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Research article

The Impact of Digital Technology Use on Farmers Quality of Life: Evidence from Rural China

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Abstract: This study examines the impact of digital technology on the quality of life of rural farmers in China using data from the 2018 China Family Panel Studies. Our analysis, based on a sample of 11,644 individuals, highlights that digital technology significantly enhances the quality of life, with notable differences across regional boundaries. The most pronounced benefits are observed in the eastern and central provinces, whereas the western provinces show minimal improvement. Further, we identify non-farm employment and job income as key mediators in the relationship between digital technology use and quality of life improvements. These findings suggest that targeted digital infrastructure investments could substantially benefit rural populations, particularly in underdeveloped areas, advocating for a region-specific approach to digital development in rural China.

Keywords: Quality of life; Digital technology; Rural farmers; Influence mechanism

1. Introduction

Quality of life (QOL) is multidimensional and complex [1]. It comprises objective and subjective factors, including health status, living environment, family social support, emotional state, and life satisfaction [2, 3]. QOL is a comprehensive reflection of people's overall evaluation of their lives and indicates social development. Improving QOL has become vital for humans and an essential aspect of well-being in social development [4,5]. Human needs are becoming increasingly diverse as the world economy and society evolve. Therefore, improving QOL has become a central issue in social policymaking. Understanding the components, influencing factors, and potential mechanisms of public QOL can fill existing theoretical gaps in social development and provide insights into managing the sustainable development of society.

A substantial gap exists in China's development process between rural and urban, commonly called a "dichotomy." Over the last few decades, rapid urbanization has increased the urbanization rate from 36.06% in 2000 to 65.22% in 2022 [6]. This trend has been attributed to the continuous migration of rural populations to cities, resulting in a decline in rural areas. The challenges faced by rural China persist in education, living conditions, and medical and healthcare services and have a profound impact on farmers' QOL [7,8,9]. Recently, rural China has implemented wide-ranging measures to adjust to urbanization. In particular, the information infrastructure development initiative [10]. According to the 51st Statistical Report on the Development Status

of the Internet in China in December 2022, the number of Chinese Internet users has grown to 1.067 billion, and the Internet penetration rate has reached 75.6%. Rural Internet users accounted for 293 million, with an Internet penetration rate of 58.8%, bringing "5G to counties and broadband to villages." China's rural areas are undergoing an information revolution and digital technology (DT) will transform rural farmers' lives and progress.

DT is widely acknowledged as a key driver of social and economic development [11]. Scholars have extensively studied DT's socioeconomic impact, exploring its macro effects on rural economic development and employment, such as the role of e-commerce in improving living standards and reducing poverty in BRICS countries [12]. Additionally, broadband use has been found to stimulate economic growth, reduce unemployment, and enhance farmers' access to information and job opportunities, thus reducing poverty vulnerability [13, 14]. From a micro perspective, researchers have focused on households and farmers, investigating the effects of internet usage on income and expenditures [15,16]. Research shows increased cell phone and Internet technology usage positively influences farm income. [17]. However, few studies have focused on individual farmers' development or DT's impact on their overall QOL.

Based on China Family Panel Studies (CFPS), this study investigates the impact of DT on rural farmers' QOL. Unlike previous studies focusing on macro areas such as rural economic development and public services, this study employs microdata to analyze the DT's effect on rural farmers' QOL. The paper's contributions are multi-fold: First, it is the first study to examine how DT affects rural farmers' QOL. Second, it attempts to establish the impact mechanism of DT on rural farmers' QOL through non-farm employment (NFE) and income levels, which can help improve and enhance their QOL. We use the instrumental variable method to address the potential endogeneity problem in classical linear regression. Finally, a heterogeneity analysis is conducted from a regional perspective to explore the varying impacts of DT on rural development in the eastern, central, and western provinces. This analysis identifies differences in the effects of DT on rural Chinese farmers' QOL.

2. Literature Review

2.1 The Relationship Between DT and Farmers' QOL

DT's impact on rural China is currently interesting to academic researchers, particularly with the continuous improvement of digital infrastructure. While there is a lack of direct analyses of the relationship between DT and rural farmers' QOL, its possible effects can be analyzed at both material and spiritual levels. First, DT can contribute to higher incomes and improved living standards for farmers. Information technology can promote the specialization of crop cultivation, expand the marketing scope of agricultural products, and improve the marketing efficiency and selling price of agricultural products [17,18]. Moreover, digital technologies broaden farmers' employment options and enhance employment rates and job stability [19]. Second, DT can improve farmers' mental well-being and positively affect their subjective well-being and life satisfaction. The availability of online entertainment, shopping, communication, and information can help reduce depression and build and maintain social relationships [20, 21, 22, 23]. The internet can also increase Chinese farmers' economic well-being [16] and facilitate communication, thereby reducing social isolation [22].

Hypothesis 1: DT contributes to the improvement of rural farmers' QOL.

2.2 NFE's Mediating Role

In the digital age, DT has expanded farmers' employment opportunities. The emergence of Internet businesses, innovations in digital consumption patterns, and the development of e-commerce have created many NFE opportunities [14]. Farmers who acquire digital skills can participate in NFE, potentially improving their QOL.

