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A Study on the Spatial Effects of the Digital Economy on Regional Economic Growth in China

Yujie Shang [1], Hyukku Lee [1,*] and Jinghao Ma [2]

[1] Department of East-Asia Studies, Graduate School, Pai Chai University, Daejeon 35337, Republic of Korea; shangyujie970302@163.com
[2] College of Economics & Management, Zhejiang University of Water Resources and Electric Power, Hangzhou 310018, China; msll2025@163.com
* Correspondence: leehk@pcu.ac.kr

Abstract: The burgeoning digital economy in China serves as a significant impetus for extensive economic growth across the nation. However, regional development within China remains imbalanced, and the issue of the digital divide cannot be overlooked. This paper is dedicated to examining the effect of the digital economy on the aggregate economic growth of China, along with a heterogeneity analysis. Using Chinese province-level data during the period of full entry into the mobile Internet era (2014–2022), this study first constructs a digital economic development index system. Using the entropy method, it calculates the digital economic index for 30 provinces in China during the 2014–2022 period. Subsequently, a panel regression model is utilized to explore how the digital economy impacts economic growth. Ultimately, the Durbin model gauges the digital economy's spatial impact on economic expansion in China. The key findings are as follows: (1) The burgeoning digital economy in China has instigated substantial expansion of the national economy. However, its impact on economic growth gradually decreases from the eastern to the western regions. (2) China reveals a notable spatial relationship linking its digital economy and economic expansion. A distinct positive spatial relationship exists between the two. Additionally, the digital economy of China presents a positive spatial spillover effect regarding economic growth. The strongest manifestation of this effect is detected in the eastern region, trailed by the central region, and the western region displays the feeblest effect. Based on these findings, it is clear the digital economy plays a pivotal role in China's economic growth. To expedite the high-quality development of the digital economy, the government could take additional steps. Specifically, it could enhance the construction of infrastructure related to the digital economy and increase investment in scientific and technological innovation resources. Enterprises can consider digital transformation to achieve the digital development of industries. In addition, considering the existence of the spatial spillover effect, the digital divide can be bridged and regional imbalances alleviated by enhancing coordinated regional development.

Keywords: digital economy; regional economic growth; panel regression model; spatial spillover effect; China

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1. Introduction

It was Tapscott who first proposed the digital economy in the 1990s [1], which mainly covers the emerging fields of computer, information, and communication technology, e-commerce, and digital payment. In recent years, countries worldwide have been shifting away from traditional economic models and exploring new growth drivers to accelerate

economic development. The digital economy has emerged as a paradigm for the global economy in the final stage of economic transformation. From enabling more efficient resource management to fostering the development of industries, the digital economy is increasingly recognized as a powerful enabler of sustainable development. Against this backdrop, many countries globally are accelerating their digital transformation and comprehensively laying out strategies for the development of the digital economy [2]. Standing at the vanguard, major economies such as the US, the EU, Germany, and the UK were among the early implementers of the evolution of the digital economy strategies (Table 1). The accelerating digitalization process is exerting a growing influence on economic development, thus establishing itself as a vital engine and driving force for the global economy [3]. In 2020, the release of "Opinions on Constructing a More Comprehensive Mechanism for Market-based Allocation of Factors" by the Central Committee of the CPC and the State Council signified that China has entered the era of the digital economy [4].

Table 1. Strategic initiatives for digital economy development in major global developed economies.

Country	Strategic Measures	Year of Introduction
United States of America	US Digital Government Strategy	2012
	US Open Data Action Plan	2014
	The Digital Economy Agenda 2016	2015
	National Strategic Plan for Research and Development of Artificial Intelligence	2016
EU	EU Cybersecurity Strategy	2013
	EU Digital Agenda (DAE)	2014
	Industry Digitization Program	2016
Germany	Digital Germany 2015	2010
	Digital Strategy 2025	2016
Britain	"Digital Great Britain" Action Plan	2009
	Digital Economy 2010 Act	2010
	The Digital Economy Strategy (2015–2018)	2015
	The UK Digital Strategy 2017	2017

Source: Compiled from relevant publicly available materials.

That the digital economy came into being is likely to induce a fundamental transformation of human activities, which include aspects of work and daily life. It not only encourages countries to begin to pay attention to the mode of economic development and the pattern of international competition, but also penetrates into all areas of the economy and society, such as agriculture, industry, and social governance, and encourages enterprises to start using digital applications to boost the circular economy [5]. The burgeoning digital economy will make substantial contributions to economic expansion, serving as a vital catalyst for resurgence. According to the Global Digital Economy White Paper 2023 published by the China Institute of Information and Communication, in 2022, in terms of scale, the US digital economy ranked first in the world, reaching USD 17.2 trillion, and China ranked second with USD 7.5 trillion. However, in terms of proportion, the digital economy of the United Kingdom, Germany, and the United States all accounted for more than 65% of GDP; in China, it was 41.5%, which was equivalent to the proportion of the secondary industry. It can be seen that although the scale of China's digital economy is not small, its proportion of GDP still lags far behind that of developed countries. But as far as China is concerned, the digital economy penetration rates of the tertiary, secondary, and primary industries are 44.7%, 24%, and 10.5%, respectively, forming a pattern in which the service industry and industrial digitization jointly fuel development. China's digital economy's total factor productivity rose from 1.66 (2012) to 1.75 (2022). The digital econ-

omy has consistently outpaced the broader national economy in terms of productivity and year-over-year growth, providing a crucial boost and driving force in enhancing overall national economic efficiency.

Furthermore, the digital economy not only boosts China's overall national economy [6–9] but also has an impact on the economic growth of different regions [8,10–12]. Simultaneously, the digital economy narrows regional differences by enhancing the late-mover advantage of less developed regions and the radiation function of economically developed regions [13]; technology's seamless fusion with core industries reshapes conventional economic growth, fostering balanced regional advancement [14,15]; and raising the marketization level of factors and improving resource misallocation also help to narrow regional gaps [16]. However, in current research, a standardized metric for evaluating digital economic progress remains absent. When selecting variables, problems such as simplicity or time lags occur. Although most calculations of the digital economy adopt the method of objective weighting, it is easy to overlook the influence of time when processing panel data. Additionally, economic activities involve both time and space dimensions. The spatial dimension can reveal the spatial differences in economic activities, yet it is often overlooked. Therefore, the research contributions and objectives of this paper are as follows: (1) With the large-scale deployment of 4G mobile base stations, China began its full entry into the mobile Internet era in 2014 [17]. This paper selects indicators that are in line with the current development of the digital economy, assesses the level of China's digital economy development through the application of the global entropy method in terms of time and space, and analyzes its development status. (2) Panel regression is employed to analyze the digital economy's impact on economic growth. (3) This paper also uses the Durbin model and combines regional spatial characteristics to investigate the spatial effects of the digital economy on regional economic growth in China.

