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The Impact and Spatial Spillover Effect of the Digital Economy in the Yangtze River Delta on the Income Gap between Urban and Rural Residents

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ABSTRACT

At present, with the rapid development of the digital economy, the issue of the income gap between urban and rural areas has drawn much attention. Based on the panel data of 41 cities in the Yangtze River Delta region from 2011 to 2022, this paper conducts a benchmark regression and finds that the development of the digital economy has a "U-shaped" impact on the income gap between urban and rural residents. Subsequently, by establishing a spatial econometric model, it is discovered that there exists a significant inverted "U-shaped" spatial spillover effect of the digital economy on the income gap between urban and rural residents. Therefore, full consideration should be given to regional differences, the process of new urbanization should be continuously promoted, the integrated development of urban and rural areas and the coordinated development of regions should be vigorously advanced to realize the integration of the Yangtze River Delta, thereby creating more favorable conditions and opportunities for narrowing the income gap between urban and rural areas.

KEYWORDS

Digital economy; Income gap between urban and rural residents; Nonlinear impact; Spatial spillover effect

1. INTRODUCTION

In 2020, on the occasion of the 100th anniversary of the founding of the Communist Party of China, China achieved a moderately prosperous society in all respects and completed its first centenary goal. Currently, China is striding forward towards the realization of the second centenary goal, that is, to build a modern socialist country in all respects. However, the realization of common prosperity for all people is the core requirement of Chinese modernization, which necessitates narrowing the income gap between urban and rural areas and increasing the degree of equalization of income distribution while maintaining steady economic growth [1].

The digital economy, as a more advanced economic form following the agricultural economy and the industrial economy in the new era, is subtly influencing people's production and life with its strong innovation and transformation capabilities. In January 2024, the National Development and Reform Commission and the National Data Administration jointly issued the "Digital Economy Promotion of Common Prosperity Implementation Plan", proposing to develop the digital economy by popularizing digital infrastructure and innovating digital technologies to reduce the gaps between regions and between urban and rural areas, indicating that the digital economy has become an important way to promote the integrated development of urban and rural areas and achieve common prosperity.

The Yangtze River Delta region is one of the most developed regions in China. Conducting research on it and exploring its internal development factors have important practical significance. Therefore, this paper chooses to deeply explore the specific impact and spatial spillover effect of the digital economy on the income gap between urban and rural residents at the municipal level in the Yangtze River Delta region, with a view to providing a basis for the Yangtze River Delta region to develop the digital economy, guide the complementary advantages among regions and achieve coordinated development.

2. THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

Since the digital economy was elevated to a national strategy at the 19th National Congress of the Communist Party of China in 2019, it has witnessed rapid development, and its proportion in GDP has been increasing year by year. In 2022, this proportion exceeded 40%, slightly higher than the proportion of China's secondary industry in GDP in the same year, demonstrating that the impact of the digital economy on people's production and life is continuously deepening.

On the one hand, through the continuous popularization of the Internet, the digital economy enables rural residents to more easily access information that was previously unavailable through traditional means. This reduces the learning cost and broadens the channels for non-agricultural employment, which is conducive to narrowing the income gap between urban and rural residents [2]. On the other hand, the problem of information asymmetry brought about by the development of the digital economy will affect the efficiency of agricultural production and the upgrading of the rural industrial structure [3, 4]. It may lead to the expansion of the income gap.

Based on this, the first research hypothesis is put forward:

H1: The impact of the digital economy on the income gap between urban and rural residents is "U-shaped".

The development of the digital economy can not only enhance the total factor productivity in the local area but also help improve the total factor productivity in neighboring areas [5]. The digital economy can break through the limitation of geographical distance, enabling neighboring areas to learn and adopt advanced production technologies and methods, which is beneficial for driving economic growth and promoting the production efficiency and innovation ability of neighboring areas. In addition, the digital economy can act on the quality of economic development in neighboring areas through the spatial spillover effect [6]. The digital economy can break through the limitations of time and space, promote the dissemination of information and knowledge, allowing knowledge to spread across spatial barriers. When local knowledge combines with external knowledge, new values are created, promoting technological innovation in rural areas and increasing the income of rural residents, thus affecting the quality of economic development in neighboring areas. Therefore, the development of the digital economy in the local area can act on the total factor productivity and the quality of economic development in neighboring areas, and it will also affect the income distribution between urban and rural residents in neighboring areas, having a promoting or inhibiting effect on the income gap.

Based on the above analysis, the second hypothesis of this paper is put forward:

H2: There exists a spatial spillover effect of the digital economy on the income gap between urban and rural residents.

