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Does the Digital Economy Promote Upgrading the Industrial Structure of Chinese Cities?

Songqin Zhao [1], Diyun Peng [1], Huwei Wen [1,2,*] and Huilin Song [3]

1 School of Economics and Management, Nanchang University, Nanchang 330031, China
2 Research Center of the Central China for Economic and Social Development, Nanchang University, Nanchang 330031, China
3 School of International Economics and Trade, Jiangxi University of Finance and Economics, Nanchang 330013, China
* Correspondence: wenhuwei@ncu.edu.cn

Abstract: As the driving force for the upgrading of the global industrial structure, digital technology has been at the helm of transforming the current economic and technological paradigm. This study empirically analyzes the role of the digital economy in the upgrading industrial structure using panel data from 237 prefecture-level cities in China from 2011–2019. Empirical results show that the development of the digital economy has a significant positive and direct effect on the upgrading of industrial structure, as measured by the two indicators of advancement and servitization. In addition, the digital economy significantly promotes upgrading of the technological progress and human capital of Chinese cities, thus promoting upgrading of the industrial structure. Moreover, the spatial autoregressive model (SAR) and the Spatial Durbin model (SDM) both show that the digital economy has a positive spatial spillover effect on upgrading of the industrial structure.

Keywords: digital economy development; industrial structure; mediation effect model; spatial Durbin model (SDM)

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1. Introduction

Digital technologies have been embedded in every economic and social activity today; nearly all industries now use digital technology to promote production and business reform. A subsequent development is the overturning of traditional business models, which in turn reshapes management, production, and supply chains, leading to new consumption systems able to create manufacturing and service themselves. Notably, digital technology changes market demand; hence, residents can enjoy the convenience of digitalization when consuming new products and services. Improvements in supply efficiency and the resulting changes of market demand lead to changes in the industrial structure. The digital economy is therefore believed to lead to the eventual upgrading of the industrial structure, accelerating the process of industrialization and improving the level of economic service.

China is the world's largest industrial economy. However, following the international financial crisis in 2008 it has been faced with the demand for industrial structure upgrading. On one hand, the rise of factor costs has reduced the cost advantage of product production, which requires supply side industrial structure upgrading. On the other hand, increases in resident incomes have increased the market demand for services, which requires industrial structure upgrading. In addition, the realization of carbon neutrality requires the industrial structure to shift to high-value-added economic activities in order to ease and extend the value chain of products [1,2]. The digital economy provides an impetus to upgrade the industrial structure. As a country with this advantage, China urgently needs to use digital technology to upgrade said industrial structure. According to the White Paper on Global Digital Economy Development Report released by the China Academy of Information and Communications Technology, the digital economy grew from USD 0.32 trillion to

USD 6.03 trillion dollars from 2005 to 2020, accounting for 14.2–38.6%, respectively, of the country's Gross Domestic Product (GDP), with its growth rate reaching 9.6% in 2020. Furthermore, the penetration rates of the digital economy of the primary, secondary, and tertiary industries are 8.9%, 21%, and 40.7%, respectively. Therefore, China's promotion of industrial structure upgrading through the digital economy is deeply pivotal for other emerging and developing countries.

The digital economy is a new and crucial force in revolutionizing scientific and technological assets, modernizing the economic system, and providing sustainable economic and environmental development, all of which China needs to promote industrial structure reform. This can be achieved in three ways. First, digital technologies and the digital economy are primary drivers of the scientific and technological revolution, which is crucial in enhancing market competition in these areas [3,4]. Second, the digital economy promotes the construction of a modern economic system. With high innovation, strong penetration, and wide coverage, the digital economy takes data as its key production factor, and is therefore both a new economic growth point and a fulcrum that optimizes and upgrades traditional industries, thereby becoming an important engine in constructing a new economic system [5,6]. Finally, in addition to the supply side, the digital economy changes the structure of demand. For example, residents are more willing to enjoy intelligent services of industrial products, with virtual reality technology providing various new entertainment items.

Several studies have discussed the role of information technology or the digital economy in changing basic industrial process and organizational activities, improving the efficiency of resource allocation, and providing industrial structure optimization [7,8]. Other studies have examined how the digital economy affects the structural changes in primary, secondary, and tertiary industry. The existing literature mainly examines the impact of the digital economy on productivity in manufacturing, services, or other specific industries, often using a single digital economy index [9,10]. For example, studies have found that the digital economy promotes green and innovative development in the industrial economy [11,12]. Other studies discuss the spatial spillover effects of the digital economy on the industrial structure [6]. The digital economy and industrial structure both have important spatial spillover characteristics, and ignoring these may greatly reduce the policy implications of research conclusions.

Digital technology is a general-purpose technology leading the fourth industrial revolution, and is having a profound impact on industrial development and its structure. However, the relationship between technology and industry is complex. Does the digital economy lead the industrial structure to change towards the goal of social development? For example, it is arguably better able to meet the service needs of residents and increase the industrial competitiveness of developing countries. Therefore, it is necessary to reveal the laws and characteristics of the digital economy and its contribution to upgrading of the industrial structure. This study empirically investigates the impact of the digital economy on the industrial structure in China in order to discover the new path and theoretical basis of the transformation and upgrading of the industrial structure and sustainable economic development. First, in contrast with existing research, which primarily uses internet penetration, digitalization, and digital finance to stand in for the digital economy, this study constructs a comprehensive index of digital economic development from four dimensions, namely, digital industrialization, industrial digitalization, digital finance, and digital infrastructure, drawing on data from 237 prefecture-level cities in China from 2010–2019. Next, this study's research perspective focuses on both the impact of the digital economy on the upgrading of the industrial structure and on the mechanisms of technological progress and human capital upgrading. Finally, this research adopts the spatial econometric model to explore the spillover effect of the digital economy on the advancement and servitization of the industrial structure by decomposing its direct and indirect effects.

The remainder of the paper is organized as follows: Section 2 provides a brief literature review; Section 3 explains the study's theoretical analysis and research hypothesis; Section 4 presents the methodology used, including model setting, data description, and data collection; and Section 5 outlines and discusses the empirical results. The final section, Section 6, concludes and discusses policy implications.

