Agricultural & Forestry Economics and Management (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/agrfem.2023.060303
ISSN 2616-2202 Vol. 6 Num. 3

# *Analysis of spatial spillover effects of digital economy on agricultural and rural modernization*

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***Keywords:*** Digital economy; Agricultural and rural modernization; Spatial spillover effect.

***Abstract:*** In this paper, the development level of digital economy and agricultural and rural modernization in different regions is measured by constructing an index evaluation system, and the spatial effect of digital economy development on agricultural and rural modernization is deeply studied. According to the research, the following conclusions are drawn: the development of digital economy can significantly improve the level of agricultural and rural modernization, and this promotion will not only drive the modernization of agricultural and rural areas in this region, but also have a positive impact on the modernization of agricultural and rural areas in surrounding areas. Therefore, we should actively improve the digital infrastructure construction in rural areas, vigorously promote the development of digital economy, and accelerate the digital transformation of traditional agriculture. Local governments should strengthen cooperation and exchanges with other regions, give full play to the spatial spillover effect of digital economy, and achieve high-quality development together with neighboring areas.

## 1. Introduction

At present, the rapid development of digital economy is constantly stimulating the new driving force of China's economy, which is leading the digital transformation in different fields and promoting the high-quality development. However, due to the unbalanced distribution of resource elements in the economic development between urban and rural areas for a long time, many unsolved economic and social problems have accumulated in rural areas, such as a lack of talents, insufficient capital and insufficient industrial support (Ma Wenwu et al., 2023) [1]. These problems have brought some obstacles to the realization of socialist modernization in China. In order to push agriculture and rural areas into the fast lane with high quality and realize the modernization of agriculture and rural areas, these existing problems must be solved. Therefore, we should firmly grasp the development tide of digital economy, make full use of the ever-changing digital technology, and constantly solve the key problems in the development of agriculture and rural areas. Then, how will the development of digital economy affect the modernization of agriculture and rural areas? It is of great practical significance for China to build a strong socialist modernization country by deeply exploring the influence of digital economy development on agricultural and rural modernization.

## 2. Theoretical analysis

By combing the literature, it is found that digital economy can promote the modernization of rural industry, ecology, culture, governance and life. First, the application of digital information technology in traditional agriculture has innovated and improved the agricultural technology level and operation mode, and promoted the optimization and upgrading of the whole agricultural industrial chain (Li Yuan et al., 2023) [2], which is conducive to the modernization of rural agriculture. Second, the perfect development of digital infrastructure construction can improve the efficiency of information dissemination between different regions, promote the joint protection and governance of the ecological environment in different regions (Zhou Wenhui et al., 2023) [3], and contribute to the effective implementation of ecological environment protection measures. Third, the application of digital technology in the field of cultural industry can solve the problems of small market scale, serious homogenization and weak innovation in the development of traditional rural cultural industry, and at the same time upgrade the production and dissemination mode of cultural products (Xiang Li et al., 2020) [4], and promote the development of cultural industry in rural areas. Fourth, the establishment of digital government processing system has brought more convenient and standardized public services to rural residents, simplified residents' business processes, and improved the efficiency of government officials in handling related affairs (Zhang Yunping et al., 2022) [5], and the transparency of grass-roots management has also been enhanced. Fifth, the digital construction of rural areas can improve the living standards of rural residents and narrow the income gap between urban and rural residents by improving the digital infrastructure (Pan Xiquan, 2023) [6].

In addition, the inclusive, convenient and effective digital economy can break through geographical barriers, develop with other regions, deepen economic association with other regions, and promote the continuous development of local surrounding areas (Si Zengchuo et al., 2023) [7]. The in-depth development of digital economy in rural areas has brought high-quality technical means to rural areas, leading to accurate and high-speed information dissemination between different regions. As a result, cooperation and communication in different regions have a strong material foundation, and the possibility of win-win cooperation between regions has greatly increased. At the same time, the region can learn the development experience of other regions to achieve faster and better development. Economies of scale formed by the development of digital economy will also have a strong radiation effect on the surrounding areas, improving its development.

