Impact of Digital Industrialization on High-quality Economic Development

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Abstract. Against the background of rapid development of global information technology, digital industrialization has become an important path to promote high-quality economic development. Based on the panel data of 30 provinces in China from 2012 to 2020, this paper constructs the digital industrialization index and the index of high-quality economic development, and adopts the two-way fixed effect model to study the impact of digital industrialization on high-quality economic development and sort out the impact mechanism. The results show that digital industrialization not only directly promotes the high-quality development of regional economy, but also further promotes the high-quality development of economy through the indirect effect of industrial upgrading. The improvement of human capital level and the increase of financial investment in research significantly enhance the promotion effect of digital industrialization on high-quality economic development. The heterogeneity results indicate that the enhancement of economic quality development by digital industrialization is only significant in the northern region, the region with higher economic level and higher investment in education.

Keywords: Digital industrialization, High-quality economic development, Industrial upgrading, Human capital, Research investment.

1. Introduction

In recent years, the rapid development of global information technology has made the digital economy a key force for economic growth and social change[1]. Among them, digital industrialization, as the core of the digital economy, not only generates new industries, new business forms and new models through new technologies, but also facilitates the digital transformation of traditional industries and significantly improves the quality and efficiency of the real economy. In China, the government attaches great importance to the role of digital industrialization in promoting high-quality economic development, and has clearly set out relevant development goals in the **14th Five-Year Plan for Digital Economy Development**.

At present, the academic research on digital industrialization and high-quality economic development mainly involves the following three aspects: First, the research on digital industrialization. It mainly focuses on the impact of digital industrialization on R&D efficiency[2], industrial productivity[3], industrial structure upgrading[4], and energy supply chain length[5]of high-tech industries. The second is about high-quality economic development, which has become a policy hotspot in the past decade. Most scholars focus on the construction of the index system[6], influencing factors [7], regional differences[8], mechanism[9] , series of policies[10] and so on, with very rich research results. Third, the impact of digital industrialization on high-quality economic development. At present, there are few studies in this field, and most of them take digital industrialization as an indicator of digital economy to study[11] [12].

Therefore, the contributions of this paper are mainly reflected in the following aspects: First, by referring to the existing literature, the paper constructs the indicators of digital industrialization and high-quality economic development from the provincial level, divides the research scope to the direction of digital industrialization, studies the impact of digital industrialization on high-quality economic development, and supplements the current research in this field. Second, it further sorted out the impact mechanism of digital industrialization on high-quality economic development, studied the action mechanism of digital industrialization on high-quality economic development from the aspects of industrial upgrading, human capital and scientific and technological investment, and

enriched the literature on relevant theories of digital industrialization and influencing factors of high-quality economic development. Thirdly, it pays attention to the different performance of the impact of digital industrialization on high-quality economic development due to regional differences, economic level differences and educational investment differences. Based on this, it conducts heterogeneity analysis to enrich research results.

2. Research Hypothesis

Digital industrialization mainly promotes high-quality economic development through the following ways: First. Improving production efficiency and optimizing resource allocation. Digital industrialization can improve production efficiency through automated and intelligent production processes, and can also achieve optimal allocation of resources and promote high-quality economic development through accurate data analysis through big data and artificial intelligence technology[13]. Second, it stimulates technological innovation and business model innovation. McAfee A et al. pointed out that the wide application of digital technology has provided enterprises with more innovation opportunities and promoted the innovative development of the economy[14]. Therefore, this paper puts forward the following reasonable assumptions:

Hypothesis H1: Digital industrialization can significantly promote the high-quality development of China's economy;

Digital industrialization not only directly promotes high-quality economic development, but also further promotes economic development through the indirect role of industrial upgrading. The following aspects are: First, to enhance the overall competitiveness of the industrial chain. The manufacturing industry realizes intelligent manufacturing through digital transformation, improves production efficiency and product quality, and drives the upgrading of the entire industry and the high-quality development of the economy[15]. The second is the technology spillover of digital industrialization. The wide application of digital technology has driven the upgrading of related industries, especially the technological innovation in artificial intelligence, big data and other fields, and promoted the technological upgrading of the overall economy [16]. Therefore, the following hypothesis is proposed:

Hypothesis H2: Digital industrialization promotes the development of our country's high quality economy through the indirect effect of industrial upgrading;

The impact of digital industrialization on high-quality economic development may be enhanced or weakened by other factors. Among them, local investment in science and technology is a key factor. Government investment in science and technology provides financial support for the research and development and application of digital technologies, reduces the innovation cost of enterprises, encourages enterprises to conduct more research and development of digital technologies, and promotes the development of enterprises[17]. Another important factor is human capital. A highly qualified workforce plays a key role in digital industrialization. They can not only promote technological innovation of enterprises in the process of applying digital technologies, but also promote the diffusion and application of technologies through labor mobility and exchanges among enterprises.[18] Therefore, the hypothesis is put forward:

Hypothesis H3: local scientific and technological input and human capital can significantly enhance the promotion effect of digital industrialization on high-quality economic development.

3. Research Design

3.1 Model Design

In order to test the above research hypothesis, firstly, aiming at the role of digital industrialization on high-quality economic development, the following bi-directional fixed effect model is designed:

$$quality_{it} = \beta_0 + \beta_1 dig_{it} + \beta X_{it} + \mu_i + \varphi_t + \varepsilon_{it} \quad (1)$$

In model (1), $quality_{it}$ represents the economic high-quality development index of the i province in the t year, and dig_{it} represents the digital industrialization level of the i province in the t year. β_0 is the intercept term, μ_i is the individual effect of the i province, φ_i is the time effect of the t year, ε_{it} is the random error term, X_{it} is the control variable. If β_1 is significantly positive, then digital industrialization can promote high-quality economic development.

3.2 Selection and Explanation of Variables

1.Explained variable Index of high-quality economic development (qulity). Although some literature has used total factor productivity as an important indicator of high-quality economic development, it focuses on the measurement of economic efficiency and ignores issues such as resources and the environment. In this paper, we take the new development concepts of "innovation, coordination, greenness, openness, and sharing" put forward by General Secretary Xi Jinping at the Fifth Plenary Session of the 18th CPC Central Committee as the theoretical basis for constructing the index system of high-quality development of the economy, take the five development concepts as the first-level index of high-quality development of the economy, and combine them with the development concepts of Chen Jinghua , Sun Hao and others[19][20]. This paper chooses the entropy weight method to measure the weights of 11 secondary indicators, and the results are shown in Table 1.

Table 1: Evaluation index system of high-quality economic development

First-level indicators	Secondary indicators	Tertiary indicators	How to measure	Attributes	Weight (%)
High-quality economic development	Innovative development	Intensity of R&D investment	R&D expenditure of industrial enterprises above designated size	Positive direction	18.799
		Technical trading activity	Technical trading turnover	Positive	29.497
	Coordinated development	Demand structure	Total retail sales /GDP	Positive	1.598
		Urban-rural structure	Urban population/total population	Positive	3.797
	Green development	Wastewater per unit of output	Wastewater discharge /GDP	Negative	1.095
		Exhaust gas produced by units	Sulfur dioxide emissions /GDP	negative	0.772
	Open development	foreign trade	Total imports and exports	Forward direction	26.558
		Foreign investment	Total foreign investment	Positive	13.757
	Shared development	Elasticity of personal income growth	Per capita disposable income growth rate/regional GDP growth rate	Positive	1.289
		Rural-urban consumption gap	Per capita consumption expenditure of urban residents/per capita consumption expenditure of rural residents	negative	1.276

	Share of natural fiscal expenditure	The proportion of expenditures on housing security, medical and health care, education, social security and employment in local budget expenditures	In the positive direction	1.561

2.Core explanatory variables. Digital Industrialization (dig). Based on the Statistical Classification of Digital Economy and Its Core Industries (2021) released by the National Bureau of Statistics of China, combined with the research of Li Zhihui , Wang Tian et al.[21][22], this paper constructs the digital industrialization evaluation index system as shown in Table 2 below, and uses the entropy method to calculate the weight to obtain the digital industrialization index of each province in each year.