2. Review of Related Literature

Previous studies have posited that the digital economy mainly refers to the information economy or network economy, which are respectively driven by information and communication technologies (ICT) [13]. ICT has led to relatively revolutionary developments in both the economic and societal arenas, and the network economy and digital economy both represent new economic formats gradually formed with the widespread adoption of ICT. In 1996, Tapscott first put forward the concept of the digital economy; Kim defined the digital economy as a new aspect of the economy beyond the existing traditional economic imagination, and research into the digital economy has received more and more attention [14,15]. The Organization for Economic Co-operation and Development (OECD) and the US Census Bureau and Telecommunication Technology Committee (TTC) in Japan have defined the concept of digital economy as well. Several scholars have studied the measurement of digital economy indicators in different dimensions. For example, Barefoot et al. [16] constructed a comprehensive measure of the digital economy using its contribution to GDP. Bukht and Heeks [17] developed a definition estimated from three scopes of relevance: the digital sector, its output based on digital goods and services, and the digitalized economy.

With the rapid development of the digital economy, scholars have begun to focus on exploring the economic and social dividends of the digital economy in an attempt to reveal the positive impact of digital economy on economic growth, social progress, sustainable development, and other aspects. Awad and Albaity [18] revealed that, in addition to the direct contribution of ICT to growth, ICT indirectly promotes economic growth through investment, openness, and education. Other studies have disclosed that digital technology provides a means to help the economy achieve sustainable development [19,20] as well as that digital facilities increase energy demand and pose additional challenges to sustainability [21]. The impact of ICT adoption on the economic performance of enterprises is the most widely discussed topic. Most studies have affirmed the economic benefits of ICT investment, while others studies suggest that a productivity paradox exists [22,23]. Although certain results remain controversial, most researchers believe that the digital economy promotes industrial development and economic efficiency, which is in turn reflected in one or more aspects of financial, environmental, and social performance [24].

On the adjustment of industrial structure, two main dimensions arise, namely, the internal (i.e., industrial structural optimization) and the external characteristics (i.e., industrial structural upgrading). The main method reflecting industrial structure optimization considers the deviation in the output value and employment structure of each industry along with each industry's difference in economic status [25]. As digitalization improves the efficiency of information transmission and promotes the opening of the regional economy [26], it improves the efficiency of resource allocation and promotes the optimization of industrial structure. According to Clark's law, industrial structure upgrading refers to the process of improving the industrial structure from a low level to a high one, including the advancement and servitization of industrial structure.

Studies have measured industrial structure advancement by the hierarchical coefficient of industrial structure [27,28]. Such studies involve the evolution of industrial proportional relations and the improvement of labor productivity [29], or simply use the ratio of added value to GDP in secondary industry and tertiary industry [30]. Digital technology dramatically affects the industrial structure of major industrialized countries, upgrading their industrial structure to the tertiary industry level. Studies have used the ratio of the added value in the service sector to the added value in the manufacturing sector as an indicator of this industrial structure upgrading [27,31,32].

Industrial structure is closely related to total factor productivity, energy efficiency, economic security, and green sustainable development [33–35], which is why many studies empirically examine the economic, environmental, and social effects of industrial structure. For example, Luan et al. [36] found that industrial structure adjustment can act as a positive measure to reduce energy intensity in China. The modernization of industrial structure is the premise of a country's industrial security and international competitiveness [37], and developing countries have great demand for industrial structure upgrading. Meanwhile, scholars have studied the path of optimizing and upgrading the industrial structure from different dimensions, such as the effectiveness of progress in capital-embodied technology, green innovation, and digital technologies in upgrading industrial structures [38,39]. Moreover, environmental regulation, ecological compensation, and low-carbon policies have been shown to have a positive effect on upgrading of the industrial structure [25,40,41].

Considering the wide application of digital technology in various industries, studies have investigated the relationship between digital technologies and industrial structure. Many studies have investigated the influence of digital technologies on specific industries. Park and Heo [9] comprehensively examined the impacts of ICT convergence on value chain changes in the electricity industry, focusing on changes in the value chain. Del et al. [10] revealed that ICT plays a positive role in improving the performance and overall financial stability of the banking industry. Other studies have explored the digital economy and industrial structure. For example, Kim and Park [42] examined the crucial role of the ICT industry in the global network based on Korean industry, showing the significance of emphasizing the outflow of ICT industrial knowledge to promote information with respect to other non-ICT industries. Li [43] found that technical change and internet development greatly reduced labor costs and led to industrial transformation in China. Su et al. [6] studied the process of upgrading the industrial structure by developing the digital economy, and explored the relationship between scientific and technological innovation and industrial structure upgrading.

3. Theoretical Analysis and Research Hypothesis

3.1. The Direct Impact of the Digital Economy on the Industrial Structure

The development of the digital economy is accompanied by artificial intelligence, blockchain, 5G, cloud computing, big data, and the internet of things (IoT). Its penetration of various industries has broken the limitations of time and space, resulting in reduced communication costs and expanded markets for products, along with other factors. Hence, digitalization can optimize the production process, efficiently connect all links in the industrial chain, create an intelligent economic ecosystem, and help enterprises to realize innovation in new production processes, products, and business models [44]. Manufacturers can improve their financial performance by introducing product add-on services, and consumers can enjoy better service. The digital economy therefore induces changes in the supply and demand structure, leading to upgrading of the industrial structure.

Specifically, this includes three aspects. First, digital industrialization promotes the new business models of digital industries, improves the development of service industries, and cultivates new industries based on information and communication, big data, software technologies, and more [45]. For example, the virtual reality industry can be applied in various service industries to promote productivity improvements and scale expansion. Second, industrial digitalization can be integrated with primary, secondary, and tertiary industries to improve the mechanization and informatization of primary industry, enhance the interconnection and intelligence of secondary industry, and enrich the diversification and customization of tertiary industry, thereby improving the efficiency of production, creating new requirements, and upgrading the industrial structure [34]. This not only promotes industrial economic development, it promotes the industrial extension of manufacturers to the service industry. Third, the digital economy changes the structure of market demand. In this era of the digital economy, consumers are more willing to accept the services of intelligent products, and the digital economy promotes the demand for entertainment and culture-related services. The structural change in market demand is the main driving force for the business adjustment of profit-seeking enterprises. In the digital economy era, the industrial economy spontaneously adapts to the increased market demand for services [46]. Based on these factors, we propose the following hypothesis.

Hypothesis 1 (H1). *The development of the digital economy can significantly promote the advancement and servitization of the industrial structure.*

3.2. The Mediation Effect of the Digital Economy on the Industrial Structure

The digital economy can expand the enterprise boundary by making it easier to exchange knowledge and information inwards and outwards and to acquire, share, and create new knowledge and information. This is advantageous in promoting innovation and improving efficiency. As a result, innovation can promote the transformation and upgrading of all links in the industrial chain and then motivate industry to achieve leapfrog upgrading [47,48]. Technological progress is the continuous driving force of industrial structure upgrading [49,50]. It is important both to improve the economic and environmental performance of industry and to promote the development of economic services through productivity improvements. Moreover, data (as the new factor) can reshape the traditional factors and improve the efficiency of resource allocation, leading the digital economy to increase the capacity of human capital to enjoy the upgrading of industrial structure by improving the matching degree of employment skills and industrial technology [51]. The development of the digital economy therefore improves the return on human capital, thus attracting more highly skilled talent, and the cycle repeats. Based on these factors, we propose the following hypothesis.