## 3. Research design

### 3.1 Variable selection

As some data are incomplete or unavailable, this paper studies the provincial panel data of 30 provinces and municipalities in Chinese mainland (excluding Tibet) from 2015 to 2021. The data used are all from the National Bureau of Statistics, China Statistical Yearbook, China Labor Statistical Yearbook and provincial statistical yearbooks, and some missing data are filled by linear interpolation method.

a. Core explanatory variable: Digital economy level (Dig). This paper draws lessons from the index system of digital economy level constructed by Liu Jun et al. (2020) [8] and Li Xiaozhong et al. (2022) [9], and combines the development characteristics of digital economy to measure the level of digital economy from three angles: informatization, digital transaction and Internet development. After standardizing the original data, the entropy method is used to weigh each index, and the digital economy index is calculated, and its natural logarithm is taken as the index data to measure the development level of digital economy. The selected specific indicators are shown in Table 1.

b. Explained variable: Agricultural and rural modernization level (Rur). This paper draws lessons

from the practice of Chen Huiqing et al. (2022) [10], and constructs the index evaluation system of agricultural and rural modernization from five aspects: rural agriculture, ecology, culture, governance and life modernization. Also, on the basis of standardizing the original data, the entropy method is used to assign weights, and the agricultural and rural modernization level index of different provinces is calculated, and the natural logarithm is taken. Among them, the selection of each index is shown in Table 1.

Table 1 Selection of indicators of digital economy development level and agricultural and rural modernization level

| | first-class index | second-class index | weights | attribute |
|---|---|---|---|---|
| Digital economy level | Informatization | Optical cable line density | 0.0440 | + |
| | | Mobile phone base station density | 0.1244 | + |
| | | Proportion of employed persons in urban units of information transportation, software and information technology services | 0.1880 | + |
| | | Total telecommunication service | 0.0903 | + |
| | | Software business income | 0.1503 | + |
| | Digital transaction | Number of websites owned per 100 enterprises | 0.0088 | + |
| | | E-commerce sales | 0.1076 | + |
| | | Proportion of enterprises with e-commerce transactions | 0.0307 | + |
| | | Online retail sales | 0.1415 | + |
| | Internet development | Number of Internet broadband access ports per capita | 0.0191 | + |
| | | Mobile phone penetration rate | 0.0222 | + |
| | | Number of computers used per 100 people | 0.0330 | + |
| | | Proportion of mobile Internet users | 0.0188 | + |
| | | Proportion of broadband Internet access users | 0.0213 | + |
| Agricultural and rural modernization level | Modernization of rural agriculture | Effective irrigation ratio | 0.0590 | + |
| | | Total power of agricultural machinery | 0.0872 | + |
| | | Gross output value of agriculture, forestry, animal husbandry and fishery | 0.0693 | + |
| | Modernization of rural ecology | Amount of chemical fertilizer used per unit area | 0.0168 | - |
| | | Harmless treatment rate of domestic garbage | 0.0045 | + |
| | | Local fiscal expenditure on environmental protection | 0.0593 | + |
| | Modernization of rural culture | Per capita library collection | 0.0875 | + |
| | | Local fiscal expenditure on science and technology | 0.1461 | + |
| | | Local financial expenditure on education | 0.0588 | + |
| | Modernization of rural governance | Endowment insurance participation ratio | 0.0281 | + |
| | | Local financial expenditure on urban and rural community affairs | 0.0716 | + |
| | | Number of village committees per 10,000 people in villages | 0.0618 | + |
| | Modernization of rural life | Engel coefficient | 0.0175 | - |
| | | Proportion of administrative villages with centralized water supply | 0.0143 | + |
| | | Rural electricity consumption | 0.1726 | + |
| | | The proportion of wage income of rural residents to total income | 0.0456 | + |

