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Analysis of the Spatial–Temporal Evolution of the Digital Economy and Its Impact on the Employment Structure in China from 2001 to 2020

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Abstract: The scale of the digital economy has increased rapidly, which, to some extent, has improved the employment environment. However, the relationship between the digital economy and the employment structure is still uncertain. The primary objective of this study is to examine whether the digital economy in China can improve the employment structure. Specifically, we research the digital economy's spatial–temporal evolution, and the heterogeneity and mechanism of this influence. The hypothesis is that "the level of digital economy development has a positive impact on the employment structure". Based on evidence from China's 30 provinces from 2001 to 2020, we construct a comprehensive system to measure the provincial digital economy and use the entropy method for calculation. Using spatial correlation analysis, the spatial distribution of the digital economy is analyzed. The relationship between the digital economy and the employment structure is explored via the ordinary least squares model, with the development level of the digital economy as the core explanatory variable and the employment structure as the explained variable. Results show that the high–high clustering gradually moves from the eastern to the central region. The development of the digital economy can significantly improve the employment structure by improving the industrial structure. However, heterogeneity exists, which is affected by the geographical location, degree of marketization, level of economic development, and whether it is located in a coastal area.

Keywords: digital economics; employment structure; spatial distribution; OLS model; China

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1. Introduction

In the past decade, the digital economy has developed rapidly, associated with technological development, becoming a new engine of national economic growth. The 20th National Congress of the Communist Party of China drew up the blueprint for the growth of the digital economy, strengthened the determination to develop the digital economy, and proposed to encourage the comprehensive integration of the digital economy with the traditional economy and construct a digital industrial cluster with global competitiveness. The "Digital China Development Report (2022)" reveals that the scale of China's digital economy ranks second in the world, with 50.2 trillion yuan; it has annually increased by 10.3%, and the proportion of the GDP has increased to 41.5%. With the penetration of the digital economy in various economic sectors, it has become an indispensable part of the present era. Currently, the line between the digital and non-digital sectors is blurring [1]. However, the level of regional digital economy varies across China due to regional disparities in resources. Thus, an exploration of the spatial distribution of the level of regional digital economy is needed for coordinated development. Additionally, the digital economy has been confirmed to influence employment situations through the upgrade and application of digital technology [2], the improvement of the employment environment [3], and changes in labor relations [4]); thus, to some extent, it may influence the employment structure. Here, we focus on the spatial distribution of regional digital economy development and explore the impacts of the digital economy on the employment structure based on spatial correlation analysis and the ordinary least squares model.

A number of studies have focused on the digital economy, but there are still uncertainties regarding its definition and measurement. Tapscott [5] first introduced the term "digital economy" and found that the Internet is a driver of digital economy development, but did not quantify the scope and scale of the digital economy. Compared to Tapscott [5], Moulton [6] suggested that e-commerce, information technology, corresponding ICT infrastructure and information transmission, communications, and the computer industry are measures of the digital economy. In addition to infrastructure, the ICT sector, and digital skills, Ismael [7] emphasized the importance of the category of digital framework indicators. The new view of digitalization proposed by Katz et al. [8] lies in the need to clarify the use of technology beyond capturing technology penetration, and, to this end, the Digital Development Level Index was developed, comprising six factors, such as the utilization of digital technology and human capital. Bukht and Heeks [9] argued that the real digital economy is the digital sector plus emerging digital and platform services. For China, the "2022 China Digital Economy Development Research Report", released by the China Electronics and Information Industry Development Research Institute, comprehensively examines the digital economy in terms of digital infrastructure, the digital economy industry, digital governance, and data value, which are broadly used in existing studies. For instance, Li and Liu [10] used the entropy approach to calculate digital economy growth from infrastructure, digital application, and digital industry development.