DT use facilitates the efficient allocation of labor resources [24]. With DT development, online transactions, and the sharing economy have facilitated the growth of the "casual labor economy," which has created considerable employment opportunities, especially for laborers in poor areas who can be employed through e-commerce consumption [25,26]. Additionally, Internet use can promote farmers' entrepreneurship and increase their possibility of NFE [27, 28, 29]. Studies have shown that the Internet, cell phones, and fixed

broadband positively impact early entrepreneurial activity [30]. The use of information and communication technologies has broadened people's horizons and brought new ideas to users, which, in turn, has increased the possibility of entrepreneurship [31]. Using a computer at home helps increase individuals' willingness to start a business and increases employment opportunities and income-generation possibilities for rural laborers [32]. Digital finance enabled by DT breaks down geographical restrictions and facilitates capital flow and distribution in rural areas, promoting entrepreneurship among farmers [33].

NFE is a key factor in improving farmers' QOL. The benefits of NFE, including physical and spiritual improvements, are critical for improving overall QOL. Materially, NFE in developing countries can provide farmers with stable household incomes and reduce uncertainties related to agricultural operating income [34, 35, 36]. Spiritually, NFE brings farmers a greater sense of self-realization and social integration. As nonagricultural work is often more complex than agricultural work, people tend to have higher levels of happiness and satisfaction when engaging in complex nonagricultural work [37]. NFE broadens farmers' social networks and promotes increased social capital [38], crucial for improving their subjective welfare [39]. Therefore, NFE promotes growth in farmers' income levels and improves their subjective welfare. In conclusion, NFE is an essential contributor to a better QOL for farmers. Accordingly, this study proposes the following hypothesis:

Hypothesis 2: NFE mediates the relationship between DT and farmers' QOL.

2.3 Mediating Role of Job Income (JI)

Technological advancement in agriculture is a significant driver of increasing productivity in rural areas, raising the income of rural residents, and reducing the rural-urban income gap [40, 41]. DT has enabled socially disadvantaged groups to access development opportunities in rural areas [42]. First, DT facilitates information transfer. Information transmission costs through DT are low, and farmers who have mastered DT can access broad-ranging market information at a lower cost. They can identify potential buyers on a broad scale, thereby reducing price risk, promoting the sale of agricultural products, and ultimately increasing earnings [43, 44, 45]. DT complements the production factors in developing countries' rural areas. Farmers use DT to share, promote, and sell their produce [46, 47, 48, 49]. Second, DT offers farmers more excellent development opportunities. Farmers can expand their pathways toward human capital accumulation by acquiring digital skills. The internet provides farmers access to agricultural technology at a lower cost, enhancing their human capital and improving their self-development capabilities [50,51]. Consequently, farmers can make more informed decisions and improve their decision-making efficiency, leading to rational economic choices that contribute to growth in their income [14].

DT's use in agriculture increases farmers' income levels, which is crucial for enhancing their QOL. This is important because higher incomes can reinforce the results of poverty reduction efforts in rural areas and prevent a return to poverty [52, 53, 54]. Improvements in material well-being brought about by income increases are undoubtedly positive for farmers. Moreover, farmers' subjective QOL is closely linked to their ability to manage personal resources effectively. The capital they possess is particularly effective in combating pessimism caused by stressful stimuli, pressure, and frustration, and hence, it can enhance their well-being [55, 56]. Therefore, we propose that income level is essential to farmers' well-being and that improving their economic condition will enhance their living standards. Consequently, DT's increased income can effectively prevent a return to rural poverty, enrich farmers' spiritual worlds, and enhance their well-being. Based on this analysis, we propose the following hypothesis:

Hypothesis 3: JI mediates the relationship between DT and farmers' QOL.

2.4 Chain Mediating Role of NFE and JI

Combined with the above analysis, this paper follows the research idea of "DT - NFE - JI – QOL" to explore the path of DT to promote farmers' QOL. The mediating roles of NFE and JI have been clarified in a previous study; however, the relationship between NFE and JI has not been explored.

First, NFE broadens farmers' horizons, allowing them to gain experience in new domains. Such experiences foster a change in their knowledge structure and enhance self-learning abilities, facilitating the

adoption of advanced agricultural production technologies and contributing to farmers' skill acquisition [57,58]. This, in turn, leads to improvements in productive skills, resulting in higher income levels. Second, DT is low-cost and rapidly developing, creating new job opportunities for farmers and driving income growth. For example, the proliferation of e-commerce in China's rural areas has boosted the growth of upstream and downstream agriculture-related industries, increasing farmers' income [59, 60]. Finally, local employment and non-farm businesses can generate part-time employment opportunities for farmers, thereby contributing to income augmentation. Farmers often migrate to economically developed areas for work opportunities, where wages tend to be higher, thus generating household remittance income [61].

Hypothesis 4: NFE and JI mediate the relationship between DT and farmers' QOL.

Therefore, the hypothetical model is proposed, as shown in Figure 1.