Table 2 Digital industrialization evaluation index system

	Secondary indicators	Tertiary indicators	Attributes	Units	Weight (%)
Digital Industrialization	Industry base	Optical cable density	Forward	Km/km2	11.851
		Number of Internet domain names	Forward	a	14.262
	Industry body Industrial scale	Internet broadband access port	Forward	a	5.481
		Software business revenue per capita	Positive	yuan	18.713
		Telecom business volume per capita yuan	Forward direction	yuan	10.763
		Number of legal persons in the information transmission, computer services and software industries	Forward Direction	a	10.465
		Employment per 10,000 people in information transmission, software and information technology services	Positive Direction	people	18.501
	Innovation effect	Number of patents granted per 10,000 people	Positive	Pieces / 10,000 people	9.965

3. Mechanism variables. (1) Industrial upgrading (stru), according to Gan Chunhui (2012), is measured by industrial upgrading, that is, the ratio of output value of tertiary industry to output value of secondary industry [23]; (2) Human capital (hum), measured by the number of students enrolled in colleges and universities with reference to the study of Bao Zhenshan (2023) [24]; (3) techin, refer to Wei Dongming's (2023) study, and measure the proportion of government fiscal expenditure on science and technology in GDP [25].

4. Control variables. In order to minimize research bias caused by missing variables, in addition to the core explanatory variables, the following control variables were selected: (1) Level of economic development (gdp), measured by the gross regional product of each province; (2) the degree of marketization (market) is measured by the proportion of the total output value of urban non-state-owned industrial enterprises in the total output value of all industrial enterprises;(3) Population density (den), measured by the proportion of permanent resident population in the area of the province at the end of the year; (4) Education level (edu), measured by local fiscal expenditure on education; (5)Residents' standard of living (clq), measured by access to water;(6) road density (dhw), expressed by the proportion of government expenditure on science and technology to GDP.

3.3 Data Sources and Descriptive Statistics

This paper selects panel data of 30 provinces in China from 2012 to 2020 (considering the availability of data, the sample in this paper does not include Tibet and Hong Kong, Macao and Taiwan) for research. The original data used in this study were all from National Bureau of Statistics of China, local statistical bureaus, ifind database and Guotai 'an database. Table 3 shows the descriptive statistical results of the main variables in this paper.

Table 3 is descriptive statistics of main variables in this paper

Variables	Sample size	Mean	Standard deviation	Maximum value	Minimum	Median
Quality	270	0.174	0.141	0.770	0.026	0.126
dig	270	0.107	0.115	0.748	0.006	0.071
stru	270	1.359	0.736	5.244	0.611	1.192
Techin	270	0.005	0.003	0.013	0.002	0.004
hum	270	91.104	53.675	249.220	4.870	76.565
market	270	0.307	0.145	0.711	0.050	0.298
GDP	270	25782.270	21036.260	111151.600	1528.500	20210.550
edu	270	886.578	536.543	3510.560	106.450	757.790
clq	270	97.902	2.090	100.000	91.120	98.455
den	270	476.776	707.547	3924.909	8.197	295.103
dhw	270	0.971	0.518	2.195	0.095	0.932

4. Analysis of Empirical Results

4.1 Benchmark Regression Results

In order to eliminate individual-specific factors, the influence of time factors on the explanatory variables, and to comprehensively capture the pattern of change in the data, this paper constructs two-way fixed effects to verify the direct impact of digital industrialization on the high-quality development of the economy, in which Column (1) is the result without considering the control variables, and Column (2) is the result considering the control variables, and the specific results are shown in Table 4 below.

Table 4 Results of benchmark regression

	(1)	(2)
	Quality	Quality
dig	0.608***	0.315***
	(13.34)	(6.63)
market		0.00421
		(0.15)
GDP		0.00000200***
		(4.41)
den		0.000165
		(1.36)
edu		0.0000659***
		(4.59)
clq		0.000857
		(0.85)
dhw		0.00308
		(0.21)
_cons	0.130***	0.474***
	(5.97)	(2.63)

Province fixed	Yes	Yes
Fixed time	Yes	Yes
N	270	270
R2	0.981	0.991

Note: ***,**,* and are significant at 1%, 5%, and 10% levels, respectively, with T-values in parentheses. The following tables are the same

It can be seen that whether control variables are added or not, digital industrialization can significantly improve the high-quality development of regional economy. Column (2) shows that when digital industrialization increases by one unit, the high-quality development of regional economy increases by 0.315 units. From a practical point of view, digital industrialization enhances production automation and intelligence through the introduction of advanced information technology, reduces waste of resources and improves production efficiency. At the same time, it has given rise to new industries such as the sharing economy and e-commerce, injecting new impetus into the high-quality development of the economy.