Existing studies have examined the effects of the digital economy from multiple perspectives. On the macro level, evidence from around the world shows that digital technologies can be transformational for development, generating economic and social benefits [11], and the digital economy can promote sustainable development [12]. Regarding the impact mechanism of the digital economy on sustainable development, the digital economy boosts the sustainable development of the region by fostering the coordinated development of urban and rural areas, innovation efficiency, the digital transformation of the real economy, ecological sustainability and environmental protection [13]. Zahorodnia et al. [14] affirmed the role of the effective use of the digital economy in ensuring information security and stability. At the same time, evidence from 217 cities in China proved that the digital economy can affect pollutant emissions through direct effects and technical effects, which is conducive to environmental protection and sustainable development [15]. At the meso level, the digital economy supports the digitization and modernization of traditional industries. Laudie and Pesch [16] delved into case studies, employed an inductive qualitative research design, and suggested that the implementation of digital technologies and digital business activities can help to improve upon traditional methods of value creation, delivery, and capture. Based on the mediating effect of heterogeneous technological innovation, Su et al. [17] confirmed that the growth of the digital economy and innovation have had a beneficial impact in encouraging the modernization of the industrial structure, and they also proved the crucial mediating role of heterogeneous technological innovation. At the micro level, for individual entrepreneurs, the network environment provided by the digital economy facilitates access to resources and information, helps to create connections between subjects, reduces management costs, and supports the accumulation of social capital [18]. As the digital economy continues to grow, so does the digital divide between advanced and emerging economies, between urban and rural areas within emerging countries, and between educated and uneducated areas [19]. In the EU, countries in the northeast of Europe (Denmark, Finland, Sweden, and the Netherlands) are ranked highly in the Digital Economy and Society Index, whereas Eastern and Southern European countries (Romania, Bulgaria, Greece, and Italy) are ranked poorly [20]. For China, Wang et al. [21] believe that, compared with the central and western regions, the digital economy has grown significantly in the eastern region, such as the Bohai Rim, the Yangtze River Delta region, and the Pearl River Delta region, and the degree of agglomeration has increased over time. Tang et al. [22] suggested that interprovincial variances in the northern area are the major cause of the regional variations in China's digital economy growth, with the degree of development in the south being much greater than that in the north. Human-centricity is a vital component of a sustainable digital economy [23] and employment is the foundation of people's livelihoods. However, the influence of the digital economy on employment is controversial. On the one hand, scholars believe that the digital economy is of great significance to employment. Robust difference-in-differences estimates and OLS regression results from three datasets covering 12 countries showed that a strong Internet connection increases access to information and communication and reduces costs, with a significant positive impact on employment and income in Africa [24]. Eichhorst et al. [25] focused on the potential or actual impact of digitalization on the labor market in Germany, finding that creative occupations; business management and consulting; and health, social, and educational occupations have had high employment growth rates over the past 20 years, and that there has been no overall decline in employment, total headcount, or workload. Focusing on a group of migrant workers, Lin and Zhu [26] found that the digital economy has improved the quality of employment, especially that of new, high-skilled employees in manufacturing, transportation, and residential services. On the other hand, scholars believe that the development of science and technology will lead to unemployment in terms of the digital economy. The acceleration of the digital transformation of various industries has had a certain impact on the low-skilled workforce. Whether technology, such as robots, will occupy the positions of humans remains an unresolved question; the digital economy focuses on robots replacing humans in the labor market, building models of robots competing with human labor in the production of different tasks. The increased use of industrial robotics in the local labor market in the United States between 1990 and 2007 may have reduced wages and contributed to unemployment [27]. Dahlin [28] examined the impact of industrialized robots on multiple types of positions with a regression model and concluded that robots are more likely to eliminate certain professions. The third perspective is that the digital economy has a nonlinear effect on employment. According to Chinese province panel statistics for 2014–2020, Wu and Yang [29] demonstrated this nonlinear impact through empirical analysis. Abbasabadi and Soleimani [30] came to a similar conclusion: using 2016 cross-sectional data from 163 countries for empirical research, they found a significant two-polynomial relationship between unemployment and digital technology, and as digital technology expanded, the unemployment rate also increased, and it began to decline after reaching a maximum.

In summary, existing studies of China have explored the construction of digital economy indicators and their impacts on the economy, society, and other aspects. However, few studies have completely covered digital economy indicators based on the digital basis, digital industry, digital innovation, and digital efficiency. In addition, while a few studies have explored the spatial distribution of the digital economy in the short term, no long-term analysis has been conducted for China. Furthermore, the effects of the digital economy on employment are still uncertain and a heterogeneity analysis is lacking. However, as the world's most populous country, the issue of employment is very important to China's social and economic development [31]. Improvements in the structure of employment can have a positive impact on society, the economy, and the environment, thereby contributing to sustainable development [32]. It is of great significance to study the relationship between the digital economy and employment, which is also of guiding significance for the achievement of sustainable development. Based on this, this paper mainly tests the following hypothesis:

Hypothesis 1. *The level of digital economy development has a positive impact on the employment structure.*

Further, to fill the gaps above, first, this study contributes by building a comprehensive evaluation system that incorporates four aspects of the digital basis, digital industry, digital innovation, and digital efficiency. Second, we analyze the spatial distribution and dynamic evolution of the digital economy development level at the provincial level. Third, based on twenty years of data, empirical research is adopted as the research method of this work. The rest of this paper is organized as follows. Section 2 covers the data sources and methodologies. In Section 3, the results and discussion are presented. Finally, we conclude this paper and propose policy suggestions in Section 4.

2. Methods and Data Sources

2.1. Entropy Method

The entropy method, initially derived from the concept of information entropy, develops a comprehensive evaluation by calculating the degree of the dispersion of indicators to determine the weights of variables [10]. Based on 22 indicators, listed in Table 1, we measure the level of the digital economy with this method, through normalization and the calculation of weights, information entropy, and the variance factor (see Section S1 of the Supplementary Materials for more details).

Table 1. Indicators of digital economy development level gathered over 2001–2020.

Categories		Indicators	Unit
Basis	Infrastructure	Length of long-distance optical cable lines	10,000 km
		Capacity of mobile phone exchanges	10,000 subscribers
	Popularization	Number of mobile phone subscribers at year-end	10,000 subscribers
		Number of Internet users	10,000 persons
Industry	Scale	Business volume of telecommunication services	100 million yuan
		Average business volume of telecommunication services per capita	10,000 yuan/person
		Revenue from principal business of electronics and telecommunication equipment manufacturing	100 million yuan
		The proportion of electronics and telecommunication equipment manufacturing to GDP	%
		Number of express mail services	10,000 pcs
		Average number of express mail services per capita	pcs/person
	Inputs	Annual average employees of electronics and telecommunication equipment manufacturing	person
		Number of enterprises of electronics and telecommunication equipment manufacturing	unit
Innovation	Investment	Full-time equivalent of R&D personnel of industrial enterprises above designated size	man-years
		Expenditure on R&D of industrial enterprises above designated size	10,000 yuan
	Output	Transaction value in technical markets	100 million yuan
		The proportion of invention applications to the number of patent applications of industrial enterprises above designated size	%
		Number of patent applications certified	pieces
		Number of patent applications certified for invention	pieces
Efficiency	Agriculture	Electricity consumed in rural areas	100 million kWh
		The gross domestic product for agriculture, forestry, animal husbandry, and fishery	100 million yuan
	Industry	New products of industrial enterprises above designated size	unit
	Service	Total retail sales of consumer goods	100 million yuan

Note: All variables have a positive effect on the development level of the digital economy.

2.2. Spatial Correlation Analysis

The local Moran's I is used to determine the categories of spatial clusters for each province in order to differentiate the spatial dependence among regions, including high–high (the digital economy's hot spots), low–low (the digital economy's cold spots), high–low, and low–high [33]. Thus, we use the local Moran's I values to investigate the spatial distribution of the regional digital economy across China. Details can be found in Section S2 of the Supplementary Materials.

