A Study on the Impact of Digital Economic Development on the Quality of Rural Revitalization

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Abstract. This research explores how the digital economy impacts the quality of rural revitalization at the institutional level. Utilizing panel data spanning from 2011 to 2020 for 30 provincial-level administrative regions in mainland China, the study employs the Entropy Weight-TOPSIS method to assess both the quality of rural revitalization and the index of digital economic development. An empirical analysis is conducted to investigate the relationship between these two factors. The Digital Inclusive Finance Index is obtained from Peking University's Digital Finance Research Center, while additional data is gathered from sources including the 'China Statistical Yearbook,' 'China Rural Statistical Yearbook,' and various provincial and municipal statistical yearbooks. Missing data points are addressed through interpolation methods and information obtained from the websites of respective provincial and municipal statistical bureaus. The findings indicate a significant positive relationship between digital economic development and the quality of rural revitalization, with technological innovation playing a crucial mediating role. Hence, it is essential to recognize the digital economy as a pivotal lever for enhancing the quality of rural revitalization in the contemporary era. This entails expediting the development of rural digital infrastructure, facilitating the transfer and application of digital technological advancements in rural areas, integrating digital technology with rural industries and governance processes, promoting the diversified application of digital technology across different rural scenarios and domains, and continuously striving to enhance the quality of rural revitalization.

Keywords: Digital Economy; Quality of Rural Revitalization; Technological Innovation

1 Introduction

The digital economy, characterized by digital resources as key elements, information networks as crucial carriers, and the driving force of technological integration applications, contributes significantly to enhancing fairness and efficiency. It holds crucial significance in overcoming the dual urban-rural structural challenges. Data from the "China Digital Economic Development Report (2022)" reveals that the digital development level in rural areas reached 39.1% in 2021. The rapid penetration of the digital economy into rural areas has become a vital catalyst for empowering rural revitalization [1]. However, it is essential to acknowledge the existing shortcomings in the comprehensive advancement of the rural revitalization strategy, such as a shortage of rural talents, weak infrastructure, and significant urban-rural disparities. The quality of rural revitalization needs further improvement, and the characteristics of the digital economy, including economies of scale, scope, and reduced

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transaction costs, can effectively address the bottlenecks in rural revitalization, comprehensively enhancing its quality [2].

2 Theoretical Mechanisms

2.1 Direct Effects of the Digital Economy on the Quality of Rural Revitalization

Firstly, the digital economy can drive the development of rural industries, promoting industrial prosperity. Initially, it can break down information barriers, narrow the urban-rural digital divide, encourage integrated urban-rural development, and reduce the gap in industrial development between urban and rural areas [3]. Secondly, the digital economy can allocate rural resources reasonably and promote agricultural production by penetrating the agricultural production process, leading to increased output, quality, and efficiency in agriculture. Thirdly, the digital economy can facilitate rural financial connectivity, with digital inclusive finance improving financial accessibility and inclusiveness [4]. It provides credit support for rural industrial prosperity, thereby promoting inclusive growth in rural areas. Lastly, digital education models can facilitate the sharing of educational resources across regions, breaking down urban-rural educational barriers. Based on the above analysis, this paper proposes the following research hypothesis:

H1: The development of the digital economy has a positively driving effect on the quality of rural revitalization.

2.2 Indirect Effects of the Digital Economy

Firstly, the digital economy contributes to improving the efficiency of technological innovation. By establishing a technological innovation support system to empower the construction of innovative platforms, it enhances the quality of technological innovation supply and increases technological innovation productivity [5]. Secondly, the digital economy helps optimize the efficiency of technological resource allocation. By breaking down information asymmetry barriers and providing conditions for factor exchange, it promotes fair competition, optimizes production functions, and achieves the optimal allocation of technological resources [6]. The digital economy also expands financing channels, enabling more funding for technological innovation activities. Thirdly, the digital economy facilitates the dissemination of technological innovation achievements [7]. The application of digital technology helps improve the social acceptance and conversion rate of technological achievements, promoting scientific popularization and mass communication.

H2: Technological innovation is a crucial pathway through which the digital economy affects the quality of rural revitalization.