This paper is structured into six sections. It commences with an introduction, followed by a review of the extant literature and the formulation of research hypotheses. Section 3 delves into the data and methodologies employed. Section 4 provides a detailed analysis of the results obtained. Subsequently, a thorough discussion in Section 5 leads to the paper's conclusion and policy implications in Section 6.

2. Literature Review and Research Hypotheses

2.1. Connotations of Digital Economy

The advent of the digital economy is traceable to Tapscott. Since then, the concept of the digital economy has been continuously clarified and has gradually become an important way to promote economic growth [1]. Kim et al. (2002) define a digital economy as a special one in which all transactions in goods and services take place in digital form [18]. Carlsson (2004) contends that the convergence of digitized info and the Internet represents a general-purpose technology. It sparks numerous novel possibilities, giving rise to the digital (new) economy. This definition portrays it as an evolving landscape, not a fixed entity [19]. Bukht and Heeks (2017) elaborate on the digital economy through core, narrow, and broad conceptualizations [20].

Although China was late to the digital economy game, Wang et al. (2001) consider it essentially the information economy under a different name. They view it as a new economic model emerging from rapid IT advancements since the 1990s, and believe it can significantly boost the real-world economy in the 21st century [21]. The G20 Digital Economy Development and Cooperation Initiative generalizes the digital economy as a fresh economic mode, considering digital knowledge and information as the vital elements for production [22]. Si et al. (2017) proposed an alternative socio-economic model surpassing the conventional digital economy [23]. To truly understand the status of China's digital

economy and promote its even better development, Zhang and Chen (2018) contend that we must analyze relevant data. They believe that, based on a sound evaluation system for measuring the caliber of the digital economy, conducting comprehensive assessments is crucial [24].

In light of the diverse approaches to defining the digital economy, a multitude of evaluation systems have emerged both domestically and internationally. Internationally, prominent entities such as the OECD, the European Union, and the United States Department of Commerce have developed and released indicator systems of particular significance. In China, institutions including the China Academy of Information and Communication Technology (CAICT), the China Center for Information Industry Development (CCID Consulting), and the Shanghai Academy of Social Sciences have also engaged in this effort, publishing their own sets of digital economy indicators that hold substantial importance.

On the whole, there is still no recognized and standardized definition of the digital economy domestically or internationally. Nevertheless, although different institutions and scholars have distinct ways of defining the digital economy, some shared characteristics can be identified. This paper summarizes the previous research, and argues that the digital economy is a new economic form. It takes the modern information network as the carrier, with digital technology as the core driving force, and realizes the digitization of production through integration with the real economy, improves the digitization of the economy and society, and promotes the renovation of economic development at an accelerated pace.

2.2. The Characteristics of the Digital Economy

Distinct from the traditional industrial economy in which the diminishing marginal revenue gradually reduces, the digital economy presents a more significant increasing marginal revenue [25]. The distinctiveness of the digital economy relies on the information attribute, which possesses non-consumption and other characteristics, different from traditional factors of production. This naturally means that its value can never be eroded in the process of production and has the comparative advantages of increasing marginal revenue and decreasing marginal costs [16]. The transformation of knowledge relies on the accumulation of large amounts of information, which increases its use value. The larger the scale of information, the greater the economy benefits. Therefore, it is indicated that the digital economy mainly manifests a feature whereby marginal revenue rises with the increase in the information scale [26].

The core component of the digital economy is information, and the rising marginal revenue of information facilitates a key feature of robust diffusion within the digital economy [8,27]. Firstly, digital technology has its own characteristics of high permeability, convergence, and growth [28]. Secondly, Tobler's First Law of Geography reveals that adjacent regions may have spatial correlations in economy, environment, culture, and other aspects, while the strong diffusivity of the digital economy also indicates its spatial spillover effect. The digital economy relies on information technology platforms as its primary media, making it easier to overcome geographical limitations and generate strong spatial spillover effects. Furthermore, the comprehensive popularization of digital technologies such as the Internet and social media enables information to be disseminated more quickly among cities and industries, significantly elevating the speed and breadth of information radiation, resulting in spillover effects among regions [29].

2.3. Impact of Digital Economy on Economic Growth

Currently, the world is in a stage of overlapping between traditional economies and the digital economy. The breakneck speed at which the digital economy is evolving has completely flipped the script on how we think about production. As the last piece of the

puzzle in this economic shift, the digital economy is now the gold standard for economies worldwide [30]. Academics are increasingly examining how the digital economy fosters economic development, specifically by boosting efficiency, and its overall contribution to higher-quality economic growth. Jing and Sun (2019) delve into the nitty-gritty at both the micro and macro scales. They argue that the breakneck speed of the digital economy's growth could really grease the wheels for China's modern economic system, offering up a superior way to connect the dots and a real shot in the arm for innovation [31]. Zhang and Qin's (2021) study revealed that the digital economy is developing in a balanced manner across the Yangtze River Economic Belt. Their findings also indicate that the digital economy plays a significant role in promoting regional economic growth [12]. Xu et al. (2024) remarked that the digital economy has a direct consequence on total factor productivity and an indirect effect on GDP in Shandong Province [10]. However, while the development of the digital economy has spawned digital dividends, it has also brought about a digital divide and a wealth gap, which exist in the current state of economic development [32]. In the digital economy, the digital divide problems are not only involved with the infrastructure access gap, but also with the digital literacy gap [23].

Previous academic endeavors have affirmed the existence of a relationship between the digital economy and economic growth within the context of China. However, it focuses more on how the digital economy can improve economic efficiency while ignoring its direct impact on economic growth. Due to the late start of research on the digital economy, it is not advisable to use a certain indicator such as "digital finance" to replace the digital economy. The digital divide disrupts the digital economy in multiple crucial aspects. Issues such as uneven infrastructure and a dearth of tech-proficient talent act as barriers, ultimately impeding economic growth in specific regions. Drawing on existing research, this study aims to develop a comprehensive, multi-dimensional index based on the established digital economy definition. This index will gauge the digital economy's impact on overall economic development. The hypothesis is as follows:

Hypothesis 1. *The digital economy is capable of spurring China's economic growth, meaning it exerts a notably positive sway over China's economic expansion.*

In terms of the analysis of spatial effects, Yang and Jiang (2021) emphasize that the growth of the digital economy has significantly enhanced total factor productivity. Moreover, this enhancement is not confined to local areas; it also engenders a substantial spatial spillover effect, thereby promoting the total factor productivity of adjacent regions [33]. Drawing upon data sourced from the Yangtze River Economic Belt, Hu (2023) also proposed and analyzed the existence and influence of the spatial spillover effect [34]. Zhao and Xu (2023), Meng (2023), and Qin and Yi (2023) conducted studies to analyze the relationship between the digital economies and economic development levels of cities along the Yangtze River Economic Belt and within the Yellow River Basin [35–37].