2.3. Regression Model

As the most fundamental form of regression analysis, ordinary least-squares (OLS) models presume that the analysis approximates the relationship between one or more explanatory variables and continuous or at least outcome variables. Results suggest a substantial link between the predictor and outcome [34]. This coincides with our research objective to explore the relationship between the level of digital economy development and the employment structure. Moreover, OLS regression is based on assumptions such as independence, homoscedasticity, and the normality of residuals, which are also relevant in this study. Thus, we use the OLS model to explore the relationship between the employment structure and the digital economy. More specifically, the employment structure is the explained variable; the digital economy is the core explanatory variable; the regional GDP, government behavior, and urbanization rate are selected as control variables; and the industrial structure is the mediating variable. The model is built as follows:

$$lnemployment_{it} = \alpha + \beta digit_{it} + \lambda X_{it} + \omega_i + \pi_t + \varepsilon_{it}$$

where subscript i indicates province, t denotes the year, $lnemployment$ represents the employment structure, and $digit$ represents the development of the digital economy. As described above, there are two methods to measure $digit$. X_{it} represents the control variables. α is an intercept (value of $lnemployment_{it}$ that cannot be explained by $digit_{it}$ and X_{it}); β is a regression coefficient representing the amount of change in $lnemployment_{it}$ associated with one-unit change in $digit_{it}$, whereas ε_{it} is a residual error. ω_i and π_t denote the province-fixed effect and the fixed effect of the year, respectively, where ω_i controls for factors that remain unchanged over time in each province. π_t represents domestic and foreign macroeconomic factors faced by all provinces in the same year.

2.4. Data Sources and Processing

Since the level of digital economy development is not directly observed, and its measurement method is not agreed upon in the academic community, scholars measure its development level from different perspectives. When constructing the first-level indicators of the digital economy, Liu and Ji [35] selected two dimensions, industrial digitalization and digital industry, and its second-level indicators divided digital industrialization into innovation ability, digital services, and industrial scale, while industrial digitalization started from agriculture, industry, the service industry, and digital finance. He et al. [36] measured the development level of the digital economy in the form of five dimensions: the digital economy infrastructure scale, the digital economy industry scale, the digital economy application scale, the digital economy market scale, and the digital economy labor force. Starting from the connotations of the digital economy, we select indicators to comprehensively cover the basic resources, industrial fields, and social life involved in the digital economy, taking into account input and output. The setting of indicators is hierarchical, and the level of digital economy development is measured from different perspectives, such as individuals and enterprises. To ensure data availability, these specific indicators are selected.

We evaluate the development of the digital economy in terms of the digital basis, digital industry, digital innovation, and digital efficiency, as shown in Table 1. The digital economy is specifically measured by 22 indicators, and more details are provided in Section S3 of the Supplementary Materials. The number of Internet users comes from "the China statistical yearbook of the tertiary industry". Revenue from the principal business of electronics and telecommunication equipment manufacturing, the proportion of electronics and telecommunication equipment manufacturing to the GDP, the annual average employees of electronics and telecommunication equipment manufacturing, and the number of enterprises of electronics and telecommunication equipment manufacturing come from "the China statistics yearbook on high technology industry". The full-time equivalent of the R&D personnel of industrial enterprises above the designated size and the expenditure on R&D of industrial enterprises above the designated size come from the "National Bureau of Statistics of China". The remaining data come from the database of "the Information Network of Development Research Center of the State Council". Missing values are filled in by interpolation.

Explained variable—employment structure (*lnemployment*): It is expressed by dividing the sum of the number of people employed in the secondary and tertiary sectors by the number of people in the primary sector [37].

Core explanatory variable—digital economy (*digit*): As shown in Table 1, this paper designs a digital economy development measurement index system, evaluates the digital economy development level of China's provinces (autonomous regions and cities), and calculates the weight of each index according to the entropy method. *Digit1* includes the length of long-distance optical cable lines, the capacity of mobile phone exchanges, the average business volume of telecommunication services per capita, the proportion of electronics and telecommunication equipment manufacturing to the GDP, the average number of express mail services per capita, the annual average employees of electronics and telecommunication equipment manufacturing, the number of enterprises of electronics and telecommunication equipment manufacturing, the number of mobile phone subscribers at year-end, the number of Internet users, the full-time equivalent of the R&D personnel of industrial enterprises above the designated size, the expenditure on R&D of industrial enterprises above the designated size, the transaction value in technical markets, the proportion of invention applications to the number of patent applications of industrial enterprises above the designated size, the number of patent applications certified, the number of patent applications certified for invention, the electricity consumed in rural areas, the gross domestic product for agriculture, forestry, animal husbandry, and fishery, new products of industrial enterprises above the designated size, and the total retail sales of consumer goods. Compared to *digit1*, *digit2*, which is used for the robustness test, adds the business volume of telecommunication services, revenue from the principal business of electronics and telecommunication equipment manufacturing, and number of express mail services. We find that both *digit1* and *digit2* are significantly positively correlated with the explained variables from the correlation analysis (see Table S1 and Figure S1, Supplementary Materials) and typical fact analysis (Figure S2, Supplementary Materials).

Control variables—regional GDP, government behavior, and urbanization rate. The regional GDP (*lnpgdp*) is measured by the per capita GDP. Government behavior (*lngovernment*) is measured by local government spending as a percentage of the region's GDP. The urbanization rate (*lnurban*) is measured by the proportion of the urban population representing the total population of the region.

Mediating variable—industrial structure (*lnindustry*): It is measured as the calculation result of "1 $\times$ the proportion of output value of the primary industry + 2 $\times$ the proportion of output value of the secondary industry + 3 $\times$ the proportion of output value of the tertiary industry". The greater its value, the greater the level of the industrial structure.