4.2 Robustness Test

1. Add control variables. Control variables Government intervention (gov) and financial scale (fin) are added. Government intervention (gov) is measured by the ratio of general budget expenditure and regional GDP of each region, and financial scale is expressed by financial practitioners in each region. The benchmark regression equation is returned when other variables remain unchanged, and the results are shown in Table 5(1) below. The influence of digital industrialization on regional high-quality development is still positive and significant (coefficient 0.336, $p < 0.01$).

2. Sample data of some years are excluded. Since the new development concept was proposed by President Xi in October 2015, the data before 2016 is excluded and then the benchmark regression is conducted, and the results are shown in Table 5 (2). The robustness test passes

3. Tail shrinkage processing. The 1% and 99% quantiles of explained variables, explanatory variables, and mechanism variables were selected for tail shrinkage processing, and then benchmark regression was carried out. It can be seen that the benchmark regression results are still robust.

Table 5 Robustness test results

	Add control variables gov and fin	Delete some data	Indentation
	(1)	(2)	(3)
dig	Quality 0.336*** (6.68)	Quality 0.305*** (3.93)	Quality 0.232*** (3.71)
Control variable	Yes	Yes	Yes
_cons	0.534*** (2.91)	0.349 (0.94)	0.467** (2.29)
Province fixed	Yes	Yes	Yes
Fixed time	Yes	Yes	Yes
N	270	150	270
R^2	0.991	0.996	0.989

4.3 Endogeneity Test

Digital industrialization and high-quality economic development may have endogeneity problems due to bidirectional causality. This paper uses the instrumental variable approach to test endogeneity. Drawing on Huang Qunhui and Zhao Tao, this paper uses the interaction term between the total volume of postal and telecommunications business of each province in China in 1984 and a time-varying variable construct as an instrumental variable for digital industrialization (data source:

National Bureau of Statistics of China)[26][27]. Post and telecommunications business was the main way of information exchange before the popularization of the Internet, which satisfies the instrumental variable correlation; while in the era of digital economy, traditional post and telecommunications tools are used less frequently, which satisfies the strict exogeneity. The 2SLS estimation results of the instrumental variable method show (Table 7) that the instrumental variable coefficients are significantly positive at the 1% level in the first stage regardless of whether control variables are considered or not, and the coefficients of digital industrialization in the second-stage regression are also significantly positive at the 1% level, which indicates that the conclusions are consistent with the previous section after endogeneity is taken into account. In addition, the F-value in the first stage is greater than 10, indicating that the instrumental variable is not a weak instrumental variable and that there is no over-identification problem due to the fact that the instrumental variable has the same number as the explanatory variable.

Table 6 Results of endogeneity test of instrumental variables method

	The first stage		Stage Two	
	(1)	(2)	(3)	(4)
	dig	dig	quality	quality
dig			0.717***	0.557***
			(7.04)	(6.85)
IV	0.00000198***	0.00000139***		
	(10.56)	(5.47)		
First stage F value	113.573***	30.208***		
	(p = 0.000)	(p = 0.000)		
Control variable	NO	YES	NO	YES
Province fixed	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
cons	0.194***	0.641	0.081	0.636***
	(5.61)	(2.08)	(1.61)	(3.68)
N	270	270	270	270

5. Mechanism test

In order to sort out the mechanism of digital industrialization on high-quality economic development, the following two mechanism inspection models are constructed. Based on the mechanism of industrial upgrading, the following models are constructed:

$$stru_{it} = \alpha_0 + \alpha_1 dig_{it} + X_{it}\alpha + \mu_i + \varphi_t + \varepsilon_{it} \quad (2)$$

