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The Impact of Digital Economy on Regional Innovation Capability

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Abstract

Based on China's inter provincial panel data from 2011 to 2019, this paper constructs a measurement index of the level of digital economy, and uses a fixed effect model to make a regression estimation of the impact of digital economy on regional innovation. Research shows that the development of digital economy has significantly promoted the improvement of regional innovation ability. Through the comparison of different groups of regression analysis, it is found that the impact of the development of digital economy on China's invention and innovation is less than that of utility model innovation, which shows that China's innovation still needs to pay attention not only to high-quality development, but also to promote high-quality development. Grasp the role of digital economy as a catalyst for innovative development, comprehensively promote the integration of digital economy and industrial transformation in various regions, narrow the differences in regional development levels, and accelerate the construction of an innovative country.

Keywords

Digital economy; Regional innovation; innovation ability.

1. Introduction

With the progress and widespread application of the Internet, Internet technology has penetrated into various industries, and traditional economy has begun to enter the era of digital economy. The concept of "digital economy" was introduced by the United States in 1996, and different understandings of it vary. Barefoot et al. (2018) defined it as consisting of three aspects: infrastructure, e-commerce, and the creation of products and services by users of the digital economy. The G20 Digital Economy Development and Cooperation Initiative in 2016 defined the digital economy as a series of economic activities that use digital knowledge and information as key production factors, utilizing information and communication technology to promote structural optimization and improve efficiency. Since the concept of "digital economy" was introduced, countries have realized that the digital economy will become a new driving force for future economic growth. In 2017, "digital economy" first appeared in China's Government Work Report, and in 2019, it has been elevated to a national strategic level.

Innovation driven development is one of the important strategies for China's current governance. In recent years, China's scientific and technological capabilities have significantly increased, scientific and technological indicators have steadily improved, and the number of patent applications and authorizations ranks first in the world, all thanks to the innovation driven national strategy. However, at the same time, China still lags significantly behind many developed countries in obtaining high-quality and high-value patents, and still needs to explore new driving forces for innovative development.

The digital economy transcends the boundaries of the information industry and the scope of internet technology, digitizing production factors and transforming production organization forms. For example, e-commerce is an innovation driven by the digital economy in business models, which generates value appreciation through the combination of network technology, information integration technology, logistics, and commercial flow. Chen Xiaohong (2018)

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pointed out that the digital economy can reconstruct the relationship between consumers and enterprises, lead personalized and real-time R&D design, facilitate the integration of R&D resources by enterprises, and drive innovation synergy. Wang Weiling and Wang Jing (2019) believe that the digital economy can disrupt the production and organizational methods of enterprises, significantly reduce production and innovation costs, and enable innovative achievements to be quickly applied and popularized.

In summary, the promoting effect of the digital economy on creativity is theoretically recognized, but most of these analyses are still limited to logical explanations, and the analysis and research on actual data are still not comprehensive enough. In addition, the key elements in the development of the digital economy are information and data. The development of the digital economy will inevitably lead to the intensification of information sharing and leakage issues, which in turn will affect the enthusiasm for innovation within the region. So, can the digital economy actually promote the improvement of regional innovation capabilities? How much impact does it have? These questions have not received detailed answers and arguments in theoretical and logical analysis, and empirical analysis is still needed to answer them.

Starting from the above issues and practical significance, this article will study the impact of digital economy on regional innovation capacity based on panel data from various provinces in China. The innovation of this article lies in the following two points: firstly, there is relatively little analysis of actual data in existing research, and there is even less overall analysis of large-scale data. Based on the availability of data, this article selects panel data from 30 provinces in China for analysis and research; Secondly, due to the lack of unified standards for accounting indicators of the digital economy and the difficulty in obtaining certain data, this article will refer to the experience of existing literature to construct an evaluation index system for the digital economy, measure the development level of the digital economy in various provinces of China, and more accurately judge the impact of the digital economy on regional innovation capabilities.

