Digital Economy, Technological Innovation and Urban-Rural Integration

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Abstract. The in-depth development and all-round expansion of digital economy has promoted China's economic development and accelerated the process of urban-rural integration. This article selects panel data from 30 provinces in China from 2013 to 2020, establishes valuation index systems to measure the level of regional digital economy and urban-rural integration, constructs fixed effect models and intermediary effect models, through empirical testing of digital economy's influence on the development of urban-rural integration and its mechanism. The research shows digital economy is positively promoting the development of urban-rural integration, moreover digital economy can play an indirect role in the development of urban-rural integration through scientific and technological innovation level. Therefore, in order to better utilize the digital economy to empower urban and rural integration, corresponding suggestions and measures are proposed.

Keywords: Digital economy · Urban-rural integration · Technological innovation

1 Introduction

The party's Report to the 20th CPC National Congress pointed out that "To comprehensively promote the revitalization of the countryside, stick to agricultural rural priority development, force promotes urban-rural fusion and coordinated regional development, and promote qualitative effective enhancement of economic attainment and a reasonable increase in volume." Integrated urban-rural development is the necessary way to rejuvenate the village in the new era, urban-rural integration is an important force to consolidate the expansion and poverty-proof achievements, accelerate the construction of an agricultural power. As a kind of novel economic situation, digital economy is enabling the integration of urban and rural relations through new technologies, new formats, and new patterns.

China should grasp the strong growth potential and development momentum brought about by digital economy, accelerate the establishment of a new type of urban-rural relationship featuring complementarity. How to bring the dividend advantage of digital economic development into full play and make urban-rural integration become an important topic of current research. Yang Mengjie (2021) [1] noted that digital economy is highly penetrant, highly valuable, highly technical and noncompetitive, which is of

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great meaning for realizing the upgrading of urban-rural industries. Tian Ge and Zhang Xun (2022) [2] have found that the development of the Internet consumption brought by the digital economy could promote the transformation of economic migration of rural low-skilled labor to low-skilled digital non-agricultural sectors. Research by Yin Qingmin and Wang Xun (2022) [3] revealed that the digital economy can mediately boost urban-rural integration by ameliorating capital factor mismatch and data factor mismatch. Huang Yongchun et al. (2022) [4] concluded based on authentic proof research that digital economy facilitates the integrated advancement of industries by narrowing the income gap between city and countryside. Sun Tao and Wang Shuo (2021) [5] proposed that digital economy can promote multi-dimensional urban-rural integration by improving the efficiency of traditional factor allocation and other ways by analyzing the development characteristics of urban-rural integration and the impact of digital economy on its path. Kurantin et al. (2019) [6] analyzed the relationship and transmission mechanism between the digital economy and regional poverty in Ghana, and found that digital economy can reduce poverty by improving innovation capabilities.

2 Theoretical Analysis and Research Assumptions

2.1 The Direct Impact of Digital Economy on Urban-Rural Integration

The rapid development of digital economy has created significant opportunities for urban-rural amalgamation development. First of all, with the further application of digital technique in the field of consumption, up-to-date business forms such as rural electronic commerce, live streaming and goods delivery have emerged the distribution channels of subsidiary farm products have been widened. Meantime, digital technology has a profound change on essential production factors like land, talent, and their allocation, smoothing the bidirectional flow of production factors, and promoting the release of factor dividends. In addition, the advancement of digital infrastructure in countryside has enabled the full use of digital technologies such as telemedicine and online education [7], realizing the cross spatial exchange of important information within organizations, and offering fresh technical inspirations for reconstructing the new urban-rural relationship.

2.2 The Indirect Impact of Digital Economy on Urban-Rural Integration

Compared to traditional rural development that relies on natural conditions such as labor and land, the important factor that affects the speed and quality of modern rural development is scientific innovation, and the technological advantages of digital economy itself is conducive to the foundation for improving the ability of technological innovation. Firstly, technological innovation can accelerate industrial upgrading and rationalization of industrial structure [8]. Technical innovation promotes the rationalization and health of urban and rural industries through R and D of new products and techniques, enhances rural income, and narrows town and village income disparity. New fields and industries like AI and Internet have been formed through technological innovation, formed Internet sharing economy to improve the employment rate of rural residents. In addition, technological innovation also enhances investment in medical care, transportation, education, and other aspects through income enhancement, and improves the level of welfare to achieve shared development between town and country.