3 Model Design

3.1 Model Construction

To examine the impact of the digital economy on the quality of rural revitalization, the following model is constructed:

$$RR_{it} = \alpha_0 + \alpha_1 DE_{it} + \sum \alpha_j X_{it} + u_i + \upsilon_t + \varepsilon_{it} \quad (1)$$

RR_{it} represents the dependent variable, indicating the quality of rural revitalization in region i during period t. DE_{it} stands for the core explanatory variable, representing the level of digital economic development in region i during period t. X_{it} encompasses a set of control variables related to the quality of rural revitalization. u_i denotes individual fixed effects, used to control for unobservable factors at the regional level that do not change over time but impact the quality of rural revitalization. v_i signifies time fixed effects, employed to control for unobservable factors that do not change across regional entities but vary over time and influence the quality of rural revitalization. ε_{it} represents the random disturbance term.

According to Wen Zhonglin and others' research, the introduction of Technological Innovation Level (SI) serves as an intermediary variable, empirically testing the mediating role of technological innovation in the process of digital economy influencing the quality of rural revitalization.

$$SI_{it} = \beta_0 + \beta_1 DE_{it} + \sum \beta_j X_{it} + u_i + \nu_t + \varepsilon_{it} \quad (2)$$

$$RR_{it} = \gamma_0 + \gamma_1 DE_{it} + \gamma_2 SI_{it} + \sum \gamma_j X_{it} + u_i + \nu_t + \varepsilon_{it} \quad (3)$$

SI_{it} represents the level of technological innovation. Equation (2) is used to test the impact of the digital economic development level (DE_{it}) on the intermediary variable (SI_{it}), while equation (3) is employed to examine the effects of both the digital economic development level (DE_{it}) and the intermediary variable (SI_{it}) on the quality of rural revitalization (RR_{it}).

3.2 Variable and Data Description

Drawing from the research of Deng Yue et al. and considering the connotations of rural revitalization, this study measures the explained variable, the quality of rural revitalization (RR), across five dimensions: industrial prosperity, ecological livability, cultural refinement, effective governance, and affluent living. The entropy weight Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is utilized to compute the RR index. The entropy weight TOPSIS method, an improvement over the traditional TOPSIS, addresses the issue of weight distribution by incorporating entropy weight. Initially, information entropy and weights are calculated based on the information provided by the indicators. Subsequently, the fitness of each solution to the ideal solution for decision-making is determined, facilitating the ranking of solution superiority or inferiority. This method excels in comprehensively considering the importance of each indicator, mitigating subjectivity, uncertainty, and enhancing decision accuracy and reliability. Indicators are selected from the five dimensions of rural revitalization, forming the evaluation indicator system for rural revitalization quality, as presented in Table 1.

Table 1. Rural revitalization quality evaluation indicators

First level indicator	Secondary indicators	Level three indicators
rural revitalization	Industry is booming	Rural per capita primary industry output value (yuan)
		Leisure agriculture operating income/primary industry gross output value (%)
		Facility agriculture area/arable land area (%)
		Agricultural labor productivity (10,000 yuan/person)
		Rural productive building area per capita (square

		meters/person)
	Ecological and livable	Rural greening coverage rate (%)
		Rural domestic waste harmless treatment rate (%)
		Number of public toilets per 10,000 people in rural areas (seats)
		Number of rural doctors and health workers per 1,000 people in rural areas (person)
		Village water penetration rate (%)
	Rural customs and civilization	Investment in village public building construction (10,000 yuan)
		Rural illiterate population/population aged 15 and above (%)
		Number of township comprehensive cultural stations per 1,000 people (number)
		Comprehensive population coverage rate of rural TV programs (%)
		Per capita cultural, educational and entertainment consumption expenditure of rural residents (yuan)
	Effective governance	Per capita disposable income of rural residents/Per capita disposable income of urban residents (%)
		Per capita consumption expenditure of rural residents/per capita consumption expenditure of urban residents (%)
		Number of village committee units per 1,000 people in rural areas (units)
	live a prosperous life	Per capita disposable income of rural residents (yuan)
		Engel coefficient of rural residents
		Actual per capita net income of rural residents (yuan/person)
		Rural self-employment ratio (%)

