

How Does Digital Inclusive Finance Affect Urban-Rural Integrated Development: An Explanation of a “U”-Shaped Relationship

Fei Ma^{1*}

¹ Guangxi Normal University, Guilin, Guangxi, China

Email Address

13720527593@163.com (Fei Ma)

*Correspondence: 13720527593@163.com

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Abstract:

Using panel data of 30 provinces in China from 2011 to 2022, this paper constructs a double machine learning model to conduct an empirical study on the impact of digital inclusive finance on urban-rural integration. The results show that the development of digital inclusive finance has a U-shaped effect on urban-rural integration, which first inhibits and then promotes the process. After a series of robustness tests, the regression results remain stable. Mechanism analysis reveals that the development of digital inclusive finance drives the development of urban-rural integration by influencing the upgrading of industrial structure.

Keywords:

Digital Inclusive Finance, Urban-Rural Integration, U-shaped Curve, Impact Effect

1. Introduction

With the rapid development of information technology, the digital economy has become an important engine for global economic growth. Among them, digital inclusive finance, as a key direction of financial innovation, is profoundly changing the way financial services are provided and the pattern of financial resource allocation due to its wide coverage, efficient service capacity and low transaction costs. As a key direction of financial innovation, digital inclusive finance leverages advanced technologies such as big data, cloud computing, and artificial intelligence to significantly lower the barriers and costs of financial services while expanding their reach. This enables residents in remote areas and low-income groups to access financial services more conveniently. Such developments are of great significance for promoting the balanced allocation of financial resources and fostering economic interaction between urban and rural areas. For a long time, there have been significant differences in financial services between urban and rural areas. Rural areas often struggle to obtain adequate financial service support due to factors such as remote geographical locations, weak economic foundations and imperfect credit systems. This has to a certain extent restricted the development of the rural economy and the progress of urban-rural integration. The rise of digital inclusive finance, however, has

provided new ideas and approaches to solving this problem. It utilizes advanced technologies such as big data, cloud computing and artificial intelligence to reduce the threshold and costs of financial services, and expand the coverage of such services. This enables remote areas and low-income groups to access convenient and efficient financial services. Such changes not only promote the balanced allocation of financial resources but also effectively drive the development of the rural economy and the interaction between urban and rural economies.

Based on this background, this paper studies whether digital inclusive finance can promote urban-rural integration and analyzes its impact mechanism. On the one hand, it can clarify how digital inclusive finance affects urban-rural integration. On the other hand, it can provide more clear empirical evidence for formulating relevant policies.

2. Literature Review and Research Questions

In the research field of urban-rural relations, the academic community has accumulated abundant theoretical achievements and practical experience. These studies not only conduct in-depth analysis of the theoretical connotation and driving mechanisms of urban-rural relations but also actively explore diverse paths for realizing the integrated development of urban and rural areas. As a deepening and expansion of the concepts of urban-rural coordination and urban-rural integration, urban-rural integration marks the establishment and formation of a new type of urban-rural relationship. Its core lies in promoting in-depth integration across multiple dimensions such as industry, institution, factors, space and governance. Nian Meng et al. (2020) [1] defined the connotative framework of urban-rural integration from the perspective of multi-dimensional integration. They emphasized the importance of industrial coordination, institutional innovation, free flow of factors, optimization of spatial layout and modernization of the governance system, providing a comprehensive perspective for understanding urban-rural integration. From the perspective of historical development, Li Yuanfeng (2018) [2] pointed out that urban-rural integration takes factor integration as the core and emphasizes a strategic path of differentiated development. This view reveals the need to focus on differences and complementarities in the process of urban-rural integration. Geographical researchers such as He Renwei (2018) [3] emphasized the importance of comprehensive integration of economy, society and ecology from the perspective of spatial layout and innovation mechanisms. They highlighted the fundamental role of geographical space in urban-rural integration and its far-reaching impact on the coordinated development of economic, social and environmental systems. In addition, studies from perspectives such as political economy, development economics, resource flow and multi-dimensional integration have enriched the theoretical system of urban-rural integration. For example, Yao Yuchun et al. (2019) [4] analyzed the institutional foundation and interest coordination mechanism of urban-rural integration from the perspective of political economy. Jin Chengwu (2019) [5] explored the economic growth effect and path selection of urban-rural integration from the perspective of development economics. Wang Wenbin (2019) [6] analyzed the key issues of optimal allocation of resources between urban and rural areas from the perspective of resource flow. Zhou Jianing et al. (2019) [7] constructed an analytical framework of multi-dimensional integration including population, space, economy, society and environment, comprehensively examining the comprehensive effects of urban-rural integration. In terms of implementation paths, scholars have put forward many constructive suggestions targeting key issues such as urban-rural factor misallocation,