3. RESEARCH DESIGN

3.1. Model Construction

In order to verify the relationship between the digital economy and the income gap between urban and rural areas, a two-way fixed effects model is constructed to control for both time and individual fixed effects. The benchmark regression model is as follows:

$$GAP_{i,t} = \alpha_0 + \alpha_1 DIG_{i,t} + \alpha_2 DIG_{i,t}^2 + \alpha_3 Control_{i,t} + \gamma_i + \lambda_t + \varepsilon_{i,t} \tag{1}$$

Among Eq. 1, the subscript *i* represents the 41 cities in the Yangtze River Delta region, and *t* represents the year. $GAP_{i,t}$ denotes the income gap between urban and rural residents, $DIG_{i,t}$ represents the development level of the digital economy, and $Control_{i,t}$ represents the group of control variables, including government intervention, the level of opening up to the outside world, the level of financial development, the level of agricultural mechanization, the industrial structure, and transportation construction. γ_i represents the individual fixed effect, λ_t represents the time fixed effect, and $\varepsilon_{i,t}$ represents the random disturbance term. The same applies hereinafter.

3.2. Spatial Durbin Model

In order to verify the spatial spillover effect of the development of the digital economy on the income gap between urban and rural residents, the following spatial Durbin model is constructed:

$$\begin{aligned} GAP_{i,t} = {} & \alpha_0 + \rho WGAP_{i,t} + \alpha_1 DIG_{i,t} + \mu_1 WDIG_{i,t} + \alpha_2 DIG_{i,t}^2 + \mu_2 WDIG_{i,t}^2 \\ & + \alpha_3 Control_{i,t} + \mu_3 WControl_{i,t} + \gamma_i + \lambda_t + \varepsilon_{i,t} \end{aligned} \tag{2}$$

Among Eq. 2, ρ is the spatial autoregressive coefficient, W is the spatial weight matrix. In this paper, the adjacency matrix is used as the spatial weight matrix. $\mu_1 WDIG_{i,t}$ and $\mu_2 WDIG^2_{i,t}$ represent the impacts from the development level of the digital economy in adjacent regions, and μ_1, μ_2 are the corresponding coefficients.

3.3. Variable Measurement and Explanation

3.3.1. Measurement of the Digital Economy.

Following the practices of existing literature [7, 8, 9], the following indicators are selected to construct the digital economy evaluation index system: the number of Internet broadband access users per 10,000 people (households), the number of mobile phone users per 10,000 people (households), the proportion of employees in the information service industry (%), the total volume of telecommunication services (10,000 yuan), the number of urban e-commerce parks (units), the Peking University Digital Inclusive Finance Index, the expenditure on science and technology (10,000 yuan), and the number of utility model patents related to the digital economy per 10,000 people (units). Through the method of principal component analysis, dimension reduction processing is carried out on the above indicators to obtain the development level of the digital economy in each city in the Yangtze River Delta region.

3.3.2. Measurement of the Income Gap between Urban and Rural Residents.

To reduce the impact of extreme values and taking into account the influencing factor of population structure changes, the Theil index is chosen to measure the income gap between urban and rural residents.

3.4. Data Sources and Descriptive Statistics

This study takes 41 cities in the Yangtze River Delta region of China from 2011 to 2022 as samples. The data are mainly sourced from the "China Urban Statistical Yearbook", the "China Regional Economic Statistical Yearbook" of previous years, and the EPS database. The descriptive statistics of each variable are shown in Table 1.

Table 1. Descriptive Statistics

Variable Type	Variable	Minimum	Mean	Maximum	Standard Deviation	Sample Size
Dependent Variable	GAP	0.015	0.057	0.172	0.030	492
Independent Variable	DIG	-1.671	0.000	3.163	0.896	492
Control Variables	Gov	0.076	0.165	0.356	0.061	492
	Open	0.018	0.312	1.813	0.321	492
	Fin	0.844	1.303	2.344	0.261	492
	Mach	3.619	5.567	6.893	0.701	492
	Third	0.234	0.455	0.741	0.085	492
	Traffic	0.156	1.169	2.634	0.489	492

It can be seen from Table 1 that the mean value of the income gap between urban and rural residents is 0.057, with the maximum and minimum values being 0.172 and 0.015 respectively. This indicates that there are significant differences in the income gap between urban and rural residents among various cities. Similarly, the mean value of the development of the digital economy is 0, with the maximum and minimum values being 3.163 and -1.671 respectively. The digital economy development index at the municipal level shows large fluctuations, which indicates that there are significant differences in the development of the digital economy among cities in the Yangtze River Delta region. In addition, control variables such as government intervention and the level of opening up to the outside world also show obvious differences among different cities.

4. EMPIRICAL ANALYSIS

4.1. Benchmark Regression

Table 2 presents the results of the benchmark regression. Columns (1) and (2) show the situations without and with the inclusion of control variables respectively. The results indicate that, at the 1% statistical level, the coefficient of the first-order term of the digital economy is significantly negative, and the coefficient of the second-order term is significantly positive. Thus, Hypothesis One is verified, that is, the impact of the digital economy on the income gap between urban and rural residents is "U-shaped".