Recent studies have paid attention to the spatial association existing between the digital economy and economic growth. Nevertheless, in most of the spatial matrix selection, the impacts of geographical distance and economic distance are not fully considered. Moreover, from the perspective of regional economies, most studies choose a certain province or economic region in China as the research object instead of focusing on the whole country. In addition, the existence of the digital divide weakens the spatial spillover effect. Developed regions can more easily influence their surrounding areas through the spillover effect, while backward regions are more prone to the loss of talent and capital, resulting in a polarization effect; thus, their economic growth is facing greater pressure. In view of this, when exploring the implications of the link between the digital economy in China and the growth of the Chinese economy, this paper not only uses an ordinary panel

model, but also adopts a spatial econometric model under an economic geography matrix, and conducts statistical tests based on the following hypothesis:

Hypothesis 2. *The advancement of the digital economy is spatially linked to overall economic growth, with the former positively influencing the latter through spatial spillover effects.*

3. Variables and Methods

3.1. The Setting of Variables

3.1.1. Explained Variable

GDP and GDP per capita are two vital indicators for measuring economic growth in each region. In reference to the research of Zhao et al. (2020) [38], this paper selects GDP per capita as the predicted variable.

3.1.2. Core Explanatory Variable

Overall, there is currently no unified indicator system for the digital economy. Drawing on relevant research, this paper selects 18 secondary indicators to calculate the development level of the digital economy (Table 2).

Table 2. The evaluation index system.

Comprehensive Index	Evaluation Dimension	Specific Indicators	Unit	Index Attribute
Digital Economy IDE	Digital Research Environment A	High-tech industry R&D personnel A1	People per year	+
		High-tech industry R&D expenses A2	CNY 10 thousand	+
		The number of effective invention patents in high-tech industries A3	Piece	+
	Infrastructure Capabilities B	The number of mobile communication base stations B1	Ten thousand	+
		Total length of optical cable lines B2	Kilometer	+
		The number of domain names B3	Ten thousand	+
		The number of IPV4 addresses B4	Ten thousand	+
		The number of Internet broadband access ports B5	Ten thousand	+
	Digital Industry Development C	Total teleservices C1	CNY 100 million	+
		Software income C2	CNY 100 million	+
		Internet-related services income C3	CNY 100 million	+
		Electronic information manufacturing income C4	CNY 100 million	+
	Digital Application Level D	Internet broadband access users D1	Million households	+
		Mobile Internet users D2	Million households	+
		The number of information-based enterprises D3	Units	+
		The number of computers per 100 people in industrial enterprises D4	Pieces/per 100 people	+
		E-commerce turnover D5	CNY 100 million	+
		The number of enterprises with e-commerce transactions D6	Units	+

3.1.3. Control Variables

Moreover, Table 3 presents the control variables implemented to mitigate omitted variable bias. The calculation method for schooling years per capita refers to the practices of scholars such as Bai (2004), Zhai (2006), and Wen (2020) [39–41].

Table 3. Description of the control variables.

Variable Name	Definition	Unit
Financial development level (fin)	Balance of deposits and loans of financial institutions at the end of the year/GDP	%
Education development level (edu)	Schooling years per capita	Year per person
Government involvement (gov)	Local fiscal expenditure/GDP	%
Urbanization level (city)	Urban population/total population at the end of the year	%
Foreign-trade dependence (open)	Total imports and exports/GDP	%
Foreign-capital dependence (fdi)	FDI/GDP	%

3.2. Measurement and Analysis of Digital Economy

3.2.1. The Construction of the Evaluation Model

By comparing the choice of method for determining the index weighting made by domestic and foreign institutions and scholars, it is found that most of them prefer the objective weighting method, and the entropy method is the most widely adopted. However, the entropy method is mainly aimed at the weighting evaluation of the panel data, ignoring the influence of the time factor. Therefore, this paper refers to the practices of scholars such as Pan (2015) et al. [42–44] and employs a more comprehensive global entropy method, drawing on the two dimensions of time and space for the weighting evaluation.

The global entropy is calculated through the following sequential procedures:

1. Establishing a global entropy method matrix

When evaluating the data of n indicators of m regions for a total of t years, we first establish a data matrix for each year, which is recorded as follows: $x^t = \{x_{ij}\}_{m\times n}$, where t represents the year and x_{ij} stands for the data of indicator j in region i. In accordance with the principle of the global entropy method, the data matrices of T years are arranged together from top to bottom in chronological order, thus forming a global matrix $mT \times n$, which is recorded as follows:

$$X = \left(x^1, x^2, \ldots, x^T\right) = \{x_{ij}\}_{mT\times n} \tag{1}$$

2. Normalizing the data

Due to the different dimensions and orders of magnitude of each index, the data are normalized, and the processed data are

$$x'_{ij} = \frac{x_j - x_{min}}{x_{max} - x_{min}}, (1 \le i \le mT, 1 \le j \le n) \tag{2}$$

3. Calculating the proportion of region i in indicator j:

$$P_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{mT} x'_{ij}}, (1 \le i \le mT, 1 \le j \le n) \tag{3}$$

The specified gravity matrix is deduced:

$$P = \{P_{ij}\}_{mT\times n}, (0 \le P_{ij} \le 1) \tag{4}$$

4. Working out the entropy value of indicator j:

$$e_j = -k\sum_{i=1}^{mT} P_{ij}\ln\left(P_{ij}\right), (k = \frac{1}{\ln mT} > 0, 0 \le e_j \le 1) \quad (5)$$

5. Figuring out the information utility value of indicator j:

$$d_j = 1 - e_j \quad (6)$$

6. Calculating the weight of each indicator:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (7)$$

7. Working out the total evaluation value:

$$E_i = \sum_{j=1}^{n} w_j x_{ij} \quad (8)$$

3.2.2. Measurement Result

Conforming to the global entropy methodology, the weights of all indices are worked out using StataMP 17.0 software, and the results are exhibited in Table 4.

Table 4. The index system for evaluating the digital economy.

