Research on the Impact of University Innovation Capacity on Regional Economic Growth in Beijing

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Abstract. This paper explores the influence of the scientific and technological innovation ability of universities in Beijing on regional economic growth. Using data of universities in Beijing from 2001 to 2020, this paper constructs a multi-level indicator system and applies the entropy method to measure the scientific and technological innovation capacity of Beijing universities. This paper finds a continuous growth trend in the scientific and technological innovation ability of Beijing's universities over the last two decades. The regression result demonstrates that this growth trend has a significant impact on regional economic growth. Despite other moderating factors, such as capital, labor, international openness, and government expansion, the optimization of the industrial structure plays a vital role in Beijing's economic growth.

Keywords: innovation ability; economic growth; entropy method.

1. Introduction

According to the theory of endogenous growth, knowledge innovation and technological progress have been regarded as the endogenous power of economic growth in the long history of human society. Due to the increasing trend of economic globalization, economic transformation and upgrading, many developed countries have gradually established a multilevel, diversified policy system for scientific and technological innovation. Accordingly, this action aims to align with the overall trend in scientific and technological innovation and to improve their overall competitiveness in the international arena. In June 2022, the State Council of China issued *The Guidelines on Strengthening the Building of a Digital Government*. These Guidelines are designed to actively comply with the increasing economic and social digital transformation trend. In accordance with the national policy, several measures have been taken by Beijing, Xiamen, Shandong, and other cities to accelerate the metaverse development through innovation to propel a new round of scientific and technological revolution and industrial revolution transformation. Increasingly, colleges and universities have become the primary expression of scientific and technological progress and knowledge innovation with the advancement of scientific and technological innovation, and through the knowledge spillover effect, have contributed to local economic development.

The distribution and R&D strength of universities in different regions of China are influenced by various factors, including their geographical location, economic development, and regional policies. Beijing, the capital of China and a significant economic and cultural center, has been home to 47 higher education institutions with 78,516 teaching and research staff by 2021. Therefore, the paper examines the impact of university innovation on regional economic growth in Beijing to provide theoretical support on the promoting effect of scientific and technological innovations of Chinese universities on economic development and to enrich the measurement dimensions of innovation-related indicators.

2. Literature Review

2.1 Innovation and Economic Growth

In terms of theories related to innovation, the concept of innovation originated from Schumpeter's *Theory of Economic Development,* published in 1912 [1]. As per his definition, innovation is the introduction of a "new combination" of production factors and conditions into the production system, and economic development is the result of the continuous realization of this "new combination" in the capitalist system. Upon reviewing the research associated with innovation, it is found that the majority of the research objects are individuals, universities, businesses, and countries. From the perspective of individuals, some studies have explored the influencing factors of individual innovation behavior and performance. Baldridge & Burnham [2], for example, suggest that administrative positions and roles affect individual participation in the innovation process, while Hammond et al., demonstrate that motivation factors contribute to creative and innovative behavior [3]. From the perspective of enterprises, a large number of studies focus on the impact of innovation on enterprise performance. As an example, enterprise innovation contributes to the growth of enterprise market value [4], which enhances enterprise competitiveness [5] and promotes enterprise survival [6]. Nationally, the research literature on innovation can be broadly divided into research on the relationship between national innovation activities and the business cycle [7, 8] and research on national innovation capability [9, 10]. The research related to the innovation activities of colleges and universities in details will be discussed in the subsequent section of this chapter.

Since the invention of innovation theory, it has gradually developed into the neo-classical school, the neo-Schumpeterian school, the neo-institutional school, and the school of the innovation state system. According to the neo-classical school, represented by Solow and Arrow, technological innovation is an endogenous variable and a significant contributor to economic growth [11]. Based on Schumpeter's ideas, the neo-Schumpeterian school emphasizes the central role of technological innovation and technological progress in economic growth. A neo-institutional school comprises an institutional school and a new institutional economic school, where the institutional school attacks the existing system. However, because of the loose structure of the institutional school, it is controversial. Economic growth is embodied rather than caused by technological innovation and progress in the new institutional economic school. Despite being isolated, innovation activities are facilitated by the national innovation system as described in the school of the innovation state system. In this regard, Nelson summarized the general institutional structure of state support for technological advancement [12].

