Measurement and Coupling Coordination Analysis of Scientific and Technological Innovation and Common Prosperity

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Abstract: This paper measures China's scientific and technological innovation level and common prosperity level through the “vertical and horizontal method”, analyzes the coupling and coordination relationship between scientific and technological innovation and common prosperity in different provinces by using the coupling coordination degree model and obstacle degree model, identifies its time evolution law and spatial distribution characteristics, and diagnoses its key obstacle factors. The results showed that: First, the level of scientific and technological innovation and common prosperity of 30 provinces in Chinese mainland（except Tibet） showed an upward trend in 2000~2019.Second, the level of coupling and coordination between scientific and technological innovation and common prosperity has gradually improved, but the specific conditions of different provinces are significantly different; Third, the main obstacles to scientific and technological innovation during the investigation period are the proportion of added value of high-tech industry, sales revenue of new products and R&D investment intensity; The main obstacles to common prosperity include per capita expenditure on basic public services, per capita education funds, per capita GDP, per capita number of beds in medical institutions, participation rate of basic old-age insurance for urban and rural residents, and ownership of public transport vehicles per 10000 people.

1 INTRODUCTION

The idea of common prosperity goes back a long way. Marx and Engels founded the scientific socialism and transformed common prosperity from a utopian concept into science. As the essential requirement of socialism with Chinese characteristics, common prosperity stands for both the goal and the final result (Fan, Xie 2018). Since the proposal of common prosperity was put forward in 1953, China's economic aggregate has doubled a hundred times, and breakthroughs have been made in the three key battles of poverty alleviation. The general idea of common prosperity was put forward at the 10th meeting of the central financial and Economic Commission in August 2021. Since then, the topic of common prosperity has attracted more attention and wider discussion in the society. To accelerate the construction of common prosperity, we must follow the economic development policy guided by scientific and technological innovation. Throughout the existing literature, most of them only measure China's existing scientific and technological innovation level or common prosperity level, and there is little research on the relationship between scientific and technological innovation and common prosperity. This paper constructs the coupling coordination evaluation index system of scientific and technological innovation and common prosperity, measures the level of scientific and technological innovation from two aspects of innovation input and innovation output, and measures the level of common prosperity from two aspects of overall prosperity and achievement sharing. The coupling coordination degree model and obstacle degree model are adopted, Taking 30 provinces in China (except Tibet) as the research object, this paper carries out the research on the coupling and coordination relationship between provincial scientific and technological innovation and common prosperity, so as to seek the characteristics and laws of their coordinated development, and provide ideas and reference for China to achieve common prosperity and other countries to improve the living standards of the whole people.

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2 MATERIALS AND METHODS

2.1 Index System

Based on the interaction between scientific and technological innovation and common prosperity, drawing on the existing measurement indicators of scientific and technological innovation and common prosperity(Liu, et al, 2021,Hu, Zhou, 2022), and according to the principles of scientificity, comprehensiveness and operability, this paper establishes an evaluation index system for the coupling and coordination of scientific and technological innovation and common prosperity, as shown in Table 1.Among them, the former includes two primary indicators of innovation input and innovation output and six corresponding secondary indicators; The latter includes two primary indicators: overall wealth and achievement sharing, as well as 10 corresponding secondary indicators.

Table 1: Evaluation index system of coupling and coordination between scientific and technological innovation and common prosperity.

	The first layer	The second layer	Attribute
Scientific and technological innovation	Innovation input	R&D expenditure intensity	Positive
		R&D personnel per 10000 people	Positive
	Innovation output	Number of invention patents authorized per 10000 people	Positive
		Number of scientific and technological papers per 10000 R&D personnel	Positive
		Proportion of new product sales revenue	Positive
		Proportion of added value of high-tech industry	Positive
Common prosperity	Overall affluence	Per capita GDP	Positive
		Total retail sales of social consumer goods per capita	Positive
		Per capita savings deposits of residents	Positive
	Degree of achievement sharing	Ratio of urban and rural per capita disposable income	Moderate
		Ratio of urban and rural per capita consumption	Moderate
		Per capita expenditure on basic public services	Positive
		Public transport vehicles per 10000 people	Positive
		Per capita education expenditure	Positive
		Number of beds in medical institutions per capita	Positive
		Participation rate of basic endowment insurance	Positive

