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Grey Relational Degree Analysis of Scientific and Technological Achievements Quantity based on Grey System Theory

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Abstract: In this paper, the grey correlation degree analysis method in the grey system theory is applied, and the grey correlation degree is taken as the measurement index to find the possible related factors that affect the number of important scientific and technological achievements at the international advanced level in Shandong Province, and the correlation degree coefficient between the number of important scientific and technological achievements and the influencing factors is calculated to reveal the influence degree of each influencing factor. The future scientific and technological innovation and output of scientific and technological achievements in Shandong Province are analyzed.

Keywords: The number of scientific and technological achievements; Grey system theory; Grey relational degree analysis; Influencing factors; Output of scientific and technological achievements; Transformation of scientific and technological achievements.

I. INTRODUCTION

A. Research Background

With the rapid development of modern science and technology and economy, scientific and technological innovation and transformation of scientific and technological achievements in various regions of China cannot be separated from the number of scientific and technological achievements, especially the number of important scientific and technological achievements at the international advanced level. At present, there are few articles on the number of scientific and technological achievements that affect the international advanced level. Most researchers focus on the transformation of scientific and technological achievements, and the transformation of scientific and technological achievements depends on more local scientific and technological achievements.

The grey system theory, first proposed by Professor Deng Julong, is a method specializing in the study of "small number, poor information uncertainty problem" [1]. After several generations of unremitting efforts, grey system theory has made great progress on the basis of Professor Deng Julong's original thought and theoretical framework [2]. Grey correlation analysis is one of the important contents of grey system theory, which specifies the relative changes between systems or among various factors in the system over time in the development process. In other words, the set shape of time series curves is analyzed, and the correlation between them is measured by the closeness of the size, direction and speed of their changes. Its main research object is the discrete form of system state variables, which is usually called time series. The closer the development trend of the series curves is, the greater the correlation degree between them, and the smaller the correlation degree is [3]. After a long period of development, grey system theory has been widely used in many fields of natural science and social science [4].

B. Research Significance

With the deepening of the economic and social development and the reform of the scientific and technological system in Shandong Province, great changes have taken place in the environment for the output of scientific and technological achievements and the transformation of scientific and technological achievements, especially in the current situation of the comprehensive implementation of the innovation-driven development strategy and the major project of the transformation of old and new kinetic energy. The transformation of scientific and technological achievements is naturally very important, and the purpose of scientific and technological achievements output is the transformation of achievements, but the changes in the quantity and quality of scientific and technological achievements output in the past ten years should also be paid attention to, especially the output quantity of international advanced level of scientific and technological achievements is related to the progress of the development of scientific and technological level of Shandong Province, and is an important indicator to measure whether the scientific and technological level of Shandong Province is leading the world.

At present, there are almost no articles on the quantity of scientific and technological achievements using grey relational analysis. The reason is that in recent years, the country has paid more attention to the transformation of scientific and technological achievements, and many policies have been launched to promote the effective and rapid transformation of scientific and technological achievements. The purpose of studying the quantity of scientific and technological achievements in this paper is to pay attention to the output of scientific and technological achievements, especially the output of important scientific and technological achievements at the international advanced level, and to mobilize scientific researchers to actively participate in scientific research work with the international advanced level.

II. Grey Relational Analysis of the Number of Important Scientific and Technological Achievements at the International Advanced Level

Grey correlation analysis is an active branch of grey systems in theory. Its basic idea is to judge whether the relation between different sequences is close according to the similarity of geometric shapes of sequence curves. The basic idea is to convert the discrete behavior observed values of system factors into piecewise continuous polylines through linear interpolation, and then construct a model of measuring correlation degree based on the geometric features of the polylines [5]. The closer the polygonal geometry is, the greater the correlation between the corresponding sequences, and the smaller the correlation is. Gray correlation degree is a measure of the correlation between two systems or two factors. Commonly used correlation degree indexes include general gray correlation degree, gray absolute correlation degree, gray relative correlation degree, gray comprehensive correlation degree, gray oblique correlation degree, etc. Among them, gray comprehensive correlation degree not only reflects the similarity degree between reference sequence curve and comparison sequence curve. It also reflects the close degree of the change rate of the reference sequence curve and the comparison sequence curve relative to the starting point, and is a quantitative index to comprehensively characterize whether the relationship between the sequences is close [6]. Therefore, this paper uses the grey comprehensive correlation index to analyze the main factors affecting the number of important scientific and technological achievements at the international advanced level.