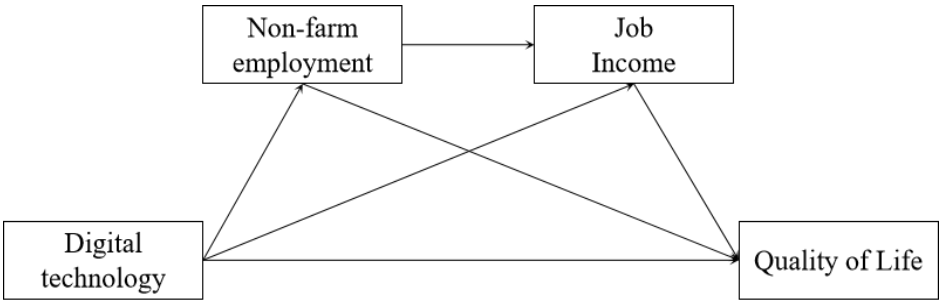

Figure 1. Theoretical model

3. Data, Measurements, and Methods

3.1 Methodological Details

The analysis utilizes empirical methods to assess digital technology's impact on rural farmers' quality of life, leveraging data from the 2018 China Family Panel Studies. Given the complexity of isolating the effects of digital technology from other variables, we employ the instrumental variable (IV) approach to address potential endogeneity issues, ensuring that our findings robustly reflect causal relationships.

Selection of Instrumental Variables: Selected monthly postal and communication expenses as instrumental variables for digital technology adoption. This choice is grounded in the premise that expenditure on communication services is closely related to digital technology usage yet plausibly exogenous to a farmer's subjective quality of life, primarily influencing it through adopting digital technologies. These expenses serve as a proxy for the intensity of digital engagement, correlating strongly with digital adoption while unlikely to be directly affected by unobserved factors influencing quality of life.

Justification and Implementation of IV Approach: Validate the relevance and homogeneity of instrumental variables by conducting tests confirming that these variables are statistically significant predictors of digital technology usage but do not directly correlate with the error terms of our main equations. The first-stage F-statistics from our IV regressions exceed the thresholds suggested by Stock-Yogo tests, indicating that our instruments are not weak.

Addressing Endogeneity: Used a two-stage least squares (2SLS) regression model, where the first stage predicts digital technology use based on our instruments, and the second stage assesses the impact of the predicted digital technology use on quality of life. This approach helps us mitigate reverse causality and omitted variable bias.

Robustness Checks: To further ensure the robustness of findings, sensitivity analyses, including varying the set of control variables and using alternative model specifications, were conducted. These tests consistently support the study's main conclusions, affirming the methodological approach's reliability.

3.1 Research Data

Data used in this study are from the CFPS 2018, a biennial tracking survey that aims to reflect the social, economic, demographic, educational, and health changes in China by tracking and collecting data at the individual, household, and community levels and to provide a database for academic research and public policy analysis. The tracking survey questionnaire consisted of three types: individual, household, and village (residence) questionnaires [62]. To study DT's impact on farmers' QOL, the main variables used in this study were data from the fifth national survey of the CFPS in 2018, which included 33,326 residents. Finally, 11,644 responses from rural farmers were retained after variable screening and missing-value processing. Compared to previous similar studies, the data in this study are relatively new and have a broader coverage and larger sample size; thus, they are more authoritative and representative.

3.2 Variable Selection

Dependent variable. QOL is the degree to which objective human needs are satisfied in an individual's or group's perception of subjective well-being. Human needs are survival, reproduction, security, and affection [63]. QOL includes objective developmental status and subjective perceptions of life [64]. Many scholars have measured residents' objective and subjective QOL in previous studies. The objective dimension mainly includes health, education level, material life, and living environment, while the subjective dimension includes happiness, security, and access [65]. Therefore, this study constructed a three-level index for measuring rural farmers' QOL at the micro level from both material and spiritual dimensions concerning existing studies, as shown in Table 1.

Stata software (version 17.0) was used to analyze the data reliability, and Cronbach's alpha of each latent variable was greater than 0.700, indicating that the data are reliable (Cronbach's alpha = 0.757). In this study, the QOL index system included material and spiritual dimensions. The material dimension includes income, property, public services, and sharing, and the spiritual dimension includes happiness, security, and gain. These indicators effectively measure each farmer's QOL, are scientifically sound, and explain QOL well. Principal component analysis was performed on the selected indicators. The variance contribution weight of each principal component was determined, and the cumulative variance contribution of the extracted components was taken as the overall weight. The principal component scores were weighted and summed to obtain the QOL index.

Independent variables. With the rapid development of information technology, connected devices, methods, and operations have undergone significant advancements in convenience, accessibility, and user-friendliness. Mobile devices (e.g., cell phones, tablets) and fixed devices (e.g., computers) are the two primary tools for social connectivity. Whether mobile or fixed devices are used to access the internet is a good measure of farmers' DT use [46]. Therefore, in this study, the CFPS 2018 items "Do you use mobile devices, such as cell phones and tablets, to access the Internet?" and "Do you use a computer to access the Internet?" measure the DT mastery of rural farmers, with the use of those devices to access the internet assigned a value of 1, otherwise assigned a value of 0.