Indicator Name	Information Entropy Value e	Information Utility Value d	Weight Coefficient w
A1	0.8360	0.1640	0.0791
A2	0.8256	0.1744	0.0841
A3	0.7523	0.2477	0.1194
A			0.2827
B1	0.9510	0.0490	0.0236
B2	0.9506	0.0494	0.0238
B3	0.8911	0.1089	0.0525
B4	0.8729	0.1271	0.0613
B5	0.9526	0.0474	0.0229
B			0.1841
C1	0.8922	0.1078	0.0520
C2	0.8319	0.1681	0.0811
C3	0.7746	0.2254	0.1087
C4	0.8174	0.1826	0.0881
C			0.3299
D1	0.9454	0.0546	0.0263
D2	0.9546	0.0454	0.0219
D3	0.9270	0.0730	0.0352
D4	0.9617	0.0383	0.0185
D5	0.8781	0.1219	0.0588
D6	0.9116	0.0884	0.0426
D			0.2033

3.3. Data Sources and Descriptive Statistics of Variables

The main data sources for the explained variable and each control variable are from the China Statistical Yearbook and the statistical yearbooks of provinces, cities, and districts. For some missing values, the linear extrapolation method and arithmetic average interpolation method are mainly employed.

The data involved in the digital economy index system are mainly derived from the China Statistical Yearbook on High Technology Industry, Annual Statistical Data of

the Communications Industry and Annual Statistics Data of Internet and Related Services Industry by Ministry of Industry and Information Technology of China, the China Statistical Yearbook, the statistical yearbooks of provinces, cities, and districts, and the China Internet Development Statistical Report by the China Internet Network Information Center (CNNIC). In addition, some missing values are processed and measured with the linear extrapolation method, arithmetic average interpolation method, and hot-deck interpolation method.

In addition, in order to make the data more stable and reduce the heteroscedasticity, the above variables are all processed logarithmically.

As shown in Table 5, the minimum value of the predicted variable is 10.1307, and the maximum value is 12.1547. The average value is 10.9821, which is on the low side and reflects that the economic development level of each province is mostly concentrated in low-value regions after taking the logarithm, and the less developed provinces have a large development potential to a certain extent. The minimum value of the core explanatory variable is −1.0847, and the maximum value is 4.3846, with a standard deviation of 1.0023. The data exhibit significant fluctuations, suggesting substantial disparities and an imbalance in the development levels of the digital economy among provinces in China. There is also a large gap between the data of the foreign-trade dependence and the foreign-capital dependence in the control variables.

Table 5. Descriptive statistics of variables.

Variable	Obs	Average	Std.Dev	Min	Max
lngdp	270	10.9821	0.4224	10.1307	12.1547
lnide	270	1.9612	1.0023	−1.0847	4.3846
lnfin	270	1.2340	0.2718	0.6790	2.0253
lnedu	270	2.2348	0.0924	2.0114	2.5480
lngov	270	3.1840	0.3786	2.3514	4.3221
lncity	270	4.1125	0.1719	3.6951	4.4924
lnopen	270	2.7860	0.9525	−0.3388	4.7177
lnfdi	270	0.0216	1.2395	−5.0851	2.4931

Moreover, Figure 1, a scatter plot, is drawn according to the data of the explained variable and the explanatory variable. It indicates a generally positive correlation between the logged figures of digital economy growth and GDP per capita. This suggests that boosting the digital economy can really kick-start local economic growth, and it also lends credence to the way our benchmark model is set up.

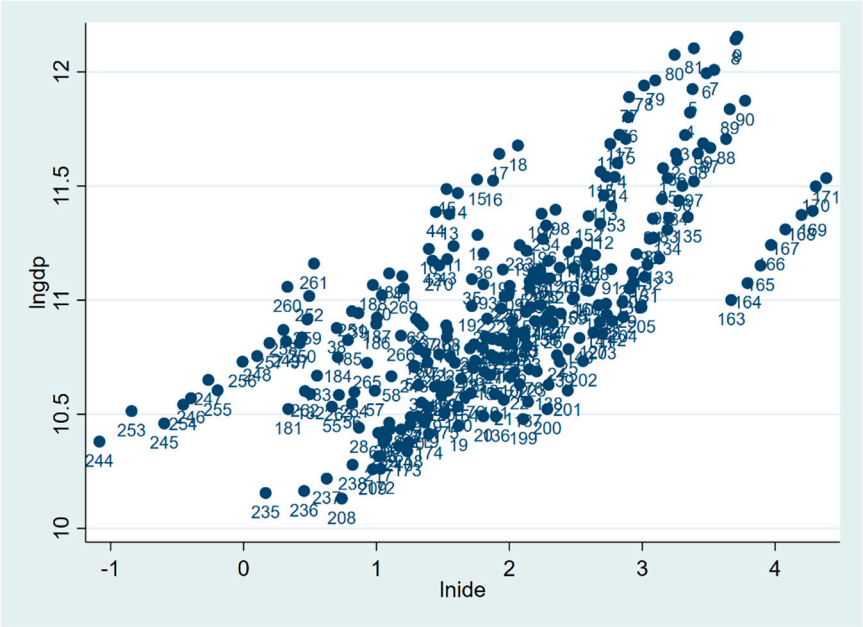


Figure 1. Scatter plot of log-transformed digital economic development level and GDP per capita.

3.4. Model Specification

3.4.1. Benchmark Model

In order to examine the function of the digital economy in economic growth, this study formulates the following model:

$$gdp_{i,t} = \alpha + \beta ide_{i,t} + \sum_{k=1}^{k}\left(\gamma X_{i,t}^{k}\right) + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (9)$$

Here, $gdp_{i,t}$ represents the level of economic development in region i at time t; $ide_{i,t}$ represents the level of digital economy development in region i at time t; X represents a set of control variables influencing region i at time t; α represents a constant term, and the coefficient of the core explanatory variable is denoted by β, while the coefficient of the control variable is denoted by γ; μ_i, λ_t, and $\varepsilon_{i,t}$ are the individual (province) fixed effect, time fixed effect, and stochastic disturbance, respectively.

3.4.2. Spatial Weight Matrix

Measuring the spatial distance between regions is essential for spatial econometric analysis, with the spatial weight matrix serving as its core and foundation. Compared with commonly used spatial weight matrices, the nested economic geography matrix better reflects the influence of spatial geographical distance and economic behavior among provinces, and the results are more reliable [34,45]. Its basic form is

$$w_{i,j} = \begin{bmatrix} 0 & \frac{G_1/d_{12}}{\sum(G_1/d_{1j})} & \cdots & \frac{G_1/d_{1j}}{\sum(G_1/d_{1j})} \\ \frac{G_2/d_{21}}{\sum(G_2/d_{2j})} & 0 & \cdots & \frac{G_2/d_{2j}}{\sum(G_2/d_{2j})} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{G_i/d_{i1}}{\sum(G_i/d_{ij})} & \frac{G_i/d_{i2}}{\sum(G_i/d_{ij})} & \cdots & 0 \end{bmatrix} \quad (10)$$

Herein, G_i represents GDP per capita of province i in 2014–2022 and d_{ij} the geographical distance between province i and province j.