fiscal decentralization, land market reform, social security mechanisms and social financialization. Liu Minghui et al. (2019) [8] believed that solving the problem of urban-rural factor misallocation is the key to promoting urban-rural integration. Sun Qunli et al. (2021)[9] discussed the supporting role of optimizing government resource allocation in urban-rural integration from the perspective of fiscal decentralization. Chen Kunqiu et al. (2019) [10] emphasized the important role of land market reform in promoting the flow and optimal allocation of urban-rural land factors. Luo Xingqi et al. (2016) [11] focused on the role of social security mechanisms in narrowing the urban-rural gap and promoting shared development. Chen Yiming et al. (2020) [12] proposed new ideas for financial support to the integrated development of urban and rural areas from the perspective of social financialization.

The academic community generally acknowledges the positive impact of digital inclusive finance on urban-rural integrated development. This impact lies not only in accelerating the process of inter-industrial integration and enhancing the balance of people's well-being but also in optimizing and upgrading the government's public service supply system[13]. Su Chunhong and Li Zhen (2023)[14], using a two-way fixed effects model, found that digital inclusive finance significantly improved the supply efficiency and coverage of government public services. Meanwhile, through the combined application of the entropy weight method and principal component analysis (PCA), Hui Ning and Ning Nan (2023) [15] further confirmed the positive effects of digital inclusive finance in enhancing fiscal transparency and alleviating local fiscal burdens. These effects have ultimately promoted the reasonable growth and quality improvement of public service expenditures. In summary, digital inclusive finance plays an indispensable role in promoting urban-rural coordinated development. It has demonstrated strong driving force in deepening industrial integration, optimizing public services, and achieving the goal of common prosperity. Future research can further refine its impact mechanisms and specific practical paths, providing more solid theoretical support and practical guidance for the practical exploration of urban-rural coordinated development.

Existing literature has conducted in-depth research on the positive impact of digital inclusive finance on urban-rural integration. However, there is relatively little research on the non-linear impact of digital inclusive finance on urban-rural integration, and even fewer studies focus on the non-linear characteristics of the impact mechanism between the two. Is the impact of digital inclusive finance on urban-rural integration non-linear? What is the specific form of this non-linear impact? What is the underlying influence path? Taking 30 Chinese provinces from 2011 to 2022 as research objects, this paper adopts a double machine learning model to empirically examine the impact effect and mechanism of digital inclusive finance on urban-rural integration, aiming to address the above questions. The marginal contributions of this paper are as follows: (1) Theoretically and empirically, it integrates digital inclusive finance and urban-rural integration into a unified analytical framework, explores their non-linear relationship, and enriches the research outcomes of urban-rural integration. (2) It employs machine learning algorithms to overcome the potential "curse of dimensionality" problem faced by traditional regression models. (3) In terms of research mechanisms, it explores the potential channels through which digital inclusive finance affects urban-rural integration, providing evidence and policy implications for improving the role of digital inclusive finance in promoting urban-rural integration.

3. Research hypotheses

3.1. *The Direct Impact of Digital Inclusive Finance on Urban-Rural Integration*

The development of digital inclusive finance can directly promote the integrated development of urban and rural areas across four dimensions: population, economy, society, and ecology. From the population dimension, digital inclusive finance helps advance rural infrastructure construction, strengthen interconnection between urban and rural areas, narrow the urban-rural gap, and facilitate two-way free flow of populations between the two regions, thereby boosting urban-rural population integration [16]. From the economic dimension, digital inclusive finance is conducive to driving the integrated development of urban and rural industries. Featuring convenience, high efficiency, and low costs, it meets the financing needs of rural industries through various modern methods. This realizes the optimal allocation of urban and rural production factors and further promotes the integrated development of urban and rural industries. From the social dimension, the development of digital inclusive finance advances urban-rural social integration in terms of medical care, consumption, and education. Firstly, it can provide financial services for both urban and rural residents facing unforeseen circumstances such as accidents and major illnesses, offering inclusive medical security to all residents. Secondly, as rural residents' income increases, their consumption demands also rise. The development of digital inclusive finance provides a wide range of financial services for urban and rural residents, helping meet their consumption needs and thus narrowing the urban-rural consumption gap. Finally, some poor rural residents struggle to continue education beyond compulsory education due to lack of financial support. Digital inclusive finance can provide financial services for these groups, offering funds for their further education. This helps reduce the knowledge and skill gap between urban and rural residents and promotes urban-rural integration [17]. From the ecological dimension, digital inclusive finance enables enterprises to obtain low-cost funds through agricultural support channels. It facilitates the low-carbon transformation of agriculture and reduces the transfer of high-pollution enterprises to rural areas, thereby promoting urban-rural ecological integration [18].