2. Literature review

The digital economy is a mature product of the development of internet technology. With the attention of national policies to the digital economy, a number of research achievements related to the digital economy have emerged in academia. Among them, a considerable number of scholars have studied the development status and accounting issues of the digital economy as an emerging phenomenon. Tian Li (2017) found that the concept of the digital economy was proposed early on, but its connotation has been continuously enriched with the passage of time and the maturity of technology. At the same time, countries have different understandings and focuses on the digital economy. In terms of the calculation of the digital economy, due to the emerging, virtual, and high penetration characteristics of the digital economy, there is currently no unified accounting standard for the digital economy internationally. OECD (2014) used a comparative approach to construct a measurement model for the level of digital economy development, incorporating factors such as intelligent infrastructure and enhancing social vitality into the measurement indicators. The China Academy of Information and Communications Technology also constructed a Digital Economy Index (DEI) in 2017. In addition, the explanatory variables of "Internet plus Index" are digital industry and cloud usage, which can also be used as an accounting method of digital economy. Overall, there are only multiple approaches to digital economy accounting, but there is no specific measurement framework.

Due to the inconsistent accounting standards of the digital economy, existing literature on the impact of the digital economy is mostly qualitative research. Luo Min and Li Liangyu (2015) explained that in the digital economy era, the value chain and the way value is created have

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changed, and supply oriented business models are gradually shifting towards demand oriented business models, where customers and manufacturers jointly create value. Sun Jie (2020) analyzed the forms of digital trade in the era of digital economy and believed that although the digital economy has endowed traditional trade with some new content and features, it is mainly aimed at serving traditional economic activities. In the era of digital economy, traditional trade and economic activities will not be overturned. Chen Xiaohui, Zhang Hongwei, and Wu Yongchao (2020) studied the penetration of the digital economy into the first, second, and third industries and found that the digital economy has a marginal increasing effect on the level of China's industrial structure. With the improvement of the development level of the digital economy, the level of industrial structure is improved, and the speed of improvement is marginal increasing. These analyses lack empirical evidence, and the contribution analysis of the digital economy still has limitations.

At present, empirical research on the impact of the digital economy is limited, and there is very little empirical analysis on the impact of innovation. According to relevant literature by Zhang Xinwei (2019), under the conditions of the digital economy, the transformation of technological paradigms has promoted the transformation of industrial organization methods on the one hand, and expanded the scope of cyberspace on the other hand, leading to the evolution of innovative methods towards networking, collaboration, and ecology on the other hand. Chen Xiaohong (2018) believes that in the era of the digital economy, the integration of new digital technologies such as big data, the Internet of Things, artificial intelligence, blockchain, and virtual reality has led to a new round of leapfrog development in information technology. At the same time, it has triggered the widespread application of digital new technologies in public management, medical services, retail industry, manufacturing, and other fields, promoting technological integration and innovative development. Fan Zhou (2019) believes that the digital economy has become a new driving force for the innovative development of the cultural industry, and the cultural and creative development in the digital economy transformation is characterized by technology as the driving force and innovation as the core. Cao Zhengyong (2018) mentioned that the digital economy provides new impetus for economic growth, improves the quality of industrial development in China, breaks through innovative key technologies and equipment, and promotes the digital transformation and upgrading of the manufacturing industry. Xia Yan et al. (2018) analyzed that the digital economy can drive the expansion of China's economy and have a significant impact on employment in technology intensive manufacturing industries [12]. Longhaiquan (2017) explored from a micro perspective and found that network resources in the digital economy have a positive impact on enterprise value, expanding the competitive advantage of enterprises [13].