Table 2 provides the descriptive statistics for the variables included in this study. Variables other than *digit1* and *digit2* are logarithmic. It can be seen that there are 600 pieces of data in total. *lnemployment* has a maximum value of 8.515, while the minimum is 3.444, which means that the gap in the employment structure between the samples is large. The composition of *digit1* and *digit2* is different, but the table shows that the numerical characteristics of the two are not notably different. In the following, *digit1* will be used for regression analysis, while *digit2* will be used for robustness testing.

The data used in this paper cover 30 provinces (cities and autonomous regions) in China from 2001 to 2020, excluding Hong Kong, Macao, Taiwan, and Tibet due to a lack of data. Quality tests of the data are described in Section S1 of the Supplementary Materials.

Table 2. Descriptive statistics of variables.

Variable	N	Mean	SD	Min	p50	Max
lnemployment	600	5.247	0.901	3.444	5.048	8.515
digit1	600	0.083	0.106	0.002	0.048	0.877
digit2	600	0.076	0.100	0.001	0.043	0.890
lnpgdp	600	10.200	0.816	8.006	10.350	12.010
lnurban	600	3.923	0.290	3.178	3.945	4.507
lngovernment	600	3.002	0.431	2.044	3.000	4.328
lnindustry	600	5.453	0.056	5.332	5.446	5.648

3. Results and Discussion

3.1. Spatial Distribution

Figure 1 depicts the spatial distribution of the level of regional digital economy in China in the form of LISA clustering maps in 2001, 2005, 2010, 2015, and 2020. The high–high clusters are significantly concentrated in Jiangsu, Shanghai, and Fujian in 2001 and 2005, moving to Heilongjiang in 2010 and Shandong, Jiangsu, Anhui, Shanghai, Zhejiang, and Fujian in 2015, and finally covering Jiangsu, Anhui, Shanghai, Jiangxi, and Zhejiang in 2020. The high–high clustering gradually moves from the eastern to the central region, indicating that the gap in the regions' digital economy development level is narrowing. This is possibly a result of the "Digital China" initiative, ICT infrastructure, and network access, which are progressively converging in the majority of China [38]. The low–low cluster was largely situated in Xinjiang and Qinghai, in the northwest of China, where the growth of the digital economy was at a low level and infrastructure was still in its infancy, with a relatively low level of digital economy development and incomplete infrastructure. In conclusion, the strong geographical autocorrelation that has developed as a result of the digital economy gives priority to the forces that drive its spatial distribution. Sichuan was where the high–low cluster was mostly found, but 2010 was an exception. Anhui and Jiangxi, the only two provinces in the low–high cluster in 2001, later transitioned into high–high clusters. There was no low–high cluster. The high–low and low–high clusters were dwindling. We observed significant changes in the spatial distribution of the level of regional digital economy across China in 2010. The 2008 financial crisis, coupled with the European debt crisis at the end of 2009, strongly affected China's economy, reduced exports and foreign direct investment, and had a great impact on employment. The eastern region has a high degree of openness to the outside world and is more susceptible to impacts such as this. At that time, the level of digital economy development was still not high enough to resist risks, and we suggest that this may have led to the development level of digital economy not playing a significant role in improving the employment structure in the eastern region.

3.2. Baseline Regression OLS

In our paper, the OLS regression model is used to validate the effect of digital economy growth on the employment structure. Table 3 displays the empirical estimation results of the model. The first column is the regression result of the model when no control variables were introduced, and columns 2–4 indicate the gradually added control variables. The R-square of the model when introducing all control variables increased from 0.827 in the first column to 0.829 in the fourth column, indicating that the fit of the model was improved after adding the control variables. As is shown, the estimated coefficients of *digit1* on *lnemployment* were significantly positive in all four regression tests, indicating that hypothesis H is proven and the growth of the digital economy has the potential to improve the employment structure. As shown in the fourth column, every 1% increase in *digit1* increases the value of the employment structure by 1.156%. The application of digital technologies such as digital instruction can improve productivity, while 3D mapping and motion capture systems can reduce worker fatigue, save time, and promote sustainable development [39]. The digital economy can have an impact on the employment structure for these reasons. In the context of specific enterprises, the decision regarding whether enterprises need to improve the employment structure through the development of the digital economy must consider the economic benefits. Practitioners or managers can consider this and make decisions about when to introduce digital technologies through decision support system assessments to maximize benefits [40].

