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Analysis of the Impact of Digital Economy on R&D Innovation

Lunzhen Ding*

School of Economics

Wuhan Business University

Wuhan, Hubei Province, China

dingsxy@163.com

Chengyang Nie*

Computer Science Department

Carnegie Mellon University

Pittsburgh, USA

cnie@alumni.cmu.edu

Abstract

The digital economy has become a key engine for the new direction of the world economic situation and a key driving force for development and innovation in the era of Industry 4.0. In recent years, China's digital economy has made significant progress in industrial digitization, infrastructure construction, digital foreign trade, digital government construction, and new forms of digital economy. It is necessary to adhere to innovation as the primary driving force for leading the development and progress of the digital economy. This article integrates 19 indicators related to the digital economy into the Digital Economy Development Index. And the R&D innovation data of 31 provinces in China from 2020 to 2023 were organized to study the impact of the digital economy on inter provincial R&D innovation in China. Panel data regression was conducted on R&D innovation, digital economy, and other control variables from 2020 to 2023, and regression analysis was conducted on the data from 2020 to 2023. It was found that the digital economy has a significant driving effect on research and development innovation in 31 provinces of China from 2020 to 2023. This article proposes relevant policy recommendations for China's future development of the digital economy and promotion of innovation based on the above research. China should continue to strengthen the construction of fixed and mobile infrastructure, vigorously promote the integration of industrialization and informatization, explore new ways to integrate the digital economy with the real economy and promote the development of new forms of digital economy in China.

CCS Concepts

• Applied computing; • Law, social and behavioral sciences; • Economics;

Keywords

Digital Economy, Research and Development Innovation, High-quality Development, Digital Industrialization

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*Corresponding author.



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1 Introduction

The digital economy guides the new trend of future development of the world economy, reshapes the structure of economic development, and gradually shifts the driving force towards innovation. In the opportunity period of high-quality development in China, innovation capability is a crucial driving factor. The digital economy has become a significant element of industrial economic transformation and a key driving force for development and innovation in the era of Industry 4.0. The Fifth Plenary Session of the 19th Central Committee of the CPC pointed out that "we should develop the digital economy, promote digital industrialization and industry digitalization, promote the deep integration of digital economy and real economy, and create a digital industrial cluster with international competitiveness". The integration and promotion of the digital economy and the real economy have greatly improved production efficiency and optimized existing production models to a certain extent, becoming an important driving force for industrial transformation and upgrading. This requires us to focus on the new stage of development, grasp the new characteristics of development, consolidate the new achievements of development, constantly gather new driving forces for the development of the digital economy, and promote the intelligent era of accelerating the transformation of China's financial industry.

In the context of Industry 4.0, China has made significant progress in industrial digitization, infrastructure construction, digital foreign trade, digital government construction, and new forms of digital economy. However, the direction and future prospects of the digital economy also face many constraints and challenges. The innovation capability in key areas of the digital economy is insufficient, and there is an urgent need to enhance the core creativity and competitiveness in the field of digital technology. Therefore, it is necessary to adhere to innovation as the primary driving force for leading the development and progress of the digital economy. This article integrates the comprehensive development index of the digital economy, links R&D innovation data from 31 provinces in China, studies the impact of the digital economy on inter provincial R&D innovation in China, and based on the research in this article, relevant policy recommendations are proposed for the development trend of the digital economy and the innovation direction of the real economy.

2 Literature Review

Some scholars believe that the digital economy has played an momentous role in promoting low-carbon economy, energy conservation and emission reduction, and high-quality economic development. After studying the impact of the digital economy on the deployment of renewable energy in 85 countries from 2003 to 2021, Hwang and Venter believed that the digital economy has a strong driving force for the rapid deployment of renewable energy, and this driving force is very important to improve the safety and reliability of the energy system.[1] Xu conducted a study on the impact of digital economy on ecological footprint in 37 OECD economies from 2007 to 2022, and ultimately found that the digital progress of OECD economies has shown great breakthroughs in simplifying industrial production processes and real-time resource management, greatly reducing ecological footprint.[2] Qian believes that in the context of global digitization, promoting the development of the digital economy is of great significance for reducing carbon emissions and improving green total factor productivity (GTFP).[3] Zhang found that the development of digital economy in 72 countries promotes industrial transformation and upgrading by improving energy efficiency, resulting in a non-linear inverted U-shaped relationship between carbon emissions .[4]