Through the literature review above, it can be found that scholars have basically reached a consensus on how the digital economy can improve productivity, and at the same time, it is also judged that the digital economy has an important impact on innovation in economic behavior. Innovation is the output behavior of a combination of multiple production factors, and innovation requires a large amount of human and material resources, with the characteristics of high risk cost, high sunk cost, and long time consumption. Therefore, enterprises with lower risk tolerance will not actively innovate. However, the development of the digital economy has achieved the digitization of production factors, and big data and artificial intelligence have shortened supply chains and targeted users, saving costs for enterprises and increasing overall profits. More funds are available for independent research and development (Thompson et al., 2013) [14]. At the same time, the digital economy can greatly solve the information gap between consumers and researchers, enabling consumers to participate more effectively in product research and development design, opening up channels for the production process of products, jointly developing products with enterprises, and reducing the risk of enterprise research and development investment (Pee, 2016) [15]. However, at the same time, the digital

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economy may have a counterproductive effect on innovative behavior, with thinner barriers to information acquisition and the most likely negative impact on intellectual property infringement categories. Under the digital economy, network infringement will have lower costs and information will become more easily intercepted, making it more difficult for regulatory authorities to detect. Since the rise of the digital economy as a national strategy in 2017, it has achieved comprehensive development, and the number of patent administrative law enforcement cases has increased by 51% year-on-year, This also confirms this situation, which can lead to companies lacking innovation motivation due to concerns about being stolen innovative achievements [16]. Due to the different impacts of the digital economy on innovation, it is necessary to use specific data to study the impact of the digital economy on regional innovation.

3. Theoretical analysis of channels of action

This article combines the theoretical analysis of existing relevant research and the logic of economic operation to summarize the main channels through which the digital economy affects regional innovation.

Firstly, for micro enterprises, they are the main body of innovation, and enterprise innovation is one of the important channels to improve their competitiveness in the market. But at the same time, innovation is a high-risk, high investment, and time-consuming business activity. Generally speaking, enterprises with high innovation enthusiasm are often the main implementers of innovation. Small and medium-sized enterprises are limited by issues such as funding and R&D personnel, and cannot upgrade their innovation in a fiercely competitive market environment. Risk averse enterprises are even less likely to take the initiative to take responsibility for innovation. The development of the digital economy has made the market more transparent, forcing enterprises to seek survival and development space in the market through innovation; At the same time, the digital economy has also opened up new channels for enterprise innovation activities. In the era of the digital economy, the information gap between customers and production enterprises is narrowing. In the past, there were often problems with boasting and strong advertising effects in enterprise marketing methods, which led to even products with poor quality being able to achieve good sales. With the development of the digital economy, consumers have access to more diverse information and product comparisons have become more transparent. If enterprises want to occupy a place in such a market, they can only achieve it through innovation, otherwise they will face the end of being eliminated. In addition, the digital economy utilizes digital technologies such as blockchain and big data to change the relationship between enterprises and consumers. Manufacturers can use digital technology to obtain surveys of consumer satisfaction and opinions on products. Consumer opinions can enable enterprises to make more accurate predictions about the future market. In the digital economy, the targeting of enterprise innovation is stronger, and the organizational structure of enterprises tends to be flatter, The reduction of internal management costs in enterprises increases their enthusiasm for innovation, and enterprise resources can be restructured around consumer needs, achieving demand oriented innovation. In this environment, innovation risks and costs are significantly reduced, and small and medium-sized enterprises can also participate in innovation activities.

Secondly, the digital economy can drive innovation in the entire industry. Under the digital economy, digital information is different from traditional factors such as labor, natural resources, and capital. Digital information is a reusable and shareable element. In the era of transparent markets and open platforms, in which digital economists share the economy, the innovative achievements of enterprises can be imitated by other enterprises, and the products of enterprise innovation will be popularized faster. The allocation of innovative resources

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transcends physical space limitations and achieves rapid integration of resources within the economic system through data transmission. Multiple innovative entities in the industry form innovation clusters, It can further improve the efficiency of resource allocation within the industry, promote new areas of industrial development, drive the technological transformation and upgrading of traditional manufacturing, and accelerate innovation.

In addition, the digital economy can break through the spatial limitations of traditional industrial agglomeration, achieve collaborative innovation among enterprises in the supply chain through the correlation effect on the supply chain, drive the improvement of production efficiency, and promote the optimization and upgrading of the industrial chain.