Formula (2) represents the industrial upgrading index of the i province in the t year, and the rest is the same as formula (1). $stru_{it}$ The following model is constructed based on the mechanism effects of human capital and science and technology input:

$$quality_{it} = \gamma_0 + \gamma_1 dig_{it} + \gamma_2 techin_{it} + \gamma_3 techin_{it} \cdot dig_{it} + X_{it}\gamma + \mu_i + \varphi_t + \varepsilon_{it} \quad (3)$$

$$quality_{it} = \delta_0 + \delta_1 dig_{it} + \delta_2 hum_{it} + \delta_3 hum_{it} \cdot dig_{it} + X_{it}\delta + \mu_i + \varphi_t + \varepsilon_{it} \quad (4)$$

Where $techin$,hum_{it} are the mechanism variable and $techin_{it} \cdot dig_{it}$,$hum_{it} \cdot dig_{it}$ is the interaction term, when the former sign of dig_{it} is positive, observe the sign before the interaction term. If it is significantly positive, this mechanism variable has a positive effect on digital industrialization promoting high-quality economic development; if it is significantly negative, this mechanism variable has a negative effect on digital industrialization promoting high-quality economic development.

5.1 Mechanism test based on industrial upgrading

The results obtained by taking the upgrading of industrial structure as the explained variable are shown in Table 7 (2) below. According to the results, it can be seen that the impact of digital industrialization on industrial upgrading is significantly positive. Moreover, many scholars have also proved that industrial upgrading has an impact on high-quality economic development. Zhu Fenghui et al have proved that industrial upgrading has a "structural dividend" on China's economic growth, which is conducive to improving green total factor productivity, and has a spatial spillover effect, which can realize green economic development[28]. In addition, Dong F et al mentioned that industrial upgrading can effectively improve labor productivity, optimize resource allocation, and promote the economic transformation from quantitative growth to quality improvement [29]. Therefore, digital industrialization can promote high-quality economic development by promoting industrial upgrading, that is, industrial upgrading plays an important role in path transmission, which verifies H2.

5.2 Mechanism test based on industrial upgrading

As in Equation (3)(4), the mechanism variables human capital and research investment are introduced to test whether local government behavior and local human capital affect the role of digital industrialization on high-quality economic development, and the results are shown in columns of Table 7(3)(4) below.

Table 7 Mechanism test results of industrial upgrading, human capital and scientific research input

	(1)	(2)	(3)	(4)
	Quality	Stru	Quality	Quality
dig	0.315***	2.263***	0.0553	0.233***
	(6.63)	(6.5)	(0.63)	(4.17)
Techin			3.564***	
			(2.76)	
Techin*tech			19.35***	
			(3.41)	
hum				0.000461
				(2.36)
Hum*tech				0.00102**
				(2.230)
Control variables	Yes	Yes	Yes	Yes
_cons	0.474***	0.567	0.629***	0.401**
	(2.63)	(0.43)	(3.77)	(2.23)
Province fixed	Yes	Yes	Yes	Yes
Fixed time	Yes	Yes	Yes	Yes
N	270	270	270	270
R2	0.981	0.982	0.993	0.991

The interaction coefficient between digital industrialization and science and technology input is 19.35, rejecting the null hypothesis at the significance level of 1%; the interaction coefficient between digital industrialization and human capital is 0.00102, rejecting the null hypothesis at the significance level of 5%, indicating that both science and technology input and human capital have a significant impact. Moreover, the dig coefficients of digital industrialization in column (2) and (3) are all positive. It can be seen that the level of local science and technology input and human capital enhances the promotion effect of digital industrialization on high-quality economic development. In the digital age, the demand for labor force is increasing. Young people with higher education background have become an important force to promote high-quality economic development with their high quality, high skills and innovative spirit. The high-tech financial input of local governments has created a favorable environment for local science and technology innovation, increased investment in science

and technology development and technology research and development, and provided the basic guarantee for high-quality development.