2.2 Research Methods and Data Sources

2.2.1 Research Methods

a) Vertical and horizontal method

The evaluation of the coupling and coordination relationship between scientific and technological innovation and common prosperity is inseparable from the measurement of their development level. In this paper, the “vertical and horizontal method” is used to determine the weight of each index on the basis of index standardization. Suppose there are n evaluated objects $S_1, S_2, \cdots, S_n$, p evaluation indexes $M_1, M_2, \cdots M_p$, q periods $t_1, t_2, \cdots t_q$, and $x_{ij}(t_k)$ represents the original value of the j index of the ith Province in the t_k year. In this paper, the zero mean standardization method is selected to process the index data dimensionless, and $x_{ij}{}^*(t_k)$ is the processed value.For time $t_k(k = 1,2,\cdots,q)$, the comprehensive evaluation function is: $y_i(t_k) = \sum_{j=1}^{p} w_j x_{ij}{}^*(t_k)$, where $w_j(j = 1,2,\cdots p)$ is the index weight coefficient.The difference between the evaluated objects can be expressed by the sum of squares of the total deviation of $y_i(t_k)$: $\sigma^2 = \sum_{k=1}^{q}\sum_{i=1}^{n}(y_i(t_k) - \bar{y})^2$.Since the original data has been processed with zero mean, $\sigma^2 = \sum_{k=1}^{q}\sum_{i=1}^{n}(y_i(t_k) - \bar{y})^2 = \sum_{k=1}^{q}[w^T H_k w] = w^T \sum_{k=1}^{q} H_k w = w^T H w$, where w is the weight coefficient vector, $H = \sum_{k=1}^{q} H_k$ is the $m * m$ order symmetric matrix, and $A_k = \begin{bmatrix} x_{11}(t_k) & \cdots & x_{1p}(t_k) \\ \vdots & \ddots & \vdots \\ x_{n1}(t_k) & \cdots & x_{np}(t_k) \end{bmatrix}, k = 1,2,\cdots,q$. If $w^T w = 1$ is limited and the maximum variance is required, the nonlinear programming problem of equation (1) must be solved to obtain w:

$$max w^T H w \quad s.t. \begin{cases} w^T w = 1 \\ w > 0 \end{cases} \tag{1}$$

b) Coupling coordination model

The coupling coordination degree model can effectively clarify the synergy and overall efficacy of the interactive development of the coupling system, so as to make up for the deficiency of the coupling degree model in the analysis of the interaction between systems. Therefore, the research uses the coupling coordination degree model to measure the coupling and coordinated development of scientific and technological innovation (U_1) and common prosperity (U_2). The model is as follows:

$$C = \frac{2\sqrt{U_1 \times U_2}}{U_1 + U_2} \tag{2}$$

$$T = \alpha U_1 + \beta U_2 \tag{3}$$

$$D = \sqrt{C \times T} \tag{4}$$

Where C is the coupling degree, which reflects the coupling relationship between variables;T is the comprehensive evaluation index, which reflects the overall development level of the variable.αand β are undetermined coefficients, $\alpha + \beta = 1$. In this paper, $\alpha = \beta = 0.5$. D is the coupling and co scheduling, $0 \le D \le 1$. Referring to the existing research, it can be divided into five types: $D \in [0,0.2)$ is the imbalance state, $D \in [0.2,0.4)$ is the antagonism state, $D \in [0.4,0.6)$ is the running in state, $D \in [0.6,0.8)$ is the coupling state, and $D \in [0.6,0.8)$ is the coordination state (Lu and Wang 2019).

c) Obstacle model

The obstacle degree model introduces three indicators: factor contribution degree, index deviation degree and obstacle degree, which can quantitatively analyze the impact of innovation input, innovation output, overall prosperity and achievement sharing degree of scientific and technological innovation on their coupling coordination degree. Based on the research of Li Mengcheng and others (Li, et al, 2020), the specific formula is as follows:

$$I_{ij} = 1 - Y_{ij} \tag{5}$$

$$h_j = \left(F_j I_{ij} / \sum_{j=1}^{m} F_j I_{ij}\right) \times 100\% \tag{6}$$

$$H_j = \sum h_j \tag{7}$$

Where Y_{ij} is the standard value of the index;I_{ij} is the index deviation degree, that is, the gap between a single index and the goal of scientific and technological innovation (or common prosperity);F_j is the factor contribution, that is, the weight of a single index to the goal of scientific and technological innovation (or common prosperity);h_j and $H_j$are the obstacles of index level indicators and factor level indicators to scientific and technological innovation (or common prosperity).