Mediating variables. In the CFPS 2018 questionnaire, income level is measured by the survey question "Total income in the past 12 months," which is a continuous variable, and income level is treated as a logarithm in the analysis; NFE is measured by the question "nature of main work," which is a dichotomous variable, with agricultural work (agriculture, forestry, animal husbandry, and fishery) assigned a value of "0" and non-farm work assigned a value of "1."

Control variables. To capture DT's effect on farmers' QOL, following the tradition of the literature referred to existing influencing factors on QOL. It selected control variables in terms of demographic individual characteristics, household characteristics, and socioeconomic characteristics. Among them, demographic characteristics include gender (male=1, female=0), age (actual age of respondents), marital status (married=1, unmarried=0), education level (years of education of the respondents), health level (unhealthy=1, average=2, relatively healthy= 3, very healthy=4, very healthy=5), religion (yes=1, no=0), and political affiliation (party member=1, mass=0); household characteristics mainly included household size (number in respondent's households), household consumption (log of annual household consumption expenditure), and

household social capital (log of gifts coming and going); and socioeconomic characteristics variables mainly included social insurance (participated=1, not participated=0).

Table 1. QOL index system

Primary Indicators	Secondary Indicators	Tertiary Indicators	Indicator Meaning
Material level	Income level	Household income per capita	Household income per capita
	Property Level	Total household assets	Total household assets
	Public Service Level	Satisfaction with Environmental	The severity of the environmental protection problem is indicated by a number, with 0 - not serious and 10 - very serious.
		Satisfaction with Employment	The severity of the employment problem is expressed in numbers, with 0 - not serious and 10 - very serious.
		Satisfaction with Education	The severity of the education problem is expressed in numbers, with 0 - not serious and 10 - very serious.
		Satisfaction with Medical	The severity of the medical problem is expressed in numbers, with 0 - not serious and 10 - very serious.
		Satisfaction with housing	The severity of the housing problem is expressed in numbers, with 0 - not serious and 10 - very serious.
		Satisfaction with Social Security	The severity of the social security problem is indicated by a number, with 0 - not serious and 10 - very serious.
		Satisfaction with government integrity	Severity of the problem of government integrity is expressed in numbers, with 0 - not serious and 10 - very serious.
	Income Disparity Level	Income Gap	Severity of the problem of income gap is expressed in numbers, with 0 - not serious and 10 - very serious.
Spiritual Level	Sense of Happiness	Residents' Happiness	Using numbers to indicate the happiness, 0 - the lowest, 10 - the highest
		Residents' sense of happiness	Using numbers to indicate the frequency of happiness. 1 - the lowest and 4 - the highest
	Sense of security	Confidence in the future	Using numbers to indicate the degree of confidence in one's future.1 - the lowest. and 5 - the highest
		Life satisfaction	Using numbers to indicate life satisfaction, 1 - the lowest and 5 represents the highest
		Opportunities to improve living standards	Using numbers to indicate the opportunity to improve life in the future.1 - the lowest and 4 - the highest
	Sense of access	Sense of self-fulfillment	Using numbers to indicate the importance of self-fulfillment. 1 – unimportant and 5 - very important
		Sense of self-fulfillment	Using numbers to indicate one's social status in the local community. 1 - very low and.5 - very high
		Cultural and artistic pursuits	Culture and entertainment expenses

3.3 Model Construction

To test the impact of DT on rural farmers' QOL, the following econometric model was established:

$$y_i = \alpha_0 + \alpha_1 Internet_i + \alpha_x X_i + \varepsilon_i \quad (1)$$

In equation (1), y_i denotes the QOL index of rural resident i, $Internet_i$ denotes the Internet skill status of farmer i, X_i denotes a set of control variables affecting farmers' QOL, α is the parameter to be estimated, and ε_i is the random disturbance term that measures the unobservable factors affecting the farmers' QOL index.

4. Results

4.1 Descriptive Statistical Analysis

Table 2. Descriptive statistical analysis

VARIABLES		Indicator Meaning	Mean	Sd
Dependent variable	QOL	Comprehensive QOL Index System	3.623	0.883
	Material dimension QOL	Comprehensive index system for QOL at the material level	4.914	1.057
	Spiritual dimension QOL	Comprehensive index system of spiritual QOL	2.398	0.727
Mediating variables	NFE	Non-farm employment = 1, engaged in agriculture = 0	0.390	0.488
	JI	Income from work throughout the year	10.317	1.288
Independent variable	DT	Whether to use the internet, yes=1, no=0	0.422	0.494
Control variables	Gender	Male=1, Female=0	0.490	0.500
	Age	Actual Age of Respondents	47.403	16.568
	Marital Status	Married = 1, unmarried = 0	0.782	0.413
	Education Level	Years of education of the respondents	6.121	4.762
	Health Level	Unhealthy = 1, average = 2, relatively healthy = 3, very healthy = 4, very healthy = 5	2.946	1.295
	Religious beliefs	Yes=1, No=0	0.030	0.171
	Political Appearance	Party members = 1, masses = 0	0.008	0.088
	Family size	Number of interviewees' households	4.395	2.087
	Household consumption	Log annual household consumption expenditure	10.667	0.868
	Family social capital	Social Capital	7.266	2.284
	Social Insurance	Participation = 1, non-participation = 0	0.939	0.240