Some scholars also believe that the digital economy has a significant promoting effect on innovation. Xiao studied manufacturing enterprises in China's Shanghai and Shenzhen A-shares from 2012 to 2022, using text analysis to calculate the regional digital economy comprehensive index.[5] The research results indicate that rational allocation of R&D personnel and R&D funds is essential for the digital economy to promote manufacturing innovation, and its role in manufacturing innovation should not be underestimated. Wang defined China's digital economy has demonstrated a rising trend in innovation and growth year over year.[6] Ke studied data from 30 provinces in China over an 11-year period and found that the digital economy can promote the upgrading of the manufacturing value chain through green technology innovation, playing a mediating role.[7] Zhou explores the driving force of the rapid rise of the digital economy on spatial innovation and examines the impact and mechanism of the digital economy on innovation output in 330 cities in China from 2011 to 2020.[8] The results indicate that the development of the digital economy has a significant contribution to innovation output. Zhang constructed China's Environmental Performance Index (EPI) from 2007 to 2021.[9] The empirical results of the model show that the growth of the digital economy has a significant negative impact on carbon emissions, and its direct impact is greater than its long-term impact. There is a positive driving force between the digital economy and environmental sustainability.

Other scholars believe that the development of the digital economy will have adverse effects on economic growth and innovation. Yu considers in the context of rapid development of the digital economy, the situation of unfair competition has also intensified, thereby disrupting normal innovative activities.[10] Zheng selected data from underdeveloped regions in China from 2001 to 2011 and empirically tested that there is an inverted "U" curve relationship between the digital economy and regional sustainable development. In the early stages of development, the digital economy relies on its own economies of scale to unleash the "digital dividend" and actively

influenced the sustainable development of regional economies; In the later stage, the "digital divide" had a positive impact on the development of regional economy.[11]

The above-mentioned scholars comprehensively examined the impact of the digital economy on economic development, environmental protection, innovation, and other aspects in different countries and regions, and discussed the effects of the progress of the digital economy on society and the environment. Overall, the digital economy can impact the sustainable development of regions, effectively reduce carbon emissions, and promote the development of street vendor economy. This article mainly analyzes the impact of the digital economy on inter provincial R&D innovation in China. The entropy method is used to calculate the weights of 19 digital economy related indicators, forming the digital economy indicator Score of this article, and further studying the impact of the digital economy on inter provincial R&D innovation in China. The innovation of this article lies in selecting 19 relevant indicators to measure digital economy indicators from five dimensions: fixed infrastructure, mobile infrastructure, digital industrialization, industrial digitization, and enterprise digitization. These five dimensions comprehensively demonstrate the current development status of the digital economy and the application direction of digital technology.

3 Materials and Methods

3.1 Methods Introduction

This article establishes a digital economy measurement index system. The development of digital economy is closely related to infrastructure construction. At the same time, with digital industrialization, industrial digitalization and enterprise digitalization as the development orientation, based on the cutting-edge technology of economic and social development, it further realizes the deep integration of "Internet plus manufacturing". This article draws on the digital economy measurement index system constructed by Yang.[12] Based on the connotation and extension of the digital economy, 19 relevant indicators are selected from five dimensions: fixed infrastructure, mobile infrastructure, digital industrialization, industrial digitization, and enterprise digitization to measure digital economy indicators. Please refer to Table 1 for specific details. The attributes of these 19 indicators related to the digital economy are all positive. This article uses the entropy method to calculate the weights of 19 indicators and obtaining the Digital Economy Development Index (Score) for this article.

3.2 Model Setting

The dependent variable is China's inter provincial R&D innovation capability (Rd). This article uses R&D funding from 31 provinces in China to measure their R&D innovation capabilities. Core explanatory variable: Digital Economy Development Index (Score). The digital economy, with data resources as its key element and modern information networks as its main carrier, is leading a new business model for China's economic development. This article assigns weights to 19 indicators related to the digital economy using the entropy method and obtains the Digital Economy Development Index (Score). Control variables: R&D personnel full-time equivalent (Rdr), number of new product development projects (Xkx),