However, the promotional effect of digital inclusive finance on urban-rural integration may not be linear. In the early stage of digital inclusive finance development, on the one hand, problems such as immature service models and limited technological application lead to deficiencies in its coverage scope, service depth and accuracy [19]. It may be difficult to reach rural areas, and instead widen the gap between urban and rural areas. On the other hand, under information constraints, rural residents tend to accept new technologies based on the principle of minimizing risks [20]. Restricted by the low penetration rate of digital inclusive finance in the early stage, rural residents may have a certain sense of unfamiliarity with its financing methods and internet platforms, making promotion more difficult. As a result, its promotional effect on rural development is limited. When digital inclusive finance develops to a relatively mature stage, its coverage scope and service depth have achieved certain progress, and its advantages of low cost, fast dissemination speed and wide audience have been fully exerted [21]. At this stage, rural residents' acceptance of digital inclusive finance has improved, thereby promoting the integrated development of urban and rural areas more effectively.

Hypothesis H1: The impact of digital inclusive finance on urban-rural integration presents a U-shaped characteristic of “first inhibiting and then promoting”.

3.2. Analysis of the Impact Mechanism of Digital Inclusive Finance on Urban-Rural Integrated Development

To analyze the impact mechanism of digital inclusive finance on urban-rural integrated development, this paper attempts to explore the impact through the path of industrial structure upgrading. On the one hand, digital inclusive finance promotes industrial structure upgrading. First, the development of digital inclusive finance provides a more efficient and convenient financing method that can cover all links of the rural industrial chain. This helps rural industries move towards the higher end of the value chain, thereby driving the transformation and upgrading of industrial structure [22]. Second, the development of digital inclusive finance is conducive to pooling scattered funds, reducing financing costs, and increasing the total supply of funds. At the same time, it also raises residents' income, which helps drive economic growth. By accelerating capital deepening and boosting economic growth, it further promotes industrial structure upgrading [23]. Finally, digital inclusive finance can alleviate enterprises' financing constraints, enabling them to have sufficient funds for innovative activities. This speeds up the elimination of backward enterprises and accelerates industrial structure upgrading. On the other hand, industrial structure upgrading creates a large number of jobs suitable for rural residents, promotes the two-way flow of urban and rural populations, and narrows the urban-rural income gap. Meanwhile, industrial structure upgrading encourages the government to advance the development of education, medical care, infrastructure and other fields in rural areas, thereby promoting urban-rural integrated development [24]. In addition, in the early stage of digital inclusive finance development, its application fields and coverage regions are relatively limited, so its ability to improve the level of industrial structure may be weak [25]. At the same time, the transformation and upgrading of industrial structure not only requires solving the problem of financing difficulties but also needs the improvement of various production factors such as technology and knowledge. In the early stage of digital inclusive finance development, it may be difficult to promote industrial structure upgrading. Therefore, this paper puts forward the following research hypothesis H2:

Hypothesis H2: The development of digital inclusive finance can influence the development of urban-rural integration through industrial structure upgrading.

4. Research Design

4.1. Econometric Model

4.1.1. Model Specification

Based on the Double Machine Learning method, this paper identifies the impact of digital inclusive finance development on urban-rural integrated development, and constructs the double machine learning model as follows:

$$URI_{it+1} = \theta_0 DIFI_{it} + g(X_{it}) + U_{it} \quad (1)$$

$$E(U_{it} | DIFI_{it}, X_{it}) = 0 \quad (2)$$

In the model: i denotes the province; t denotes the year; URI_{it+1} represents the level of urban-rural integrated development; $DIFI_{it}$ stands for the level of digital inclusive finance development; θ_0 is the coefficient of digital inclusive finance development, which is the key focus of this paper; X_{it} denotes control variables, and the specific

form of $\hat{g}(X_{it})$ needs to be estimated based on machine learning algorithms; U_{it} is the error term.

