indicating that it has passed the endogenous test.

6 Conclusions and recommendations

This paper analyzes the relationship and transmission mechanism between the digital economy, consumption structure upgrading, and rural economic transformation and empirically tests the impact of the digital economy and consumption structure upgrading on rural economic transformation based on provincial panel data from 2013 to 2020. The study found that: First, the development of the digital economy can significantly promote the transformation of the rural economy, and this conclusion is still valid after considering endogenous problems and undergoing many robustness tests. Secondly, the mediating effect shows that the digital economy can promote rural economic transformation by upgrading the consumption structure; that is, for every 1 unit increase in the digital economy, 0.047 units can promote the level of rural economic transformation through the consumption structure path, and the mediating effect accounts for 13.783%. Third, the threshold effect shows that the level of consumption structure has a single threshold effect on this promotion. When the level of consumption structure is higher than 1.216, the influence coefficient of the digital economy on rural economic transformation is positive and more significant, which confirms that under the condition of improving the level of consumption structure, the digital economy has a progressive promoting relationship with rural economic transformation. Fourth, the heterogeneity analysis shows that for the northern region, the promotion effect of the digital economy development on rural economic transformation is more prominent.

Based on this, this paper draws the following policy implications. First, the government should fully realize the vital role of digital economy development in rural economic transformation. The digital economy is an essential means to promote the transformation of the rural economy and a new driving force for the transformation of the rural economy under the new normal. It is necessary to put the integration of the digital economy and rural development in the strategic position of rural economic transformation, use policy means and financial means to support

the development of the digital economy, take the construction of new infrastructure such as mobile communication network and optical cable as the guide, take the application of core technologies such as big data and artificial intelligence as the goal, accelerate the supporting of relevant laws and regulations and local policies, and comprehensively enhance the efficiency of the digital economy in rural economic transformation. Specifically, we will strengthen the construction of digital infrastructure and promote the establishment of a digital rural system. Governments at all levels should improve the depth of digital network integration in rural areas by accelerating the laying of broadband network lines and the layout of mobile network terminals, and focus on filling the gaps in rural digital infrastructure construction. At the same time, the government should avoid hindering digital agriculture in terms of regulatory standards, administrative approvals, etc., strengthen the collaborative guarantee mechanism of basic information resource sharing and regulatory methods, unify standards in digital agriculture construction, and reduce technological frictions in the development of digital agriculture. Second, actively innovate and promote digital technology, constantly expand and strengthen the consumer Internet, and give full play to the intermediary role of consumption structure upgrading. Promote the application and promotion of digital technology in the consumer field, accelerate the digital empowerment of life services, continuously expand and enrich consumer content and scenarios, and promote the popularization and application of new forms and models of consumption. Especially in the fields of transportation, communication, tourism, leisure and entertainment, we will accelerate the construction of digital infrastructure, standardize the development of live streaming economy and online e-commerce platforms, promote sustained and healthy growth of consumption, and comprehensively adapt to the trend of residents' consumption upgrading and transformation from multiple perspectives, thereby promoting the development of the economic cycle. Further expand cross-border e-commerce business, build a new pattern of dual circulation development at home and abroad, and form a powerful engine to drive economic development and promote rural economic transformation and upgrading. At the same time, we must fully tap into the consumption potential of rural residents. On the one hand, we should vigorously promote "Internet plus agriculture," expand agricultural product sales channels, improve the disposable income of rural residents, and lay a material foundation for the upgrading of rural residents' consumption; On the other hand, continuously narrowing the gap in circulation efficiency between urban and rural areas, improving the efficient connection between diversified production and rural residents' consumption needs, and promoting the continuous expansion and upgrading of rural residents' consumption. Thirdly, adapt to local conditions and strive to achieve coordinated development. Given the heterogeneity of the impact of the digital economy on rural economic transformation, the government should take the goal of rural economic transformation as policy guidance and fully leverage the driving role of the digital economy in rural economic transformation. Stimulate the development potential of digital economy in various provinces and promote coordinated development between regions. Develop differentiated digital economy development strategies, promote complementary advantages in technology, industry, and application among different regions, reduce the gap in digital infrastructure between regions, and promote the development of digital economy through regional coordination. For the southern regions with a relatively high level of digital economy development, promote the sustainable development of the digital economy; For the underdeveloped northern regions of the digital economy, it is necessary to increase financial support and investment, provide conditions for the development of the digital economy in the northern region, and narrow the gap in digital economy development between regions. At the same time, we will strengthen the cultivation of digital skills for the digital poor, popularize digital information technology usage skills in rural areas, eliminate barriers to the use of digital information technology, and weaken the constraints of the digital divide on rural economic transformation. Finally, increase financial support for science and technology. Especially increase financial support for digital technology innovation in northern regions, consolidate and enhance the dividend effect of digital economy on rural economic transformation.

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

YL: Data curation, Writing – original draft. WC: Investigation, Validation, Writing – review & editing. XZ: Methodology, Writing – review & editing. WL: Methodology, Project administration, Software, Writing – review & editing.

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Conflict of interest

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2025.1565067/full#supplementary-material

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