Industrial Prosperity: Includes indicators such as per capita value of the primary industry, the development level of recreational and facility agriculture, measuring the integration and volume of rural industries. It also considers agricultural labor productivity and per capita value of the tertiary industry to gauge the level of rural industrial infrastructure. Ecological Livability: Encompasses indicators like rural afforestation coverage to measure the ecological environment. It includes the harmless treatment rate of rural domestic waste, the quantity of public toilets per ten thousand people, and the number of rural doctors and health workers per thousand people, reflecting the livability of rural areas. Cultural Refinement: Involves indicators such as the investment in public construction in villages, the number of comprehensive cultural stations per thousand people in towns and villages, and TV program coverage to evaluate the infrastructure level of cultural refinement. It also considers the illiteracy rate and per capita expenditure on education, culture, and entertainment to measure the soft power of cultural refinement. Effective Governance: Takes into account the ratio of disposable income per capita of rural residents to that of urban residents, and the ratio of per capita consumption expenditure of rural residents to that of urban residents to assess urban-rural income disparity. It also considers the number of village committee units per thousand people to measure the effectiveness of rural governance. Affluent Living: Encompasses indicators like rural residents' income, Engel coefficient, etc., to gauge the level of affluence in rural living standards. Drawing from the studies of Pan Weihua et al. (2021) and Tang Yaojia

et al., this study, utilizing the entropy weight Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method, assesses the level of digital economic development from three perspectives: information infrastructure, industrial digitization, and digital industrialization. Information Infrastructure Construction: This dimension represents the hardware support required for the development of the digital economy and is deemed a necessary prerequisite for achieving high-quality development in the digital economy. Industrial Digitization: This aspect measures the level at which digital technology is applied to traditional industries, serving as an extension of the digital economy into conventional sectors. Digital Industrialization: Reflecting the value-added model of the digital economy, this dimension gauges the scale of development in relevant digital new formats under the backdrop of the digital economy. The indicator system for evaluating the digital economy is outlined in Table 2.

Table 2. Digital economy evaluation indicators

First level indicator	Secondary indicators	Level three indicators
digital economy	Information infrastructure	Rural Internet penetration rate (%)
		Internet broadband access ports per capita in rural areas (number)
		Rural optical cable line coverage (km)
		Mobile phone penetration rate (%)
	Industrial digitalization	Average population served by rural postal outlets (10,000 people)
		Peking University Digital Financial Inclusion Index
		Total online retail sales of consumer goods per capita in rural areas (10,000 yuan)
	Digital industrialization	Fixed investment in rural digital industry (10,000 yuan)
		Fixed investment in rural digital services (10,000 yuan)
		Per capita telecommunications business volume in rural areas (10,000 yuan)

The mediating variable, technological innovation (SI), is measured by the intensity of investment in technological innovation. It is represented by the proportion of local technological expenditure to general public budget expenditure. The following variables are employed as control variables in this study. Degree of Trade Openness (TO): This variable, influencing rural revitalization quality through factors like rural resident income, is measured by the proportion of the total value of goods imports and exports multiplied by the exchange rate from US dollars to Chinese yuan, relative to GDP. Industrial Structure (IS): Impacting rural revitalization quality through aspects such as rural production methods, this variable is measured by the proportion of the output value of the tertiary industry to GDP. Urbanization (Urban): Affecting rural revitalization quality by altering urban-rural disparities, this variable is measured by the proportion of the urban population to the total population. Level of Industrialization (IL): Influencing rural revitalization quality through aspects like rural employment and income, this variable is measured by the proportion of industrial output value to GDP. The study utilizes panel data from 30 mainland Chinese provincial-level administrative regions (excluding Tibet due to incomplete data) for the years 2011–2020. Descriptive statistics for rural revitalization quality, digital economy, technological innovation, and all control variables are provided in Table 3. Data sources include the Beijing University

Digital Finance Research Center for the Digital Inclusive Finance Index, and other data are extracted from the "China Statistical Yearbook," "China Rural Statistical Yearbook," and various provincial and municipal statistical yearbooks. Missing values are addressed through interpolation methods and supplementation from the statistical bureau websites of each province and municipality.