If we directly estimate Equations (1) and (2), the results will be biased. The reason is that in high-dimensional or complex model specifications, machine learning models must introduce regularization terms for dimensionality reduction. Although this avoids excessive variance of the estimator, it also brings about regularization bias of the function, making it difficult for $\hat{\theta}$ to converge to θ_0 . To solve this problem, the constructed auxiliary regression is as follows:

$$DIFI_{it} = m(X_{it}) + V_{it} \quad (3)$$

$$E(V_{it} | X_{it}) = 0 \quad (4)$$

In the equation: $m(X_{it})$ is the regression function of the treatment variable on high-dimensional control variables, and its specific form needs to be estimated based on machine learning algorithms. The specific method is as follows: Firstly, use a machine learning model to estimate $m(X_{it})$ and obtain the estimator $\hat{m}(X_{it})$. Then calculate the estimator of the residual term V_{it} as $\hat{V}_{it} = TF_{it} - \hat{m}(X_{it})$. Next, use $\hat{V}_{it}$ as the instrumental variable for $DIFI_{it}$ to conduct estimation. Finally, continue to use machine learning algorithms to estimate the estimator $\hat{g}(X_{it})$ of the function $\hat{g}(X_{it})$ and obtain an unbiased estimate

$$\theta_0 = \left(\frac{1}{n} \sum_{i \in I, t \in T} V_{it} DIFI_{it} \right)^{-1} \frac{1}{n} \sum_{i \in I, t \in T} V_{it} (URI_{it+1} - g(X_{it})) \quad (5)$$

4.1.2. Variable Selection

Four types of variables are specifically selected as follows:

Dependent Variable: Level of Urban-Rural Integration

This paper takes the level of urban-rural integrated development (URI) as the dependent variable. Referring to the research findings of Wang Songmao et al. [26], and Wang Shuo et al. [27], this paper constructs a comprehensive evaluation index system for urban-rural integration (see Table 1). To eliminate dimensional differences among different indicators, the indicator data are processed through standardization. The entropy weight method is adopted to determine the weights, based on which the comprehensive level of urban-rural integration is calculated.

Table 1. Comprehensive Evaluation Index System of Urban-Rural Integration.

Dimension	Indicator	Indicator Explanation	Unit	Attribute
Urban-Rural Population Integration	Ratio of Non-agricultural to Agricultural Employment Proportion	Proportion of employees in the secondary and tertiary industries / Proportion of employees in the primary industry	%	Positive
	Employment Contrast Coefficient	Employment proportion of urban residents - Employment proportion of rural residents	%	Negative
	Education Contrast Coefficient	Difference between the proportion of urban and rural residents with junior high school education or above	%	Negative
	Urban-Rural	Urban-Rural Population Migration	%	Positive

Dimension	Indicator	Indicator Explanation	Unit	Attribute
	Population Interaction	Rate		
	Population Urbanization Level	Urban population / Total population	%	Positive
Urban-Rural Spatial Integration	Land Urbanization Level	Built-up area / Total land area	%	Positive
	Urban Spatial Expansion	Crop sown area / Built-up area	%	Positive
	Transportation Network Density	(Highway operating mileage + Railway operating mileage) / Total land area	km/km ²	Positive
	Passenger Turnover	-	100 million passenger-kilometers	Positive
	Per Capita Private Car Ownership in Urban and Rural Areas	Private car ownership of urban and rural residents / Total population	vehicles/person	Positive
Urban-Rural Economic Integration	Ratio of Per Capita Income of Urban and Rural Residents	Per capita disposable income of urban households / Per capita disposable income of rural households	%	Negative
	Ratio of Wage Income of Urban and Rural Residents	Per capita wage income of urban residents / Per capita wage income of rural residents	%	Negative
	Ratio of Per Capita Consumption of Urban and Rural Households	Per capita consumption of urban households / Per capita consumption of rural households	%	Negative
	Ratio of Urban-Rural Engel's Coefficient	Urban Engel's coefficient / Rural Engel's coefficient	%	Positive
	Dual Contrast Coefficient	(Output value of the primary industry / Employees in the primary industry) / (Output value of the secondary and tertiary industries / Employees in the secondary and tertiary industries)	%	Positive
Urban-Rural Social Integration	Urban-Rural Transportation and Communication	Per capita transportation and communication expenditure in urban areas / Per capita transportation and communication expenditure in rural areas	%	Negative
	Urban-Rural Cultural, Educational and Entertainment Contrast Coefficient	Per capita cultural, educational and entertainment expenditure of urban households / Per capita cultural, educational and entertainment expenditure of rural households	%	Negative
	Urban-Rural Basic Education Contrast Coefficient	Basic education fund input in urban areas / Basic education fund input in rural areas	%	Negative
	Urban-Rural Per Capita Medical and Health Care Contrast Coefficient	Per capita medical and health care expenditure in urban areas / Per capita medical and health care expenditure in rural areas	%	Negative
	Ratio of Per Capita Physicians in Urban and Rural Areas	Per capita number of physicians in urban areas / Per capita number of physicians in rural areas	%	Negative