In terms of empirical studies on the relationship between innovation and economic growth, it is widely believed that R&D and innovation systems directly affect the development and economic growth of a country and that R&D efficiency is significantly positively correlated with the country's per capita GDP [13, 14]. However, the capacity to translate R&D expenditures into innovation and economic growth varies. Through the example of the European Union region, Benat & Andres demonstrate that this difference results from differences in the economic characteristics of diverse regions [15], whereas the results of the study of Cainelli et al., suggest that the difference depends on whether a company is innovative or not [16], and those innovative institutions are more likely to convert innovation funds into economic growth. In the context of international economic cooperation in science and technology, some studies have shown that enterprise R&D generally has an externality, spillover effect, and reciprocity [17]. According to this view, innovation can be found in developed and developing countries [18]. Aside from the fact that domestic firms can benefit from the R&D activities of foreign firms, foreign government research may also stimulate domestic private research [19]. A time-span perspective indicates that innovation is not only positively influenced by past economic performance but is also responsible for stimulating future economic growth and productivity [20].

2.2 Research on the Innovation Capacity of Universities

During the past few years, most research on universities' innovation and R&D capabilities has been based on the innovation theory, emphasizing the index composition, current state, evaluation, and influencing factors. Accordingly, Saunila & Ukko have proposed a framework to measure innovation capability based on the existing theory and literature on innovation capability and performance measurement [21]. From the perspective of affecting universities' innovation and R&D capability, Hvide & Jones examined the significant decline in entrepreneurship and patent application rates of university researchers caused by the change from the "professor's privilege" mode to the current mode in Norway [22]. Accordingly, university R&D and innovation capabilities were significantly affected by policy reform. It is argued by Agrawal & Goldfarb that the advent of Bitnet and the Internet could reduce communication costs between universities [23], thereby facilitating research collaboration between top business schools and second-tier institutions. Furthermore, several studies have examined universities' R&D and innovation capabilities in the context of university-industry partnerships and explored the influencing factors of university-industry partnerships [24, 25], and demonstrated the typical role of scholars in academy-industry partnerships as consultants and researchers [26]. With a lag effect of approximately five years [27], this partnership proved beneficial for enterprises leveraging university scientific research for industry innovation [28]. Based on these findings, policies to stimulate industrial and technological innovation through increased collaboration between industry and researchers can be justified.

2.3 The Influence of Scientific and Technological Innovation Capacity of Universities on Economic Growth

There has been substantial empirical evidence showing that university innovation and R&D positively impact regional economic growth and development. A large amount of empirical evidence shows that university innovation and R&D have a positive impact on regional economic growth and development [29]. There may not necessarily be a dramatic change, but the economic growth generated by novel ideas and cutting-edge technologies can be dynamically reflected in the evolution of employment and GDP [30]. The contribution of colleges to innovation and economic development has been explored using an eight-paradigm framework by Lawton-Smith [31]. In contrast, Hausman has found that increased federal funding for university R&D results in improved local economic benefits, resident health, and national security [32]. Furthermore, Bramwell & Wolfe assert that the university contributes far more to regional economic dynamism than this description implies [33]. Besides producing qualified research scientists and commercially available knowledge, universities are also capable of facilitating knowledge transfer by attracting top talent and providing technical assistance. By providing physical capital to universities and using R&D resources to support university research, enterprises gain access to the critical factor of economic growth: the flow of knowledge [34]. The universities, in turn, stimulate corporate R&D expenditures and patent activities through commercial spillovers [35]. Regional economies will gradually transition from an agricultural economy to an industrial economy and finally to an innovation-driven economy as universities transition from performing traditional educational functions to playing a central role in promoting innovation and R&D through knowledge [36].

Furthermore, researchers have found that a limited spatial spillover effect exists between universities' scientific and technological innovation capabilities and economic growth. The effect can extend up to approximately 145 miles [37], and there is an imbalance between regions, which is reflected in the fact that universities in regions with more intense competition can contribute more wealth than universities in regions with less fierce competition [38].