Hypothesis 2 (H2). *The digital economy promotes industrial structure upgrading through the intermediary mechanism of technological progress and human capital upgrading.*

3.3. The Spatial Spillover of the Digital Economy on the Industrial Structure

According to Zhao et al. [52], the upgrading of the industrial structure has significant spatial spillover effects. The digital economy weakens the space and time constraints of information transmission and expands the effective circulation of data elements, which in turn strengthens the depth and breadth of coordinated economic development between regions. With the digitalization of industry, enterprises in the industrial chain can share knowledge, the convenience of technology and management is improved, and cooperation between the upstream and downstream industrial chains among regions can be strengthened [19]. In addition, digital finance can meet the demands of consumers and enterprises in different regions, promoting the flow and sharing of elements between regions by foregoing geophysical limitations, thus improving the effect of resource allocation and upgrading the industrial structure between regions [53]. Furthermore, the development of digital finance is conducive to increasing e-commerce and enhancing the level of tertiary industry. The digital economy has intensified competition among regions. It has a network effect, which may cause high-end industries to gather in developed areas. Based on this premise, we propose the following hypothesis.

Hypothesis 3 (H3). *The development of the digital economy has a special spillover effect on industrial structure upgrading.*

4. Model Setting and Data Description

4.1. Model Setting

4.1.1. Panel Data Model

To test the relationship between the development of the digital economy and the industrial structure, this paper adopted Ordinary Least Squares (OLS) with clustering robust standard deviation under time and individual dual fixed effects, expressed herein as Equation (1):

$$lnIndustry\_str_{i,t} = \alpha_0 + \alpha_1 lnDigital_{i,t} + \alpha_m lnX_{i,t} + \eta_t + \mu_i + \varepsilon_{i,t} \tag{1}$$

where i and t represent prefectural-level cities and time, respectively; *lnIndustry_str* is the dependent variable, which was measured from two dimensions, the advancement of industrial structure (*lnIndustry_gh*) and the servitization of industrial structure (*lnIndustry_ser*); *lnDigital* is the digital economy development index; X is a series of control variables; η_t is a time fixed effect; u_i is an individual fixed effect; ε_{it} is a random perturbation term; and α_1 and α_m are the coefficients to be estimated. In order to control for the heteroscedasticity and multicollinearity of the model, this study used the natural logarithmic form for all the explanatory variables.

4.1.2. Mediation Effect Model

The digital economy may affect the industrial structure through technological progress and human capital. To study the potential indirect impacts of the digital economy on the advancement and servitization of the industrial structure, we adopted the mediation effect model to carry out further empirical investigation:

$$lnMediation_{i,t} = b_0 + b_1 lnDigital_{i,t} + \alpha_m lnX_{i,t} + \eta_t + \mu_i + \varepsilon_{i,t} \tag{2}$$

$$lnIndustry\_str_{i,t} = c_0 + c_1 lnDigital_{i,t} + \lambda lnMediation_{i,t} + \alpha_m lnX_{i,t} + \eta_t + \mu_i + \varepsilon_{i,t} \tag{3}$$

where *lnMediation* represents the mediation variables, including the technological progress (*lnRD*) and human capital (*lnHR*), and b_1 represents the effect of the digital economy on mediation variables. Among the mediating variables, c_1 represents the direct effect of the digital economy on the industrial structure, λ represents the effect of mediating variables on the industrial structure, b_0, c_0 represents the coefficient constant, and the other variables are the same as in Equation (1).

4.1.3. Spatial Econometric Model

We selected Moran's I index to test the spatial autocorrelation before conducting our empirical analysis. The formula for Moran's I is as follows:

$$Moran's\ I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(y_i - \overline{Y}\right)\left(y_i - \overline{Y}\right)}{\sum_{i=1}^{n}\left(y_i - \overline{Y}\right)^2} = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(y_i - \overline{Y}\right)\left(y_i - \overline{Y}\right)}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{4}$$

where $S^2 = \sum_{i=1}^{n}\left(y_i - \overline{Y}\right)^2$ and $\overline{Y} = \frac{1}{n}\sum_{i=1}^{n} y_i$.

We tested the spatial correlation between cities using the local Moran's I, for which the formula is as follows: $I_i = z_i \times \sum_{j=1}^{n} w_{ij} z_j$, where $z_i = y_i - \overline{Y}$ and $z_j = y_j - \overline{Y}$ are the deviation between the observed value and the mean, respectively.

The industrial structure and development of the digital economy in China show spatial correlation characteristics [52,54]. This paper adopted the spatial econometric model to study the relationship between the digital economy and industrial structure. However, the approach of the main spatial econometric models to the applicable objects is quite different. The main spatial econometric models include a spatial autoregressive model (SAR), a spatial error model (SEM), and a spatial Durbin model (SDM). Elhorst [55] found that spatial interaction effects must be analyzed before building a spatial econometric model.

A spatial autoregressive model (SAR) is mainly used to analyze whether the explained variable has a spatial spillover effect after involving the spatial lag variable of the explained variable. This model is expressed below:

$$lnIndustry\_str_{i,t} = \alpha_0 + \rho \sum_{j=1}^{N} W_{ij} lnIndustry\_str_{i,t} + \beta_1 lnDigital_{i,t} + \delta_i X_{i,t} + \mu_i + \varepsilon_{i,t} \quad (5)$$

where i and t represent prefecture-level cities and time, respectively; *lnIndustry_str* is the dependent variable; *lnDigital* represents the explanatory variable for digital economy development; X is a series of control variables; ρ is the spatial spillover coefficient of the industrial structure; α_0, β_1, and δ_i are series of coefficients; μ_i is a city fixed effect; ε_{it} is a random perturbation term; and W_{ij} is an $N \times N$ order spatial weight matrix.

The Spatial Error Model (SEM) mainly analyzes the spatial effects of missing variables or unobservable random shocks (Yang et al., 2018). The SEM model is constructed as follows:

$$lnIndustry_{stri,t} = \alpha_0 + \beta_1 lnDigital_{i,t} + \delta_i X_{i,t} + u_{i,t} \quad (6)$$

$$u_{i,t} = \lambda \sum_{j=1}^{N} W_{ij} u_{i,t} + \varepsilon_{i,t} \quad (7)$$

where λ is the spatial error coefficient.