Dimension	Indicator	Indicator Explanation	Unit	Attribute
	Urban-Rural Endowment Insurance Coverage Rate	-	%	Positive
	Urban-Rural Unemployment Insurance Coverage Rate	-	%	Positive
	Student-Teacher Ratio in Regular Middle Schools	Number of teachers in regular middle schools / Number of students	-	Positive
Urban-Rural Ecological Integration	Urban-Rural Greening Level	Green coverage rate of built-up areas	%	Positive
	Urban-Rural Domestic Waste Treatment	Harmless treatment rate of domestic waste	%	Positive
	Urban-Rural Energy Conservation and Emission Reduction	Total energy consumption / GDP	10,000 tons of standard coal / 10,000 yuan	Negative
	Forest Coverage Rate	Forest area / Total land area	%	Positive
	Industrial Solid Waste Discharge	-	10,000 tons	Negative
	Industrial Sulfur Dioxide Emission	Industrial sulfur dioxide emission	tons	Negative
	Industrial Nitrogen Oxide Emission	Industrial nitrogen oxide emission	tons	Negative
	Sewage Treatment	Centralized treatment rate of sewage treatment plants	%	Positive

Core Explanatory Variable: Digital Inclusive Finance

The core explanatory variable in this paper is the Digital Inclusive Finance Index (DIFI). This paper uses the China Digital Inclusive Finance Index to measure digital inclusive finance. Compiled based on big data from Ant Group's transaction accounts, this index has high research value and credibility. Since the Digital Inclusive Finance Index and the dependent variable (level of urban-rural integration) differ in order of magnitude, logarithmic transformation is applied to the index [28].

Control Variables

Drawing on existing studies, this paper sets five control variables as follows: Government Intervention (GOV): Characterized by the ratio of the government's general budget expenditure to GDP. Degree of External Dependence (OPEN): Represented by the proportion of total import and export volume of each province to GDP [29]. Financial Development Level (FIN): Expressed by the ratio of the balance of deposits in financial institutions to GDP. Education Input (EDU): Measured by the proportion of education expenditure in the government's general budget expenditure. Digitalization Level (INTER): Indicated by the number of urban internet broadband access ports.

Mechanism Variable

Industrial Structure Upgrading (IND): Expressed by the ratio of the added value of the tertiary industry to that of the secondary industry.

4.2 Data Description

This paper uses panel data of 30 provinces in China from 2011 to 2022 as the research sample. Tibet is excluded due to a large number of missing indicator data. The data used in this study are sourced from the China Statistical Yearbook, China Rural Statistical Yearbook, China Household Survey Yearbook, China Education Finance Statistical Yearbook, China Environmental Statistical Yearbook, China Population and Employment Statistical Yearbook, China Forestry Statistical Yearbook and statistical yearbooks of various provinces. For a small amount of data missing in some years, the interpolation method is adopted to supplement them. The results of descriptive statistics are shown in Table 2.

Table 2. *Variable Description and Descriptive Statistics.*

Variable Category	Variable Name	Abbreviation	Number of Observations	Mean	Standard Deviation	Minimum Value	Maximum Value
Explained Variable	Urban-Rural Integration	URI	360	0.321	0.079	0.171	0.669
Explanatory Variable	Digital Inclusive Finance	DIFI	360	5.338	0.666	2.909	6.133
Control Variables	Government Intervention	GOV	360	0.247	0.102	0.107	0.643
	Degree of External Dependence	OPEN	360	2.825	0.982	-0.369	5.042
	Financial Development Level	FIN	360	1.864	0.781	0.840	5.587
	Educational Input	EDU	360	0.164	0.026	0.099	0.222
	Digitalization Level	INTER	360	0.501	0.239	0.096	1.075
Mechanism Variable	Industrial Structure	IND	360	1.284	0.699	0.549	5.297