However, some scholars have reached different conclusions. Despite its apparent advantages in scientific research, Johns Hopkins University, for example, has not brought any clear economic benefits to the local area over its 125-year history because of a lack of incentives for commercial activities and difficulties in transferring technology [39]. Similarly, Feller agrees that using university R&D for economic growth is not a wise strategy [40]. As he asserts, universities derive their intellectual and political capital not only from their scientific knowledge but also from their role as symbolically indifferent participants in the graying discourse system.

In conclusion, although multiple studies have investigated the influence of scientific and technological innovation activities on regional economies at universities, there is no consensus among different schools. Consequently, integrating innovation into the economic development research system from a theoretical perspective and exploring university innovation and economic growth from an empirical perspective may facilitate academic development and practical guidance regarding economic growth transformation and national competitiveness improvement.

3. The Scientific and Technological Innovation Capacity of Universities in Beijing

In light of past research, the appropriate measurement indicators will be chosen in this chapter to construct a scientific and technological innovation indicator system in universities in Beijing, as well as methods for measuring and observing the results based on that research.

3.1 The Construction of a Scientific and Technological Innovation Indicator System for Universities

This paper references innovation and R&D capacity of related research and technological innovation output theory [41, 42, 43], which is derived from the inputs and outputs of science and technology innovation in universities, and the ability to successfully transform them. As shown in *Table 1*, we have constructed a multi-level indicator system based on the representation of the indicator system design, systematic, scientific, and operational principles and established a scientific and technological innovation capacity indicator system for Beijing universities.

Table 1. Scientific and Technological Innovation Indicator System

Level Indicators	Secondary Indicators	Unit	Positive / Negative
The Input Ability of Science and Technology Innovation in Universities in Beijing	The Number of R&D Staff	Per Person	Positive Indicator
	The Amount of Personnel Involved in Implementing R&D Results and Providing Scientific and Technological Services	Per Person	Positive Indicator
	Scientific Research Fund	One Thousand Yuan	Positive Indicator
	Special Fees for Competent Departments	One Thousand Yuan	Positive Indicator
The Output Ability of Science and Technology Innovation in Universities in Beijing	The Number of R&D Projects	Per Item	Positive Indicator
	Number of R&D Results Implemented and Science and Technology Service Projects	Per Item	Positive Indicator
	National Science and Technology Awards	Per Item	Positive Indicator
	The Number of Academic Papers Published	Per Article	Positive Indicator
	The Number of Scientific and Technological Works Published	Per Item	Positive Indicator
	The Number of Patents Applied	Per Item	Positive Indicator
	The Number of International Project Acceptances	Per Item	Positive Indicator
The Transforming Ability of Science and Technology Innovation in Universities in Beijing	Actual Income from Patent Transfers in the Current Year	One Thousand Yuan	Positive Indicator
	Actual Income from Technology Transfer in the Current Year	One Thousand Yuan	Positive Indicator
	The Number of Dispatched Persons for International Cooperation and Exchanges	Person-time	Positive Indicator
	The Number of Attendees of International Academic Conferences	Person-time	Positive Indicator

3.2 The Score of Scientific and Technological Innovation Capacity of Universities in Beijing

The academic community assesses universities' scientific and technological innovation capability by constructing an evaluation indicator system. In broad terms, the methods selected may be divided into two categories: the first category consists of objective weighting methods, such as an analytic hierarchy process or a Delphi process. Furthermore, there are subjective weighting methods, such as principal component analysis, cluster analysis, etc. This paper uses the entropy method to evaluate the scientific and technological innovation capabilities of universities in Beijing to avoid the influence of individual subjectivity on index construction.