Table 2. Benchmark Regression Results

Variable	(1)	(2)
DIG	-0.010^{***} (-3.67)	-0.017^{***} (-6.38)
DIG^2	0.005^{***} (7.78)	0.005^{***} (7.71)
Control	NO	YES
R^2	0.658	0.765

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels respectively. The numbers in parentheses are t-values. The same applies hereinafter.

However, some scholars found that there are certain flaws in simply judging the "U-shaped" relationship based on the signs and significance of the coefficients of the first-order and second-order terms of the variables [10]. Therefore, an appropriate test for the "U-shaped" relationship was derived based on this. Besides the requirement that the signs and significance of the variable coefficients need to meet specific conditions, it is also required that the slope of the curve be negative at the left endpoint and positive at the right endpoint, and meanwhile the extreme point of the curve should be located within the interval of the corresponding indicator. Table 3 presents the results of the "U" test conducted using the models in columns (1) and (2) of Table 3. It can be seen that the extreme points are all located within the interval, and the slopes at the left and right endpoints are negative and positive respectively. The conclusion of the "U-shaped" relationship in the benchmark regression has been further verified.

Table 3. Results of the "U" Test

Model	FE			
	(1)		(2)	
Dependent Variable	GAP		GAP	
Independent Variable	DIG		DIG	
α_1	-0.0103		-0.0170	
α_2	0.0045		0.0048	
Extreme Point	1.1390		1.7859	
Endpoint	Min	Max	Min	Max
Endpoint Value	-1.6708	3.1627	-1.6708	3.1627
Slope	-0.0255	0.0184	-0.0330	0.0131
Conclusion	“U” shape		“U” shape	

4.2. Spatial Spillover Effect Test

Table 4. Moran's I Index of Theil Index from 2011 to 2022

Year	Theil Index		
	Moran’s I	Z-score	P-value
2011	0.4855	5.3634	0.0000
2012	0.4666	5.1752	0.0000
2013	0.4562	5.0681	0.0000
2014	0.3516	3.9612	0.0001
2015	0.4168	4.6257	0.0000
2016	0.4373	4.8365	0.0000
2017	0.4317	4.7794	0.0000
2018	0.4303	4.7637	0.0000
2019	0.4264	4.7194	0.0000
2020	0.4656	5.1334	0.0000
2021	0.4734	5.2061	0.0000
2022	0.4886	5.3669	0.0000

To determine whether adjacent cities are spatially clustered and to identify the spatial correlation pattern, the Moran's I index of the Theil index in the Yangtze River Delta region from 2011 to 2022 was first calculated with the help of the adjacency matrix. Overall, although the Moran's I index of the Theil index fluctuated to some extent during the sample period, the amplitude was relatively small, and it was always significantly greater than 0. This indicates that there is a certain regularity in the spatial distribution of the Theil index among different cities, showing a tendency towards clustering characteristics. That is, cities with a relatively large income gap between urban and rural residents are often surrounded by cities with similarly high values, while cities with a relatively small income gap between urban and rural residents are often surrounded by cities with similarly low values.

Although there is a significant spatial autocorrelation of the Theil index in the Yangtze River Delta region, a series of pre-tests on the model are still required before verifying the spatial spillover effect of the digital economy on the income gap between urban and rural residents through the spatial Durbin model. As shown in Table 5, first, the LM test was conducted, including the spatial error model test and the spatial lag model test. The null hypothesis is that there is no spatial autocorrelation. It can be seen that the P-values are all less than 0.05. Therefore, the spatial autocorrelation model should be selected for empirical analysis. Secondly, the Wald test and the LR test were carried out, and the P-values are all less than 0.01. It is considered that compared with the SEM model and the SAR model, it is more appropriate to select the SDM model for research. Finally, the space-time - time fixed effect test was adopted, and the results all passed the 1% significance test, indicating that when selecting the SDM model, it is necessary to control the individual and time fixed effects. Therefore, the SDM model with two-way fixed effects of city and time was selected for the test.