Table 2 reports the means and standard deviations of the sample of 11,644 farmer groups from the CFPS 2018. The mean value of the QOL index obtained from the principal component analysis of this paper's independent variables was 3.623, with a standard deviation of 0.883. Meanwhile, to examine the impact of DT on farmers' QOL at the material and spiritual levels, this paper also performed principal component analysis on both levels, and the mean values are 4.914 (material) and 2.398 (spiritual). This shows that rural Chinese farmers' QOL is currently higher in material than spiritual terms.

As for mediating variables, the percentage of farmers working in agriculture was 61, and NFE was 39. The average income level of the farmers was 10.317. Individually, 49% of the respondents were male, and 51% were female, with marriage status 78.2%. Regarding farmers' education level, on average, the interviewed

farmers had 6.121 years of education, indicating that most Chinese farmers have received only elementary and junior high school education. The number of religious farmers was relatively low, at 3% of the total number of farmers. Finally, 0.8 % of the interviewed group was involved in politics. The mean interviewees household size was 4.395 persons, annual household consumption expenditure (logarithm) was 10.667, and total household social capital was 7.266. Altogether, 93.9% of the farmers had social insurance; participants had a high level of social security.

4.2 Bivariate Relationship among Key Variables

A correlation analysis was conducted to examine the correlations among the key variables (Table 3). DT was positively correlated with QOL, the material dimension of quality of life (MQOL), and the spiritual dimension of quality of life (SQOL). The correlation coefficient between DT and farmers' QOL was 0.255, indicating a significant predictive effect of DT on farmers' QOL. The correlation coefficient between DT and the material dimension is 0.263, showing that DT has a greater impact on farmers' MQOL than overall QOL. In contrast, the correlation coefficient between DT and farmers' SQOL was 0.015, which was significant only at the 10% level. Second, DT was positively correlated with NFE and JI. The correlation coefficient between the DT and NFE was 0.452, which was significant. The correlation coefficient between DT and JI is 0.209 and is significant, indicating a significant positive prediction of DT for NFE and JI. Third, NFE, work income, and QOL were positively correlated. NFE was significantly and positively correlated with QOL. The correlation coefficient between JI and QOL was 0.236, and JI was a significant positive predictor of QOL.

Table 3. Bivariate relationship among key variables

	1	**2**	**3**	**4**	**5**
1.QOL	1				
2.MQOL	0.943***	1			
3.SQOL	0.354***	0.067***	1		
4.DT	0.255***	0.263***	0.015*	1	
5.NFE	0.203***	0.208***	0.009	0.452***	1
6.JI	0.236***	0.242***	0.149***	0.209***	0.227***

Note: *** p<0.01, ** p<0.05, * p<0.1

4.3 Impact of DT on Rural Farmers' QOL

Table 4 reports the baseline regression results of DT's impact on farmers' QOL. Models (1), (3), and (5) include only DT in the regressions and are estimated using OLS models, which are found to be significantly positive, indicating that farmers' DT can positively impact QOL and can improve the physical as well as spiritual QOL. In model (1), for example, DT has a positive impact on QOL (β=0.443, p<0.001). Models (2), (4), and (6), which include individual variables, household variables, and social variables in the regression, were also estimated using OLS models, and the results show that DT is significantly positive. In model (2), for example, DT has a positive impact on QOL (β=0.190, p<0.001). This indicates that DT positively impacts rural farmers' QOL, contributing more to the physical than spiritual QOL. This verifies the validity of hypothesis 1.

The control variables also significantly affected the farmers' QOL, which decreases as age increases. Married farmers had a higher QOL than unmarried farmers. The regression results show that education and health levels are positively related to farmers' QOL, and an increase in education level and an improvement in health status are conducive to improving farmers' QOL. In addition, household consumption and social capital significantly affected rural farmers' QOL. Finally, farmers who participate in social security have a lower QOL than those who do not participate in social security.