Table 1: Digital economy measurement index system

Criterion level	Index level	Unit	attribute	weight
Fixed infrastructure	Length of optical cable line	kilometer	Positive	3.15397
	Number of Domain Names	Ten thousand	Positive	6.64376
	Number of pages	Ten thousand	Positive	14.02767
	Long distance optical cable line length	kilometer	Positive	2.90743
	Number of IPv4 addresses	Ten thousand	Positive	8.54159
	Internet broadband access port	Ten thousand	Positive	3.03308
Mobile infrastructure	Total number of mobile telephone exchanges	Ten thousand households	Positive	2.95207
	Number of mobile phone base stations	Ten thousand	Positive	3.14423
	Mobile phone penetration rate	Department/100 persons	Positive	2.21677
Digital Industrialization	Software business revenue	trillion yuan	Positive	11.17301
	Information technology service revenue	trillion yuan	Positive	11.54259
Industrial digitalization	Total telecommunications business volume	trillion yuan	Positive	6.80187
	Urban broadband access users	Ten thousand households	Positive	2.84836
	Rural broadband access users	Ten thousand households	Positive	4.44905
Enterprise digitalization	Number of computers used per 100 people	tower	Positive	0.73901
	Number of websites owned by the enterprise	individual	Positive	6.18063
	Number of websites per hundred enterprises	individual	Positive	1.08833
	Number of enterprises engaged in e-commerce transactions	individual	Positive	6.03851
	Proportion of e-commerce transaction activities	percentage	Positive	2.51808

Table 2: Descriptive statistics of variables

Variable	Mean	SD	Min	p50	Max
Rdr	1.2e+05	1.7e+05	173.00	51053.50	7.7e+05
Rd	5.3e+06	6.8e+06	5574.00	3.1e+06	3.2e+07
Xkx	28325.06	44008.41	27.00	14389.00	2.2e+05
Xkjz	6.8e+06	9.8e+06	6657.00	3.7e+06	5.2e+07
Xxs	8.7e+07	1.2e+08	34487.00	4.6e+07	5.1e+08
Score	18.40	14.94	2.78	13.20	66.20

new product development expenditure (Xkjz), and new product sales revenue (Xxs).

This article selects panel data from 31 provinces in China from 2020 to 2023 as the research object, forming a total of 124 observation values. The original data is sourced from the China Statistical Yearbook and provincial statistical yearbooks. To test the impact of the digital economy on China's inter provincial R&D and innovation capabilities, we used a regression model with the following specific model settings:

Descriptive statistics of variables are shown in Table 2.

3.3 Main Results

Table 3 presents the regression results of the digital economy on inter provincial R&D innovation in China. The first column shows the regression results from 2020 to 2023. According to the regression results, the impact coefficient of the digital economy development

index on 31 provinces in China from 2020 to 2023 is 25148.2, and it is significantly positive at the 5% significance level, indicating that the digital economy has a significant promoting effect on research and development innovation.

Columns (2), (3), (4), and (5) in Table 3 show the regression results for 2020, 2021, 2022, and 2023, respectively. From the regression results of 2020, 2021, 2022, and 2023, the impact coefficients of the digital economy on R&D innovation in 31 provinces of China in 2020, 2021, 2022, and 2023 were 34837.5, 32831.1, 25963.4, and 30444.5, respectively, and were significantly positive at the 10% significance level, indicating that the digital economy has a significant promoting effect on R&D innovation. Among them, the impact coefficient in 2020 is the highest. In 2020, affected by COVID-19, the digital economy developed rapidly, and a variety of new types of digital economy businesses ushered in an extremely rapid development momentum. Therefore, compared to other years, the impact

Table 3: The regression results of the digital economy on inter provincial R&D innovation in China

	(1) Rd	(2) Rd	(3) Rd	(4) Rd	(5) Rd
Score	25148.2** (2.17)	34837.5** (2.15)	32831.1** (2.29)	25963.4* (1.88)	30444.5* (1.78)
Rdr	34.04*** (9.34)	52.95*** (5.40)	41.47** (2.45)	41.73*** (8.20)	46.41*** (8.47)
Xkx	-59.06*** (-5.76)	-201.3*** (-4.95)	-117.1** (-2.74)	-67.11*** (-5.52)	-51.46*** (-3.93)
Xxs	0.0262*** (5.58)	0.0406*** (3.16)	0.0315* (1.83)	0.0197** (2.62)	0.00859 (1.49)
cons	215383.9 (1.21)	114004.7 (0.36)	64376.7 (0.14)	212455.4 (0.94)	347197.4 (1.21)
N	124	31	31	31	31
R2	0.9685	0.9701	0.9510	0.9874	0.9821

Table 4: Multicollinearity test

Variable	VIF	1/VIF
Rdr	4.08	0.245
Xxs	6.91	0.145
Xkx	7.77	0.129
Score	1.01	0.990
Mean VIF	4.94	

of the digital economy on research and development innovation is greater in 2020. The impact coefficient of the digital economy on R&D innovation in 31 provinces of China has decreased in 2021 and 2022, indicating that the momentum of rapid development of the digital economy has declined in 2021 and 2022. In 2023, the impact coefficient of the digital economy on research and development innovation in 31 provinces of China will increase again.