The value requirements are

$$w_{i,j} = \begin{cases} \frac{G_i/d_{ij}}{\sum(G_i/d_{ij})} & , i \neq j \\ 0 & , i = j \end{cases} \quad (11)$$

3.4.3. Spatial Autocorrelation

The spatial correlation of variables is mainly used to test whether the observed value of a certain element in a spatial unit has a connection with that of a neighboring spatial unit. Regarding the spatial autocorrelation test, the global and local Moran's I are typically employed.

Global autocorrelation is mainly inspected by the global Moran's I to analyze the spatial correlation of variables. It ranges from −1 to 1. The calculation formula is

$$Moran's\ I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \quad (12)$$

Here, n stands for the total number of samples of provinces (i.e., 30); $w_{i,j}$ represents the spatial weight matrix; x_i and x_j represent the observed values of provinces i and j; and $S^2 = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n}$ is the variance of the samples, with $\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}$ being the sum of all the spatial weights.

The local Moran's I is calculated as follows:

$$I_i = \frac{(x_i - \overline{x})}{S^2} \sum_{j=1}^{n} w_{ij}(x_i - \overline{x}) \quad (13)$$

4. Results

4.1. Baseline Regression

First of all, it has been found through tests such as the Hausman test that the fixed effects model is more appropriate than the pooled regression model and the random effects model. At the same time, each variable also passes the panel cointegration test. This suggests that there is a long-term equilibrium relationship between each variable and the explained variable. This paper will proceed to investigate the particular relationships between them through regression analysis, and the results are shown in the table below.

As illustrated in Table 6, the incorporation of control variables in a sequential manner has been demonstrated to result in a substantial decline in the coefficient of the digital economy. However, it consistently hangs in there, remaining significant at the 1% confidence level. This generally lines up with the research results of Li (2022) [2] and Liu (2023) [16], lending credence to Hypothesis 1.

The coefficient of the digital economy in model 1 is 0.5571, which suggests that the economic growth of China will rise by 0.5571 units for every unit of increase in the development level of the digital economy without considering other control variables. In model 7, the coefficient of the digital economy becomes 0.2187, which is still significant at the 1% confidence level. This proves that after the control variable is added, China's economy will grow by 0.2187 units with the improvement in the development level of the digital economy.

Table 6. Results of baseline regression.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
lnide	0.5571 ***	0.5526 ***	0.3900 ***	0.3691 ***	0.2172 ***	0.2259 ***	0.2187 ***
	(33.14)	(29.42)	(18.03)	(19.37)	(7.02)	(6.76)	(6.48)
lnfin		0.0421	−0.0324	0.2144 ***	0.1245 **	0.1192 *	0.1156 *
		(0.54)	(−0.51)	(3.41)	(2.06)	(1.95)	(1.90)
lnedu			2.6797 ***	1.7809 ***	1.5084 ***	1.4968 ***	1.4556 ***
			(10.74)	(7.36)	(6.55)	(6.48)	(6.26)
lngov				−0.5140 ***	−0.4748 ***	−0.4681 ***	−0.4552 ***
				(−8.61)	(−8.47)	(−8.22)	(−7.91)
lncity					1.1021 ***	1.0654 ***	1.0820 ***
					(6.00)	(5.75)	(5.66)
lnopen						0.0185 **	0.0133 *
						(1.69)	(1.69)
lnfdi							−0.0010
							(−1.43)
cons	9.8894 ***	9.8464 ***	4.2684 ***	7.6500 ***	4.0108 ***	4.1043 ***	4.1200 ***
	(295.95)	(114.61)	(8.14)	(12.68)	(4.85)	(4.89)	(4.92)
F	1089.09 ***	547.58 ***	578.75 ***	586.62 ***	546.20 ***	454.24 ***	391.36 ***
	(1, 239)	(2, 238)	(3, 237)	(4, 236)	(5, 235)	(6, 234)	(7, 233)
R	0.8213	0.8215	0.8799	0.9086	0.9208	0.9209	0.9216
FE	YES	YES	YES	YES	YES	YES	YES
obs	270	270	270	270	270	270	270

Note: ( ) is the t-statistic; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

With regard to the control variables, the results of each variable in model 7 are basically consistent with the existing relevant academic research [16,26,46]. The correlation between financial development and economic growth, as well as the significance of foreign trade in this regard, is positive, with the significance level of these variables reaching 10%. Every unit of increase in the financial development level will boost China's economic growth by 0.1156 units, while an increase of 1 unit in foreign-trade dependence will accelerate economic growth by 0.0133 units. The impact of the education development level and urbanization level on China's economic growth shows a significant positive correlation at the 1% confidence level, showing that China's economic growth will be enhanced by the increase in education years per capita and the improvement in the urbanization level. Therein, the education development level has the greatest impact on economic growth from model 3 to model 7. An improvement of 1 unit in China's education advancement will drive economic growth by approximately 1.4556 units, while a similar rise of 1 unit in urbanization will contribute an additional 1.0820 units to economic development. In addition, government involvement also passes the significance test, but each unit increase in government involvement would reduce economic growth by 0.4552 units. This is because, in order to stimulate economic vitality, the government often intervenes in the market economy. However, with the intensification of government intervention, both the impetus of coupled industries and the efficiency of economic growth experience a significant decline. This dual-pronged effect fails to contribute to the enhancement of the quality of economic growth or local economic development; instead, it has a negative impact [47]. Furthermore, the effect of foreign-capital dependence on economic growth does not pass the significance test, for the ways of foreign investment are complicated and a large investment gap exists in the regions of China. Therefore, the specific effect of foreign-capital dependence on China's economic growth cannot be determined.

4.2. Endogeneity Test

Considering that the panel regression model mentioned above may not be able to avoid endogeneity problems, which could result in inaccurate outcomes, endogeneity analysis is conducted.

Referring to Wang and Wen (2020) [48], this paper adopts 2SLS to deal with endogeneity problems with internal instrumental variables and external instrumental variables. In the regression analysis involving internal instrumental variables, the development level of the digital economy is selected as the instrumental variable, with the first-order lag being used in this instance. When using external instruments in the regression, adapting the methodology of Yang et al. (2022) [49], the authors select optical fiber cable length (gl) as the instrumental variable of the development level of the digital economy, whose data originate from the China Statistical Yearbook. As demonstrated in Table 7, the findings of the test demonstrate that the endogeneity problem in the benchmark regression model is effectively mitigated, thus corroborating the conclusions of the aforementioned model.

Table 7. Endogeneity analysis.

Variable	Internal Instrumental Variables	External Instrumental Variables
lnide	0.0912 *** (3.63)	0.0334 *** (2.75)
Controls	YES	YES
Weak identification test	3115.4000 {16.38}	258.4010 {16.38}
R-sq	0.8721	0.8706
FE	YES	YES
obs	240	270

Note: ( ) is the t-statistic; *** $p < 0.01$; { } is the critical value at the 10% significance level of the 2SLS weak identification test (5% Wald test).