Table 4. The impact of DT on the QOL of rural farmers

VARIABLES	QOL		MQOL		SQOL	
	(1)	(2)	(3)	(4)	(5)	(6)
DT	0.443***	0.190***	0.551***	0.225***	0.020*	0.045***
	(30.97)	(9.01)	(32.20)	(8.92)	(1.68)	(2.58)
Gender		-0.042***		-0.016		-0.071***
		(-2.61)		(-0.84)		(-5.41)
Age		-0.003***		-0.006***		0.008***
		(-4.70)		(-7.57)		(13.13)
Marital status		0.099***		0.117***		0.060***
		(4.86)		(4.81)		(3.58)
Years of education		0.019***		0.023***		0.005***
		(9.17)		(8.95)		(2.65)
Health status		0.041***		-0.004		0.137***
		(6.35)		(-0.53)		(26.05)
Religious belief		0.052		0.052		0.068*
		(1.16)		(0.97)		(1.82)
Political status		0.059		0.052		0.077
		(0.67)		(0.49)		(1.05)
Family size		0.003		-0.005		0.014***
		(0.63)		(-0.90)		(4.03)
Family expense		0.140***		0.168***		0.105***
		(13.02)		(13.07)		(11.85)
Family social capital		0.011***		0.021***		0.001
		(2.97)		(4.59)		(0.39)
Social Insurance		0.063*		0.091**		0.061**
		(1.92)		(2.33)		(2.27)
Constant	3.441***	2.304***	4.685***	3.449***	2.392***	0.662***
	(361.69)	(9.34)	(411.75)	(11.69)	(299.93)	(3.23)
Observations	14,374	11,644	14,427	11,647	14,686	11,856
R-squared	0.063	0.128	0.067	0.129	0.000	0.104

Note: *** p<0.01, ** p<0.05, * p<0.1

4.4 Heterogeneity Analysis of DT on Rural Farmers' QOL

There is a large development gap in China between the eastern, middle, and western regions [66, 67]. Due to the different natural endowments and economic bases, there is a certain degree of imbalance in the information infrastructure of different regions in China; there are large differences in information technology in different regions. Farmers in different regions may have different digital skill masteries that directly affect their QOL. In contrast, the eastern and central regions have a better economic foundation, richer economic resources, and a more efficient resource flow, directly affecting local farmers' QOL. For these reasons, this study conducted a regional heterogeneity analysis.

Table 5 reports DT's impact on rural farmers' QOL in the eastern, central, and western provinces. DT can effectively improve the QOL level in the rural areas of eastern and central provinces. In the eastern provinces' rural areas, DT had a positive impact on farmers' QOL (β=0.176, p<.001), on MQOL (β=0.197, p<.001), and on SQOL (β=0.211, p<.001). In the central provinces' rural areas, DT had a positive impact on farmers' QOL (β=0.217, p<.001), on MQOL (β=0.229, p<.001), and SQOL (β=0.251, p<.001). In contrast, in the western provinces' rural areas, DT did not significantly affect QOL but positively affected farmers' SQOL (β =0.068, p<.005).

Table 5 Heterogeneity analysis

VARIABLES		QOL (1)	MQOL (2)	SQOL (3)
Panel A： East Region	DT	0.176***	0.197***	0.211***
		(4.79)	(4.74)	(6.43)
	Control variables	YES	YES	YES
	Province fixed effect	YES	YES	YES
	Constant	1.911***	2.125***	1.808***
		(9.82)	(9.27)	(9.30)
	Observations	4,106	3,146	4,392
	R-squared	0.122	0.116	0.095
Panel B： Central Region	DT	0.217***	0.229***	0.251***
		(4.90)	(4.62)	(6.45)
	Control variables	YES	YES	YES
	Province fixed effect	YES	YES	YES
	Constant	3.039***	3.526***	3.012***
		(12.96)	(12.87)	(13.09)
	Observations	4,108	3,147	4,392
	R-squared	0.125	0.130	0.093
Panel C： Western Region	DT	0.010	0.044	0.068**
		(0.33)	(1.29)	(2.47)
	Control variables	YES	YES	YES
	Province fixed effect	YES	YES	YES
	Constant	0.100	0.082	0.442***
		(0.63)	(0.44)	(2.73)
	Observations	4,189	3,223	4,444
	R-squared	0.112	0.094	0.067

Note: *** p<0.01, ** p<0.05, * p<0.1

4.5 Endogeneity Treatment

Farmers with a higher QOL are more likely to use DT to counter the reverse causality problem of DT and QOL. Furthermore, the omitted variables may present challenges. To address these concerns, we used the instrumental variable method to overcome the endogeneity problem, and the selection of appropriate instrumental variables required them to satisfy both the correlation and homogeneity conditions. In this study, we selected monthly postal and communication expenses as the instrumental variable. These expenses include telephone, cell phone, Internet access, and mail, representing the average monthly amount spent. These variables were selected based on the assumption that the adoption of DT is closely related to households' monthly postal and telecommunication expenses. Farmers who use the internet frequently and have higher levels of digital skills are also likely to spend more on postal and telecommunications. Moreover, we controlled for contextual effects, such as community characteristics. We found that monthly postage and electricity costs were relatively exogenous and less likely to impact rural farmers' QOL directly. Therefore, these variables are appropriate for this study's instrumental variables.

First, according to the empirical strategy of Stock and Yogo [68], the results of the first stage of the weak instrumental variable test show that the Cragg-Donald statistic of the weak instrumental variable test is 12.132, which is greater than the critical value of 8.96 under a 15% bias; that is, the hypothesis of the weak instrumental variable is rejected, using monthly postage and electricity costs as the instrumental variable. The Durbin-Wu-Hausman endogeneity test result is 19.49, which rejects the hypothesis that DT is an exogenous variable that needs to be treated with instrumental variables. Second, the results of the two-stage regression

showed that DT positively affects rural farmers' QOL, indicating that this study's findings are robust and plausible (see Table 6).