Thirdly, the impact of the above on enterprises and industries will ultimately manifest as the scale effect of the digital economy in a region. Under economies of scale, it can effectively save R&D costs for enterprises. Sharing resources within a region can accelerate the diffusion and innovation speed of technology, and enhance the innovation capacity of the entire region. However, at the same time, innovative knowledge sharing within the region inevitably leads to infringement of intellectual property rights and leakage of innovative technologies, which to a certain extent will have a restraining effect on innovation behavior within the region. However, overall, the positive impact of the digital economy on innovation within the region is still greater than the negative impact.

In summary, it is inferred through theoretical analysis that the development of the digital economy will promote the improvement of innovation capabilities within the region. However, there is insufficient research experience and empirical analysis so far, and there is a lack of completeness in understanding the role of the digital economy. Empirical testing of the impact of the digital economy on regional innovation capabilities is particularly necessary.

4. Research design

4.1. Modeling

4.1.1. Innovation output model

Innovation is the result of investment in factors such as human resources, capital, and technology. The core of the digital economy is the digital production factor, which can be seen as a technological input in the production process. The C-D production function can be used to construct a function that drives innovation output in the digital economy:

$$Y = f\ （DIG, Z）\tag{1}$$

Among them, Y represents the innovation output of a certain region; DIG is the Digital Economy Development Index, which is the core explanatory variable of the model; Z represents the set of control variables in the model, representing other variables that can affect innovation capability. The control variables selected in this article include conventional influencing factors such as regional GDP, foreign direct investment, government intervention level, infrastructure level, and internet finance. After concretizing all indicators, the following empirical model can be constructed:

$$Y = \alpha + \beta_1 DIG + \beta_2 GDP + \beta_3 FI + \beta_4 GOV + \beta_5 BF + \beta_6 UB + \epsilon \tag{2}$$

Among them, β_1 is the estimated parameter of the digital economy development index, which is the explanatory variable of this article. The possible impact of the digital economy on innovation has been explained in the previous text, and the variable coefficient predicting the impact of the digital economy is positive; The Gross Domestic Product (GDP) of a region is often accompanied by changes in regional consumption demand, which in turn promotes the innovation and transformation of individual industries and enterprises in the region, contributing to the improvement of regional innovation capabilities; Foreign investment can

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improve the overall quality of labor in a region through spillover effects, and at the same time, obtain more capital and technology inflows within the region, which can enhance the overall innovation capacity of the region; Indicating the degree of government intervention, relevant literature has verified that government intervention can improve innovation performance and high-quality innovation within a region through tax incentives. Government R&D subsidies have a crowding out effect on the innovation performance and quality of enterprises [18]; The level of infrastructure, especially information infrastructure, can increase communication channels, improve production and transaction processes, significantly reduce transaction costs, and enable enterprises to obtain greater innovation benefits and improve innovation efficiency. At the same time, infrastructure has the characteristics of high permeability and strong externalities. A well-developed infrastructure strengthens the diffusion effect of information technology, freeing it from being confined within the industry and between segmented industries, which helps to improve the innovation efficiency of high-tech industries [19]; Indicating the level of urbanization, the higher the level of urbanization, the closer the connections within a region. Whether it is labor factors or information factors in the new era, the factor density in urban areas is much higher than that in rural areas, and high factor density often means innovation efficiency; Is the intercept term; Is a random perturbation term.

4.1.2. Construction of Digital Economy Index

The difficulty of digital economy accounting is high, and there is a lack of unified accounting standards internationally. The main reason is that countries have different understandings of the digital economy, and there are also differences in its classification. There are currently two main accounting methods for the digital economy.

The first method is comparative analysis. The OECD's model for measuring the level of digital economy development includes comparisons of intelligent infrastructure, promoting growth and employment, but most of them are conceptual frameworks that have not been verified in practice, and their reliability is questionable [5]; The White Paper on the Development of China's Digital Economy released by the China Academy of Information and Communications Technology in 2017 includes the added value of the primary industry, industrial value added, and tertiary industry value added as part of the scale of the digital economy; The Global Digital Economy Index released by KPMG in 2018 includes digital infrastructure, digital consumers, digital industry ecology, digital scientific research, and digital public services. However, the comparative method has practical difficulties in measuring the broad scope and difficulty in obtaining indicators, and the accuracy of the actual measurement method is also worth considering.