4.3. Robustness Test

4.3.1. Substituting the Explained Variable

Drawing on the practice of Feng and Nie (2017) [50], the robustness of the model is tested by alternating the predicted variable, i.e., replacing GDP per capita with GDP. The regression results after alternating the predicted variable are displayed by model 1 in Table 8, which suggests that lnide has a positive enhancing influence upon GDP at the 1% significant level. This result aligns with the findings from both the initial benchmark model and the endogeneity analysis, thereby significantly highlighting the reliability of our model.

Table 8. Robustness test.

Variable	Model 1	Model 2	Model 3
lnide	0.2064 *** (5.64)		0.1830 *** (5.49)
lndfin		0.6357 *** (20.40)	
Controls	YES	YES	YES
F	360.88 *** (7, 233)	969.26 *** (7, 233)	294.49 *** (7, 173)
R-sq	0.9156	0.9668	0.9226
FE	YES	YES	YES
obs	270	270	210

Note: ( ) is the t-statistic; *** $p < 0.01$.

4.3.2. Replacing the Explanatory Variable

While this paper assesses the digital economy's progress across four dimensions, a real-world perspective reveals the evaluation index system's inherent complexity. As such, the aforementioned system may still be susceptible to issues like omitted variable bias. Therefore, with reference to Zhong and Zheng (2021) [51], the Peking University Digital Financial Inclusion Index of China (dfin) acts as an explanatory variable herein for regression. As depicted in model 2 of Table 8, digital financial inclusion evidently exerts a positive impact on per capita GDP, thus further validating the soundness of our baseline model.

4.3.3. Shortening Sample Life

Announced in December 2015, the Digital China strategy spurred numerous policies supporting the digital economy. This paper refers to the practice of Li and Tian (2021) [46] to shorten the sample life to 2016–2022 for the robustness test. As demonstrated by the regression results of model 3 in Table 8, the digital economy has persisted in exerting a significantly positive influence on promoting China's economic growth since 2016. This finding is consistent with previous conclusions.

4.4. Heterogeneity Test

In view of the disequilibrium in regional development and the variegated developmental phases of the digital economy across disparate regions, it becomes imperative to embark on a more profound inquiry. The objective is to expound upon the precise mechanisms through which the digital economy propels economic growth within each specific regional context. The results are shown in Table 9.

Table 9. The panel regression results of different regions.

Variable	Eastern	Central	Western
lnide	0.3810 ***	0.1995 ***	0.1218 ***
	(6.18)	(4.66)	(3.94)
cons	3.1488 **	4.0507 ***	4.9431 ***
	(2.56)	(2.90)	(5.54)
Controls	YES	YES	YES
F	166.55 ***	309.55 ***	500.71 ***
	(7, 81)	(7, 57)	(7, 81)
R-sq	0.9350	0.9744	0.9774
FE	YES	YES	YES
obs	99	72	99

Note: ( ) is the t-statistic; *** $p < 0.01$, ** $p < 0.05$.

As indicated by the regression findings for various regions in Table 9, the digital economy in the three primary regions has been demonstrated to have a significant impact on regional economic growth at the level of 1%. This finding indicates that, despite the evident disparities in economic development between the eastern, central, and western regions, the influence of the digital economy on economic growth remains consistent. This observation is in alignment with the findings from the entire sample of China.

4.5. Spatial Effect Test

In light of the theoretical analysis on the effect of the digital economy on economic growth, it is observable that the digital economy generates spillover effects. The digital economy has not just boosted local economies; it has also given a leg-up to neighboring regions. To really dig into how the digital economy impacts China's economic growth across different areas, this study takes a spatial approach. First, we use a spatial weight

matrix to see if there is a relationship between digital economy activity and economic development levels across China. After that, we build a spatial econometric model tailored to our specific needs. Finally, the data are classified by region to analyze the spatial effects in different regions, so as to confirm whether this influence is consistent across the country.

4.5.1. Spatial Autocorrelation Test

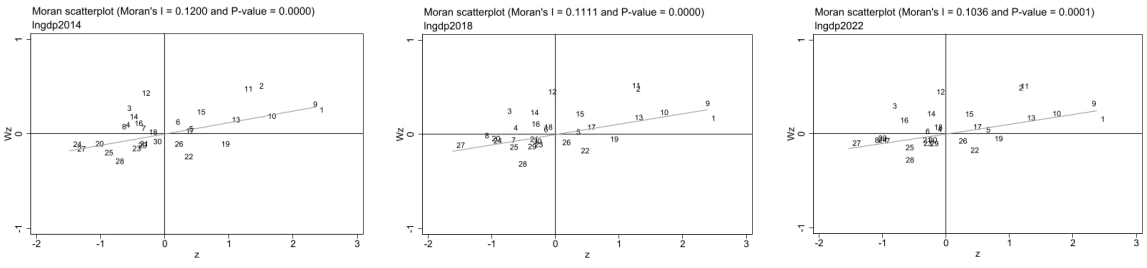
The spatial autocorrelation test results are shown in Table 10. According to the spatial autocorrelation test results of economic growth and the digital economy, they pass the significance test in 2014–2022, exhibiting a significant positive spatial autocorrelation. This validates Hypothesis 2.

Table 10. Results of spatial autocorrelation test.

Year	lngdp	lnide
2014	0.1200 ***	0.0999 ***
	(4.3030)	(3.7459)
2015	0.1144 ***	0.1004 ***
	(4.1419)	(3.7454)
2016	0.1097 ***	0.0997 ***
	(4.0163)	(3.7196)
2017	0.1094 ***	0.0899 ***
	(4.0148)	(3.4537)
2018	0.1111 ***	0.0818 ***
	(4.0648)	(3.2293)
2019	0.1105 ***	0.0844 ***
	(4.0466)	(3.3056)
2020	0.1087 ***	0.0781 ***
	(4.0061)	(3.1400)
2021	0.1070 ***	0.0826 ***
	(3.9522)	(3.2434)
2022	0.1036 ***	0.0989 ***
	(3.8467)	(3.6957)

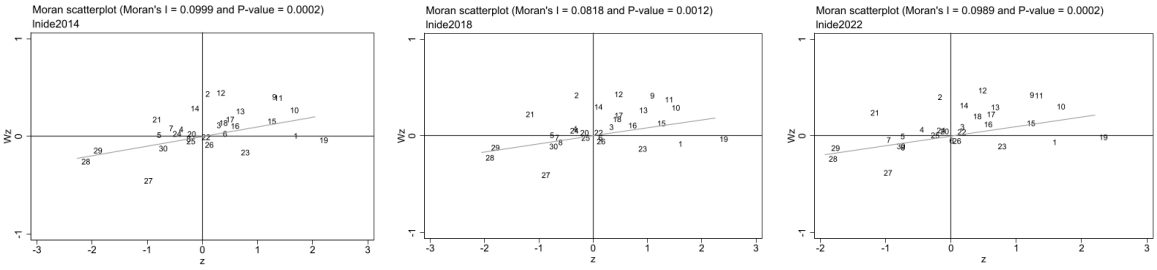
Note: ( ) is the Z-statistic; *** $p < 0.01$.

