Empirical Analysis of the Impact of Technological Innovation on Economic Development

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Abstract: This article applies the synergy theory to construct an indicator system for the technological innovation system and the economic development system, and calculates the order and synergy of the two systems to empirically analyze the impact of technological innovation on economic development.

1. Introduction

Technological innovation, as an important engine for promoting economic development, has become the core competitiveness of various countries. In order to promote technological innovation, countries have increased investment in scientific and technological research and development, encouraged innovation and entrepreneurship, and established innovation support systems. The development model driven by technological innovation can cultivate innovative talents, enhance the country's technological strength, and promote sustained economic growth. This article establishes a scientific and technological innovation indicator system and an economic development indicator system to empirically measure the adaptability and synergy between scientific and technological innovation and economic development, thereby understanding the impact of scientific and technological innovation on economic development, and proposing feasible development suggestions [1-2].

2. Build indicator systems for Technological Innovation and Economic Development

On the basis of reading a large amount of academic literature at home and abroad, based on the relevant research results of domestic and foreign scholars, this article designs two indicator systems for the technology innovation system and the economic development system through the design standards of systematicity, relevance, and operability[3]. The specific indicator composition is shown in Table 1. This article selects relevant data from 2014 to 2022 for empirical calculation, and the specific data is shown in Tables 2 and 3 [4].

Table 1 Indicator System for Technological Innovation System and Economic Development System

System	Primary indicators	secondary indicators
Technological Innovation System	investment	annual R&D expenditure (1)
	patent	number of valid patents (2) number of patent licensing (3)
	reserve of talents	annual enrollment of graduate education (4)
Economic Development System	economic growth	growth rate of gross domestic product (5)
	economic structure	the proportion of added value of the tertiary industry to GDP (6)
	economic quality	growth rate of per capita consumption expenditure of residents (7) total number of graduates from ordinary undergraduate and vocational colleges (8) the proportion of clean energy consumption (9)

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Table 2 Relevant Data of Technology Innovation System from 2014 to 2022

Index / year	investment	patent		reserve of talents
	(1) billion	(2) ten thousand	(3) ten thousand	(4) ten thousand
2022	30870	1787.9	432.3	124.2
2021	27864	1542.1	460.1	117.7
2020	24426	1219.3	363.9	110.7
2019	21737	972.2	259.2	91.7
2018	19657	838.1	244.7	85.8
2017	17500	714.8	183.6	80.5
2016	15500	628.5	175.4	66.7
2015	14220	547.8	171.8	64.5
2014	13312	464.3	130.3	62.1

Source: Annual Data of the Bureau of Statistics of the People's Republic of China

Table 3 Relevant Data of the Economic Development System from 2014 to 2022

index / year	growth	structure	economic quality		
	(5) %	(6) %	(7) %	(8) ten thousand	(9) %
2022	3.0	52.8	-0.2	967.3	25.9
2021	8.1	53.3	12.6	826.5	25.5
2020	2.3	54.5	-4.0	797.2	24.3
2019	6.1	53.9	5.5	758.5	23.4
2018	6.6	52.2	6.2	753.3	22.1
2017	6.9	51.6	5.4	735.8	20.8
2016	6.7	51.6	6.8	704.2	19.7
2015	6.9	50.5	6.9	680.9	17.9
2014	7.4	48.2	7.5	659.4	16.9

Source: Annual Data of the Bureau of Statistics of the People's Republic of China

3. Establish a collaboration model

We use the letter S_j to represent subsystems and $j\in[1, 2]$, useμ_j represents the order parameter in the subsystem and$\mu_j = (\mu_{j1}, \mu_{j2}, \cdots\cdots, \mu_{jn})$ .Formula (1) is the calculation formula for order degreeμ_{1i}, μ_{2i}:

$$\mu_j(\mu_{ji}) = \begin{cases} \dfrac{\mu_{ji}-\beta_{ji}}{\alpha_{ji}-\beta_{ji}}, (\mathrm{i}\in[1,m]) \\ \dfrac{\alpha_{ji}-\mu_{ji}}{\alpha_{ji}-\beta_{ji}}, (\mathrm{i}\in[m+1,\mathrm{n}]) \end{cases} \tag{1}$$