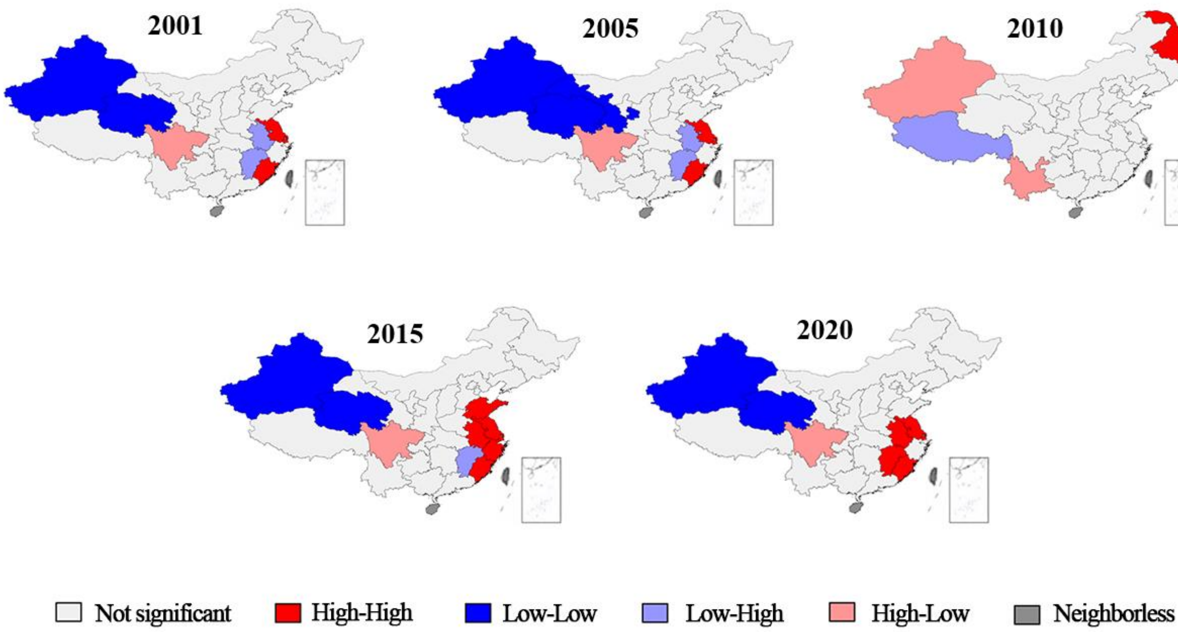

Figure 1. Spatial distribution of the level of regional digital economy across China in 2001, 2025, 2010, 2015, and 2020.

Table 3. Baseline OLS regression.

Variables	(1) *lnemployment*	(2) *lnemployment*	(3) *lnemployment*	(4) *lnemployment*
digit1	1.163 ***	1.108 ***	1.131 ***	1.156 ***
	(0.146)	(0.148)	(0.149)	(0.153)
lnpgdp		−0.122 *	−0.213 **	−0.190 *
		(0.066)	(0.092)	(0.098)
lnurban			0.207	0.186
			(0.146)	(0.149)
lngovernment				0.065
				(0.092)
Constant	4.630 ***	5.729 ***	5.790 ***	5.481 ***
	(0.031)	(0.592)	(0.593)	(0.739)
Province fixed	Yes	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes
Observations	600	600	600	600
R-squared	0.827	0.828	0.829	0.829
Number of province	30	30	30	30

Notes: ***, **, and * stand for significance levels of 1%, 5%, and 10%, respectively. Standard errors are in parentheses.

3.3. Robustness Test

We also carry out the subsequent robustness test, which is shown in Table 4, to confirm the dependability of the regression findings. We replace explanatory variable *digit1* with *digit2* for the regression test, in order to avoid measurement errors in the digital economy indicators. The differences between the columns are the same as in Table 3. Findings reveal that the digital economy's coefficient is considerable and positive at the 1% level, reconfirming the reliability of hypothesis H.

Table 4. Robustness test.

Variables	(1) lnemployment	(2) lnemployment	(3) lnemployment	(4) lnemployment
digit2	1.204 ***	1.150 ***	1.167 ***	1.181 ***
	(0.149)	(0.151)	(0.151)	(0.155)
lnpgdp		−0.133 **	−0.214 **	−0.199 **
		(0.065)	(0.092)	(0.098)
lnurban			0.184	0.170
			(0.146)	(0.149)
lngovernment				0.042
				(0.092)
Constant	4.629 ***	5.821 ***	5.880 ***	5.681 ***
	(0.031)	(0.588)	(0.590)	(0.730)
Province fixed	Yes	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes
Observations	600	600	600	600
R-squared	0.827	0.829	0.829	0.829
Number of province	30	30	30	30

Notes: *** and ** stand for significance levels of 1% and 5%, respectively. Standard errors are in parentheses.

3.4. Heterogeneity Analysis

The aforementioned regression results indicate that the growth of the digital economy is beneficial to improve the employment structure without analyzing heterogeneity. In this section, heterogeneity analysis is performed.

(1) Heterogeneity analysis: geographic location

Existing research indicates that the digital economy is geographically reliant [41]. The research samples are separated into four categories, which are the eastern, central, western, and northeastern regions. The eastern region in China includes Beijing, Tianjin, Shanghai, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan. The central region includes Shanxi Province, Henan Province, Hubei Province, Anhui Province, Hunan Province, and Jiangxi Province. The western region includes the Inner Mongolia Autonomous Region, the Xinjiang Uygur Autonomous Region, the Ningxia Hui Autonomous Region, Shaanxi Province, Gansu Province, Qinghai Province, Chongqing Municipality, Sichuan Province, the Guangxi Zhuang Autonomous Region, Guizhou Province, and Yunnan Province. Northeast China includes Heilongjiang Province, Jilin Province, and Liaoning Province. An interregional analysis is presented. Table 5 shows the individual regions' regression results.

Firstly, in terms of the impact of the digital economy on the employment structure at the regional level, the regression coefficients of the four regions are positive, indicating that the digital economy has a positive promotional effect on the improvement of the employment structure of the four major regions. The regression coefficient in the eastern region is significant at the level of 1%, the regression coefficient in the northeast region is significant at the level of 5%, and the regression coefficient in the central region and the western region does not pass the significance test. Secondly, there are also differences in the values of the regression coefficients at the regional level. Every doubling of the added value of the digital economy can promote an increase in the sum of employment in the secondary and tertiary industries (compared with the primary industry) by 53.8% in the eastern region, while this value reaches 357.1% in the northeast region. At the same time, this value reaches 357.1% in the northeast region. This shows that the digital economy has a stronger positive effect on the employment structure in Northeast China. Thirdly, in terms of the control variables at the regional level, the increase in the urbanization rate has a significant effect on the improvement in the employment structure in the eastern, central, and western regions; only in the central region does it exert a significant positive effect. In the east and west, it has a significant inhibitory effect, while the inhibitory effect on the western region is greater. Government action is only significantly promoted in the northeast.