Another measurement method is the direct method, which mainly measures indicators related to the digital economy such as income, industrial value-added, employment scale, etc. By determining the weights of each indicator, the motion entropy weight method and principal component analysis method are used to construct the digital economy index. Most existing research on the digital economy adopts this method to evaluate the development of the digital economy. Compared with the comparative method, this method has the advantages of high data availability and high calculation credibility. However, at the same time, this method has poor operability at the secondary regional level, and macro statistical data indicators also comprehensively capture the added value of the digital economy.

This article refers to existing literature on the measurement methods of the digital economy index and uses the entropy method to measure the digital economy development index. The specific selection of secondary indicators is based on Liu Jun et al. (2020), which took internet development as the measurement core and added it to the evaluation system of the digital economy index [20]. Referring to the digital economy index measurement method adopted by Zhao Tao (2020), the Internet development and digital inclusive finance index are included in

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the measurement [21]. Drawing on the method of Huang Huiqun et al. (2019), four indicators were included in the measurement: internet penetration rate, number of internet related practitioners, internet related output, and mobile phone penetration rate [22]. In summary, the construction indicators of the digital economy index selected in this article are shown in Table 1.

Table1. Selection of indicators for measuring the digital economy index

Primary indicators	Secondary indicators	Third level indicators	Indicator attribute
Digital Economy Index	Internet penetration rate	Internet users per hundred people	+
	Number of Internet related practitioners	The proportion of computer service and software professionals	+
	Internet related outputs	Per capital total telecommunications services	+
	Number of mobile internet users	Number of mobile phone users per 100 people	+
	Development of digital inclusive finance	China Digital Inclusive Finance Index	+

4.2. Related variable measurement

4.2.1. Digital Economy Index Measurement - Entropy Method

The entropy method can overcome the subjectivity of manually determining weights and the overlap of information between multiple indicator variables, and is widely used in research fields such as social economy. Entropy refers to the measurement of the degree of disorder in a system. The greater the degree of variation of a certain indicator, the smaller the information entropy, the greater the amount of information provided by the indicator, and the greater the weight of the indicator; On the contrary, the weight of the indicator will be smaller [23]. The weight of each indicator can be calculated using the entropy method.

The specific processing method is to perform dimensionless processing on n evaluation indicators of m samples., The reason for dimensionless processing is that the statistical units of various indicators in the evaluation index system of basic public service level are inconsistent, making it impossible to directly perform mathematical aggregation. So let the dataset consisting of n evaluation indicators from m samples be $(x_{ij})_{m\times n}$, where x_{ij}represents the jth indicator value of the i-th sample, and use the extremum method to perform dimensionless processing on each indicator.

For positive indicators:

$$x'_{ij} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}} \tag{3}$$

For negative indicators:

$$x'_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}} \tag{4}$$

Among them, x'_{ij} represents the standardized value, while x_{min} and x_{max} represent the maximum and minimum values of indicator j. Obtain the dimensionless processed dataset $(x'_{ij})_{m\times n}$.

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For the obtained dataset $(x'_{ij})_{m\times n}$, calculate the proportion P_{ij} of the i-th sample value under the j-th indicator in the dataset.

$$P_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} \tag{5}$$

In the formula, x'_{ij} represents the standardized indicator value, and P_{ij} represents the proportion of the i-th city indicator value under the j-th indicator.

The information entropy value of the jth indicator is:

$$e_j = -K\sum_{i=1}^{m} P_{ij} \ln P_{ij} \tag{6}$$

Among them, K is a constant,$K=1/\ln m$, $K > 0$; e_j is the entropy value of the item indicator,$e_j \geq 0$.