This article uses linear weighting method for analysis, assuming that there are n indicators in the subsystem, and their correlation matrix is represented as follows[5]:

$$\mathrm{E}=\begin{bmatrix} e_{11} & e_{12} & \dots\dots & e_{1n} \\ e_{21} & e_{22} & \dots\dots & e_{2n} \\ \dots\dots & \dots\dots & \dots\dots & \dots\dots \\ e_{n1} & e_{n2} & \dots\dots & e_{nn} \end{bmatrix}, e_{ii}=1\ (\mathrm{i}=1,2,\ \cdots\cdots,\ \mathrm{n})$$

Let $E_i = \sum_{j=1}^{n}|e_{ij}| - 1$, $(\mathrm{i} = 1,2, \ \dots\dots, \ \mathrm{n})$

E_i represents the total impact of the i-th indicator in the matrix on the other (n-1) indicators. According to formula (2), the weight of each indicator in the indicator system can be calculated:

$$w_i = \frac{E_i}{\sum_{i=1}^{n} E_i}, \quad (\mathrm{i} = 1,2, \ \dots\dots, \ \mathrm{n}) \tag{2}$$

Calculate the total contribution of orderliness according to formula (3), as shown in:

$$\mu_j(\mu_i)=\sum_{i=1}^{n} w_i\mu_j(\mu_{ji}),\sum_{i=1}^{n} w_i=1, w_i\geq 0 \tag{3}$$

Calculate the synergy between two systems based on formula (4):

$$c=\lambda\sqrt{\prod_{j=1}^{2}\left|\mu_j^1(\mu_j)-\mu_j^0(\mu_j)\right|}$$

$$\lambda=\begin{cases}1 & \mu_j^1(\mu_j)-\mu_j^0(\mu_j)\geq 0\\ -1 & \text{other}\end{cases} \tag{4}$$

4. Empirical Calculation

Next, the collaborative model and calculation formula constructed in the previous section will be applied to calculate the orderliness of the two systems [6-7]. Because the natural units of each indicator in the two systems are different, we need to standardize the indicators to eliminate dimensional interference and obtain matrices M_1, M_2:

$$M_1=\begin{bmatrix} -1.17567 & -1.09614 & -1.14416 & -1.15505\\ -1.02849 & -0.91455 & -0.8019 & -1.05322\\ -0.82101 & -0.73905 & -0.77221 & -0.95987\\ -0.49683 & -0.55137 & -0.70459 & -0.37433\\ -0.1472 & -0.28322 & -0.20068 & -0.14945\\ 0.18995 & 0.00841 & -0.0811 & 0.10089\\ 0.62582 & 0.54579 & 0.78239 & 0.90707\\ 1.18309 & 1.24779 & 1.57577 & 1.20408\\ 1.67034 & 1.78234 & 1.3465 & 1.47988 \end{bmatrix}$$

$$M_2=\begin{bmatrix} 0.70509 & -2.02391 & 0.48665 & -1.13729 & -1.52228\\ 0.45327 & -0.82003 & 0.36030 & -0.90528 & -1.21371\\ 0.35254 & -0.24426 & 0.33925 & -0.65384 & -0.65828\\ 0.45327 & -0.24426 & 0.04445 & -0.31283 & -0.31886\\ 0.30218 & 0.06979 & 0.21291 & -0.12398 & 0.08229\\ 0.05036 & 0.95961 & 0.06551 & -0.06787 & 0.48343\\ -1.86344 & 1.27366 & -1.93488 & 0.34976 & 0.76114\\ 1.05763 & 0.64556 & 1.56054 & 0.66595 & 1.13142\\ -1.51090 & 0.38384 & -1.13473 & 2.18538 & 1.25485 \end{bmatrix}$$