Table 5. Results of Spatial Econometric Model Tests

Spatial Panel Model Tests		Value	P-value
LM Test	Moran's I	2.368	0.018
	LM Spatial error	106.421	0.000
	Robust LM Spatial error	115.677	0.000
	LM Spatial lag	4.087	0.043
	Robust LM Spatial lag	13.343	0.000
Wald Test	Wald-SDM/SEM	52.72	0.000
	Wald-SDM/SAR	30.10	0.000
LR Test	LR-SDM/SEM	96.04	0.000
	LR-SDM/SAR	181.97	0.000
Space-Time Fixed Effect Tests	LR-both/ind	54.56	0.000
	LR-both/time	569.25	0.000

The results of the spatial econometric regression are presented in Table 6. Columns (1) to (3) introduce the spatial weight matrix on the basis of the benchmark regression. The results show that the spatial spillover coefficients of the individual fixed effect, time fixed effect, and two-way fixed effect models all exhibit good significance. The spatial spillover coefficient of the first-order term is approximately 0.0151, and that of the second-order term is approximately -0.0029. This indicates that the digital economy of other adjacent cities has a significant inverted "U-shaped" impact on the income gap between urban and rural areas in this city, with the inflection point value being approximately 2.6, thus verifying Hypothesis Two of this paper, that is, the digital economy has a spatial spillover effect on the income gap between urban and rural residents.

In the initial stage of digital economy development, due to limited resources, each city faces relatively fierce competition in the digital economy field. With the improvement of the development level, the talent siphon effect will become more prominent, and adjacent cities will face the problem of brain drain, thereby widening the income gap between urban and rural residents.

Combined with the results of the benchmark regression, it can be found that the inflection point value of the spatial spillover effect is on the right side of the inflection point value 2.0217 of the benchmark regression, indicating that after exceeding the inflection point value, the coordinated development of the digital economy between this city and adjacent cities helps to alleviate the problem of the continuous widening of the income gap between urban and rural areas caused by the overly rapid development of the digital economy in this city.

When the digital economy of adjacent cities reaches a relatively high level, it can realize industrial transfer and complementary advantages, broaden cross-regional employment opportunities, contribute to the joint construction and sharing of infrastructure, and narrow the income gap between urban and rural areas.

In column (4) of Table 6, the ratio of urban and rural residents' income is used to replace the Theil index for regression, and the signs and significance of the coefficients of each variable in the regression results do not change significantly, indicating that the original regression results are robust.

Table 6. Results of Spatial Econometric Regression

Variable	(1)	(2)	(3)	(4)
	ind	time	both	both
DIG	-0.0231*** (-8.24)	-0.0231*** (-8.58)	-0.0219*** (-7.99)	-0.1718*** (-5.28)
DIG^2	0.0052*** (8.34)	0.0057*** (6.97)	0.0049*** (7.94)	0.0313*** (4.30)
W*DIG	0.0170*** (5.09)	0.0448*** (9.32)	0.0151*** (2.85)	0.1702*** (2.74)
$W*DIG^2$	-0.0026** (-2.50)	-0.0111*** (-7.38)	-0.0029** (-2.30)	-0.0316** (-2.15)
ρ	0.3741*** (7.22)	0.4371*** (8.55)	0.1532** (2.45)	0.3516*** (6.37)
Control	YES	YES	YES	YES
N	492	492	492	492
R^2	0.7660	0.0928	0.7648	0.6903

5. RESEARCH CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper focuses on 41 cities in the Yangtze River Delta region of China, selects panel data from 2011 to 2022, conducts descriptive statistics, benchmark regression, and spatial spillover effect tests, and studies the impact of the digital economy on the income gap between urban and rural residents as well as the spatial spillover effect. It is found that there is a significant "U-shaped" relationship between the digital economy and the income gap between urban and rural residents, as well as a significant inverted "U-shaped" spatial spillover effect.

Based on the research conclusions regarding the impact of the digital economy on the urban-rural income gap obtained in this paper and combined with the current development situation in the Yangtze River Delta region, the following policy recommendations are put forward:

First, pay close attention to and rationally guide the development of the digital economy. The government should closely monitor the development status of the digital economy in cities. If a city is in the initial stage of digital economy development, targeted policies can be formulated, such as strengthening the construction of digital infrastructure in urban and rural areas, increasing the funding for scientific and technological research, enhancing the subsidy intensity for high-tech enterprises, introducing policies for outstanding talents to settle down and encouraging them to use digital technologies for innovation and entrepreneurship, so as to achieve rapid development of the digital economy, enhance the foundation of digital technologies and talent reserves in a short period of time, and fully exert the role of reducing the income gap. When the digital economy develops to a relatively high level in the region and enters the stage of widening the income gap, the government should take preemptive measures to cope with the situation of the continuously widening digital divide.

Second, strengthen inter-regional cooperation and exchanges. The Yangtze River Delta region should strengthen regional cooperation, promote information sharing, experience exchanges, and cooperative development among cities. Cities with advanced digital economy development should assist those with backward digital economy development, providing support for the common development of the digital economy and alleviating the income gap between urban and rural residents. Build a regional digital economy cooperation platform, strengthen academic exchanges and communication cooperation in terms of digital technology improvement and application among cities, jointly create digital economy industrial clusters, and form a complete digital economy industrial chain. At the same time, strengthen the interconnection, sharing of transportation, information and other infrastructure among provinces and between cities, and improve the degree of regional integration development.

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