Research on the Impact of the Digital Economy on Regional Income Disparities: Empirical Evidence Based on a Double-Fixed Spatial Durbin Model

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Abstract: With the increasing level of digital economic development, the deepening synergy between data elements and other production factors will have a profound impact on regional income patterns. Based on panel data from 30 provinces and cities in China (excluding Tibet) from 2011 to 2021, this paper calculates the Theil index of regional income and employs a double-fixed spatial Durbin model for empirical testing. The findings reveal that: (1) The level of digital economic development and regional income disparities in the 30 provinces and cities exhibit spatial correlation, and the development of the digital economy generally significantly exacerbates income disparities across different economic regions; (2) The impact of the digital economy on regional income disparities shows significant spatial heterogeneity among different provinces and cities in China. Specifically, the development of the digital economy significantly widens income disparities in the central and western regions, while it somewhat alleviates income inequality in the eastern regions. Finally, based on the analysis of the research findings, three targeted recommendations are proposed to narrow regional income disparities through the digital economy.

Keywords: Digital economy; Regional income disparities; Spatial spillover effects

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1. Introduction

(1) Research background and significance

1) Research background

① Digital economy has become a focus of attention both domestically and internationally

In the current era, the digital economy has emerged as aforerunners in the global technological revolution and industrial transformation, representing a key area of focus in the new round of international competition. According to the 2024 Digital Economy Report released by the China Academy of Information and Communications Technology (CAICT), in 2023, the scale of China's digital economy reached RMB 53.9 trillion, with growth expanding into a relatively stable range, accounting for approximately 42.8% of GDP. The contribution of digital economy growth to GDP growth reached 66.45% [①], effectively supporting steady economic growth.

② Narrowing regional income disparities is an essential requirement for achieving common prosperity

Common prosperity for all people is an essential requirement of Chinese-style modernization and a key focus of people's livelihood construction that the Communist Party of China has consistently adhered to. Currently, through

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reviewing existing literature, it is found that some studies indicate that the digital economy expands opportunities for people to become affluent and contributes to the realization of common prosperity. However, some research suggests that regional imbalances in the digital economy widen regional income disparities.

In view of this, this paper establishes an indicator system to measure the development of the digital economy, selecting a total of twelve evaluation indicators. By utilizing panel data from 30 provinces and municipalities in China (excluding Tibet) from 2011 to 2021, it investigates the impact of the digital economy on regional income disparities, providing favorable empirical and theoretical support for promoting common prosperity.

2) Research significance

The rapid development of the digital economy has made outstanding contributions to China's pursuit of high-quality development. Although there is an increasing number of research studies exploring income disparities from the perspective of digital economy development, substantial variations exist in research conclusions due to differences in research methodologies and model selections. Therefore, this paper innovatively incorporates spatial factors into the analytical framework of the impact of the digital economy on regional income disparities using the Spatial Durbin Model. This deepens the theoretical understanding of how the digital economy affects regional income disparities. It not only enriches the cross-disciplinary research field of regional economics and spatial economics but also expands the research scope of factors influencing income disparities, providing a new methodological perspective and empirical evidence for related fields.

(2) Literature review

In recent years, with the rapid development of the digital economy, extensive research has been conducted by the academic community on the digital economy and its impact on regional income disparities. This paper conducts a literature review from three aspects: the connotation of the digital economy, measurement methods of the digital economy, and the impact mechanism of the digital economy on income distribution.

1) The connotation of the digital economy

As a new economic form, the connotation and characteristics of the digital economy have always been the focus of academic attention. Xu Xianchun et al.[1] (2020), based on a systematic review of the evolution of the information economy, internet economy, and digital economy, extracted the connotation and forming elements of the digital economy and constructed a framework for accounting the scale of the digital economy. Han Fengqin et al[2] (2022), by reviewing the origin and evolution of the concept of the digital economy, found that the definition of the digital economy varies widely, with different institutions or scholars having differing definitions in terms of scope, measurement methods, and data standards. They also pointed out that the development of the digital economy needs to address challenges in various aspects such as statistics, data security, the digital divide, supporting regulation, tax policy improvement, and digital governance. Zhang Yifan et al.[3] (2024), starting from the concept of the digital economy, classified existing domestic and international measurement frameworks for the digital economy into two broad categories: narrow and broad, and based on this framework, summarized existing indices and indicator systems related to the digital economy into four types: a univariate perspective based on digital industrialization and the impact of digitalization on society, and a composite perspective based on the narrow and broad fields. Xu Lan et al.[4] (2024), by reviewing existing literature, summarized the basic scope, connotation, and characteristics of the digital economy, finding that it has the value creation effect of production factors, the mediation effect of promoting industrial efficiency improvement and economic structure optimization, and the platform effect of driving the alignment of global resource supply and demand.