Regarding the differences in the regional significance levels, we hold the following opinions. In the eastern region, the level of digital economy development is higher, with a rapid development speed, and more capital enters the primary industry to replace labor, resulting in high labor outflow in the primary industry. Moreover, with a solid foundation for the digital economy, the development of the digital economy in the eastern region can foster the emergence of more industries and increase employment in the tertiary sector. Therefore, the development of the digital economy in the eastern region plays the most important role in fostering the restructuring of the labor force. In the northeast region, agriculture is flourishing due to natural conditions, and the ancient industrial foundation is solid. On the one hand, the growth of the digital economy can increase agricultural productivity and decrease the labor demand in the primary sector through initiatives such as digital farm demonstration projects and the implementation of intelligent irrigation equipment. Moreover, it can promote the digital transformation of traditional industrial enterprises, absorb employment through the secondary industry, and significantly promote the development of the employment structure. However, in the central and western regions, the industrial foundation is weak, with insufficient economical infrastructure, and the level of the digital economy is low, with a low development speed. Thus, the effect on the improvement in the employment structure is not significant.

Table 5. Regional regression results.

	(1)	**(2)**	**(3)**	**(4)**
Variables	**Eastern Region**	**Central Region**	**Western Region**	**Northeast Region**
digit1	0.538 ***	0.635	0.588	3.571 **
	(0.155)	(1.266)	(0.998)	(1.735)
lnpgdp	0.087	−0.302	0.070	0.397 **
	(0.149)	(0.219)	(0.233)	(0.165)
lnurban	−0.580 ***	2.033 ***	−1.031 ***	−0.147
	(0.205)	(0.447)	(0.393)	(0.788)
lngovernment	0.091	0.524	0.147	0.636 ***
	(0.120)	(0.347)	(0.211)	(0.095)
Constant	6.463 ***	−1.266	6.695 ***	−0.016
	(1.113)	(2.568)	(2.299)	(3.706)
Province fixed	yes	yes	yes	yes
Year fixed	yes	yes	yes	yes
Observations	200	120	220	60
R-squared	0.933	0.916	0.773	0.963
Number of province	10	6	11	3

Notes: *** and ** stand for significance levels of 1% and 5%, respectively. Standard errors are in parentheses.

(2) Heterogeneity analysis: degree of marketization

China's economy has transitioned from a planned economy to a market economy. Although this change has been incremental, it has also been unequal throughout. Based on the main factor analysis method, Fan et al. [42] constructed several index dimensions, such as the relationship between the government and the market, the goods and factory markets, the development degree of the non-state-owned economy, the market's intermediary organizations, and the legal environment, and they measured the marketization degree of each province for a comparative analysis. In order to clarify whether the difference in the degree of marketization will lead to a gap in the impact of the digital economy on the employment structure, the sample is divided into two groups according to the degree of marketization by the Fan Gang index.

As shown in Table 6, it is determined that the impact of the investigated target varies between the two categories based on the degree of marketization. (The group with a low degree of marketization includes 16 provinces (Tibet, Qinghai, Gansu, Xinjiang, Ningxia, Shaanxi, Yunnan, Shanxi, Heilongjiang, Inner Mongolia, Guangxi, Hainan, Jilin, Hunan, Jiangxi), and the group with a higher degree of marketization includes 14 provinces (Hubei, Hebei, Sichuan, Henan, Anhui, Chongqing, Liaoning, Shandong, Tianjin, Beijing, Fujian, Jiangsu, Shanghai, Guangdong, Zhejiang)). It is significantly positive at the significance level of 1% in the group with a high degree of marketization, but not in the group with a low degree of marketization. The reason may be that the increase in marketization is more conducive to the free flow of factors, and the employed population is more likely to move to the secondary and tertiary industries. At the same time, the market economy attaches great importance to technological progress [43]. The higher the level of marketization, the stronger the promotion of technological advancement and innovation [31]. One of the most important characteristics of the digital economy is digital technology; in areas with a high degree of marketization, digital technology has been vigorously developed. This improves the efficiency of labor resource allocation and maximizes the contribution of the digital economy to the improvement in the employment structure.

Table 6. Regression results of different degrees of marketization.

	(1)	**(2)**
Variables	**High Degree of Marketization**	**Low Degree of Marketization**
digit1	0.941 ***	0.457
	(0.171)	(1.007)
lnpgdp	−0.152	0.090
	(0.126)	(0.176)
lnurban	0.069	0.145
	(0.197)	(0.237)
lngovernment	0.234 *	0.185
	(0.127)	(0.167)
Constant	5.574 ***	2.463
	(0.865)	(1.630)
Province fixed	yes	yes
Year fixed	yes	yes
Observations	300	300
R-squared	0.885	0.766
Number of province	15	15

Notes: *** and * stand for significance levels of 1% and 10%, respectively. Standard errors are in parentheses.

(3) Heterogeneity analysis: level of economic development

The samples are grouped based on their level of economic development to test whether their results are still significant. The degree of economic development is determined by the average per capita income level, and provinces above the median average income level are included as economically developed areas, while provinces below the median are included in the group of economically backward areas. Table 7 shows the regression results. The degree of significance and impact differ in both groups. In relatively economically developed regions, the significance level of the coefficients of each variable is higher, and the impact of the digital economy development level on the employment structure is notably positive at the 1% level, while, in the economically backward areas, it has a significant positive impact at the 5% level. However, when the level of digital economy development doubles, only 52.2% growth will occur in economically developed areas, which means that it promotes an increase in the sum of employment in the secondary and tertiary industries (compared with the primary industry) by 52.2% in the relatively economically developed region, and this change in economically backward areas will reach 166.2%.