6. Heterogeneity analysis

1.Geographical regional heterogeneity. In this paper, the geographic region is divided into the south and the north . The results of regional heterogeneity, as shown in Table 10, show that digital industrialization in the northern region has a significant positive effect on the high-quality development of the economy, while the positive effect in the southern region is not significant. The reason may be that the northern region, historically, is dominated by heavy industry and has a relatively homogeneous industrial structure. And digital industrialization helps traditional industries to transform into high-end manufacturing industries such as smart manufacturing and industrial IoT, thus promoting high-quality economic development. In contrast, the southern region already has a more developed foundation in areas such as light industry and services, and the transformation needs of digital industrialization may not be as urgent as those of the northern region.

2. Heterogeneity of economic level. In this paper, the sample is divided into 2 groups according to the median GDP, called the high economic level group and the low economic level group. The results are shown in Table 10 below, and it can be seen that digital industrialization in the high economic level group has a significant role in promoting high-quality economic development, while the low economic level group is not significant. The reasons may include: high GDP regions have stronger innovation ability, more perfect industrial chain and supply chain system, as well as larger market size and consumption demand, and these advantages make digital industrialization more capable of promoting high-quality economic development.

3. Heterogeneity in educational attainment The sample is divided into two groups according to the median education level (edu) of the control variable, and the test results (Table 10 below) show that the promotion of digital industrialization to high-quality economic development is significant in the high-education group, while it is not significant in the low-education group. This may be due to the fact that regions with high financial education expenditure can provide better education resources and cultivate more high-quality and innovative talents, who play a key role in digital industrialization and promote high-quality economic development. At the same time, high financial expenditure on education also creates a social atmosphere that emphasizes scientific literacy and innovation, which is conducive to the development of digital industrialization.

Table 10 Results of heterogeneity analysis

	quality					
	Area		GDP variance		Educational attainment	
	(1)	(2)	(3)	(4)	(5)	(6)
	South	North	High economic level	Low economic level	High level of education	Low level of education
Dig	0.137	0.367***	0.333***	0.093	0.372***	0.11
	(1.3)	(6.62)	(4.9)	(1.11)	(3.97)	(1.43)
Control variables	YES	YES	YES	YES	YES	YES
_cons	0.222***	0.0194	0.907***	0.0945	1.096***	0.234*
	(3.43)	(0.07)	(3.22)	(0.46)	(2.77)	(1.65)
Province fixed	YES	YES	YES	YES	YES	YES
Fixed time	YES	YES	YES	YES	YES	YES
N	135	135	135	135	135	135
R2	0.993	0.989	0.992	0.976	0.994	0.989

7. Conclusions and Policy Recommendations

The main conclusions of this paper are as follows: **First,** digital industrialization can directly promote the high-quality development of regional economy, which accords with the current situation of China's economic development; **Second,** in addition to the direct impact, digital industrialization also acts on the high-quality economic development through the indirect effect of industrial upgrading, and promotes the realization of high-quality economic development. **Third,** the good level of human capital and financial investment in science and technology in the region have enhanced the role of digital industrialization in promoting high-quality regional economic development. **Fourth,** the heterogeneity results show that the promotion effect of digital industrialization on high-quality economic development is only significant in the northern region, the region with higher economic level and higher education input. In view of this, this paper puts forward the following policy recommendations:

1. Strengthen the direct promoting effect of digital industrialization: increase investment in network infrastructure, improve network coverage and capacity; Encourage the growth of software business and cultivate more competitive digital industry enterprises; And attach importance to personnel training to ensure that the talent pool meets the needs of industrial development. **2. Promote industrial upgrading:** Formulate policies to guide the integration of traditional and digital industries, and promote the transformation of traditional industries into digital and intelligent industries; Increase support for industrial upgrading projects. **3. Increase financial input in human capital and science and technology**: increase fiscal expenditure on education to ensure a balanced distribution of educational resources; Increase investment in scientific and technological innovation, encourage industry-university-research cooperation, and promote the transformation of scientific and technological achievements. **4. Consider heterogeneity and formulate differentiated policies:** the northern region should step up efforts to promote digital industrialization; The southern region should thoroughly analyze the constraints and formulate corresponding policies; Regions with a high economic level should support the development of high-end digital industries, while regions with a low economic level should raise the level of basic digitalization. Regions with a high level of education should promote the integration of education and industry, while regions with a low level of education should increase investment in education and improve professional skills training.

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