Substitute the standardized processing result matrix into formula (1) to obtain the order parameter matrices M_1', M_2':

$$M_1'=\begin{bmatrix} 0 & 0 & 0 & 0\\ 0.051715 & 0.063085 & 0.125834 & 0.038646\\ 0.124617 & 0.124055 & 0.13675 & 0.074074\\ 0.238523 & 0.189256 & 0.161611 & 0.296296\\ 0.361373 & 0.282413 & 0.346877 & 0.381642\\ 0.479837 & 0.383727 & 0.390841 & 0.47665\\ 0.632988 & 0.570416 & 0.708309 & 0.782609\\ 0.828795 & 0.814294 & 1 & 0.895329\\ 1 & 1 & 0.915707 & 1 \end{bmatrix}$$

$$M_2' = \begin{bmatrix} 0.879311 & 0 & 0.692772 & 0 & 0 \\ 0.793103 & 0.365081 & 0.656625 & 0.069826 & 0.111111 \\ 0.758619 & 0.539685 & 0.650603 & 0.1455 & 0.311113 \\ 0.793103 & 0.539685 & 0.566264 & 0.248132 & 0.433332 \\ 0.741379 & 0.634922 & 0.614458 & 0.304969 & 0.57778 \\ 0.655171 & 0.904763 & 0.572289 & 0.321856 & 0.722224 \\ 0 & 1 & 0 & 0.447547 & 0.822223 \\ 1 & 0.809526 & 1 & 0.542708 & 0.955555 \\ 0.120689 & 0.730159 & 0.228914 & 1 & 1 \end{bmatrix}$$

Perform correlation processing on the standardized matrices M_1, M_2, and obtain the correlation matrices E_1, E_2:

$$E_1 = \begin{bmatrix} 1 & 0.994 & 0.971 & 0.990 \\ 0.994 & 1 & 0.975 & 0.978 \\ 0.971 & 0.975 & 1 & 0.974 \\ 0.990 & 0.978 & 0.974 & 1 \end{bmatrix} \quad E_2 = \begin{bmatrix} 1 & -0.525 & 0.961 & -0.609 & -0.509 \\ -0.525 & 1 & -0.399 & 0.615 & 0.871 \\ 0.961 & -0.399 & 1 & -0.408 & -0.312 \\ -0.609 & 0.615 & -0.408 & 1 & 0.885 \\ -0.509 & 0.871 & -0.312 & 0.885 & 1 \end{bmatrix}$$

According to formula (2), calculate the number of weights, as shown in Table 3: Table 3 Weights Calculation Results of Indicators for Technology Innovation System (S_1) and Economic Development System (S_2) (See Tbale 4)

Table 4 Weight calculation results

	W_1	W_2	W_3	W_4	W_5
S_1	0.25119	0.25051	0.248215	0.250085	
S_2	0.209681	0.198394	0.179195	0.20462	0.20811

According to formula (3), the total contribution of the orderliness of the scientific and technological innovation system and the economic development system can be calculated, as shown in Table 5 and Figure 1:

Table 5 Calculation Results of the Order Degree of Technology Innovation System and Economic Development System from 2014 to 2022

	2014	2015	2016	2017	2018	2019	2020	2021	2022
u_1	0	0.069692	0.114848	0.221539	0.343063	0.432873	0.673427	0.884297	0.979077
u_2	0.308516	0.393804	0.477241	0.515794	0.57417	0.635588	0.461084	0.859391	0.623915