The term "entropy" was initially used in thermodynamics but was later applied to the field of information theory. Based on the reasoning and calculations of the scholars, an entropy method for calculating index weight was developed. Using the entropy method, we can measure the amount of information and degree of uncertainty in the system, with a negative correlation between entropy and uncertainty. From 2001 to 2020, a sample of universities in Beijing was selected for this study. The chosen index data originate from the *Compilation of Science and Technology Statistics of Institutions of Higher Learning* from 2001 to 2021. The data were analyzed using Stata 17.0, and the entropy method was applied to assign a value to universities' scientific and technological innovation capability. This paper presents the weight score of the scientific and technological innovation capability of universities in Beijing over the past twenty years. It provides the basis for assessing the comprehensive ability of universities in Beijing in terms of scientific and technological innovation capability through an indicator system. In *Table 2*, the results are presented. The data from the table were cleaned and visualized using Python 3.9.10, based on the scientific and technological innovation capability score, and a line chart illustrating the change in the scientific and technological innovation capacity score from 2001 to 2020 was obtained. *Fig. 1* demonstrates the results.

Table 2. Score of Scientific and Technological Innovation Capacity

Year	Score
2001	0.08431
2002	0.09677
2003	0.10868
2004	0.19873
2005	0.12951
2006	0.20145
2007	0.21014
2008	0.21490
2009	0.28366
2010	0.27806
2011	0.40059
2012	0.44107
2013	0.45304
2014	0.50167
2015	0.51369
2016	0.65846
2017	0.72570
2018	0.72451
2019	0.81098
2020	0.77517

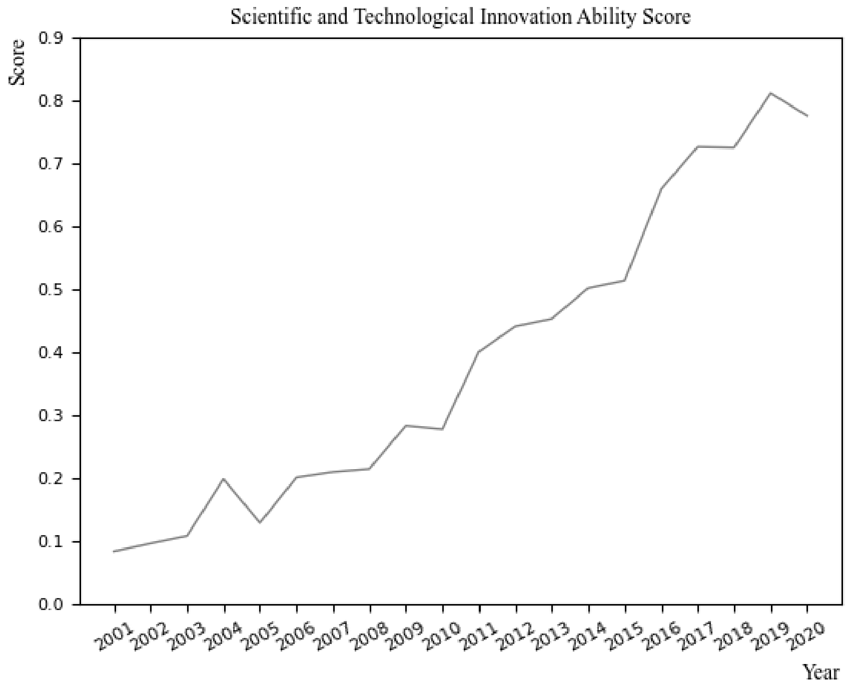

Fig. 1 The Change of the Scientific and Technological Innovation Capacity Score

It can be seen from *Fig. 1 t*hat the score calculated by the entropy method reflects the scientific and technological innovation capability of universities in Beijing well. Data over 20 years from 2001 to 2020 shows that universities in Beijing have demonstrated a continuous growth trend in scientific and technological innovation, and that trend has been rapid. The scientific and technological innovation capability index of Beijing's universities increased approximately eightfold between 2001 and 2020, as Beijing plays a central role in science, education, and culture. In addition, the Chinese government has adopted a strategy to rejuvenate China through science and education as part of its rejuvenation strategy. Besides being home to the most significant number of higher education institutions in China, a large number of research and development personnel are also in Beijing.