c. control variables: Government support (Gov), foreign trade level (Fot), industrial structure (Ais), scientific and technological level (Inn), population situation (Pop) and rural Internet level (Int). In this paper, Luo Zhenjun et al. (2023) [11] and Zhou Bing et al. (2023) [12] are used for reference to set the above control variables. Among them, government support is measured by the proportion of local general budget expenditure to local GDP; The level of foreign trade is measured by the natural logarithmic value of the total import and export volume where the business unit is located; The industrial structure is measured by the ratio of the added value of the local tertiary industry to the regional GDP; The level of science and technology is measured by the natural logarithm of the turnover in the technology market; The population situation is measured by the dependency ratio of the elderly population; The level of rural Internet is measured by the natural logarithm of the number of rural Internet broadband access users, and some missing data are filled by linear interpolation. Table 2 below shows descriptive statistics of each variable.

Table 2 Descriptive statistics

| | Variable | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Core explanatory variable | Dig | 2.418 | 0.678 | 1.117 | 4.237 |
| Explained variable | Rur | 3.169 | 0.403 | 2.113 | 4.114 |
| control variables | Gov | 0.112 | 0.032 | 0.058 | 0.245 |
| | Fot | 6.260 | 1.610 | 1.202 | 9.457 |
| | Ais | 0.522 | 0.079 | 0.399 | 0.837 |
| | Inn | 7.573 | 1.777 | 3.086 | 11.157 |
| | Pop | 0.166 | 0.040 | 0.096 | 0.267 |
| | Int | 7.588 | 1.417 | 2.639 | 9.655 |

## 3.2 Model design

In order to explore the spatial spillover effect of the development of digital economy on the development of agricultural and rural modernization, this paper uses the spatial econometric model to study it, and constructs the spatial Durbin model (SDM) as follows:

$$Rur_{it}=\theta_1 Dig_{it}+\rho W Rur_{it}+\theta_3 W Dig_{it}+\theta_4 Con_{it}+\theta_5 W Con_{it}+\theta_0+\mu_i+\sigma_t+\varepsilon_{it} \quad (1)$$

In the above formula, $Rur_{it}$ represents the agricultural and rural modernization level of i region in the t year, $Dig_{it}$ represents the digital economy level of i region in the t year, $Con_{it}$ represents all control variables, and W represents the corresponding spatial weight matrix. In addition, $\mu_i$ represents the fixed effect of each region, $\sigma_t$ represents the fixed effect of each year, and $\varepsilon_{it}$ represents the error interference term.

## 4. Analysis of empirical results

### 4.1 Spatial autocorrelation test

Before testing whether there is a spatial effect, it is necessary to test the spatial autocorrelation of the digital economy index and agricultural and rural modernization index constructed above to test their spatial dependence. Therefore, this paper adopts the method of Sun Xuetao et al. (2022) [13]. Table 3 shows the spatial dependence test results of the two under the economic geography weight matrix constructed by using per capita GDP. It can be seen from the table that Moran's I index of digital economy level and agricultural and rural modernization level in different years has passed the spatial autocorrelation test, and both are positive. It shows that the development level of digital economy and the level of agriculture and rural modernization are classified and clustered, and there is spatial autocorrelation.

Table 3 Global Moran's I of digital economy and agricultural and rural modernization level

| Year | Digital economy level | | | Agricultural and rural modernization level | | |
|---|---|---|---|---|---|---|
| | Moran's I | z | p-value | Moran's I | z | p-value |
| 2015 | 0.494 | 3.324 | 0.000 | 0.392 | 2.665 | 0.004 |
| 2016 | 0.469 | 3.168 | 0.001 | 0.411 | 2.774 | 0.003 |
| 2017 | 0.458 | 3.099 | 0.001 | 0.357 | 2.442 | 0.007 |
| 2018 | 0.448 | 3.035 | 0.001 | 0.348 | 2.385 | 0.009 |
| 2019 | 0.466 | 3.145 | 0.001 | 0.346 | 2.373 | 0.009 |
| 2020 | 0.446 | 3.022 | 0.001 | 0.347 | 2.380 | 0.009 |
| 2021 | 0.476 | 3.230 | 0.001 | 0.282 | 1.971 | 0.024 |