Table 6. Endogenous treatment

	Independent variable: DT	**Dependent variable: QOL**
	Phase I	**Phase II**
DT		2.777***
		(2.81)
Instrument Variables	0.013***	
	(3.48)	
Constant	0.505***	1.088**
	(4.63)	(1.83)
Control variables	YES	YES
Provincial fixed effects	YES	YES
Observations	11644	11644
Cragg-Donald Statistical quantities	12.132	
Stock-Yogo bias critical value	8.96（15%）	
Endogeneity Test		
Durbin-Wu-Hausman χ^2 test	19.49	
P-value	0.000	

Note: *** p<0.01, ** p<0.05, * p<0.1

4.6 Analysis of the Impact Mechanism of DT for Rural Farmers' QOL

Table 7. Results of the multiple mediation model analysis of DT and farmers' QOL

VARIABLES	**NFE**	**JI**	**QOL**
	(1)	**(2)**	**(3)**
DT	0.132***	0.094***	0.164***
	(12.37)	(3.11)	(7.08)
NFE		0.227***	0.072***
		(7.85)	(3.24)
JI			0.088***
			(11.15)
Control variables	YES	YES	YES
Constant	0.500***	4.296***	1.899***
	(4.22)	(12.91)	(7.40)
Observations	9,558	9,481	9,276
R-squared	0.356	0.267	0.138

Note: *** p<0.01, ** p<0.05, * p<0.1

In this study, a bootstrap sample with a capacity of 1000 was obtained using Stata 17.0, with repeated put-back sampling to test for the chain-mediating effect (Table 8). If Bootstrap 95% does not contain 0, the effect is significant. DT has a positive effect on rural farmers' QOL. NFE, JI, and NFE → JI significantly mediate the relationship between DT and rural farmers' QOL. The total mediating effect value was 0.021, 11.35% of the total effect (0.185). DT affects rural farmers' QOL through three paths: DT → NFE → QOL (0.010, 5.41% of the total effect); DT → JI → QOL (0.009, 4.86% of the total effect); and DT → NFE → JI → QOL (0.003, 1.08% of the total effect). This result supports hypotheses 2, 3, and 4.

This study employed hierarchical regression analysis to investigate the chain-mediating role of NFE and JI in the association between DT and rural farmers' QOL (see Table 7). The results indicate that DT has a significant and positive effect on farmers' QOL (β=0.164, p<.001), and it also significantly and positively predicts NFE (β=0.132, p<.001) and JI (β=0.094, p<.001). Furthermore, NFE has significantly and positively impacted JI (β=0.227, p<.001). When DT, NFE, and JI were simultaneously entered into the regression equation, all three factors significantly and positively influenced rural farmers' QOL. Therefore, NFE and JI play chain-mediating roles in the relationship between DT and rural farmers' QOL.

Table 8. Analysis of the mediating effects of NFE and JI

Path	b	Bootstrap S.E.	z	p	Bootstrap 95% CI
Direct effect					
DT→QOL	0.164	0.022	7.56	0.000	[0.121, 0.206]
Mediating effect					
DT→NFE→QOL	0.010	0.003	3.36	0.001	[0.004, 0.015]
DT→JI→QOL	0.009	0.003	3.12	0.002	[0.003, 0.014]
DT→NFE→JI→QOL	0.003	0.000	5.50	0.000	[0.001, 0.004]
Total effect	0.185	0.022	8.50	0.000	[0.142, 0.228]

Note: *** p<0.01, ** p<0.05, * p<0.1

5. Discussion and Conclusion

Recently, with society's continuous development, research on QOL has entered a new stage of rapid development. This study used data from CFPS 2018 to examine the individual effects of DT and the combined effects of DT, NFE, and JI on farmers' QOL. Therefore, analyzing the mediation effect of this chain can help us understand the factors that affect farmers' QOL and provide valuable insights for improving the QOL of people in underdeveloped regions.

DT use has the potential to improve rural farmers' QOL significantly. The DT revolution in rural China has effectively improved farmers' living standards. DTs on farmers' QOL are reflected in both material and spiritual dimensions. Continuous innovation and the development of DT in rural China can help increase farmers' NFE opportunities, which directly impact JI and ultimately help improve farmers' QOL. There are several mediating factors between DT and farmers' QOL, including NFE and JI. This study provides valuable insights into the impact of DT on rural farmers' QOL and offers suggestions for promoting the overall development of residents in underdeveloped areas.

5.1 DT and Farmers' QOL

This study demonstrates that DT positively impacts rural farmers' QOL materially and spiritually. DT also facilitates their lives, supporting hypothesis 1. There has long been a substantial development gap between urban and rural areas in China, with rural public services lagging behind their urban counterparts. This disparity disproportionately negatively affects farmers' QOL [69], creating a need for intervention. However, with the continuous development of DT in rural areas, agricultural informatization, finance, e-commerce, improved education, and medical care can effectively address the lack of basic public service facilities. The application of DT in agricultural production, marketing, finance, education, and medical care can enhance farmers' QOL, promote the development and progress of rural economies and societies, and provide valuable insights into improving the QOL of residents in impoverished and underdeveloped regions worldwide [70] (Miller & West, 2009).