4. Model Specification

According to the Cobb-Douglas production function model, the main factors affecting economic growth are labor input, fixed asset input, and comprehensive technological level. Furthermore, economic growth is closely correlated with labor quality, regional industrial structure, and other factors in the commonly used econometric models. Upon reading the literature on economic growth, it is also discovered that a number of studies have demonstrated that the scale of higher education, government, and openness to foreign countries significantly impact regional economic growth. These factors were controlled in the empirical analysis to improve the level of explanation and perfection of the regression model:

$$\ln Y_t = \beta_0 + \beta_1 Score_t + \beta_2 \ln K_t + \beta_3 \ln L_t + \beta_4 \ln T_t + \beta_5 \ln O_t + \beta_6 \ln G_t + \varepsilon_t \tag{1}$$

As such, the subscript t stands for the year, Y for the regional economic growth, Score for the total score of the capacity of Beijing's universities to innovate in science and technology, and K for the scale of capital investment in Beijing. Specifically, L refers to the input of labor, T to the development of tertiary industry, O is the level of international openness, G is the size of the government, ε_t is the random error, and β_i is the estimated coefficients of each variable.

5. The Empirical Research

This chapter will analyze the effect of scientific and technological innovation of universities in Beijing on economic growth using the scores of the scientific and technological innovation capacity of universities in Beijing derived in Chapter 3 and the regression model developed in Chapter 4.

5.1 Variables Selection and Data Processing

In this paper, the variables are as follows: The explained variable is the economic growth level (Y), which is expressed as the GDP of Beijing. The explanatory variable in this study is the scientific and technological innovation capability of universities in Beijing (Score), which is measured by the entropy method in the third chapter. This paper contains the following control variables: (1) the scale of capital investment in Beijing (K), which is calculated by the net value of fixed assets invested in the whole society of Beijing. (2) Beijing's labor input scale (L), expressed as an expression of the number of employees in Beijing. (3) The development of the tertiary industry in Beijing (T), measured by the total output value of the tertiary industry in Beijing. (4) The level of international openness (O), represented by Beijing's total import and export trade. (5) Beijing municipal government's scale (G) can be expressed in terms of its fiscal expenditure level. In addition, this paper also used unified logarithmic processing on the explained variables and control variables in the process of econometric analysis to address the problem of data instability and heteroscedasticity.

Relevant data for Beijing from 2001 to 2020 is examined in this paper, primarily drawn from the *Beijing Statistical Yearbook (*2002-*2021)*. Stata 17.0 is used for statistical analysis. Since the *Beijing Statistical Yearbook* does not contain data for the specific index selected for measuring capital investment scale (K), namely the net value of fixed asset investments for the entire Beijing society, the data source of this index for 2018 to 2020 is the Qianzhan database.

5.2 The Regression

In this section, descriptive statistics are computed on all variables in *Equation 1* (see *Table 3*), and then OLS multiple regression is applied to all samples. *Table 4* shows the results of the regression analysis.

Table 3. Descriptive Statistics Analysis Results

Variable	Obs	Mean	Std. Dev.	Min	Max
lnY	20	9.561	0.717	8.259	10.494
Score	20	0.391	0.245	0.084	0.811
lnK	20	8.497	0.596	7.333	9.225
lnL	20	6.913	0.214	6.444	7.149
lnT	20	9.304	0.780	7.884	10.318
lnO	20	9.645	0.616	8.358	10.263
lnG	20	8.163	1.081	6.421	9.608

Table 4. Regression Analysis Results

lnY	Coef	St.Err.	t-value	P-value	[95% Conf	Interval]
Score	0.102***	0.031	3.30	0.006	0.035	0.169
lnK	0.088***	0.026	3.35	0.005	0.031	0.145
lnL	0.04	0.066	0.61	0.553	-0.102	0.183
lnT	0.721***	0.044	16.49	0.000	0.627	0.816
lnO	0.029**	0.011	2.58	0.023	0.005	0.054
lnG	0.049*	0.023	2.11	0.055	-0.001	0.100
Constant	1.096***	0.214	5.11	0.000	0.633	1.559
Observations	20		F test		0.000	
R-squared	1.000		Prob > F		0.000	

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The above regression analysis shows that, when considering the equation's overall goodness of fit, the integrity of fit R^2 is 1.000, which indicates a perfect fitting effect. Results of the regression indicate that the total score of the scientific and technological innovation capacity of universities in Beijing is positively related to the GDP of Beijing at the significance level of 0.01, and the coefficient is 0.102. A positive coefficient can be found for all control variables in this research, including capital investment and labor input. This supports the hypothesis that capital and labor, two of the essential factors of production, all contribute to economic growth under normal conditions. Moreover, the development of tertiary industries, the level of international openness, and the size of government also significantly impact economic growth in accordance with expectations. Furthermore, it is noteworthy that the coefficient of the development of tertiary industries is the largest of all variables, measuring 0.721, which indicates that upgrading industrial structures played a significant role in Chinese economic growth during the early 21st century.