3 Variables and Model Design

3.1 Variable Description

Explained variable: Urban-rural integration development (Urid). To understand the connotation of urban-rural integration and combine the research focus of this article, this article refers to the research of Yu Tonghui and Xiao Yanyu (2023) [9], constructs an indicator system for measuring the level of urban-rural integration development with 5 dimensions of "economy human society space ecology" and 15 basic indicators. Entropy method is used to assign weights after standardization of each index. Calculate the urban-rural integration development index. See Table 1 for specific indicators.

Table 1. Comprehensive evaluation index system for urban-rural integration development

Indicator dimension	Basic indicators	Indicator description	Attribute
Economic integration	Science and technology as a share of financial expenditu	Regional science and technology expenditure/regional financial expenditure	+
	Per capita income for both urban and rural residents	Disposable income per capita in cities and towns/disposable income per capita in rural areas	-
	Consumption ratio of town and country residents per capita	Urban per capita consumption expenditure/rural per capita consumption expenditure	-
Human integration	Urbanization level of population	Urban population/total population	+
	Basic education level	Number of junior high school educatees aged 6 years and over/total number over 6	+
	Urban and rural spatial circulation subject	Volume of passenger transportation	+
Social integration	Health workers	Number of health workers	+
	Per capita public library collections	Per capita public library collections	+
	Number of participants in Social care insurance coverage town and country residents	Social care insurance coverage for urban and rural residents	+

(*continued*)

Table 1. (*continued*)

Indicator dimension	Basic indicators	Indicator description	Attribute
Space integration	Urban spatial expansion	Built-up area/sown area of crops	+
	Urban and country per capita private car ownership	Private car ownership/total population	+
	Traffic network density	(Highway mileage + railway operating mileage)/land area	+
Ecological integration	Harmless treatment rate of domestic waste	Harmless treatment amount of domestic waste/domestic waste production amount	+
	Urban and rural ecological greening	Forest coverage	+
	Ratio of environmental protection expenditure to fiscal expenditure	Environmental protection expenditures/regional fiscal expenditures	+

Explanatory variable: Digital economy development level (DE). Referring to the research of Liu Jun et al. (2020) [10], this paper constructs a comprehensive evaluation index system for the level of digital economic development from three perspectives: Information technology development, Internet development, Digital transaction development, as shown in Table 2.

Intermediate variable: Technological innovation level (Inn). Expressed by the per capita patent application authorization.

Control variables: Using relevant research for reference, add control variables that may affect the regression results: Industrialization level (Indus, the ratio of added value of secondary and tertiary industries to GDP), Government financial expenditure (Gov, the proportion of local financial expenditure to GDP), Economic development level (Lnagdp, the logarithmic value of GDP per capita), Labor capital (Lab, the average number of years of education received by residents), Agricultural modernization level (Agmo, the total power of machinery per 1000 rural people), The level of opening-up (Open, proportion of total regional imports and exports to regional GDP).

3.2 Data Description

This article selects panel data from 30 provinces in Chinese Mainland (except Tibet) from 2013 to 2020 as empirical samples. The data are sourced from the China Statistical Yearbook, the China Rural Statistical Yearbook, and the statistical yearbooks of various provinces. Partial missing data are supplemented by linear interpolation, and non-ratio form variables are logarithmized to eliminate the impact of heteroscedasticity.

Table 2. Comprehensive evaluation index system of digital economy

Indicator dimension	Basic indicators	Indicator description	Attribute
Information development	Fundamentals of informatization	Optical cable density	+
		Cellular phone base station density	+
		Percentage of IT Professionals	+
	Factors of informatization	Total telecommunication service	+
		Software business income	+
Internet development	Fundamentals of fixed-end internet	Internet access port density	+
	Fundamentals of mobile	Mobile internet penetration	+
	Fixed-end internet influence	Percentage of broadband internet users	+
	Mobile Internetwork influence	Proportion of mobile Internet users	+
Digital transaction development	Digital transaction basis	Number of websites owned by every 100 enterprises	+
		Computer use in enterprises	+
		Proportion of e-commerce enterprises	+
	Digital transaction impact	E-commerce sales	+
		Online retail sales	+

3.3 Model Building

Based on the above analysis, for discussing the direct impact of digital economy on urban-rural integration, the following benchmark model is constructed:

$$\mathrm{Urid_{it}} = \alpha_0 + \alpha_1 \mathrm{DE}_{it} + \alpha_2 Controls_{it} + \mu_i + \theta_t + \varepsilon_{it} \quad (1)$$

In the formula, i and t indicate province and time, respectively, Urid represents the level of urban-rural integration development, DE represents the level of digital economy development, and Controlsit is the control variable; μ_i represents the fixed effect of provinces, θ_t represents the fixed effect of year share, ε_{it} is a random error term.