5. Analysis of Empirical Results

5.1. Benchmark Regression Results

Drawing on previous studies[30], this paper sets the sample splitting ratio of the double machine learning method to 1:4 and uses the random forest algorithm for prediction. Table 3 presents the results of the impact of digital inclusive finance development on urban-rural integrated development. Columns (I) to (IV) show the regression results without including fixed effects, controlling only for time fixed effects, controlling only for city fixed effects, and controlling for both time and city fixed effects, respectively. It can be seen that in all regression results, the estimated coefficient of the quadratic term of digital inclusive finance is significantly positive at the 1% level, while the estimated coefficient of its linear term is significantly negative at the 5% level. This indicates that the development of digital inclusive finance has an impact on urban-rural integration that first inhibits and then promotes it. This regression result is consistent with the theoretical analysis above, thus verifying Hypothesis H1. The reason is that in the early stage of digital inclusive finance development, there are certain deficiencies in coverage scope, service depth and accuracy. At the same time, rural residents find it relatively difficult to accept digital

inclusive finance, and its role in driving economic development may hardly reach rural areas, which in turn widens the urban-rural gap. However, in the relatively mature stage of digital inclusive finance development, its coverage scope and service depth have improved. First, the development of digital inclusive finance has promoted infrastructure construction and accelerated the two-way flow of urban and rural populations. Second, the characteristics of digital inclusive finance, such as convenience, high efficiency and low cost, help solve the financing constraints of rural industries and rural residents, drive the development of rural industries, improve rural residents' access to medical care, consumption and education, and promote urban-rural integrated development. Finally, digital inclusive finance can also obtain low-cost funds through agricultural support channels, curb the transfer of high-pollution enterprises to rural areas, and promote green development in rural areas.

Table 3. *Impact Results of Digital Inclusive Finance on Urban-Rural Integration.*

Variable	(I)	(II)	(III)	(IV)
	URI	URI	URI	URI
DIFI ²	0.008*** (0.002)	0.009*** (0.002)	0.007*** (0.001)	0.009*** (0.002)
DIFI	-0.032** (0.015)	-0.034** (0.017)	-0.031** (0.014)	-0.040** (0.020)
_cons	0.000 (0.001)	0.001 (0.001)	0.000 (0.001)	0.001 (0.001)
Control Variables	Yes	Yes	Yes	Yes
Machine Learning Model	Random Forest Algorithm	Random Forest Algorithm	Random Forest Algorithm	Random Forest Algorithm
Time Fixed Effects	No	Yes	No	Yes
City Fixed Effects	No	No	Yes	Yes
Sample Size	360	360	360	360

5.2. Robustness Tests

5.2.1. Outlier Treatment

Since extreme values may affect regression results, this paper conducts 1% winsorization on both the upper and lower tails of the variables. The regression results are shown in Column (I) of Table 4.

5.2.2. Changing Machine Learning Method.

This paper replaces the random forest algorithm with the support vector machine (SVM) algorithm to reduce the impact of the choice of machine learning model on the regression results. The regression results are presented in Column (II) of Table 4.

5.2.3. Adjusting Cross-Validation Ratio

An excessively large or small sample splitting ratio in double machine learning may lead to reduced model learning ability or overfitting [31]. Therefore, this paper adjusts the splitting ratio to 1:9 and 1:3 for re-regression. The results are displayed in Columns (III) and (IV) of Table 4, respectively.

5.2.4. Endogeneity Test

Although double machine learning helps overcome the potential “curse of dimensionality” in traditional regression models, the development of digital inclusive

finance may be affected by various unobservable factors, and there may still be omitted variable bias. Referring to the approach of Zhang Hongchang and Wang Yue (2025) [32], this paper introduces the lagged term of the dependent variable (urban-rural integration development) and adopts the system GMM model to alleviate the endogeneity problem. The results are shown in Column (V) of Table 4. The quadratic term of the core explanatory variable (digital inclusive finance) is significantly positive, and its linear term is significantly negative. This indicates that the development of digital inclusive finance has an impact of first inhibiting and then promoting urban-rural integration, further verifying Hypothesis H1. For the system GMM estimation results, the p-value of the AR(2) test is greater than 0.1, and the p-value of the Hansen test is also greater than 0.1. This shows that there is no serial autocorrelation in the residual terms and the selected instrumental variables are valid. The empirical test results confirm that the basic hypothesis of this paper still holds after considering the omitted variable bias.