The SDM is a synthesis between the aSAR model and SEM, with more general results in practical applications. The SDM includes both endogenous and exogenous interaction effects, with each controlling the spatial effects of the explanatory variables, which makes the parameter estimation results more robust. We constructed the SDM as follows:

$$\begin{gathered} lnIndustry\_str_{i,t} = \alpha_0 + \rho_1 \sum_{j=1}^{N} W_{ij} lnIndustry\_str_{i,t} + \beta_1 lnDigital_{i,t} + \rho_2 \sum_{j=1}^{N} W_{ij} lnDigital_{i,t} + \sigma_i X_{i,t} + \\ \rho_i \sum_{j=1}^{N} W_{ij} X_{i,t} + \mu_i + \varepsilon_{i,t} \end{gathered} \quad (8)$$

where i and t represent prefecture-level cities and time, respectively; *lnIndustry_str* is the dependent variable; *lnDigital* represents the explanatory variable for digital economy development; X is a series of control variables; and ρ is a series of the SAR coefficient. Other variables are similar, as explained above.

In this study, a 0–1 rook spatial weight matrix and inverse distance geographic matrix were used to measure the spatial spillover effect. The 0–1 rook spatial weight matrix (W_1) is defined as $W_{i,j} = \begin{cases} 1,\ i \neq j \\ 0, i = j \end{cases}$, where prefecture-level city i has a common boundary with city j. Then, W_{ij} = 1; otherwise, W_{ij} = 0. The inverse distance geographic matrix (W_2) is defined as $W_{ij} = \begin{cases} \frac{1}{d_{ij}},\ i \neq j \\ 0, i = j \end{cases}$, where d_{ij} is the surface distance of the prefectural-level city as calculated by its latitude and longitude.

4.2. Data Description

4.2.1. Industrial Structure

Following Gong et al. [56], we constructed an industrial structure advancement indicator that reveals both the shift trend from primary industry to secondary and tertiary industry and the change trend from secondary to tertiary industry. The detailed measurement of industrial structure advancement (*Industry_gh*) was conducted as follows:

$$Industry\_gh_{i,j,t} = \sqrt{(q_{i,2,t} + q_{i,3,t})\left(q_{i,2,t} + \frac{q_{i,3,t}}{q_{i,1,t} + q_{i,2,t}}\right)} \quad (9)$$

here, j = 1, 2, 3 and $q_{i,j,t}$ represents the ratio of the output value of different industry levels to the regional GDP, with $q_{i,1,t} + q_{i,2,t} + q_{i,3,t} = 1$.

Referring to the servitization of the industrial structure according to Zheng et al. [27], we measured this indicator through the ratio of tertiary to secondary industry, $Industry\_ser_{i,t} = q_{i,3,t} / q_{i,2,t}$.

4.2.2. Comprehensive Digital Economy Development

Digital economy development (*lnDigital*) is a new and relatively complex systematic concept. Therefore, a single simple indicator such as internet development cannot sufficiently reflect the development of China's actual digital economy. Thus, we built a comprehensive indicator system to reflect the current level of China's digital economy development in combination with the development of digital finance [28] (see Table 1). The present study uses an objective weighting method to accurately estimate objects based on the information entropy principle, and uses time variables for a reasonable analysis of the digital economy index.

Table 1. Evaluation system of digital economy comprehensive index.

Target Level	Standard Level	Index Level	Index Interpretation
Comprehensive digital economy index	Digital infrastructure	Mobile infrastructure	Total number of mobile phones
		Internet infrastructure	Total number of internet users
	Digital industrialization	Employment of digital industries	Employees in information transmission, software, and information technology
		Business scale of digital industries	Total sales value of telecom service
	Industry digitalization	The market of digital business	Total value of e-commerce sales
	Digital finance	The coverage of digital finance	The coverage breadth of digital finance
		The usage depth of digital finance	The index of payment, credit, insurance, credit, investment, and money funds.
		The digitization in finance	The digitization level of digital finance

4.2.3. Mediating Variables

We selected both technological progress (*lnRD*) and human capital (*lnHR*) as moderating variables. Using investment in research and development as a proxy for technological progress, technological progress was found to improve resource utilization and production efficiency, thus affecting the upgrading of the industrial structure [6]. Modelled as the number of university students per 10,000 people in the region [57], human capital (*lnHR*) significantly improved the use of resource elements, enhanced capacity for technological absorption, and even promoted upgrading of the industrial structure [5].

4.2.4. Control Variables and Data Sources

To minimize errors in the regression results from the omission of variables, the following control variables were selected for the models. Economic development (*lnGDP*) was expressed as the growth speed of regional GDP. Foreign direct investment (*lnFDI*) stimulates the upgrading of industrial structure in local industries by bringing in new capital and advanced technologies. The cities' public finance budget expenditure (*lnGovernment*), total fixed assets invested (*lnInvestment*), deposits from residents (*lnFinance*), and the proportion of the urban population with respect to the local permanent population (*lnURB*) all promote changes to the industrial structure [58].

All data for these indicators were from the following sources: the China Environmental Statistical Yearbook, Statistical Report on China's Internet Development Status, China Financial Statistics Yearbook, China Statistical Yearbook on Science and Technology, and the National Bureau of Statistics. Relevant missing data were filled in by interpolation. Table 2 presents the descriptive statistics for the variables used in this study. The LLC test is the panel unit root test, and certain variables report the results of the trend unit root test as well. This shows that the results of the panel unit-root test (LLC Test) reject the null hypothesis at the 1% significance level, indicating that these variables are stationary or trend stationary.

Table 2. Descriptive statistics.

Variables	S.D.	Mean	Min	Max	Correlation1	Correlation2	LLC Test
lnIndustry_gh	0.144	0.025	−0.550	0.826	1.000	-	−2.087 ***
lnIndustry_ser	0.464	−0.141	−1.743	1.643	-	1.000	−6.492 ***
lnDigital	0.559	−2.607	−4.437	−0.388	0.632 ***	0.566 ***	−12.974 ***
lnGDP	0.933	7.426	5.231	10.549	0.570 ***	0.198 ***	−4.098 ***
lnFDI	2.012	10.058	0.000	14.705	0.418 ***	0.083 ***	−18.698 ***
lnGovernment	0.772	14.900	12.031	18.241	0.530 ***	0.390 ***	−9.306 ***
lnFinance	2.522	8.277	5.309	20.495	0.419 ***	0.381 ***	−5.445 ***
lnInvestment	0.914	7.151	2.732	9.792	0.509 ***	0.173 ***	−36.912 ***
lnURB	0.280	3.977	0.311	5.929	0.523 ***	0.206 ***	−13.959 ***
lnRD	1.412	1.242	−2.622	6.775	0.581 ***	0.228 ***	−7.193 ***
lnHR	1.000	4.756	0.737	7.147	0.462 ***	0.163 ***	−37.382 ***

Note: *** indicates significance at 1% level. Correlation refers to the correlation coefficients between industrial structure and other variables.