5.3 Robustness Test

For this article's conclusion to be more reliable, an alternative study on the explained variable, economic growth level (Y), has been conducted. The logarithm of Beijing's GDP per capita (lnGDPPC) is used to replace the logarithm of Beijing's GDP, while the explanatory and control variables remain unchanged. The regression study is then repeated.

Table 5. Robustness Test Results

lnGDPPC	Coef	St.Err.	t-value	P-value	[95% Conf	Interval]
Score	0.272**	0.116	2.33	0.036	0.020	0.523
lnK	-0.252*	0.129	-1.95	0.072	-0.530	0.026
lnL	0.292	0.191	1.53	0.150	-0.121	0.705
lnT	0.982***	0.188	5.21	0.000	0.575	1.388
lnO	-0.008	0.043	-0.18	0.862	-0.100	0.085
lnG	-0.179	0.113	-1.58	0.138	-0.423	0.066
Constant	3.667***	0.585	6.27	0.000	2.404	4.931
Observations	20		F test		0.000	
R-squared	0.998		Prob > F		0.000	

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The regression results are shown in *Table 5* after the replacement of variables. At this time, it is evident that the fitting degree of the results obtained is still relatively high, with a goodness of fit R^2 of 0.998. It has been demonstrated that at the significance level of 0.05, the total score of the explanatory variable science and technology innovation ability among universities in Beijing is positively correlated with per capita GDP, with the corresponding coefficient being 0.272, which is greater than the corresponding coefficient obtained by regression of Beijing GDP. Except for some control variables, namely capital investment (K), international openness (O), and government scale (G), the significance levels and coefficient signs of other variables have not changed significantly, which indicates a robust model. Based on the study's results, it is evident that Beijing's universities' scientific and technological innovation capacity substantially impacts its overall economy and per capita GDP. The contribution of scientific and technological innovation of universities to Beijing's per capita GDP at present, however, is still significantly lower than that of the industrial structure, indicating that there is still considerable potential for the development of the tertiary industry.

6. Conclusions and Policy Recommendations

From the perspective of the development of the innovation capability of universities in Beijing, over the past two decades, the innovation capability of universities in Beijing has shown a growing trend. As China's capital, Beijing draws a large number of outstanding talents and scientific research resources, which can significantly support the development of universities' technological and scientific innovation capabilities. Moreover, the empirical analysis results indicate that improving the innovation capability of Beijing's universities has a significant impact on regional economic growth, consistent with the view expressed in the literature review that university innovation facilitates economic growth by attracting talent and promoting information flow and spillover effect. Additionally, the input of capital and labor, the upgrading of the industrial structure, the improvement of international openness, and the expansion of government all contribute to Beijing's economic growth. Nevertheless, economic growth in the modern Chinese market is more dependent upon improving economic efficiency due to industrial structure optimization.

Based on the above research and conclusions, the following suggestions are made in this paper. Initially, the government should pay special attention to the power source of university innovation and promote the improvement of university scientific and technological innovation by strengthening policy guidance and financial support. In addition, universities should adopt scientific technology, a talent introduction system, and resource allocation under the premise of government support and enterprise cooperation to build a better incentive mechanism and innovation environment for the industry, universities, and researchers. Finally, the transformation of regional scientific and technological achievements is also dependent upon scientific and technological intermediaries such as intellectual property service institutions. A further enhancement of the service system provided by science and technology intermediary institutions will facilitate the development of a science and technology industrial innovation chain connected by government, enterprises, and universities and assist in developing high-tech industries in the region.

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