2) Measurement methods of the digital economy

Regarding the measurement methods of the digital economy, Liu Jun et al.[5] (2020) measured the level of

digital economy development in 30 provinces in China from 2015 to 2018 based on statistical yearbook data and analyzed the driving factors of the digital economy using the Spatial Autoregressive (SAR) model. The study found that there exists a regional "digital economy divide" and polarization in China's digital economy development, with the digital economy level in the eastern region significantly higher than that in the central and western regions. Zhou Yuanren et al.[6] (2023) mentioned various measurement methods, including the production approach, expenditure approach, growth accounting method, econometric methods, index compilation method, and the establishment of a digital economy satellite account method. They pointed out that there are still many challenges in measuring the digital economy, necessitating further clarification of the scope and boundaries of digital economy measurement, continuous updating and improvement of statistical methods for digital economy measurement, and strengthening the collection of basic data on digital economy statistics. Chen Yongwei et al[7] (2023), based on the connotative characteristics of the digital economy and the development practices of regional digital economies, constructed an indicator system from four dimensions: digital infrastructure, digital industries, digital integration, and digital environment. They used an improved index method to measure and evaluate the level of digital economy development in various provinces in China. The study found that from 2015 to 2020, the level of digital economy development in all provinces in China showed an increasing trend, but there were significant regional differences.

3) Literature review

In summary, the existing literature has conducted relatively in-depth research on the connotation of the digital economy, measurement methods, and its impact on income distribution. However, there are still the following shortcomings: Firstly, a unified conclusion has not been reached regarding the mechanism through which the digital economy influences regional income disparities. Secondly, current studies predominantly utilize traditional econometric methods, with insufficient consideration of spatial dependence. Lastly, there is relatively scant research focusing on the unbalanced development of the digital economy among regions in China. Therefore, this paper intends to adopt the Spatial Durbin Model, combined with relevant data on the development of the digital economy in China, to delve into the impact of the digital economy on regional income disparities and its spatial spillover effects. The aim is to provide a new perspective and empirical evidence for related research.

2. Model Construction, Variable Selection, and Data Sources

(1) Model constructio

1) Spatial Lag Model (SLM)

$$y_{it} = \rho w_i^{'} y_t + x_{it}^{'} \beta + \mu_i + \gamma_i + v_{it}$$

The Spatial Lag Model is also known as the Spatial Autoregressive Model (SAR). This model reflects the influence that a variable in one region has on variables in other regions, indicating the existence of a certain spatial correlation between two regions.

2) Spatial Error Model (SEM)

$$y_{it} = x_{it}^{'} \beta + \mu_i + \gamma_i + \varepsilon_{it}$$
$$\varepsilon_{it} = \lambda m_i^{'} \varepsilon_t + v_{it}$$

The Spatial Error Model (SEM) removes the lagged term from the Spatial Lag Model (SLM) and incorporates an error term. This error term captures the spatial spillover effect resulting from the spatial error shocks of the dependent variable across geographical locations.

3) Spatial Durbin Model (SDM)

$$y_{it} = \rho w_i^{'} y_t + x_{it}^{'} \beta + d_i^{'} x_t \delta + \mu_i + \gamma_i + \varepsilon_{it}$$

The Spatial Durbin Model (SDM) encompasses both the spatial dependency effects of the explanatory variables and the spatial dependency effects of the dependent variable. Compared to the previous two models, its results are more convincing. However, the specific spatial econometric model adopted in this paper will be determined through a series of subsequent tests.

In the above equation, y represents the dependent variable, x represents the explanatory variables; ρ denotes the spatial autocorrelation coefficient; w denotes the spatial weight matrix; β denotes the coefficients of the independent variables; ε denotes the residual error; γ represents the spatial residual correlation coefficient;d and m are spatial weight matrices and $\rho w_i^{'} y_t$ denotes the spatial lag term.

(2) Selection of variables

1) Dependent variable

Theil Index: Regarding the measurement of income disparity, existing literature primarily employs three methods: firstly, the urban-rural income ratio, which overlooks the issue of urban-rural population structure and lacks precision; secondly, the Gini coefficient, which is sensitive to changes in the middle-income class; and thirdly, the Theil Index. The Theil Index is unaffected by population size, meaning even cities with smaller populations can be reasonably reflected in the calculations. This is particularly important for comparisons among provincial-level cities, where there may be significant differences in population size. Moreover, this index provides a more comprehensive picture of disparities across different times, regions, and levels. Therefore, drawing inspiration from the income disparity measurement methods of scholars such as Song Peng et al.[9] (2024) and Liu He et al.[10] (2022), this paper uses the Theil Index as an indicator to measure income disparity. Additionally, since the value of this index is relatively small compared to other indicators selected in this paper and does not fall within the same dimension, the numerator value of this index as a percentage of 100% is used as the raw data. A higher Theil Index value indicates a higher degree of regional income inequality, i.e., greater regional income disparity.