5. Empirical Results and Discussion

5.1. Estimated Results of Baseline Regression

To make the results more comparable, columns (1) and (3) list the results of the panel model under city fixed effect, while columns (2) and (4) show the results of the panel model under time and city fixed effects. According to Table 3, the results of the Hausman test are significant at the 5% and 1% level, while the likelihood ratio (LR) test results are all significant at the 1% level, which means that the results can be regressed with clustering robust standard deviation under time and city fixed effects.

Table 3. The direct impact of digital economy development on industrial structure.

Variables	(1)	(2)	(3)	(4)
	lnIndustry_gh	*lnIndustry_gh*	*lnIndustry_ser*	*lnIndustry_ser*
lnDigital	0.015 ** (0.007)	0.019 ** (0.008)	0.211 *** (0.037)	0.127 *** (0.027)
lnGDP	0.226 *** (0.036)	0.143 *** (0.041)	0.803 *** (0.281)	0.313 (0.333)
lnFDI	0.001 (0.002)	0.003 (0.002)	0.000 (0.008)	0.012 * (0.006)
lnGovernment	0.035 *** (0.009)	0.012 (0.009)	0.226 *** (0.064)	0.054 (0.068)
lnFinance	0.001 * (0.000)	−0.001 (0.001)	−0.000 (0.002)	−0.009 *** (0.003)
lnInvestment	0.003 (0.007)	0.013 * (0.007)	0.014 (0.022)	0.033 (0.022)
lnURB	0.043 (0.028)	0.028 (0.021)	0.185 (0.143)	0.086 (0.084)
Hausman test		15.82 **		147.81 ***
LR test		336.95 ***		510.91 ***
City fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	No	Yes	No	Yes
R-squared	0.735	0.774	0.823	0.861
Observations	2133	2133	2133	2133

Note: The prefix "*ln*" before the explanatory variables denotes a logarithmic form. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Figures in () are standard errors.

Empirical results show that the direct effect of digital economy development on the advancement of industrial structure is significantly positive at the 5% level, while the direct effect on the servitization of the industrial structure is significant at the 1% level. This indicates that the development of the digital economy can promote the three levels of industry (primary, secondary, and tertiary), enhancing the advancement and servitization of the industrial structure and thereby proving the first hypothesis. Two reasons can explain these findings: first, the integration of digital technologies occurs mainly in secondary and tertiary industry; for example, in 2020, digital industrialization and industrial digitization accounted for 7.3% and 31.2% of GDP, respectively, with the ratio even reaching 40.7% for the service industry. Second, the existence of many new models and forms of business emerging in the consumption and service sectors breaks space and time limitations, promoting the development of a new service industry and the servitization of digital industry.

Moreover, the regression results of other factors basically meet the theoretical expectations. With economic development (*lnGDP*) and investment (*lnInvestment*) having positive effects on the upgrading of the industrial structure, the newly increased economic activity in Chinese cities mainly comes from advanced or service-oriented industries. Foreign direct investment (*lnFDI*) can stimulate enhancement of servitization in the industrial structure. However, higher deposits from residents (*lnFinance*) leads to reduced spending, which hinders the development of tertiary industry. The impact of urbanization on industrial structure remains uncertain.

5.2. Estimated Results of the Mediation Effect Model

Table 4 reports the estimation results of the mediation effect model using technological progress (*lnRD*) and human capital upgrading (*lnHR*) as mediation variables. Columns (1) to (3) use technological progress as the mediation variable, while columns (4) to (6) use human capital upgrading. Columns (1) and (4) show that the effect coefficients of the digital economy on technological progress (0.109) and human capital upgrading (0.165) are significantly positive, indicating that the digital economy can promote technological progress and enhance human capital levels.

Table 4. Estimated results of mediation effect.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	lnRD	***lnIndustry_gh***	***lnIndustry_ser***	***lnHR***	***lnIndustry_gh***	***lnIndustry_ser***
lnDigital	0.109 ** (0.046)	0.087 *** (0.007)	0.152 *** (0.012)	0.165 *** (0.059)	0.086 *** (0.007)	0.151 *** (0.012)
lnGDP	0.017 (0.098)	0.142 *** (0.015)	1.402 *** (0.025)	0.850 *** (0.126)	0.121 *** (0.015)	1.384 *** (0.025)
lnFDI	0.156 *** −0.011	−0.001 (0.002)	−0.000 (0.003)	0.063 *** (0.014)	0.001 (0.002)	0.002 (0.003)
lnGovernment	0.682 *** (0.056)	−0.071 *** (0.009)	0.020 (0.015)	−0.577 *** (0.072)	−0.038 *** (0.008)	0.047 *** (0.015)
lnFinance	0.003 (0.007)	0.002 ** (0.001)	0.000 (0.002)	0.007 (0.009)	0.002 ** (0.001)	0.001 (0.002)
lnInvestment	0.070 * (0.039)	0.006 (0.006)	0.022 ** (0.010)	0.214 *** (0.051)	0.003 (0.006)	0.019 * (0.010)
lnURB	0.588 *** (0.068)	0.095 *** (0.010)	0.142 *** (0.018)	0.453 *** (0.087)	0.099 *** (0.010)	0.146 *** (0.017)
lnRD		0.027 *** (0.003)	0.022 *** (0.006)			
lnHR					0.025 *** (0.002)	0.021 *** (0.004)
Indirect effect		0.003 ** (0.001)	0.002 ** (0.001)		0.004 *** (0.002)	0.004 ** (0.001)
Sobel_z value		2.273	2.021		2.676	2.422
Observations	2133	2133	2133	2133	2133	2133
Adjust R-squared	0.779	0.527	0.866	0.268	0.535	0.866

Note: The prefix "*ln*" before the explanatory variables denotes a logarithmic form. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Figures in () are robust standard errors.

It is evident from columns (2) and (5) that the regression coefficients for the relationship between technological progress, human capital level, and advancement of the industrial structure are all significantly positive at the 1% level, at 0.087 and 0.086, respectively. These results pass the Sobel test, indicating that the digital economy can positively upgrade the industrial structure by promoting technological progress and human capital levels. In light of these results, we can see that the indirect effects of the digital economy on industrial structure advancement through technological progress and human capital level are significantly positive, at 0.003 and 0.004, respectively.