To further examine the mechanism and path of town-country integration and development in the endowment of digital economies, drawing on the study of Wen Zhonglin et al. [11], the following model is constructed:

$$\mathrm{Inn_{it}} = \beta_0 + \beta_1 \mathrm{DE}_{it} + \beta_2 Controls_{it} + \mu_i + \theta_t + \varepsilon_{it} \tag{2}$$

$$\mathrm{Urid_{it}} = \gamma_0 + \gamma_1 \mathrm{DE}_{it} + \gamma_2 Inn_{it} + \gamma_3 Controls_{it} + \mu_i + \theta_t + \varepsilon_{it} \tag{3}$$

In which, Inn as Intermediate Variable: Science and technology Innovation Level, β, γ are the coefficient to be estimated. Equation (2) tests the influence of digital economy on intermediary variables. Equation (3) tests the joint effect of digital economy and intermediary variables on the level of urban-rural integration.

4 Empirical Analysis and Testing

4.1 Benchmark Regression Analysis

The Hausman test results indicate that the fixed effect model should be used in this article. Table 3 of benchmark regression estimation results of the impact of digital economy on urban-rural integration.

Column (1) in Table 3 represents the effect of digital economy on urban-rural integration. The estimated coefficient is significantly positive, indicating that the development of digital economy during 2013–2020 has promoted city and rural integration at the provincial level in China. Column (2) is the regression result after introducing control variables based on column (1). It can be seen that after adding control variables, the digital economy still has a marked implication for urban-rural integration, and the development of digital economy development has a remarkable positive effect on urban-rural integration at the level of 1%. The core conclusion of this article is still valid after controlling for other factors, but the estimated coefficient value decreases after adding control variables.

In column (2), the estimated coefficient of industrialization level is negative and passes the significance test of 5%. This is because when nonagricultural industries develop well, farmers tend to choose to work in urban areas instead of using cultivated land, which reduces the commercial value of rural construction land and is not conducive to urban-rural integration. Gov is significantly positive at the 1% level, possibly because government financial expenditure provides basic financial support for integrated infrastructure construction, which can help improve people's livelihood and expand productivity, and solve the problem of uneven urban and rural development. Economic development level has significantly promoted urban-rural integration. The improvement of labor capital is a long-term process, so the impact of labor capital on urban-rural integration is not significant in the short term. Although the level of agricultural modernization is promoting economic development to a certain extent, it also brings pollution and high energy consumption, thereby weakening the promotion of urban-rural integration. Open degree has a negative regression coefficient, which fails the significance test. China's export trade is chiefly concentrated in industrial manufactured goods, imports mainly focus on bulk commodities, the share of the farm products relatively small, so the effect of opening up on urban-rural integration is not significant.

Table 3. Benchmark Regression and Intermediary Effect Regression Results

Variables	(1)	(2)	(3)	(4)
	Urid	Urid	Inn	Urid
DE	0.195***	0.167***	0.00754***	0.0580
	(0.0304)	(0.0299)	(0.000572)	(0.0396)
Indus		-0.342**	0.000507	-0.349**
		(0.166)	(0.00317)	(0.160)
Gov		0.118*	-0.00165	0.142**
		(0.0608)	(0.00116)	(0.0589)
Lnagdp		0.0942***	-0.000204	0.0971***
		(0.0283)	(0.000541)	(0.0273)
Lab		0.00870	0.0000362	0.00818
		(0.00720)	(0.000137)	(0.00694)
Agmo		-0.102***	-0.00225***	-0.0695*
		(0.0385)	(0.000736)	(0.0380)
Open		-0.00964	-0.000669***	0.000000297
		(0.00665)	(0.000127)	(0.00685)
Inn				14.42***
				(3.604)
Cons	0.185***	-0.596*	0.00234	-0.629*
	(0.00459)	(0.338)	(0.00645)	(0.325)
Province &Year	Yes	Yes	Yes	Yes
R^2	0.7342	0.7675	0.8194	0.7851
N	240	240	240	240