The calculation formula is as follows:

$$Theil_t = \sum_{i=1}^{n} \left(\frac{I_{it}}{I_t} \right) ln \frac{I_{it}/P_{it}}{I_t/P_t}$$

Where, i represents the ith region; I_{it} represents the total income of the ith region in the tth year; I_t represents the total income of all regions in the tth year; tP_{it} represents the population of the ith region in the tth year; and P_t represents the total population of all regions in the tth year.

2) Explanatory variables

Digital Economy (DIE): The core explanatory variable in this paper is the level of digital economy development. Firstly, due to the broad scope of the digital economy and its continuously evolving connotation and extension, it is difficult to clearly define the scope and boundaries of its measurement. Secondly, the rapid development of digital technologies, especially the emergence of emerging technologies such as blockchain and the Internet of Things, poses new challenges for measuring the digital economy, making it difficult for traditional measurement indicators to comprehensively reflect the new characteristics of the digital economy. Lastly, current scholars have constructed various measurement indicator systems for the digital economy based on different theoretical frameworks and research perspectives. These indicator systems have their own emphases, some focusing on current digital infrastructure, some on technological innovation and research capabilities, and others on the scale of digitalization,

among others. This diversity makes it difficult to reach a consensus. In summary, existing academic achievements have not reached a consensus on the measurement of digital economy development levels. Therefore, this paper mainly refers to Zhao Wei et al.[8] (2022) and Huang Shuchang[11] (2023) and measures the level of digital economy development from three aspects: digital infrastructure level, digital scale level, and R&D level. Fourteen secondary measurement indicators are selected, including mobile phone penetration rate, Internet penetration rate, number of domain names, number of web pages, Internet broadband access ports, number of IPv4 addresses, length of long-distance optical cable lines, total postal business volume, total telecommunications business volume, express delivery volume, number of patent applications, and linearly interpolated R&D expenditures. The entropy method is used to calculate the weight of each indicator, all of which are positive indicators. Finally, the weights of the three primary indicators and the level of digital economy development are obtained, as shown in Table 3.1:

Table 3.1 Measurement of Digital Economy Development Level

target level	Level 1 indicators	weights	Secondary indicators	weights	Indicator properties
Level of development of the digital economy	Level of digital infrastructure	0.2713	Cell phone penetration rate	0.0092	+
			Internet Penetration Rate	0.0097	+
			Number of domain names	0.0567	+
			Number of web pages	0.0987	+
			Internet broadband access ports	0.0341	+
			Number of IPv4 addresses	0.0491	+
			Length of long distance fiber optic cable lines	0.0138	+
	Level of digital scale	0.2961	Total Postal Business	0.0859	+
			Total telecommunications business	0.0439	+
			Volume of Express Delivery	0.1082	+
			Number of patent applications	0.0581	+
	Digital R&D level	0.4327	Linear Interpolation R&D Expenditures	0.4327	+

3) Control variables

This paper uses panel data from 30 provinces and municipalities in China from 2011 to 2021 as the research sample, excluding Tibet, Hong Kong, Macao, and Taiwan. Based on the theoretical analysis presented earlier, as well as consideration of other factors that may influence income disparities, and drawing on the research findings of Xian Chengyi et al.[12] (2024) and Li Jianjun et al.[13] (2020), this paper selects the following five variables as control variables: education scale (EDU), degree of government intervention (GOV), financial development level (FDL), innovation level (IL), and marketization level (ML).

(3) Data sources

This paper analyzes panel data from 30 provincial-level cities in China spanning from 2011 to 2021, amounting to a sample size of 330 observations across 11 years and 30 provinces. The relevant data are primarily sourced from the "China City Statistical Yearbook," Peking University Open Research Data Platform, China National Research Data Service Platform (CNRDS), and the statistical yearbooks of various provincial-level cities. A small amount of missing data was imputed using interpolation methods. The number of sample observations is 330.

3. Empirical Measurement of the Impact of the Digital Economy on Income Distribution

(1) Spatial correlation test

To employ spatial econometric models, it is necessary to ensure the existence of spatial correlation in the data. Next, the spatial effects of the digital economy on income distribution among the 30 provincial-level cities are tested using the inverse distance weight matrix constructed above. Currently, Moran's I test is the most widely used and popular method for testing spatial effects in existing literature, as employed by Qian Pengsui et al.[14] (2019) and Zhou Hui et al[15] (2022). Global spatial correlation is typically measured by the Moran's I index, while Moran's scatter

plot is mainly used to measure local spatial correlation.

It is found that the values of the Moran index calculated through the inverse distance weight matrix from 2011 to 2021 are all positive and all of them pass the significance test of 0.1%, indicating that the digital economy has a significant positive spatial correlation on the income distribution of the 30 provincial and municipal cities.