Columns (3) and (6) show that the impact coefficients of technological progress and human capital level between the servitization of industrial structure are all significantly positive at the 1% level, at 0.152 and 0.151, respectively. These results pass the Sobel test as well, with T-values of 2.021 and 2.422, respectively. This indicates that the digital economy can positively promote the development of the industrial structure servitization by promoting technological progress and human capital level. Hence, the servitization of the industrial structure is indirectly enhanced by the digital economy, with values of 0.002 and 0.004, respectively.

The two possible reasons for the above-mentioned results are as follows. First, the digital economy can allow entrepreneurs to more conveniently obtain innovative resources, greatly improving innovation efficiency [6]. Digital technology can be applied to new industries, such as new chips, basic software, intelligent hardware, etc., to promote industrial modernization [39]. The digital economy can integrate with traditional industries, promote the intelligent development of traditional industries, and push enterprises to manufacture products for consumers and provide full life-cycle services. Moreover, as digitalization needs highly educated and skilled labor, human capital improves through increased sharing of knowledge among platforms and easier access to knowledge, improving management and technological progress and promoting the advancement of the industrial structure. Nevertheless, the digital economy may lead to wage polarization and income inequality, which decreases its potential to increase industrial efficiency and impedes upgrading of the industrial structure [59].

5.3. Estimated Results of the Spatial Durbin Model

5.3.1. Spatial Correlation Test

In this study, Moran's I index is used to evaluate the spatial correlation of industrial structure in various Chinese regions. Table 5 shows that the global Moran's I index values for the advancement of industrial structure (*lnIndustry_gh*), the servitization of industrial structure (*lnIndustry_ser*), and digital economy development (*lnDigital*) from 2011–2019 are significantly positive at the 1% level. The null hypothesis of no spatial autocorrelation is significant; therefore, China's industrial structure and digital economy development have significant spatial autocorrelation, and conducting spatial econometric analysis is appropriate.

Table 5. Moran's index for industrial structure and digital economy development.

	lnDigital			*lnIndustry_gh*			*lnIndustry_ser*		
Time	**I**	**z**	***p*-Value**	**I**	**z**	***p*-Value**	**I**	**z**	***p*-Value**
2011	0.253	5.943	0.000	0.323	7.556	0.000	0.133	3.164	0.001
2012	0.216	5.095	0.000	0.335	7.823	0.000	0.140	3.308	0.000
2013	0.184	4.381	0.000	0.329	7.678	0.000	0.154	3.638	0.000
2014	0.191	4.557	0.000	0.323	7.55	0.000	0.205	4815	0.000
2015	0.162	3.886	0.000	0.327	7.647	0.000	0.243	5.686	0.000
2016	0.145	3.505	0.000	0.309	7.233	0.000	0.231	5.406	0.000
2017	0.136	3.274	0.001	0.304	7.116	0.000	0.209	4.906	0.000
2018	0.117	2.819	0.002	0.271	6.361	0.000	0.197	4.615	0.000
2019	0.190	4.470	0.000	0.221	5.211	0.000	0.180	4.239	0.000

5.3.2. Model Selection Test

Table 6 shows the diagnostic test results for the spatial econometric model under the 0–1 rook spatial weight matrix (W_1) and the inverse distance geographic matrix (W_2). For advancement of the industrial structure, the value of the Lagrange multiplier (LM) test, robust Lagrange multiplier (LM) test, and Wald test are all positive. Therefore, the choice of the spatial Durbin model is reasonable. Meanwhile, for the servitization of the industrial structure, we found that the values for the robust LM (lag) test are insignificant. Hence, we report the results for the SAR model instead.

Table 6. Diagnostic test results for spatial model.

Test	*lnIndustry_gh* (under W_1)		*lnIndustry_gh* (under W_2)		*lnIndustry_ser* (under W_1)		*lnIndustry_ser* (under W_2)	
	Value	*p*-Value	Value	*p*-Value	Value	*p*-Value	Value	*p*-Value
LM (error) test	33.548	0.000	28.535	0.000	11.975	0.001	24.425	0.000
Robust LM (error) test	21.049	0.000	3.255	0.071	10.470	0.001	17.780	0.000
LM (lag) test	15.333	0.000	28.656	0.000	1.545	0.214	8.207	0.004
Robust LM (lag) test	2.833	0.092	3.272	0.066	0.040	0.842	0.562	0.454
Wald test spatial lag	47.290	0.000	82.800	0.000	168.960	0.000	176.870	0.000
Wald test spatial error	90.560	0.000	38.390	0.000	104.930	0.000	166.230	0.000

5.3.3. Spatial Effect Estimation Results

Table 7 reports the estimation results of the spatial econometric models. Columns (1) and (2) report the estimation results of the digital economy on advancement of the industrial structure based on SAR under W_1 and W_2. The regression coefficients all are positive, with 0.011 at the 5% level. Columns (3) and (4) show the results of servitization of the industrial structure based on SDM under W_1 and W_2. Evidently, the coefficients are all positive, at 0.140 and 0.105 at the 1% level. These results are consistent with the estimated coefficients for the basic models in Table 3, showing the robustness of our spatial econometric models. This indicates that the development of the digital economy can significantly upgrade the industrial structure.

Table 7. Estimation results of spatial econometric models.

Variables	*lnIndustry_gh*		*lnIndustry_ser*	
	(1) W_1	**(2) W_2**	**(3) W_1**	**(4) W_2**
lnDigital	0.011 ** (0.005)	0.011 ** (0.005)	0.140 *** (0.013)	0.105 *** (0.013)
lnGDP	0.167 *** (0.012)	0.135 *** (0.012)	0.581 *** (0.038)	0.311 *** (0.039)
lnFDI	0.001 (0.001)	0.002 *** (0.001)	0.001 (0.003)	0.010 *** (0.003)
lnGovernment	0.026 *** (0.006)	0.017 *** (0.006)	0.155 *** (0.020)	0.061 *** (0.020)
lnFinance	0.002 *** (0.001)	0.000 (0.001)	−0.002 ** (0.001)	−0.009 *** (0.001)
lnInvestment	0.000 (0.003)	0.007 ** (0.003)	0.010 (0.010)	0.024 ** (0.010)
lnURB	0.035 *** (0.005)	0.029 *** (0.005)	0.138 *** (0.019)	0.089 *** (0.018)
lnRD	0.006 *** (0.002)	0.006 *** (0.002)	0.012 ** (0.006)	0.018 *** (0.006)
lnHR	0.001 (0.001)	0.003 * (0.001)	−0.010 ** (0.005)	0.003 (0.004)

Table 7. *Cont.*

Variables	***lnIndustry_gh***		***lnIndustry_ser***	
	(1) W_1	**(2) W_2**	**(3) W_1**	**(4) W_2**
rho	0.378 *** (0.024)	0.831 *** (0.051)	0.354 *** (0.018)	0.783 *** (0.030)
sigma2_e	0.001 *** (0.000)	0.010 *** (0.000)	0.010 *** (0.000)	0.010 *** (0.000)
Observations	2133	2133	2133	2133
R-squared	0.150	0.419	0.515	0.229
Number of cities	237	237	237	237

Note: The prefix "*ln*" before the explanatory variables denotes a logarithmic form. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Figures in () are standard errors.