On the basis of calculating the global Moran's I, this paper also tests the local Moran's I index of digital economy and agricultural and rural modernization level, and draws the Moran scatter diagram of them. Figure 1 shows Moran scatter charts of 2015 and 2021, with the upper two charts showing

digital economic index and the lower two charts showing agricultural and rural modernization index. It can be seen from the results that most regional samples are distributed in the first and third quadrants, which further shows that there is a strong spatial positive correlation between digital economy and agricultural and rural modernization level index. Therefore, it is necessary to study the spatial spillover effect when analyzing the impact of digital economy development on agricultural and rural modernization.

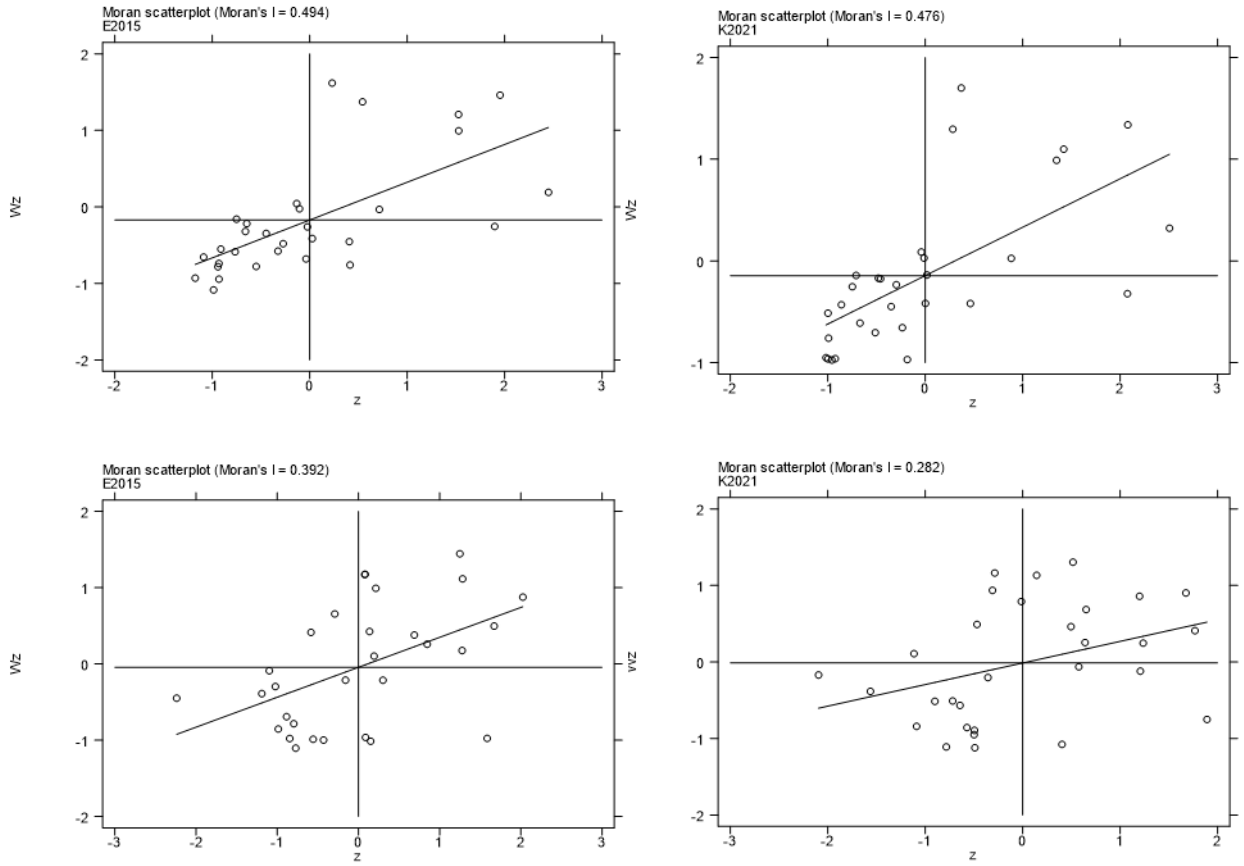


Figure 1 Moran scatter diagram of digital economy level (upper row) and agricultural and rural modernization (lower row)