The development trend of China's digital economy has become an important pillar leading economic growth under the new situation, and the high-quality development of the digital economy has also driven progress in research and innovation. The digital economy uses digital information as a necessary medium of dissemination and modern electronic information technology as an important carrier, driving China to officially enter the Industry 4.0 era. The digital economy has integrated elements of innovative development in fields such as digital industrialization, industrial digitization, enterprise digitization, and infrastructure construction. Therefore, the development of the digital economy should promote the progress of research and development innovation.

3.4 Robustness check

The multicollinearity test was conducted on the variables, and the results are shown in Table 4. The VIF values were all less than 10, indicating that the model does not have multicollinearity and the regression analysis results are reliable.

To test the robustness of the impact of the digital economy on research and development innovation, we chose to remove one of the variables, new product sales revenue. The regression results

are shown in Table 5. The first column shows the regression results from 2020 to 2023. Columns (2), (3), (4), and (5) show the regression results for 2020, 2021, 2022, and 2023, respectively. According to the regression results, the impact coefficient of the digital economy development index on 31 provinces in China from 2020 to 2023 is positive. The impact coefficients of the digital economy on R&D innovation in 31 provinces in China in 2020, 2021, 2022, and 2023 are also positive, and are significantly positive at the 10% significance level, indicating that the digital economy has a significant promoting effect on R&D innovation, and the results are robust.

4 Conclusion

Based on the above analysis, the digital economy, as a key force driving high-quality development of the Chinese economy, has had a substantial economic impact on China's research and development innovation. This article analyzes the current situation of the development of the digital economy and the driving path of the digital economy for China's research and development innovation. This article starts from five dimensions: fixed infrastructure, mobile infrastructure, digital industrialization, industrial digitization, and enterprise digitization, and selects 19 relevant indicators to measure digital economy indicators. And using the Digital Economy Development Index (Score) as a measure of the development of the digital economy, panel data regression was conducted on R&D innovation, digital economy, and other control variables from 2020 to 2023, and regression analysis was conducted on the data from 2020 to 2023. The conclusion drawn is that the level of digital economy

Table 5: Robustness tests

	(1)	(2)	(3)	(4)	(5)
	Rd	Rd	Rd	Rd	Rd
Score2	33042.1** (2.57)	55528.9** (2.15)	46986.4* (1.72)	41065.4** (2.59)	30360.8* (1.74)
Rdr	47.88*** (16.38)	67.95*** (6.86)	67.22*** (6.81)	52.31*** (15.27)	52.45*** (13.98)
Xkx	-45.12*** (-4.05)	-162.2*** (-3.63)	-145.6*** (-3.51)	-57.64*** (-4.50)	-51.03*** (-3.81)
cons	322871 (1.63)	143255.4 (0.39)	55998.2 (0.12)	231183.4 (0.93)	437807.8 (1.52)
N	124	31	31	31	31
R2	0.9601	0.9552	0.9445	0.9833	0.9817

development in 31 provinces of China has a significant driving and promoting impact on research and development innovation.

China should continue to strengthen the construction of fixed infrastructure and mobile infrastructure and vigorously promote the integration of the two industries. The digital economy has promoted the transformation of old and new driving forces, which not only promotes the integration and progress of new and old formats, but also extends the industrial chain and promotes the aggregation of the industrial chain. The deepening development of the digital economy has greatly improved the traditional structure of resource supply and distribution. The prosperous development of the digital economy has also promoted the construction of new digital platforms and cultivated new growth drivers. Through digital platforms and tools, more development opportunities are also provided. The application of big data technology and artificial intelligence not only leads to new growth points in the economy but also guides innovation directions. The application of big data technology and artificial intelligence not only leads to new growth points in the economy but also guides innovative directions.

In the process of promoting the progress of digital technology and electronic information technology in various provinces of China, further create innovation points in the digital economy. Intensify investment in the digital economy, improve basic and applied research in the field of digital technology, and continuously enhance the benefits of digital economy for technological innovation. At the same time, promoting the application of digital technology in various fields, further optimizing the efficiency of digital technology from five dimensions: fixed infrastructure, mobile infrastructure, digital industrialization, industrial digitization, and enterprise digitization, empowering the technological innovation system with digital elements, and fully stimulating the innovation spillover effects of the digital economy.

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