Calculate the coefficient of difference:

$$g_j = 1 - e_j \tag{7}$$

In the formula, g_j is the coefficient of difference for the evaluation index of item j.

Calculate weights:

$$w_j = \frac{g_j}{\sum_{j=1}^{n} g_j} \tag{8}$$

In the formula, w_j represents the weight of j indicators.

Calculate the comprehensive score for each city:

$$DIG_{ij} = \sum_{j=1}^{n} x'_{ij} w_j \tag{9}$$

In the formula, DIG_{ij} represents the development index of the digital economy, x'_{ij} represents the dimensionless value of each indicator, and w_j represents the weight of each indicator.

Substitute the relevant indicators selected in Table 1 into the calculation. Considering the availability of data, this article selects provincial panel data from the corresponding tables of 30 provinces in China from 2011 to 2019 for calculation. The original data of the relevant indicators can be obtained from the China Urban Statistical Yearbook. For the development of digital finance, the China Digital Inclusive Finance Index is adopted, which was jointly compiled by the Digital Finance Research Center of Peking University and Ant Financial Group (Guo Feng et al., 2020) [24]. The calculated results are shown in Table 2.

Table 2. Measurement results of digital economy index

area	2015	2016	2017	2018	2019
Beijing	0.5863	0.5648	0.6394	0.7727	0.8955
Tianjin	0.3642	0.3679	0.4283	0.5328	0.6275
Hebei	0.2991	0.3137	0.3748	0.4524	0.5329
Shanxi	0.3135	0.3242	0.3766	0.4497	0.5334
Neimenggu	0.3290	0.3358	0.3926	0.4776	0.5673
Liaoning	0.3618	0.3593	0.4176	0.4863	0.5540
Jilin	0.3190	0.3262	0.3877	0.4629	0.5389
Heilongjiang	0.3112	0.3199	0.3791	0.4362	0.5037
Shanghai	0.4861	0.4723	0.5493	0.6650	0.7703
Jiangsu	0.3785	0.3750	0.4414	0.5505	0.6472
Zhejiang	0.4289	0.4160	0.4908	0.6048	0.7192
Anhui	0.2943	0.3097	0.3704	0.4569	0.5462

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Fujian	0.3917	0.3844	0.4485	0.5408	0.6250
Jiangxi	0.2899	0.3014	0.3649	0.4452	0.5292
Shandong	0.3240	0.3335	0.3892	0.4661	0.5383
Henan	0.2870	0.3024	0.3664	0.4533	0.5308
Hubei	0.3264	0.3344	0.3994	0.4856	0.5699
Hunan	0.2884	0.2984	0.3573	0.4364	0.5204
Guangdong	0.4172	0.4082	0.4861	0.6025	0.6987
Guangxi	0.2937	0.3037	0.3608	0.4527	0.5356
Hainan	0.3499	0.3439	0.4182	0.5231	0.6034
Chongqin	0.3271	0.3333	0.3987	0.4898	0.5810
Sichuan	0.3191	0.3237	0.3846	0.4692	0.5422
Guizhou	0.2802	0.2945	0.3706	0.4760	0.5873
Yunnan	0.2950	0.3009	0.3702	0.4600	0.5565
Xizang	0.2915	0.2992	0.3471	0.4135	0.5519
Shanxi	0.3391	0.3463	0.4086	0.5178	0.6053
Gansu	0.2870	0.2868	0.3523	0.4420	0.5320
Qinghai	0.3119	0.3076	0.3831	0.5005	0.5900
Ningxia	0.3268	0.3221	0.3996	0.4960	0.5894
Xinjiang	0.3138	0.3066	0.3534	0.4283	0.5433

Note: Due to space limitations, this table only lists the data measured in the past 5 years

The data obtained from analysis and calculation shows that the development level of the digital economy in China's entire province is showing a continuous upward trend, with a significant increase in growth since 2017. It is believed that this is due to the inclusion of the digital economy in the national strategic key construction. In addition, the development level of digital economy in the eastern coastal provinces is significantly higher than that in the central and western provinces of China, which is objectively in line with the development level of the eastern, central and western regions of China. The development level of digital economy in the Beijing Tianjin Shanghai municipalities, Jiangsu, Guangdong, and Zhejiang regions is among the top in the country, while the gap in development level in other regions is relatively small.