## 4.2 Determine the spatial model

Table 4 Spatial model test results

| Test Methods | Statistical value | P-value |
|---|---|---|
| LM_Spatial_error | 24.497 | 0.000 |
| LM_Spatial_lag | 4.805 | 0.028 |
| Hausman | 33.10 | 0.005 |
| LR_ sar | 17.06 | 0.017 |
| LR_ sem | 24.34 | 0.001 |
| Wald_Spatial_error | 25.69 | 0.000 |
| Wald_Spatial_lag | 17.40 | 0.015 |

Before spatial effect analysis, a series of tests such as LM test, Hausmann test, LR test and Wald test are needed, and the test results are shown in Table 4. First of all, the results of LM test show that the spatial error and spatial lag effect are significant at 1% level, which indicates that the spatial panel model should be used for analysis. Secondly, the results of Hausmann test are significant at 1% level, which indicates that the fixed effect model should be used for test. After that, according to the LR test

results, it can be judged that SDM model will not degenerate into SAR or SEM model, so it is reasonable to use SDM model for analysis. Finally, according to Wald test results, SDM model is more suitable for regression. Therefore, this paper finally determines to use the fixed spatial Durbin model (SDM) model to test the spatial effect of digital economy development on agricultural and rural modernization.

### 4.3 Spatial effects model estimation

Columns (3) and (4) in Table 5 below are the results of testing by using spatial Durbin model. The results in Column (3) show that the impact coefficient of the development of digital economy on agricultural and rural modernization is 0.132, which is significant at the level of 1%, indicating that the better the development of digital economy in this province, the higher the level of agricultural and rural modernization. The results show that the ρ value is 0.384, which is significant at 1% level, indicating that the development of agricultural and rural modernization among provinces promotes each other, and the level of agricultural and rural modernization among adjacent regions is significantly positively correlated. At the same time, Column (4) is the regression result of explaining the spatial lag term of variables. From the results, it can be seen that the development of digital economy has a significant role in promoting the modernization of agriculture and rural areas in adjacent areas, and can form a positive spatial spillover effect, thus promoting the benign interaction between digital economy and the modernization of agriculture and rural areas in adjacent spaces. In addition, it is found that government support only promotes the development of agricultural and rural modernization in this region, and there is no spatial spillover effect.

Table 5 Spatial effects regression results

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | SAR | SEM | SDM (Main) | SDM (Wx) |
| Dig | 0.149*** | 0.103** | 0.132*** | 0.186** |
| | (0.049) | (0.050) | (0.048) | (0.074) |
| Gov | 0.880** | 0.977** | 0.902** | -0.386 |
| | (0.400) | (0.414) | (0.402) | (0.540) |
| Fot | 0.021 | 0.016 | 0.020 | 0.028 |
| | (0.019) | (0.020) | (0.019) | (0.027) |
| Ais | 0.264 | 0.249 | 0.247 | 0.015 |
| | (0.267) | (0.272) | (0.267) | (0.390) |
| Inn | -0.000 | 0.003 | -0.002 | -0.011 |
| | (0.008) | (0.007) | (0.008) | (0.010) |
| Pop | -0.824** | -0.757** | -0.578 | -0.462 |
| | (0.329) | (0.352) | (0.356) | (0.550) |
| Int | 0.000 | 0.003 | -0.007 | 0.022 |
| | (0.014) | (0.014) | (0.015) | (0.028) |
| ρ | 0.411*** | | 0.384*** | |
| | (0.063) | | (0.065) | |
| λ | | 0.383*** | | |
| | | (0.068) | | |
| $R^2$ | 0.425 | 0.360 | 0.401 | |
| year | Yes | Yes | Yes | |
| province | Yes | Yes | Yes | |

Note: ***, * *, * represent the significance at 1%, 5% and 10% levels respectively, and standard errors are in brackets, the same below.