Hoping to further understand the spatial aggregation of different provinces and other provinces, this section presents a local autocorrelation test, which is performed by calculating the local Moran I and drawing a Moran scatter chart (Figures 2 and 3).



(**a**) (**b**) (**c**)

Figure 2. Scatter graphs of the local Moran I of the variable denoted as lngdp: (**a**) scatter plot of the local Moran index of variable lngdp in 2014; (**b**) scatter plot of the local Moran index of variable lngdp in 2018; (**c**) scatter plot of the local Moran index of variable lngdp in 2022. The numerical codes in the Moran scatter plots correspond to the following: 1—Beijing; 2—Tianjin; 3—Hebei; 4—Shanxi; 5—Inner Mongolia; 6—Liaoning; 7—Jilin; 8—Heilongjiang; 9—Shanghai; 10—Jiangsu; 11—Zhejiang; 12—Anhui; 13—Fujian; 14—Jiangxi; 15—Shandong; 16—Henan; 17—Hubei; 18—Hunan; 19—Guangdong; 20—Guangxi; 21—Hainan; 22—Chongqing; 23—Sichuan; 24—Guizhou; 25—Yunnan; 26—Shaanxi; 27—Gansu; 28—Qinghai; 29—Ningxia; 30—Xinjiang.



(**a**) (**b**) (**c**)

Figure 3. Scatter graphs of the local Moran I of the variable denoted as lnide: (**a**) scatter plot of the local Moran index of variable lnide in 2014; (**b**) scatter plot of the local Moran index of variable lnide in 2018; (**c**) scatter plot of the local Moran index of variable lnide in 2022. The numerical codes correspond to those in the figure above.

As can be seen from Figure 2, all sample points of economic growth are mainly concentrated in the first quadrant (HH) and the third quadrant (LL), in nearly the same amount, indicating two positive spatial aggregations in the level of economic growth. From the analysis of Figure 3, what can be seen is that the number of provinces located in the first quadrant (HH) is the largest, which suggests that high–high aggregation is a symbol of the digital economy of China. Then, the third quadrant (LL) is occupied by more provinces, which also confirms the significant positive spatial autocorrelation of the digital economy. This also validates Hypothesis 2.

4.5.2. Baseline Spatial Regression Analysis

Regarding spatial econometric models, the specific conditions are analyzed according to the cases, and the appropriate model for empirical analysis is selected. Next, diagnostic tests, such as the LM, Hausman, LR, and Wald tests, are conducted; based on the results, this study selects the spatial Durbin model with fixed effects under an economic geography nested matrix for empirical analysis, with the estimation results shown in Table 11.

Table 11. Results of spatial panel regression.

Variable	Main 1	Spatial 2	Variance 3	Direct 4	Indirect 5	Total 6
lnide	0.1292 ** (2.29)			0.0275 ** (2.26)	0.0658 *** (2.66)	0.0933 *** (2.85)
Controls	YES	YES	YES	YES	YES	YES
FE	YES	YES	YES	YES	YES	YES
rho		0.6239 ** (2.25)				
sigma2_e			0.0008 *** (11.47)			
R-sq	0.6149	0.6149	0.6149	0.6149	0.6149	0.6149
Log-l	583.0818	583.0818	583.0818	583.0818	583.0818	583.0818
obs	270	270	270	270	270	270

Note: ( ) is the t-statistic; *** $p < 0.01$, ** $p < 0.05$.

The core explanatory variable passes the significance test at the 5% level in the main model, model 1, implying that the digital economy substantially boosts China's economic expansion. Nevertheless, compared with the basic regression results, it is found that the regression coefficient decreases after considering the spatial effect. This proves that without considering the spatial effect, the effect of the interaction between the two variables will be overexaggerated. According to model 4, model 5, and model 6, a spatial spillover effect of

the digital economy on economic growth appears in the spatial Durbin model. This confirms that the growth of the digital economy not only gives a shot in the arm to local economies but also influences surrounding regions. A 1-unit increment in the development of the digital economy corresponds to a 0.1292-unit rise in overall economic growth. When decomposed, the direct impact contributes 0.0275 units, and the indirect impact adds 0.0658 units.

4.5.3. Spatial Heterogeneity Analysis

Synthesizing the preceding examination reveals marked regional disparities in China's digital economy's advancement and its effect on economic expansion. Consequently, spatial panel regression is conducted for the three major regions, and the specific results are shown in Table 12.

Table 12. Spatial panel regression results of different regions.

Variable	Eastern				Central				Western			
	Main	Direct	Indirect	Total	Main	Direct	Indirect	Total	Main	Direct	Indirect	Total
	1	2	3	4	5	6	7	8	9	10	11	12
lnide	0.2016 **	0.0269 **	0.0643 ***	0.0913 ***	0.1620 ***	0.1380 ***	0.1174	0.2554 **	0.0635 *	0.2246 **	0.0199	0.2445 **
	(2.05)	(2.15)	(2.72)	(2.89)	(3.63)	(4.20)	(1.06)	(2.03)	(1.93)	(2.12)	(0.72)	(2.13)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
rho	1.2083 ***	1.2083 ***	1.2083 ***	1.2083 ***	0.7970 ***	0.7970 ***	0.7970 ***	0.7970 ***	1.2283 ***	1.2283 ***	1.2283 ***	1.2283 ***
	(5.36)	(5.36)	(5.36)	(5.36)	(3.73)	(3.73)	(3.73)	(3.73)	(3.80)	(3.80)	(3.80)	(3.80)
sigma_e	0.0003 ***	0.0003 ***	0.0003 ***	0.0003 ***	0.0002 ***	0.0002 ***	0.0002 ***	0.0002 ***	0.0003 ***	0.0003 ***	0.0003 ***	0.0003 ***
	(6.33)	(6.33)	(6.33)	(6.33)	(5.42)	(5.42)	(5.42)	(5.42)	(6.17)	(6.17)	(6.17)	(6.17)
R-sq	0.3471	0.3471	0.3471	0.3471	0.9481	0.9481	0.9481	0.9481	0.2159	0.2159	0.2159	0.2159
Log-l	253.2497	253.2497	253.2497	253.2497	197.5158	197.5158	197.5158	197.5158	263.8017	263.8017	263.8017	263.8017
obs	99	99	99	99	72	72	72	72	99	99	99	99

Note: ( ) is the t-statistic; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

First and foremost, the results of the main models, models 1, 5, and 9, are basically consistent with those of scholars such as Chen (2022) [52] and Zhang et al. (2022) [53]. The digital economy in the eastern, central, and western regions has significant spatial effects on China's economic growth, which is most obvious in the eastern regions. The impact coefficients are 0.2016, 0.1620, and 0.0635, respectively, decreasing from east to west stepwise, again proving the existence of a digital divide among provinces and regions.