(2) Spatial durbin model test

To accurately estimate the impact of digital economy development on regional income disparities among 30 provinces and municipalities excluding Tibet, and thus verify the plausibility of Hypothesis 1, it is necessary to assess the appropriateness of the Spatial Durbin Model (SDM). Passing the relevant tests,Finally, after selecting the model with both individual and time-period fixed effects, a Spatial Durbin Model is constructed, and the LR test and Wald test are used to determine whether it can be degraded to a Spatial Lag Model (SLM) or a Spatial Error Model (SEM). As shown in Table 4.1, under the inverse distance weight matrix, the values of LR-error, LR-lag, Wald-error, and Wald-lag all pass the significance test at the 1% level, indicating that the Spatial Durbin Model cannot be degraded to either the Spatial Error Model or the Spatial Lag Model.

Table 3.1 LM, LR, Wald, and Hausman Test Results

Test Methods	Test results
LM-error	45.020***
LM-lag	76.423***
Robust LM-error	2.650*
Robust LM-lag	34.053***
LR-error	82.24***
LR-lag	65.77***
Wald-error	68.76***
Wald-lag	90.76***
Hausman test	-9.35

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

In summary, this study needs to establish a Spatial Durbin Model with both individual and time-period fixed effects to complete the relevant analysis. Next, panel data on the impact of digital economy development on regional income disparities among 30 provinces and municipalities will be used for spatial regression. To estimate the robustness of the model, the regression results of both the Spatial Error Model and the Spatial Lag Model are also presented in Table 3.2. The specific regression results are shown in the following table:

Table 3.2 Overall Spatial Regression Results

variable name	Model SDM	Model SEM	Model SAR	variable name	Model SDM	Model SEM	Model SAR
DE	4.968***	3.332***	3.905***	W*DE	22.339***	-	-
	(6.01)	(3.96)	(4.60)		(5.48)	-	-
EDU	-5.480*	-9.839***	-10.840***	W*EDU	-32.503	-	-
	(-1.75)	(-2.92)	(-3.29)		(-1.41)	-	-
GOV	4.655*	4.301	4.123	W*GOV	25.101	-	-
	(1.82)	(1.58)	(1.52)		(1.44)	-	-
FDL	0.191**	0.199**	0.225**	W*FDL	1.273***	-	-
	(2.11)	(2.02)	(2.41)		(2.69)	-	-
IL	-0.227**	0.010	-0.044	W*IL	-2.958***	-	-
	(-2.01)	(0.09)	(-0.39)		(-3.82)	-	-
ML	-0.252***	-0.285***	-0.298***	W*ML	-0.867**	-	-
	(-4.43)	(-4.55)	(-4.94)		(-2.13)	-	-
R2	0.6742	0.0284	0.0057	ρ	0.674***	-	0.794***
					(7.11)	-	(12.37)
sigma2_e	0.179***	0.226***	0.213***	Lambda	-	0.768***	-
	(12.61)	(12.54)	(12.54)		-	(10.58)	-

Log-likelihood	-190.8425	-231.9650	-223.7272	-	-	-	-
				-	-	-	-

Note: The values in parentheses are t-values, with ***, **, and * indicating significance at the 1%, 5%, and 10% levels, respectively.

From the table, it can be seen that the spatial correlation coefficient ρ is 0.674 and passes the test at the 1% significance level, indicating that the development of the digital economy has a significant spatial spillover effect on the regional income disparities among the 30 provinces and municipalities. Specifically, a 1% increase in the digital economy development index will lead to a 0.674% increase in regional income disparities. The coefficient of the core explanatory variable, the digital economy index, is 4.968 and significant at the 1% level, suggesting that further development of the digital economy will result in an expansion of the Theil index, i.e., widening regional income disparities. Among the five control variables included, the estimated coefficients for financial development and innovation are significantly positive, indicating that increases in government intervention and financial development will significantly widen regional income disparities.

4. Conclusions and Recommendations

In this paper, we selected panel data from 30 provinces and municipalities in China (excluding Tibet) spanning from 2011 to 2021. Using the Theil Index as a proxy for regional income disparity, we measured the level of digital economy development in terms of digital infrastructure, digital scale, and R&D level. We also utilized 14 secondary measurement indicators to assess China's digital economy development and constructed a spatial econometric model to examine the impact of digital economy development on regional income disparities and its spatial spillover effects. The main conclusions are as follows:Both the development of the digital economy and regional income disparities exhibit positive spatial autocorrelation, and the development of the digital economy has a positive spatial spillover effect on regional income disparities.

Notes

① From the Research Report on the Development of China's Digital Economy released by the China Institute of Information and Communication Research on August 29, 2024.

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