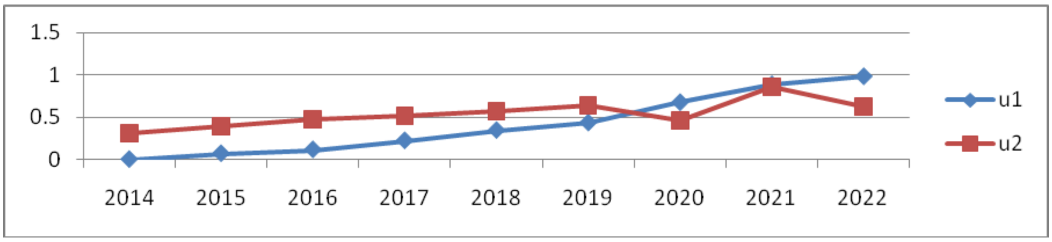

Figure 1: Trend of orderly development of science and technology innovation system and economic development system from 2014 to 2022

Based on formula (4) and the data in Table 5, we can calculate the measurement results of the synergy between the scientific and technological innovation system and the economic development system, as shown in Table 6 and Figure 2:

Table 6 Calculation Results of Synergy between Technology Innovation System and Economic Development System from 2014 to 2022

	2015	2016	2017	2018	2019	2020	2021	2022
c	0.077097	0.061381	0.064135	0.084226	0.074269	0.20489	0.289812	0.149399

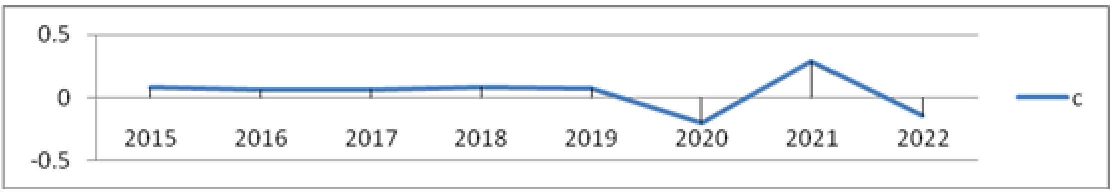

Figure 2 Trend of Synergy between Technology Innovation System and Economic Development System from 2014 to 2022

5. Conclusions and Recommendations

According to the calculation results in Table 4 and the trend chart shown in Figure 1, it can be seen that the orderliness of the scientific and technological innovation system has been increasing year by year from 2015 to 2022, from 0.069692 in 2015 to 0.979077 in 2022, showing a good development trend, indicating that the implementation effect of scientific and technological innovation is significant. Meanwhile, the level of order in the economic development system continued to improve from 0.308516 in 2014 to 0.635588 in 2019. The data reflects that the national economy has maintained a stable and rapid development trend in recent years, and has achieved significant achievements. Although the order of the economic system decreased to 0.461084 in 2020, the main reason was due to the impact of the uncontrollable epidemic, which had a certain impact on both domestic demand and international trade, leading to poor economic growth. According to the calculation results in Table 5, it can be seen that the synergy between the technological innovation system and the economic development system was positive from 2014 to 2019, indicating that the development of the two systems was relatively coordinated. Although the degree of order in the development of the two major systems in the graph is not fully fitted, the development of the economic system has always been higher than that of the technological innovation system from 2014 to 2019. However, during this period, the two systems have been showing a trend of convergence and fitting, and the gap is getting smaller and smaller.

Overall, the implementation effect of technological innovation is good. Faced with the opportunities and challenges of the new normal of the economy, there is still a lot of room for improvement in the implementation effect of scientific and technological innovation. The specific suggestions in this article are as follows: first, strengthen the construction of a high-level scientific research team: focus on cultivating the original innovation ability of university students, while fully utilizing the mobility of talents, widely attracting domestic and foreign scientific research talents, improving the treatment of scientific research talents, improving the training mechanism of scientific research talents, and creating a good scientific research environment; Secondly, improving the ability to transform scientific research achievements: it is necessary to guide researchers to combine scientific research achievements with practical social needs, so as to create higher economic benefits for the economy through scientific research achievements; Thirdly, increase investment in R&D: By establishing scientific research funds, tax reductions, financial subsidies, and other forms, relevant enterprises and research institutions can be encouraged to invest in long-term and fundamental scientific research, creating better environmental conditions for scientific and technological innovation practices.

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