5.2 Mediating Roles of NFE and JI

This study found that NFE significantly mediates between DT and farmers' QOL, thus verifying hypothesis 2. The progress of DT in rural areas has brought about many entrepreneurial and employment opportunities [71], and the advancement of e-commerce has enhanced farmers' entrepreneurial vigor. This development has also facilitated the extension of related industrial chains and stimulated the growth of

segments such as express delivery, storage, packaging, and training, thus creating novel non-farm jobs and promoting the transfer of excess rural labor to NFE [72, 73]. The diversification of income sources through NFE has the potential to enhance farmers' socioeconomic well-being. This can be crucial in promoting urban-rural integration and cultural exchange, thereby boosting farmers' social statuses. The consequential social and cultural benefits that arise from such integration can enhance farmers' self-perception and sense of self-worth, further contributing to improvements in their QOL.

Second, this study revealed that JI plays a crucial mediating role in the relationship between DT and QOL among farmers. Thus, hypothesis 3 is confirmed. With the growing popularity of DT in Chinese rural regions, farmers have greater access to information regarding employment opportunities through the internet and other channels. Consequently, they can leverage DT to engage in various high-paying jobs, including e-commerce and Internet marketing, which are typically more lucrative than traditional agricultural work. This increase in JI provides farmers better access to education, medical care, and improved living conditions. These findings are consistent with those of previous studies. Pirinsky (2013) found that an increase in income is positively correlated with an improvement in confidence. Additionally, higher income can enhance farmers' social status and recognition, boosting their self-confidence and satisfaction. Thus, these analyses collectively suggest that JI is a critical mediating factor between farmers' DT and QOL. [74].

Finally, the study reveals that NFE and JI have a chain-mediating effect on the relationship between DT and farmers' QOL, thus confirming hypothesis 4. DT growth has led to the emergence of new fields of NFE, including e-commerce, mobile payments, and online education. Expanding these new fields has created more opportunities for farmers to engage in NFE. Furthermore, the widespread adoption of DT in rural areas has enhanced farmers' efficiency and productivity, improving their work skills and quality [46, 75]. Enhanced skills and improved quality can offer farmers additional NFE opportunities that generally yield higher incomes than agricultural work. Consequently, DT has enabled Chinese farmers to secure more opportunities for NFE, leading to higher income levels and ultimately significantly improving their QOL.

5.3 Implications and Applications

The findings of this study underscore the transformative potential of digital technology in enhancing the quality of life for rural farmers in China. The significant improvements in the eastern and central provinces highlight the need for regionally targeted digital policies. Governments and stakeholders should consider several strategic initiatives:

Regional Strategy Development: Given the regional disparities in digital benefits, development strategies should be tailored. For regions like the western provinces with less pronounced impact, policies could focus on foundational digital literacy programs and infrastructure development that specifically address local needs and barriers.

Investment in Digital Infrastructure: The study suggests that robust digital infrastructure in rural areas can catalyze improved quality of life. Investments should prioritize not only physical infrastructure but also the accessibility and affordability of digital services. This includes expanding broadband access, increasing mobile internet penetration, and supporting the adoption of emerging technologies.

Enhancing Digital Literacy: Training programs that improve digital skills for rural populations can empower farmers to leverage digital tools for better agricultural practices, market access, and financial services, which are critical for improving non-farm employment opportunities and job income.

Support for Digital Entrepreneurship: Encourage and facilitate the integration of digital technologies in agricultural practices and beyond. This includes supporting e-commerce platforms that allow farmers to sell their products directly to consumers, thus bypassing intermediaries and increasing their income potential.

Monitoring and Evaluation: Implement ongoing monitoring and evaluation mechanisms to assess the effectiveness of digital interventions on quality of life in rural areas. This will help fine-tune policies and ensure that the benefits of digital technology are equitable.

Collaboration with Tech Companies: Foster partnerships with technology companies to develop localized solutions that address specific challenges faced by rural farmers. This could include innovations in agricultural technology, such as precision farming tools, that can increase crop yields and reduce labor costs.

By focusing on these areas, policymakers and development agencies can enhance the impact of digital technology on rural development, contributing to more equitable economic growth and social inclusion. This approach will improve the quality of life for rural populations and contribute to the broader goal of reducing urban-rural disparities in China.

5.4 Limitations and Directions

This study has certain limitations that must be acknowledged. First, it employed cross-sectional data from 2018. Given the rapid development of DT in rural China, data limitations have impeded our ability to assess the impact of recent DT on rural farmers' QOL. Second, the independent variables selected in this study were relatively narrow, measuring DT in rural areas solely from the perspective of mobile devices such as cell phones and tablets and fixed devices such as computers. Therefore, it fails to provide a comprehensive and accurate measurement of the popularity and use of DT in rural areas. Third, the mediating effects of NFE and JI on the relationship between DT and rural farmers' QOL may be influenced by social structural factors such as social class, career, and organization; therefore, other influential factors need to be further examined.

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