Economically backward areas frequently have a feeble industrial base and an unbalanced structure, primarily in the primary industry, while there is a problem of surplus labor within the primary industry and a significant discharge of labor. The development of the digital economy has resulted in the creation of jobs in the secondary and tertiary sectors, which can assimilate labor effectively and enhance the employment structure. Due to the weak foundation of the digital economy, its marginal contribution to the improvement of the employment structure is greater than that of economically developed regions.

Table 7. Regression results of different degrees of economic development.

Variables	(1) Economically Relatively Developed	(2) Economically Relatively Backward
digit1	0.522 ***	1.662 **
	(0.155)	(0.685)
lnpgdp	−0.760 ***	0.275 *
	(0.143)	(0.155)
lnurban	0.458 *	0.327
	(0.243)	(0.224)
lngovernment	0.485 ***	0.306 **
	(0.121)	(0.145)
Constant	9.044 ***	−0.102
	(0.801)	(1.311)
Province fixed	yes	yes
Year fixed	yes	yes
Observations	300	300
R-squared	0.906	0.781
Number of province	15	15

Notes: ***, **, and * stand for significance levels of 1%, 5%, and 10%, respectively. Standard errors are in parentheses.

(4) Heterogeneity analysis: coastal area or not

According to whether they belonged to the coastal area, the samples were divided into two groups, coastal areas and non-coastal areas, and the heterogeneity was tested. According to the circular of the State Development Planning Commission and the State Bureau of Statistics on the division of coastal areas and inland areas, the coastal areas include 11 provinces, Liaoning, Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Guangxi, while the rest are non-coastal areas. The results in Table 8 show that distinctions between the two groups exist. In coastal areas, the impact of the digital economy on the employment structure is significant at the 1% level, while, in non-coastal areas, it is at the 10% level. At the same time, the impact of urbanization rates in coastal areas on the improvement of the employment structure differs between the two groups. One possible reason is that after the reform and opening up, the coastal areas as the frontier have a very obvious advantage in developing first. Due to the superior geographical location, convenient transportation conditions, relatively perfect infrastructure, and the changes in people's ideas and attitudes, various economic resources are prioritized in the coastal areas, and the development speed is rapid. For example, generally speaking, import and export businesses such as e-commerce in coastal areas are more developed, and the foundation of the digital economy is good.

Table 8. Regression results grouped by type of area.

Variables	(1) Coastal Area	(3) Non-Coastal Areas
digit1	0.964 ***	1.309 *
	(0.163)	(0.673)
lnpgdp	0.405 **	−0.544 **
	(0.163)	(0.223)
lnurban	−1.041 ***	0.293
	(0.225)	(0.341)

Table 8. *Cont.*

Variables	(1) Coastal Area	(3) Non-Coastal Areas
lngovernment	0.187	0.135
	(0.126)	(0.199)
Constant	4.741 ***	7.518 ***
	(1.172)	(2.277)
Province fixed	yes	yes
Year fixed	yes	yes
Observations	220	260
R-squared	0.901	0.781
Number of province	11	13

Notes: ***, **, and * stand for significance levels of 1%, 5%, and 10%, respectively. Standard errors are in parentheses.

3.5. Further Mechanism Testing

The effect of the level of digital economy development on the employment structure has been demonstrated above. More people are employed in the secondary and tertiary industries than in the primary industry, as a result of the continuous growth of the digital economy. Here, we verify the specific trajectory of the effect.

Most of the literature shows that the digital economy can promote the modernization and optimization of the industrial structure. The three basic channels of influence are as follows. Firstly, the digital economy unleashes the potential of the digital industry and optimizes the industrial structure by enriching the digital talent pool [44]. At the same time, technological progress is also a major path. Based on an empirical analysis in China, Zhao et al. [45] found that the digital economy may enhance technological progress and human capital, thereby upgrading the local industrial structure and its servitization. In addition, technological innovation is also a major carrier of this influence. By measuring industrial structure transformation and upgrading from both qualitative and quantitative dimensions, Guan et al. [46] found that the development of the digital economy has a significant positive effect on the quantity and quality of industrial structure upgrading by stimulating the level of regional innovation. Under the digital economy, innovative technologies emerge one after another and keep pace with the times, and technological improvement, innovation, and breakthrough progress are the propelling forces behind the transformation and upgrading of the industrial structure [17].

Additionally, numerous studies examine the effects of the digital economy on specific industries. For instance, the development of the digital economy will promote the improvement of factor input–output efficiency [3], the upgrading of labor-intensive, capital-intensive, and knowledge-intensive services [47], and the development of the tourism service trade [48]. In conclusion, we believe that in China, the digital economy will result in an industrial structure upgrade. In this paper, the correlation coefficient between the industrial structure and employment structure reaches 0.838 (Table S1, Supplementary Materials). Here, a model is constructed to explore the relationship between the industrial structure and employment structure. Table 9 displays the empirical estimation results. Control variables are gradually added from the first column to the fourth column. In the results of the four regressions, the coefficient of the industrial structure to the employment structure was positive at the level of 1%, demonstrating that the enhancement of the industrial structure will substantially enhance the employment structure. Therefore, we conclude that the digital economy will improve the employment structure through industrial structure upgrading.

Table 9. OLS regression on the industry and employment structure.

Variables	(1) *lnemployment*	(2) *lnemployment*	(3) *lnemployment*	(4) *lnemployment*
lnindustry	1.573 ***	1.541 ***	1.525 ***	1.575 ***
	(0.562)	(0.557)	(0.562)	(0.563)
lnpgdp		−0.217 ***	−0.232 **	−0.271 ***
		(0.067)	(0.096)	(0.101)
lnurban			0.035	0.074
			(0.153)	(0.156)
lngovernment				−0.113
				(0.094)
Constant	−3.875	−1.755	−1.658	−1.420
	(3.045)	(3.090)	(3.121)	(3.126)
Province fixed	yes	yes	yes	yes
Year fixed	yes	yes	yes	yes
Observations	600	600	600	600
R-squared	0.810	0.813	0.813	0.814
Number of province	30	30	30	30

Notes: *** and ** stand for significance levels of 1% and 5%, respectively. Standard errors are in parentheses.