## 4.4 Decomposition effect

According to Guo Feng et al. (2021) [14], the influence coefficient of spatial interaction term obtained by SDM model regression cannot fully represent spillover effect, so it is necessary to use the practice of LeSage et al. (2009) [15] to further decompose the influence effect of the variables into the direct, indirect, and total effects by partial differential. Table 6 shows the decomposed spatial effect. Among them, the direct effect represents the influence of variables on local agricultural and rural modernization; Indirect effect represents the influence of neighboring variables on local agricultural and rural modernization and its spatial spillover effect; The total effect is the sum of direct and indirect effects.

It can be seen from the results that the influence coefficients of direct, indirect and total effects of digital economy level are significantly positive, which shows that the development of digital economy in local and neighboring areas will significantly and positively affect the modernization of agriculture and rural areas in this region, and that the development of digital economy is able to bring positive spatial spillover effect to the modernization of agriculture and rural areas.

Among the control variables, government support has a significant positive direct impact on agricultural and rural modernization, but the indirect effect and total effect are not significant, which shows that government support mainly promotes t agricultural development and rural modernization in this region, and there is no spillover effect on local agricultural development and rural modernization by government support in neighboring regions. The direct effect of population situation is significantly negative, while the indirect effect and total effect are not significant, indicating that a higher dependency ratio of the elderly population will inhibit the development of local agricultural and rural modernization, but there is no significant spillover effect on the surrounding areas.

Table 6 Decomposition effect result

| | (1) | (2) | (3) |
|---|---|---|---|
| | Direct | Indirect | Total |
| Dig | 0.173*** | 0.341*** | 0.514*** |
| | (0.052) | (0.102) | (0.131) |
| Gov | 0.887** | 0.014 | 0.901 |
| | (0.404) | (0.761) | (0.956) |
| Fot | 0.028 | 0.054 | 0.082 |
| | (0.020) | (0.040) | (0.051) |
| Ais | 0.255 | 0.119 | 0.374 |
| | (0.275) | (0.561) | (0.713) |
| Inn | -0.004 | -0.016 | -0.020 |
| | (0.008) | (0.016) | (0.021) |
| Pop | -0.684* | -1.027 | -1.711 |
| | (0.382) | (0.864) | (1.088) |
| Int | -0.004 | 0.032 | 0.028 |
| | (0.017) | (0.042) | (0.054) |

## 5. Conclusions and suggestions

In this paper, the panel data of 30 provinces or municipalities in Chinese mainland from 2015 to 2021 are used to construct the index evaluation system of digital economy level and agricultural and rural modernization level, and the entropy method is used to calculate the index, so as to deeply study the spatial effect of digital economy development on agricultural and rural modernization development. According to the research, the following conclusions are drawn: the development of digital economy can significantly improve the level of agricultural and rural modernization, and this

promotion will not only drive the modernization of agricultural and rural areas in this region, but also have a positive impact on the modernization of agricultural and rural areas in surrounding areas. Based on this conclusion, this paper puts forward the following suggestions:

First of all, we should improve the digital infrastructure construction in rural areas and vigorously promote the development of digital economy. We should speed up the digital transformation of rural areas, strengthen the construction of digital facilities such as Internet, Internet of Things and smart logistics, provide more convenient services for rural residents, improve their quality of life, enhance their happiness and promote rural modernization. At the same time, we should speed up the digital transformation of traditional agriculture, actively grasp the digital trend, intelligently upgrade agriculture, improve the efficiency of agricultural production, processing, transportation and sales, and give full play to the advantages of digitalization in all fields of agriculture, so as to better promote the development of agricultural modernization. In addition, local governments should strengthen cooperation and exchanges with other regions, jointly build and share relevant digital resources, give full play to the spatial spillover effect of digital economy, achieve high-quality development together with neighboring regions, and jointly move towards the development goal of agricultural and rural modernization.

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