Note: *** < 0.01, ** < 0.05, * < 0.1; the number in brackets is the t-stat;

4.2 Analysis of Action Mechanism

The previous article analyzed the transmission role of technological innovation in the process of enabling urban-rural integration through digital economy. This article makes use of the mediator effect model to examine. The regression results are shown in Table 3. Column (3) shows the influence of digital economy on technological innovation, and the results show that the regression coefficient is significantly positive at 1%, confirming that digital economy has a positive impaction on the improvement of the technology innovations capabilities. Column (4) is the regression result after adding the intermediary variable Inn to column (2). The results showed the coefficient of Inn is 14.42 and significantly positive, while the regression coefficient of DE is not significant, displaying that technological innovation plays a completely mediating role between digital economy and urban-rural integration.

Table 4. Robustness Test

Variables	(1)	(2)	(3)	(4)
DE	0.000736***	-0.0552***	0.0360***	
	(0.000179)	(0.00738)	(0.0144)	
L.DE				0.152***
				(0.0400)
Control variable	Control	Control	Control	Control
Cons	-0.182	-0.0502	-0.512***	-0.558
	(0.359)	(0.0832)	(0.141)	(0.357)
Province &Year	Yes	Yes	Yes	Yes
R^2	0.7522	0.8755	0.9354	0.7641
N	240	240	208	210

Note: *** < 0.01, ** < 0.05, * < 0.1; the number in brackets is the t-stat;

4.3 Robustness Test

First, replace the independent variables and dependent variable. To verify the reliability of the benchmark regression, the inclusive financial index calculated by Peking University was used as the core explanatory variable. The smaller the Thiel index, the smaller the urban-rural income gap. Therefore, the Thiel index is used as the explanatory variable. The results are shown in column (1) (2) of Table 4. The benchmark regression results are stable and reliable. Second, delete 4 municipalities. The digital economy level of municipalities is relatively in the forefront, and the data from municipalities may amplify the enabling role of the digital economy. Therefore, the sample of the municipality will be deleted and re-estimate. The results are shown in column (3) of Table 4. The analysis results show that digital economy still has a significant promoting effect on urban-rural integration after deleting data from four municipalities. Third, lag the explanatory variable by one period. Considering that there may be an opposite causal relationship between digital economy and urban-rural integration development. Therefore, the lagged phase digital economy is selected as the explanatory variable in this analysis. The results are shown in column (4) of Table 4. The regression coefficient of the digital economy in the t-1 period is significantly positive, so the empirical results of this study are relatively reliable.

5 Research Conclusions and Countermeasures

5.1 Conclusion

Based on the panel data of 30 provinces in China from 2013 to 2020, this paper uses panel fixed effect model and intermediary effect model to empirically test the direct and indirect influence of digital economy on urban-rural integration development. The main

conclusions are as follows: First, digital economy has significantly facilitated the urban-rural integration development, and digital economy has proved to be the major driving force for the development of urban-rural integration. Robustness and endogeneity tests have again verified the reliability of this conclusion. Second, the intermediary effect make known that the digital economy will boost urban-rural integration development by promoting regional technological innovation levels.

5.2 Countermeasures

In order to further promote urban-rural integration through digital economy, efforts need to be continued in the following areas: Firstly, accelerate the construction of information infrastructure in countryside and set a firm foundation for digital economic development. Advance rural information infrastructure optimization and upgrade, and constantly improve the level of equalization of town and country public services. Secondly, integrate urban-rural elements and promote the integration of resource advantages. Grasp the opportunities brought by industrial digitization and digital industrialization, accelerate breakthroughs in agricultural core technologies, and further integrate digital economy with the traditional industry. Accelerate the digital transformation of agriculture, advance the effective connection of agricultural production, circulation, and consumption, enable agriculture to achieve deep links with modern industries and modern service industries. Thirdly, explore the establish the joint training mechanism of urban and rural talents, focus on cultivation of rural digital talents. Allow full play to the driving role of information flow in talent flow, vigorously carry out activities for informatization talents to go to the countryside. Fourthly, carry out the digital management in the countryside to enable to modernize the rural governance systems and governance capabilities. Give impetus to the extension of "Internet + Government service" to the countryside, implement digital projects such as rural cultural inheritance and ecological protection, and bring rural digital governance into the nationwide integrated online government service platform.

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