Table 4. Robustness Test Results.

Variable	(I)	(II)	(III)	(IV)	(V)
	OutlierHandling	Changing MachineLearning Method	Changing Cross-ValidationRatio	Changing Cross-ValidationRatio	Endogeneity Test
DIFI2	0.009***	0.010***	0.009***	0.009***	0.003*
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
DIFI	-0.039**	-0.077***	-0.040*	-0.041**	-0.032**
	(0.019)	(0.013)	(0.021)	(0.020)	(0.015)
Control Variables	Yes	Yes	Yes	Yes	Yes
Machine LearningMethod	Random Forest Algorithm	Support Vector Machine Algorithm	Random Forest Algorithm	Random Forest Algorithm	-
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
City Fixed Effects	Yes	Yes	Yes	Yes	Yes
Sample Size	360	360	360	360	330

5.3. Mechanism Test

The research hypothesis of this paper indicates that the development of digital inclusive finance affects urban-rural integrated development by influencing industrial structure upgrading. To verify whether this mechanism holds, this paper examines the impact of digital inclusive finance on this mechanism variable, and the regression results are shown in Table 5. As presented in Table 5, the estimated coefficient of the quadratic term of digital inclusive finance is significantly positive at the 10% significance level, while the estimated coefficient of its linear term is significantly negative at the 10% significance level. This shows that digital inclusive finance has an impact of first inhibiting and then promoting industrial structure upgrading. The reason may be that in the early stage of digital inclusive finance development, its support and coverage for rural areas are insufficient, making it difficult to drive industrial structure upgrading. With the further development of digital inclusive finance, it reduces financing costs for industries, increases residents' income, drives economic growth and the transfer of industries to higher value chains, thereby promoting industrial structure upgrading. At the same time, industrial structure upgrading provides a large number of jobs for rural residents. While increasing rural

residents' income, it promotes the two-way flow of urban and rural populations and advances urban-rural integrated development. In addition, industrial structure upgrading also drives the development of education, medical care and other fields in rural areas, thereby accelerating the process of urban-rural integration. Consistent with the theoretical analysis above, this verifies Hypothesis H2.

Table 5. *Impact Mechanism Test of Digital Inclusive Finance Development on Urban-Rural Integration.*

Variable	IND
DIFI2	0.132* (0.071)
DIFI	-0.959* (0.514)
_cons	0.009 (0.012)
Control Variables	Yes
Machine Learning Model	Random Forest Algorithm
Time Fixed Effects	Yes
City Fixed Effects	Yes
Sample Size	360

6. Research Conclusions and Policy Implications

Based on the panel data of 30 Chinese provinces from 2011 to 2022, this paper empirically examines the impact of digital inclusive finance development on urban-rural integrated development. The main conclusions and policy recommendations are as follows:

6.1 Research Findings

(1). The double machine learning results show that the development of digital inclusive finance has a U-shaped impact on urban-rural integration—first inhibiting and then promoting. This conclusion remains valid after a series of robustness tests.

(2). The results of the mechanism effect model indicate that digital inclusive finance development affects urban-rural integrated development through the path of influencing industrial structure upgrading.

6.2 Policy Implications

Based on the above conclusions, this paper puts forward the following policy recommendations:

(1). Strengthen infrastructure construction. The government should increase investment in rural infrastructure, especially in network coverage and intelligent terminal equipment, to provide a solid material foundation for the development of digital inclusive finance.

(2). Improve residents' digital literacy. Through education and training, publicity and guidance, enhance rural residents' digital literacy and financial knowledge, reducing the threshold and cost for them to use digital finance services.

(3). Improve the regulatory system. Establish and improve the regulatory framework for digital finance, strengthen the prevention and crackdown on financial risks, protect consumers' legitimate rights and interests, and enhance the reputation and credibility of digital finance.

(4). Promote industrial integration and innovation. Encourage financial institutions to cooperate with rural enterprises, farmers and other entities, innovate financial products and service models, and drive the optimization and upgrading of rural industrial structure as well as the development of agricultural modernization.

(5). Strengthen regional cooperation and coordination. Promote information sharing and resource integration among adjacent provinces, enhance regional cooperation and coordination, and jointly advance urban-rural integrated development.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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