In the eastern region, the digital economy's direct influence is statistically significant, hitting the 5% level. Furthermore, the indirect effects are even more pronounced, exhibiting a substantial positive impact at the 1% level. This finding indicates that the digital economy in the eastern provinces exerts a substantial impact on neighboring regions, generating a ripple effect that contributes to overall growth, with an estimated impact of approximately 0.0643. In terms of the direct impact, the digital economy significantly promotes economic growth in the central and western regions, with statistically significant effects at the 1% and 5% levels, and coefficients of 0.1380 and 0.2246, respectively. However, the central region has the largest spillover coefficient, but like the western region, it does not show a significant positive impact. This reveals that the digital economy in regions other than the eastern region is generally underdeveloped. Digital technologies and the digital economy lack effective integration, failing to boost growth in surrounding areas. Any positive impacts are spatially confined, reflecting digital isolation and insufficient spillover effects.

5. Discussion

By collating relevant studies on the digital economy and economic growth, this paper confirms the conclusions that the digital economy drives economic growth, and that there is a significant spatial spillover effect [2,16,52]. Unlike previous research, we refined the digital economy measurement in the temporal and spatial dimensions, probed its relationship with economic development, and considered the intricate interplay of geographical and economic distances among regions in the digital era. However, this study has constraints and areas for further exploration.

(1) Due to the complex and diverse nature of the digital economy, it is currently impossible to take all of its influencing factors into account. With the rapid development of the digital economy and the in-depth research into related theories, new infrastructure indicators (5G base stations, big data centers, etc.) can be further considered in future research, the impact of agricultural digitalization can be considered in industrial digitalization, and the digital literacy of different groups can be considered. In this way, the digital economy indicator system can be improved.

(2) Constrained by data availability, this analysis focuses on provincial-level trends, which may overlook nuanced differences and unique characteristics. Future research can explore the impact of prefecture-level cities and reflect regional differences in a more refined manner, especially the spillover effects of first-tier cities and provincial capitals. However, the collection of urban data may be a challenge for future research.

(3) This paper assesses digital economy progression across thirty Chinese provinces. However, spatial patterns related to this metric remain unexplored. Future studies could examine the digital economy's spatial correlations. Specifically, they can focus on the development characteristics of different regions in various dimensions. This approach can thereby provide stronger support for examining regional heterogeneity.

6. Conclusions and Policy Implications

6.1. Conclusions

Utilizing provincial panel data spanning from 2014 to 2022, this research delves into the relationship between the digital economy and economic growth in China. A fixed effects model is employed to conduct an in-depth analysis of the interaction between these two factors. The stability of the model is validated through endogenous analysis and robustness tests, and a regional heterogeneity analysis is conducted. Furthermore, a spatial Durbin model assesses the geographic influence of China's digitized economy on its financial expansion, leading to the following key findings.

First, China's digital economy serves as a significant driver of economic growth. From 2014 to 2022, multiple analytical methods, such as benchmark regression, instrumental variable regression, and robustness checks, consistently demonstrate a distinct positive effect. Specifically, a 1-unit increase in the digital economy is associated with approximately a 0.2259-unit rise in overall economic growth. Nevertheless, this impact exhibits regional disparities. The eastern region benefits most significantly, followed by the central and western regions in a sequential manner. This distribution reflects China's current economic situation, where the eastern region is more developed, boasting superior infrastructure and a higher density of scientific and technological talent.

Second, a significant spatial effect exists between the digital economy and economic growth in China. A 1-unit increment in digital economy development results in a 0.1292-unit elevation in economic growth. When decomposed, the direct impact amounts to 0.0275 units, and the indirect effects contribute 0.0658 units. Cumulatively, the total effect reaches 0.0933 units. Regional-level analysis reveals that the digital economy in the eastern region not only directly propels its local economic growth but also generates a notable spatial spillover effect, influencing neighboring regions. Conversely, the digital economies in the central and western regions predominantly contribute to their local direct economic growth, with nonexistent spatial spillover effects. Evidently, distinct disparities persist among these three regions.

6.2. Policy Implications

The following policy implications for the digital economy and regional growth are presented in light of the outcomes of this research:

(1) The latest wave of digital technologies is upon us, encompassing everything from big data and blockchains to cloud computing, artificial intelligence, and 5G. To ensure the digital economy continues to thrive, the government needs to pump more resources into these technologies. And in the planning of digital infrastructure construction, the concept of green development should be integrated. Stringent energy efficiency standards should be formulated to improve utilization rates and reduce waste, and efforts should be made to promote the development of digital infrastructure in a comprehensive, green, and sustainable direction.

(2) The digital economy is far from evenly distributed, with a marked disparity between the eastern seaboard and the central and western heartlands. Consequently, each region needs to tailor its digital economy strategies and supporting documentation to its specific circumstances. The East is well positioned to champion both the advancement of digital industries and the integration of digital technologies across all sectors. By leveraging its already substantial digital footprint, the East can really set the pace, demonstrating best practices and triggering knock-on growth in neighboring areas. The central and western regions, on the other hand, would do well to prioritize building out their digital infrastructure. They can also take advantage of national-level support programs to foster digital economy innovation among businesses and to modernize established industries. This approach can help narrow the economic gap with the eastern region and promote more balanced and sustainable regional economic growth across the nation.

(3) To effectively stimulate regional economic growth, particularly in the central and western regions, fine-tuning of the industrial structure is necessary. The digital economy can be a transformative factor, directing data resources towards superior enterprises, industries, and regions. By surmounting geographical constraints, it facilitates industrial restructuring, data optimization, and urban–rural integration.

(4) Due to the ecological development and borderless characteristics of the digital economy, digital technologies can be utilized to promote the efficient use and optimal allocation of resources. Enterprises can reduce resource waste, improve production efficiency, and lower energy consumption by monitoring market demand, thereby achieving the sustainable supply of energy. However, it is also necessary to face up to the challenges brought about by the development of the digital economy. Special attention should be paid to the unbalanced development caused by the digital divide, as well as the energy consumption of data centers and the issue of electronic waste. Only in this way can we ensure the joint advancement of economic development and sustainable development goals.

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