4.2.2. Measurement of Regional Innovation Capability and Control Variables

According to existing research, the number of patent applications and the number of patent authorizations are often used as common tools for measuring innovation capabilities. The former mainly reflects the enthusiasm of innovation applicants for innovation. Due to many application projects not being approved, it cannot reflect the specific research and development capabilities; The latter can reflect actual research and innovation capabilities. This article selects the number of domestic utility model patent applications accepted, domestic utility model patent applications authorized, and domestic invention patent applications authorized from 30 provinces in China from 2011 to 2019 based on data availability to reflect regional innovation capabilities. The data mainly comes from the China Statistical Yearbook over the years.

In the measurement of control variables, foreign investment is measured by the amount of foreign investment; The level of government intervention is measured by the ratio of general budget expenditure to GDP; Infrastructure level is measured by the level of fixed assets investment in GDP; The regional gross domestic product and urbanization level are measured by the variables themselves, and the main explanatory variables are described in Table 3.

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Table 3. Description of main explanatory variables

Variable	Observation sample size	mean value	standard deviation	minimum value	Maximum value
Digital Economy Index	270	0.3410	0.1505	0.0773	0.8955
Foreign investment amount/100 million US dollars	270	82.8247	79.4288	0.0446	357.5956
Infrastructure level/ratio of fixed assets investment to GDP	270	0.7938	0.2562	0.2100	1.4795
Government intervention level/ratio of general budget expenditure to GDP	270	0.2642	0.1150	0.1200	0.7583
Regional GDP/100 million yuan	270	24653.1100	19602.1000	1670.4400	107671.0000
Urbanization level	270	58.5529	12.8377	31.43	88.73

5. Empirical results and conclusions

In order to assess the impact of the digital economy on regional innovation capabilities, this article selected panel data from 30 provinces in China from 2011 to 2019 for validation. Firstly, multicollinearity tests were conducted on each explanatory variable, and the average VIF value obtained from the test was 3.63. The VIF value was less than 10, indicating that there was no significant collinearity between the explanatory variables. Secondly, for the three dependent variables selected for the model, logarithmic treatment was applied to the explanatory variables with large data for fixed effects and random effects regression, respectively. The Hausman test was used, and the test results showed that Prob>chi2=0.0000, indicating a significant choice of a fixed effects model. The regression results of the fixed effects model are shown in Table 4.

Table 4.Regression results of digital economy on regional innovation

	Domestic invention application authorization volume	Number of domestic utility model patent applications authorized	Acceptance volume of domestic utility model patent applications
Digital economy index	0.837***	1.739***	1.026***
	(3.08)	(6.99)	(3.92)
Infrastructure level	0.379***	0.280**	0.342***
	(3.28)	(2.65)	(3.07)
Foreign investment	-0.0515	-0.0445	-0.0651
	(-1.41)	(-1.34)	(-1.86)
Government intervention level	1.954***	0.309	0.904*
	(2.82)	(0.49)	(1.36)
GDP	0.6672***	0.181	0.423***
	(4.57)	(1.35)	(4.57)
Urbanization level	0.932***	0.965***	1.287***
	(4.51)	(5.11)	(6.47)
Goodness of fit	0.804	0.8381	0.8274

Note: * * *, * *, * * represent significant levels of 1%, 5%, and 10%, respectively; Robust standard error in parentheses