4 Empirical Results

4.1 Direct Impact of the Digital Economy on Rural Revitalization Quality

To commence, a Hausman test was performed on the model, yielding results that reject the null hypothesis. This indicates that assessing the impact of the digital economy on rural revitalization quality necessitates adopting a model with bidirectional fixed effects, while also controlling for individual and time effects. Concurrently, the dependent variable, RR, passes the stationarity test. Post-controlling for time and individual fixed effects, the estimation outcomes regarding the digital economy's influence on rural revitalization quality are presented in Table 3. Model 1 reveals that the digital economy effectively enhances rural revitalization quality. Introducing control variables successively from Model 1 to Model 5, the estimated coefficients' absolute values for the digital economy's influence on rural revitalization quality vary. Nevertheless, they consistently remain significantly positive at the 1% level. This underscores the digital economy's substantial positive impact on rural revitalization quality. Clearly, the ongoing evolution of the digital economy empowers high-quality rural development, effectively elevating rural revitalization quality, thus affirming Hypothesis H1.

Table 3. Direct Impact of the Digital Economy on Rural Revitalization Quality

variable	Model 1	Model 2	Model3	Model4	Model5
DE	0.269*** (0.025)	0.290*** (0.020)	0.252*** (0.136)	0.148*** (0.026)	0.153*** (0.027)
TO	-	0.095** (0.473)	0.095** (0.047)	0.056*** (0.019)	0.062*** (0.021)
IS	-	-	0.110* (0.076)	0.046 (0.053)	0.054 (0.054)
Urban	-	-	-	0.547*** (0.090)	0.520*** (0.100)
IL	-	-	-	-	0.040* (0.057)
_cons	0.193*** (0.193)	0.162*** (0.014)	0.120*** (0.034)	-0.094*** (0.040)	-0.064* (0.058)
fixed effects	YES	YES	YES	YES	YES
N	300	300	300	300	300
R2	0.902	0.876	0.872	0.848	0.802

In Model 2, with the inclusion of the trade openness variable, its regression coefficient on rural revitalization quality is significantly positive. This implies that trade openness plays a significant driving role in rural revitalization. This is because expanding trade openness can increase farmers' income and simultaneously increase cultural consumer goods, contributing to the enrichment of rural residents' lives. Moreover, after expanding trade openness, the effect

of the digital economy driving rural revitalization shows a significantly enhanced trend, indicating that trade openness can serve as an important lever to promote rural revitalization.

In Model 3, with the inclusion of the industrial structure variable, its regression coefficient on rural revitalization quality is significantly positive. This suggests that upgrading and rationalizing industrial structure can radiate into rural areas, promoting agricultural transformation and upgrading, driving prosperity in rural industries, and increasing farmers' income. The expansion of employment channels resulting from industrial transformation is beneficial for flexible employment, promoting the high-quality development of rural industries, improving efficiency, and reducing resource waste. In Model 4, the introduction of the urbanization variable shows a significantly positive regression coefficient on rural revitalization quality. This indicates that new urbanization can achieve integrated development with rural revitalization. Cities and villages form an organic community of mutual benefit, and their deep integration contributes to sustainable development. Additionally, urbanization can promote rural industrial development, accelerate the flow of resources between urban and rural areas, and improve the inclusiveness of public service resources in rural areas, effectively supporting rural revitalization. In Model 5, the introduction of the industrialization level variable shows a positive regression coefficient on rural revitalization quality. This suggests that an increase in the level of industrialization can promote rural revitalization. This is because an elevated level of industrialization provides more job opportunities for rural areas, increases farmers' income, enhances the convenience of rural living, and thereby promotes the improvement of rural revitalization quality.

4.2 Examination of the Impact Pathway of the Digital Economy

Table 4 displays the findings concerning the indirect impacts of the digital economy on rural revitalization quality. Within this table, Model 6 mirrors the overall effect of the digital economy on rural revitalization quality, aligning with Model 5 from Table 3. Models 7 and 8 correspond to Equations (2) and (3), respectively. Model 7 elucidates the role of technological innovation within the digital economy, with a significantly positive coefficient at the 1% level, indicating a notable driving force of technological innovation within the digital economy. This underscores how technological innovation can foster the development, dissemination, and application of novel digital technologies. Model 8 evaluates the influence of both the digital economy and technological innovation on rural revitalization quality, revealing significantly positive coefficients for both factors. This indicates substantial contributions from both elements towards rural revitalization, with technological innovation serving as a partial mediator in the process of the digital economy driving rural revitalization. Furthermore, sobel tests and bootstrap tests were conducted on the mediating effect model. The bootstrap test yielded a p-value of 0.003, and the value 0 did not fall within the 95% confidence interval irrespective of bias adjustments. This confirms the passing of both the sobel and bootstrap tests, further affirming the robustness of the mediating effect model. In essence, the digital economy enhances rural revitalization quality through technological innovation, thus validating Hypothesis H2.