To further analyze the effect of digital economy development on regional industrial structure, this paper deconstructs the impact of the digital economy on industrial structure into both direct and spillover effects under W_1 and W_2 based on SDM for advancement of the industrial structure and SAR for servitization of the industrial structure, shown in Table 8. Looking at the results of columns (1) and (2), the coefficients of the direct effect of the digital economy on the advancement of the industrial structure are significantly positive at 0.010. However, the coefficients of the indirect effect are all negative, at −0.017 and −0.156; despite its under W_1, it not significant under W_2. It is evident that while the development of the digital economy can upgrade the industrial structure of local regions, it impedes upgrading of the industrial structure in neighboring regions. In columns (3) and (4), the coefficients of the direct and indirect effect based on SAR under W_1 and W_2 are all significantly positive at the 1% level. This indicates that the development of the digital economy can enhance the level of industrial structure servitization in both local and neighboring regions.

Table 8. Estimation results of decomposition effects.

Effect	***lnIndustry_gh***		***lnIndustry_ser***	
	(1) W_1	**(2) W_2**	**(3) W_1**	**(4) W_2**
Direct effect	0.010 * (0.005)	0.010 ** (0.005)	0.144 *** (0.014)	0.107 *** (0.013)
Indirect effect	−0.017 * (0.009)	−0.156 (0.119)	0.071 *** (0.007)	0.385 *** (0.069)
Total effect	−0.007 (0.009)	−0.146 (0.119)	0.215 *** (0.019)	0.491 *** (0.074)

Note: The prefix "*ln*" before the explanatory variables denotes a logarithmic form. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Figures in () are standard errors.

In essence, the development of the digital economy promotes the advancement and servitization of the industrial structure in local regions and enhances the servitization of the industrial structure of neighboring ones. However, it hinders upgrading of the industrial structure in neighboring regions. This can be explained by the following reasons. First, the development of the digital economy can promote the development of technological progress and human capital, which upgrades the industrial structure and enhances the servitization of the industrial structure in local regions. Next, the digital economy can strengthen the advantages of the local industrial structure, which promotes further upgrading within the local industrial structure from labor-intensive and capital-intensive industries to technology-intensive and green-intensive ones. Hence, it impedes upgrading of the industrial structure of neighboring regions. Third, the development of digital servitization gives rise to new business models, which both enriches the variety of tertiary industries and expands the scope of service, bringing an increasing level of tertiary industry to both local and neighboring areas.

5.4. Estimated Results of Robustness Analysis

The 2SLS method is a feasible method for solving problems related to endogenous explanatory variables [60]. As the lagged terms of the independent variables satisfy the exogeneity and correlation conditions, they are usually selected as instrumental variables. In this study, we chose the first-order lag term of the development of digital economy as the instrumental variable. In order to avoid measurement deviation in the digital economy indicators, we adopted broadband infrastructure as a proxy variable for the digital economy. According to Zhou et al. [61], broadband is a modern infrastructure serving the digital economy. In 2014, China officially selected pilot cities to implement China's broadband strategy and increase their construction of broadband infrastructure. This paper defines these pilot cities as the treatment group, other non-pilot cities as the control group, and uses the difference-in-differences (DID) design to evaluate the causal relationship between the digital economy and industrial structure.

Finally, from the perspective of the three major industries, the upgrading of industrial structure means that the proportion of primary industry continues to decline, the proportion of secondary industry first rises then subsequently falls, and the proportion of tertiary industry continues to rise. To avoid the influence of deviation in the index measures on our estimation results, we refer to Zheng [27] in replacing the calculation method for the industrial structure in our robustness test. This study calculates the industrial structure, expressed as $Industry\_ser_1 = q_1 \times 1 + q_2 \times 2 + q_3 \times 3$, where q_i represents the ratio of output value of different industry to the regional GDP, $i = 1,\ 2,\ 3$.

Table 9 presents the results of the linear regressions. Columns (1) and (3) report the results of the advancement and servitization of industrial structure under 2SLS, showing that the coefficients are all significantly positive, at 0.240 and 0.265 at the 1% level. Columns (2) and (4) report the results of DID estimation, showing that the Broadband City strategy significantly upgrades the industrial structure and promotes servitization at the 1% level, reconfirming the reliability of our findings. Columns (5) and (6) report the results of OLS without control variables, while columns (7) and (8) show the results of OLS with control variables. As the results of the Hausman and LR tests are all significant at the 1% level, this study adopts the Ordinary Least Squares (OLS) with clustering robust standard deviation under time and individual dual fixed effects in columns (6) and (8). It is clear that the coefficients of digital economy on upgrading of the industrial structure are significantly positive, at 0.018 and 0.021 at the 1% level. This indicates the robustness of positive effect of digital economy on upgrading industrial structure.

Moreover, Table 10 reports the results of the robustness test of the mediation effect with technological progress and human capital, showing that the coefficients of the mediation effects are at 0.001 and 0.001 at the 1% level of significance. The robustness results of the spatial effect are shown in Table 11, showing that the direct effects are significant at 0.012 and 0.013 under W_1 and W_2. However, the indirect effects are significantly negative at -0.008 and -0.193, respectively. Therefore, these results indicate that while the development of the digital economy can upgrade the industrial structure in local regions by prompting technological progress and human capital, it impedes the same development in neighboring regions. This matches the results in Tables 4 and 8, demonstrating the robustness of the mediation effect and spatial effect between the digital economy and upgrading of the industrial structure.

Table 9. Robustness test of linear regression.