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Analyzing the regression results in Table 4, the first column shows the number of domestic invention patent applications authorized as the dependent variable, the second column shows the number of domestic utility model patent applications authorized as the dependent variable, and the third column shows the number of domestic utility model patent applications accepted as the dependent variable. It can be found that the digital economy has a significant positive driving ability for innovation growth. For the standardized data digital economy index, if the development index in a certain region is doubled by the standard deviation, the regional invention patent application authorization volume will increase by 0.837%, the domestic patent application authorization volume will increase by 1.739%, and the domestic patent application acceptance volume will increase by 1.026%. This indicates that in the digital economy, open and transparent information can indeed aggregate information and intensify market competition; At the same time, the degree of monopoly has been reduced, and in order to survive, enterprises must accelerate the innovation of technology and products. The digital economy has achieved point-to-point interaction between enterprises and users, enabling enterprises to make factual judgments on changes and development directions in market demand. The market demand recognition of R&D departments has also shifted from traditional manual recognition mode to artificial intelligence recognition, improving the quantity and quality of innovation. In addition, in the era of digital economy, digital technology has changed the business logic of enterprises, and the application of e-commerce has significantly reduced the operating and transaction costs of enterprises; At the same time, it has also achieved the docking and sharing of information resources between enterprises, consumers, and platforms. The open nature allows more entities to participate in product development and technological innovation, creating an upper and lower industrial chain, forming a model led by enterprises and involving multiple assistants in innovation; Furthermore, digital information is a low-cost information element, and as the user base expands, the economies of scale brought about by the digital economy will deepen its integration with the real economy, ultimately enhancing the innovation capability of the entire region.

The regression results of some control variables are consistent with expectations. Infrastructure level, government intervention, regional gross domestic product, and urbanization factors all show significant correlation with innovation in the partial regression, while foreign investment has not shown a good correlation. Considering the significant economic growth in China, the innovation momentum and incentives of independent research and development can already meet most of the needs of innovation behavior in China, The impact of foreign investment has been diluted.

5.2. The impact of digital economy on different types of innovation

This article analyzes the authorization volume of domestic invention applications and domestic patent applications respectively. Invention applications include applications for products, methods, or improved technical solutions, and the regression results show that the impact of the digital economy on utility model patents is much greater than that of invention patents. The requirements of China's patent law are that invention patents need to have outstanding and significant progress, while utility patents require substantive features and progress. Under the influence of the digital economy, the originality and progressiveness of China's invention and innovation are still not strong, and further improvement is needed. The regression coefficient between the acceptance and authorization of patent applications shows that the impact of the digital economy on the authorization of patents in China is greater than the authorization, indicating that the quality of innovation in China has been effectively improved under the digital economy and needs to be further improved and developed.

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6. Policy recommendations

(1) To comprehensively lead the high-quality and sustainable development of the digital economy, we should increase innovation support in the core areas of the digital economy such as big data, artificial intelligence, cloud computing, blockchain, etc. At the same time, we should improve the infrastructure factors that the digital economy relies on by building and improving mobile communication networks and information infrastructure. At the same time, we should continue to promote the construction and application of internet platforms in the new era and promote data and information sharing in the manufacturing industry.

(2) The government should implement precise policies. Currently, there is still a serious imbalance in the development of China's digital economy. The government's policies need to do a good job in the overall layout of digital technology applications. In addition, it is necessary to accelerate the digital transformation of local industries and avoid the digital development of the consumption sector caused by the digital economy. It is important to avoid excessive adjustment of the consumption sector towards online entertainment, online payments, and other aspects, Avoid the transition of industrial structure to service-oriented. Promote the integration of digital technology and traditional manufacturing industry, support the digital and intelligent transition development of local advantageous industries, achieve the transformation of new and old industries, enhance the independent innovation ability in the region, while avoiding innovation similarities, and develop distinctive innovation in the region.

(3) Although China's innovation capability has significantly improved in the era of digital economy, it is still in a situation where invention patents are far less than practical patents. We should use the digital economy as a catalyst to guide industries in the region to focus on high-quality innovation, achieve the transformation from improvement and imitation innovation to independent, deep, and new innovation, build an innovative country, and realize the beautiful vision of Made in China 2025. At the same time, we will tap into the innovation potential of the central and western regions, improve talent introduction policies, and solidly promote the development of the digital economy and the improvement of innovation capabilities nationwide.

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