A. Data selection

This paper uses the grey relational analysis method to take the relevant data of the number of important scientific and technological achievements of international leading and advanced level in Shandong Province from 2011 to 2020 as samples. Select the number of important scientific and technological achievements in Shandong Province, the number of universities in Shandong Province, the number of fresh graduates in Shandong Province, the number of professional university teachers in Shandong Province, the number of ordinary middle school graduates in Shandong Province, the number of technical school graduates in Shandong Province, the number of primary school graduates in Shandong Province, the gross regional product in Shandong Province, and the per capita gross regional product in Shandong Province. All the data are from Shandong Statistical Yearbook 2022 [7]

B. Grey relational degree data calculation

The reference series and comparison series that affect the international leading scientific and technological achievements are listed. X_0 represents the number of important scientific and technological achievements at the international leading and advanced level in Shandong Province, which is the reference series. $X_1, X_2, \ldots, X_9$ respectively represent the number of important scientific and technological achievements in Shandong Province, the number of universities in Shandong Province, the number of fresh graduates in Shandong Province, the number of professional teachers in universities in Shandong Province, the number of ordinary middle school graduates in Shandong Province, the number of technical school graduates in Shandong Province, the number of primary school graduates in Shandong Province, the gross regional product of Shandong Province, and the per capita gross regional product of Shandong Province, which are comparative series. The specific data are shown in Table 1.

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Table 1 Shandong Province international leading scientific and technological achievements grey correlation reference series and comparative series

A given year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
X_0 /quantity	647	609	681	817	967	762	610	416	735	485
X_1 /quantity	2379	2393	2332	2955	3011	3016	2537	1791	2552	2342
X_2 /person	139	137	140	142	143	144	145	145	146	152
X_3 /person	472882	474266	475858	464076	474195	509142	571220	585871	577980	605379
X_4 /person	94621	96058	98685	101380	104724	107748	110807	112717	117609	124215
X_5 /10000 person	157.80	153.20	156.04	153.73	156.01	156.62	151.42	148.46	157.56	166.72
X_6 /person	123404	113066	121782	108046	98154	89629	103815	96351	91679	95962
X_7 /10000 person	106.82	106.16	103.30	101.02	98.92	107.15	110.96	111.52	117.75	125.16
X_8 /100 million yuan	39064.93	42957.31	47344.33	50774.84	55288.79	58762.46	63012.10	66648.87	70540.48	72798.17
X_9 /yuan	40581	44348	48673	51933	56205	59239	62993	66284	69901	71825

Calculation steps of Grey correlation degree [6]:

Step 1: Find the initial value image of each sequence,

$$X_i' = \frac{X_i}{\overline{X_i}} = \left(x_i'(1), x_i'(2), \cdots, x_i'(n)\right), i = 0,1,2,\cdots,m.$$

Step 2: Find the absolute value sequence of the difference between the corresponding components of the initial value image of X_0 and X_i,

$$\Delta_i(k) = \left|x_0'(k) - x_i'(k)\right|, \Delta_i = \left(\Delta_i(1), \Delta_i(2), \cdots, \Delta_i(n)\right), i = 1,2,\cdots,m$$

Step 3: Find the maximum and minimum values of

$$\Delta_i(k) = \left|x_0'(k) - x_i'(k)\right|, k = 1,2,\cdots,n; i = 1,2,\cdots,m.$$

Respectively recorded as:

$$M = \max_i \max_k \Delta_i(k), m = \min_i \min_k \Delta_i(k).$$

Step 4: Calculate the correlation coefficient:

$$\gamma_{0i}(k) = \frac{m + \xi M}{\Lambda_i(k) + \xi M}, \xi \in (0,1), k = 1,2,\cdots,n; i = 1,2,\cdots,m.$$

Step 5: Find the average of the correlation coefficients:

$$\gamma_{0i} = \frac{1}{n}\sum_{k=1}^{n} \gamma_{0i}(k), i = 1,2,\cdots,m.$$

We get calculation result of Grey relational degree: If $\xi = 0.5,$ the correlation coefficients are calculated as follows.