Table 4. Indirect Impact of the Digital Economy on Rural Revitalization Quality

variable	Model 6	Model 7	Model 8
DE	0.153*** (0.027)	0.027*** (0.005)	0.071* (0.039)
TO	0.062*** (0.021)	0.280*** (0.003)	-0.051** (0.023)
IS	0.054 (0.054)	0.005 (0.011)	0.137* (0.076)
Urban	0.520*** (0.100)	0.017** (0.008)	0.540*** (0.055)
IL	0.040* (0.057)	0.029*** (0.008)	0.050 (0.055)
SI	-	-	1.357** (0.411)
Sobel	-	-	0.036*** (0.0173)
_cons	-0.064* (0.059)	-0.014** (0.007)	-0.173*** (0.048)
fixed effects	YES	YES	YES
N	300	300	300
R2	0.802	0.699	0.694

4.3 Robustness Tests

Winsorizing and Truncation Procedures: To mitigate the potential impact of outliers on regression results, the data were subjected to both 1st and 99th percentile winsorizing and truncation procedures. Subsequently, the regression was conducted again using Equation (1), and the results are presented in Models 9 and 10 of Table 5. According to the test results, whether employing winsorizing or truncation, the impact of the digital economy on rural revitalization quality remains significantly positive at the 1% level. This implies that the baseline regression results are not affected by extreme values, thereby validating the robustness of the baseline model. Shortening the Time Window: Given that the rural revitalization strategy was introduced in 2017, an analysis was conducted with a shortened time window spanning from 2011 to 2017. This aims to assess whether the introduction of the strategy influenced the effect of the digital economy on rural revitalization quality. The regression was performed based on the baseline model, and the results are shown in Model 11 of Table 5. It can be observed that even with a shortened time window, the impact of the digital economy on rural revitalization quality remains significantly positive at the 1% level. This indicates that the baseline regression results are not affected by the introduction of the strategy, further affirming the robustness of the baseline model.

Table 5. Robustness Test Results

variable	Model 9	Model 10	Model 11	Model 12	Model 13
DE	0.150*** (0.036)	0.162*** (0.039)	0.378** (0.061)	0.252** (0.169)	0.477*** (0.033)
TO	0.048 (0.036)	0.005 (0.043)	0.046 (0.037)	0.004 (0.042)	0.493*** (0.173)
IS	-0.051 (0.107)	-0.035 (0.116)	0.048 (0.036)	0.005 (0.043)	0.495*** (0.171)

Urban	0.520*** (0.148)	0.495*** (0.171)	0.048 (0.036)	0.004 (0.042)	0.493*** (0.173)
IL	-0.043 (0.107)	-0.037 (0.118)	0.048 (0.036)	0.005 (0.043)	0.495*** (0.171)
_cons	-0.060*** (0.094)	-0.047 (0.104)	0.175*** (0.011)	0.027 (0.069)	0.139*** (0.010)
fixed effects	YES	YES	YES	YES	YES
N	300	273	210	300	270
R2	0.847	0.851	0.920	0.689	0.415

5 Conclusion

The study investigates the interplay between the digital economy, rural revitalization quality, and technological innovation, with robustness tests conducted to validate the empirical findings. The primary conclusions are as follows: (1) The digital economy significantly enhances rural revitalization quality, a finding supported by various robustness tests. There exists a symbiotic relationship between the digital economy and rural revitalization, fostering a positive developmental cycle. Sub-analysis reveals that the digital economy notably fosters industrial growth, ecological sustainability, cultural enrichment, efficient governance, and improved living standards. This underscores the integral role of the digital economy across diverse facets of rural development. However, the digital economy's contribution to industrial growth and the efficacy of digital governance exhibit relative weaknesses and necessitate bolstering efforts. (2) Technological innovation, acting as a pivotal mediating factor, serves as a critical conduit through which the digital economy propels rural revitalization. The digital economy demonstrably fosters technological innovation, which subsequently empowers rural development, thereby augmenting the quality of rural revitalization. Consequently, the digital economy indirectly influences rural revitalization by harnessing the potential of technological innovation.

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