Variables	*lnIndustry_gh*		*lnIndustry_ser*		*lnIndustry_ser1*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lnDigital	0.016 *** (0.005)	0.240 *** (0.020)	0.124 *** (0.028)	0.265 *** (0.053)	0.052 *** (0.001)	0.018 *** (0.004)	0.020 *** (0.003)	0.021 *** (0.003)
lnGDP	0.055 ** (0.026)	0.083 *** (0.030)	−0.397 ** (0.159)	1.312 *** (0.138)			0.090 *** (0.018)	0.043 ** (0.019)
lnFDI	−0.003 (0.003)	0.001 (0.002)	−0.031 *** (0.012)	0.003 (0.006)			0.001 (0.001)	0.002 * (0.001)
lnGov	0.087 *** (0.023)	−0.072 *** (0.013)	0.697 *** (0.148)	0.018 (0.046)			0.015 *** (0.005)	0.000 (0.004)
lnFin	0.004 *** (0.001)	−0.001 (0.002)	0.021 *** (0.003)	0.001 (0.002)			−0.001 (0.001)	−0.001 *** (0.001)
lnInvest	0.003 (0.008)	0.034 *** (0.008)	0.015 (0.049)	0.034 ** (0.017)			0.003 (0.003)	0.007 *** (0.003)
lnURB	0.059 * (0.032)	0.080 *** (0.020)	0.340 * (0.186)	0.127 *** (0.029)			0.022 * (0.013)	0.013 (0.008)
Constant	−1.938 *** (0.161)	0.843 *** (0.222)	−8.919 *** (0.992)	−1.267 *** (0.347)	0.963 *** (0.003)	0.858 *** (0.014)	0.375 *** (0.084)	0.759 *** (0.090)
City fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2133	1896	2133	1896	2133	2133	2133	2133
R-squared	0.650	0.529	0.588	0.862	0.674	0.779	0.765	0.810

Note: The prefix "*ln*" before the explanatory variables denotes a logarithmic form. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Figures in () are standard errors.

Table 10. Robustness test of mediation effect.

Variables	(1)	(2)	(4)	(5)
	lnRD	*lnIndustry_ser*$_1$	*lnHR*	*lnIndustry_ser*$_1$
lnDigital	0.109 ** (0.046)	0.041 *** (0.003)	0.165 *** (0.059)	0.041 *** (0.003)
lnRD		0.011 *** (0.001)		
lnHR				0.009 *** (0.001)
Constant	−15.398 *** (0.777)	0.939 *** (0.052)	5.766 *** (1.000)	0.719 *** (0.048)
Indirect effect		0.001 ** (0.001)		0.001 *** (0.001)
Sobel_z value		2.275		2.634
Observations	2133	2133	2133	2133
Adjust R-squared	0.779	0.578	0.268	0.578

Note: The prefix "*ln*" before the explanatory variables denotes a logarithmic form. *** and ** indicate significance at the 1% and 5% level, respectively. Figures in () are robust standard errors.

Table 11. Robustness test of spatial effect.

Variable	*Spatial Weight Matrix: W*$_1$				*Spatial Weight Matrix: W*$_2$			
	(1) *Main Effect*	(2) *Direct Effect*	(3) *Indirect Effect*	(4) *Total Effect*	(5) *Main Effect*	(6) *Direct Effect*	(7) *Indirect Effect*	(8) *Total Effect*
lnDigital	0.012 *** (0.002)	0.012 *** (0.002)	−0.008 * (0.004)	0.004 (0.004)	0.014 *** (0.002)	0.013 *** (0.002)	−0.193 * (0.108)	−0.179 * (0.109)
rho	0.449 *** (0.022)				0.879 *** (0.038)			
sigma2_e	0.000 *** (0.000)				0.000 *** (0.000)			
Observations	2133	2133	2133	2133	2133	2133	2133	2133
R-squared	0.023	0.023	0.023	0.023	0.269	0.269	0.269	0.269
Number of cities	237	237	237	237	237	237	237	237

Note: The prefix "*ln*" before the explanatory variables denotes a logarithmic form. *** and * indicate significance at the 1% and 10% level, respectively. Figures in () are standard errors.

6. Conclusions and Policy Recommendations

The challenge of climate change has brought external requirements to the upgrading of the industrial structure [62], while digitalization has brought internal impetus to the same. This study constructs a comprehensive measurement system for the digital economy and then investigates the impact of the digital economy on the industrial structure based on panel data from 237 prefectural-level cities in China from 2011–2019. It adopts panel regression to empirically analyze the direct impact of the digital economy on upgrading the industrial structure, and uses a mediation model to prove the mediation effect of technological progress and human capital upgrading. Furthermore, this study reveals the spatial spillover effect of the digital economy on the advancement and servitization of the industrial structure based on the SDM and SAR models.

Our main research conclusions are as follows. First, development of the digital economy can promote the transformation and adjustment of industrial structure in local regions from a low-level state to a high-level one. Robustness tests, such as the method of calculating the digital economy and industrial structure, that is, the 2SLS method, show that this finding is robust. Second, the digital economy can promote upgrading of the urban industrial structure through the intermediary mechanisms of promoting technological progress and human capital upgrading. Finally, there exists a spatial spillover effect between the digital economy and industrial structure upgrading. Specifically, development of the digital economy can promote the servitization of the industrial structure in a region and its surrounding areas. Although the digital economy can promote the advancement of the industrial structure in this region, however, it hinders advancement of the industrial structure in surrounding areas.

Based on these findings, the following policy recommendations are proposed. All regions can take advantage of the digital technology dividend to promote industrial upgrading and service orientation. With the declining international demand for manufacturing and the country's rising internal production costs, China's industrial structure faces an urgent need for transformation and upgrading. In addition to improving digital infrastructure, developing countries need to formulate industrial policies for the digital economy in order to help industries realize advanced and service-oriented upgrading through digital transformation. The effectiveness of the industrial policy for development of the digital economy deserves attention, as it is the key to determining a region's competitive advantage in the opportunity period of global industrial structure adjustment [63,64]. Moreover, it is important for enterprises to improve the knowledge, experience, and skills of their human resources and more effectively match their current pool with their organizational needs through development of the digital economy in order to improve production efficiency, management efficiency, and strategic development. Finally, the government should pay attention to the spatial spillover effect of the digital economy on industrial structure upgrading and strengthen spatial cooperation in industrial upgrading [65]. In the era of the digital economy, regional competition and cooperation between industries are more important. The government should formulate regional coordination policies for digital economic development in order to promote cooperation in industrial development.

This paper presents a preliminary discussion about the relationship between the digital economy and the industrial structure; however, there are deficiencies in this study and more remains to be done. First, it would be better to use an integrated index for both the digital economy and industry in order to reveal the effect of development of the digital economy on the industrial structure. However, we were only able to construct a comprehensive index of the digital economy, as we lacked official statistics for an integrated index. Second, while this paper has tried to investigate the impact of the digital economy on the industrial structure, our results do not reflect the effects on the internal structure of manufacturing. The upgrading of the internal structure of manufacturing in the digital economy era is one of the topics that must be studied in the future. In addition, studies in specific regions may be helpful in providing more targeted policy implications.

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