γ_{0i}	γ_{01}	γ_{02}	γ_{03}	γ_{04}	γ_{05}	γ_{06}	γ_{07}	γ_{08}	γ_{09}
RESULT	0.77680775	0.68552414	0.642059034	0.667088202	0.683912971	0.578783836	0.665138638	0.536286348	0.551384658

C. Result Analysis of Grey Relational Degree

Based on the calculation of the above Grey correlation degree, the following table 2 is made to facilitate the analysis of the results.

Table 2 Calculation results and ranking of Grey correlation degree

Index	Grey correlation degree	Sort
Number of important scientific and technological achievements in Shandong Province (X_1)	0.7768	1
Number of universities in Shandong Province (X_2)	0.6855	2
Number of ordinary middle school graduates in Shandong Province (X_5)	0.6839	3
Number of professional university teachers in Shandong Province (X_4)	0.6671	4
Number of primary school graduates in Shandong Province (X_7)	0.6651	5
Number of fresh graduates in Shandong Province (X_3)	0.6421	6
Number of graduates from Shandong Technical College (X_6)	0.5788	7
Per capita GDP of Shandong Province (X_9)	0.5514	8
Gross regional product of Shandong Province (X_8)	0.5363	9

It can be seen from Table 2 that all grey correlation degrees are greater than 0.50, which indicates that each comparison series has a significant impact on the number of important scientific and technological achievements at the international advanced level in Shandong Province, that is, the calculation results are of great reference value. Theoretically speaking, the closer the grey correlation degree is to 1, the greater the role of the comparison sequence in improving the number of international leading scientific and technological achievements [6]. In general, the grey correlation degree of the comparison series is higher than 0.70, which is called the key influencing factor. Between 0.60 and 0.69, as an important influencing factor; Below 0.60, it is regarded as an insignificant influencing factor. It can be seen from the calculation results that, according to the data from 2011 to 2020, there is a certain gap in the correlation coefficient on the whole. Among them, the most influential factor on the number of internationally leading important scientific and technological achievements in Shandong Province is the number of important scientific and technological achievements in Shandong Province, followed by the number of universities in Shandong Province, followed by the number of ordinary middle school graduates in Shandong Province. Among them, the number of professional university teachers in Shandong Province and the number of primary school graduates in Shandong Province have the same influence on the number of internationally leading important scientific and technological achievements in Shandong Province, and the less influential factor is the regional GDP of Shandong Province.

III. Conclusion and Prospect

A. Conclusion

According to the calculation result of grey correlation degree, the correlation degree between the number of important scientific and technological achievements in Shandong Province and the number of important scientific and technological achievements in Shandong Province is the highest. This result confirms the rationality of grey correlation degree analysis, because only with the increase of the number of important scientific and technological achievements can more of them be of international leading and advanced level. Encouraging institutions of higher learning, research institutes and enterprise research institutions to continuously increase innovation and research and development is the most critical factor to increase the number of important scientific and technological achievements at the leading international advanced level. The results of correlation degree show that the number of universities in Shandong Province and the number of ordinary middle school graduates in Shandong Province is also highly correlated with the number of international advanced level of important scientific and technological achievements in Shandong Province. It can be seen that the state continues to increase investment in education, increase the number of universities and the popularization of basic education, which is an important means to improve the number of scientific and technological achievements. The correlation results also show that the correlation between the per capita GDP and the number of important scientific and technological achievements of Shandong Province and the international advanced level is more than 0.5, indicating that the development of national economy and the increase of people's income also have a promoting effect on the output of scientific and technological achievements.

B. Prospect

Looking up at the vast sky, "Beidou" shines brightly; Overlooking the blue sea, the "dragon" dives deep. With the continuous development of China's scientific and technological undertakings, "can reach the moon in the nine days and catch turtles in the five oceans" is no longer just a beautiful vision of the future that exists in the poem, but has really become a reality [8]. If China's economy continues to grow at a high rate and more and more money is invested in scientific research, then China will be on the road to becoming a scientific and technological power [9]. The new round of scientific and technological revolution and industrial transformation has greatly enhanced the penetration and diffusion capacity of science and technology, and made it possible for innovation achievements to enter the economic and social cycle on a larger scale, at a faster speed and with higher quality. At the same time, the combination of constantly improving systems and mechanisms, grand market scale, relatively complete industrial system, diversified consumer demand and the improvement of innovation efficiency in the Internet era provides an inexhaustible strong power for China's scientific and technological innovation [10].

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