4. Conclusions and Policy Implications

The digital economy has grown considerably since it was proposed in the 1990s, and it has now become the dominant economic form after the agricultural economy and the industrial economy, affecting the economy, society, and the environment. The main purpose of this paper is to study the relationship between the digital economy and employment structure, so an empirical analysis is used to test the hypothesis that "the level of digital economy development has a positive impact on the employment structure". Based on the data from 30 provinces in China from 2001 to 2020, this paper first constructs a measurement system for the development level of the digital economy and uses the entropy method to perform specific calculations. The spatial correlation is analyzed through the Moran's *I* value. The regression analysis of the impact of the digital economy on the employment structure is carried out using the OLS model, and the results also pass the robustness test. Meanwhile, a number of heterogeneity analyses and mechanism analyses further improve the research.

Several key findings emerge. First, the results demonstrate spatial autocorrelation in the development of China's digital economy, which exhibits four spatial agglomeration modes, high–high, low–low, high–low, and low–high, with high–high clusters primarily located in the eastern region and low–low clusters in the central and western regions. The digital economy is unevenly developed, but the disparity between regions is narrowing. OLS regression verifies that the development of the digital economy can effectively improve the employment structure. With the continuous improvement of the development level of the digital economy, the degree of employment in the secondary and tertiary industries has increased significantly compared with the degree of employment in the primary industry. Third, the effect of the improvement of the development level of the digital economy on the improvement of the employment structure is heterogeneous, and it is affected by the geographical location, degree of marketization, and level of economic development, as well as whether the areas is coastal. At the regional level, the impact is more pronounced in the eastern and northeastern regions than in the central and western regions. Areas with a high degree of marketization, relatively economically developed areas, and coastal areas with an improved employment structure are more likely to be affected by the development level of the digital economy. Finally, one of the essential ways in which the digital economy, with its role in enriching talent reserves, promoting technological progress, and encouraging innovation, affects the improvement of the employment structure is through the improvement of the industrial structure. Diverse industries have varying degrees of digital advancement and varying effects on the enhancement of the employment structure. Therefore, we recommend making full use of such characteristics, accelerating the digital transformation of key industries, and fostering the optimization of the employment structure.

Employment is the foundation of people's livelihoods, and it can be enhanced and optimized to foster exceptional economic growth. Given that the development of the digital economy in China is unbalanced and has an impact on the employment structure, it is necessary for the government to play a leading role and for enterprises and workers to actively cooperate to improve the employment structure with the help of the digital economy, in order to correct the imbalance in the development of the digital economy, improve the employment structure, and promote sustainable economic growth.

For the government, in order to effectively solve the problem of unbalanced development between different regions of China's digital economy and promote the development of the digital economy to improve the employment structure, it is crucial to give full play to the decisive role of the market in resource allocation, widely implementing major regional strategies, main functional area strategies, and new-type urbanization strategies, and optimizing the layout of major productive forces. It is also necessary to deepen regional cooperation and build a regional economic layout and spatial system with complementary advantages and high-quality development. We must also increase policy support for the central and western regions to further promote the development of the digital economy, and encourage economic development first for economically backward areas, while coastal areas and non-coastal areas can cooperate to promote the coordinated development of Beijing–Tianjin–Hebei, the integrated development of the Yangtze River Delta, and the integrated development of the Pearl River Delta, and to promote the coordinated development of the digital economy. In this way, the digital economy can become a new driving force for the improvement of the employment structure; accelerate the development of the digital economy; accelerate the application of 5G commercialization, big data, and artificial intelligence; and improve the infrastructure for the development of the digital economy. At the same time, the role of the industrial structure in improving the employment structure of the digital economy should be utilized. We should promote the integration of the digital economy and the real economy, create an internationally competitive digital industry cluster, and improve the digital economy's integration function for employment in order to create jobs, so as to promote high-quality full employment. We should also increase support for colleges and universities to cultivate digital talent, foster high-quality digital employees, and meet the requirements of the digital economy era for the quality of workers.

For enterprises, as the primary source of employment, they should actively respond to the development of the digital economy, increase their investment in digital innovation, enhance their digital efficiency, leverage the digital transformation, drive industrial transformation and upgrading, and contribute to the improvement of the employment structure. For colleges and universities, firstly, it is necessary to improve teachers' scientific literacy, pay attention to social needs, and update teaching content in time. Secondly, we must integrate research and teaching resources and provide convenient and sufficient learning resources for teachers and students, as well as cultivate students' innovation ability, which is necessary in the digital economy, and guide them to invent and create. For workers and college students who are seeking employment, the development of the digital economy can enhance the employment structure, while the secondary and tertiary industries have more stringent requirements for labor quality. They should take advantage of the convenient flow of knowledge and factors in the digital economy era, partake in online education and skills training to enhance their knowledge and abilities, improve their knowledge and skill levels to adapt to the employment needs in the digital economy, and achieve high-quality employment to foster sustainable development.

The findings presented in this report have some limitations. Firstly, the index of the digital economy is somewhat limited. We referred to the definition and measurement methods of the digital economy in various studies, combined with the availability of data, and constructed the digital economy index from the digital basis, digital industry, digital innovation, and digital efficiency. Secondly, some areas showed statistically insignificant results. We primarily focused on the impact of the digital economy on the structure of employment, and the employment structure was expressed by dividing the sum of the number of people employed in the secondary and tertiary sectors by the number of people in the primary sector, without focusing on the age and gender structure and educational backgrounds of employees, which are important in the employment structure. Future research should be intensified in this field. In addition, it should be noted that the specific reasons that the digital economy affects the employment structure have not yet been investigated.

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