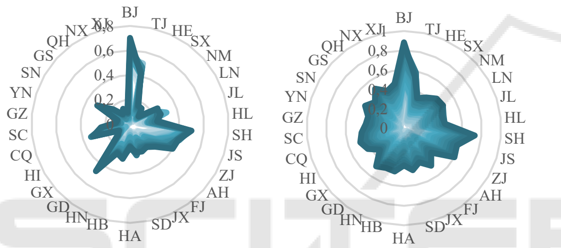
2.2.2 Data Sources

This paper takes the panel data of 30 inland provinces in China (except Tibet) from 2000 to 2019 as the sample. The data sources include China Statistical Yearbook, China Science and technology statistical yearbook, EPS data platform and provincial statistical yearbooks. Due to the long investigation period and a small number of missing values, the unified treatment method in this paper is as follows: for the missing values of individual annual indicators in a province, the average value of the two years before and after the missing value or the value of the years before and after the missing value are used to fill in; For the missing indicators of individual years in all provinces, the interpolation method is used to fill in.

3 RESULTS AND DISCUSSION

3.1 Evaluation of Scientific and Technological Innovation and Common Prosperity

Figure 1 shows the development level of scientific and technological innovation and common prosperity of 30 provinces from 2000 to 2019.The curve with the lightest color in the figure represents the corresponding index of each province in 2000, and the corresponding curve color gradually deepens with the increase of years.



(a) scientific and technological innovation

(b)common prosperity

Figure 1: Scientific and technological innovation and common prosperity.

It can be seen from Figure 1 (a) that the scientific and technological innovation level of each province increased year by year during the investigation period, and the innovation ability among regions was extremely uneven. The top 3 provinces in the level of scientific and technological innovation in 2019 are Beijing (0.703), Shanghai (0.501) and Guangdong (0.469). As the most economically developed provinces in China, these three places have sufficient innovation resources such as R&D personnel and R&D funds; Scientific papers, international patents and other innovative achievements are relatively rich; The momentum of innovation in finance, information, science and technology is strong. In addition, from 2000 to 2019, the level of scientific and technological innovation in Guangdong, Zhejiang and Jiangsu increased greatly, which has relatively high development potential in the new era led by innovation. As can be seen from Figure 1 (b), the common prosperity level of China's provinces increased year by year from 2000 to 2019.Among them, the level of common prosperity in Beijing, Shanghai, Zhejiang, Jiangsu and Tianjin is relatively high, and the development degree of common prosperity in central and western provinces such as Chongqing, Shaanxi, Sichuan, Hunan and Hubei has increased significantly during the investigation period. It shows that the eastern coastal areas of China have better realized the concept of "development achievements shared by the people". Due to the support of national policies, the progress of infrastructure construction in the central and western inland areas has been accelerated, and the people's living standards have been greatly improved.

3.2 Analysis on the Coupling and Coordination between Scientific and Technological Innovation and Common Prosperity

Based on the analysis of the development level of scientific and technological innovation and common prosperity, the coupling coordination degree model is used to calculate the coupling coordination dispatching, and analyze the coupling coordination relationship between the two provinces from 2000 to 2019. The specific results are shown in Table 2. According to the above judgment criteria, at the beginning of the investigation period, the coupling coordination degree between scientific and technological innovation and common prosperity in most provinces belongs to antagonistic type. Over time, the running in provinces gradually increase. By 2019, Beijing has become the only coordinated Province in China.

In terms of spatial distribution, the coupling and coordination level of 30 provinces basically shows a distribution pattern of "high coastal and low inland", the driving effect of coastal areas is gradually spreading to inland areas, and the spatial gap between regions is gradually narrowing; In terms of coupling types, the coupling coordination levels of 30 provinces during the investigation period include "maladjustment type", "antagonism type", "running in type", "coupling type" and "coordination type". The intermediate state of coupling coordination is mainly "antagonism type" and "running in type", and the overall "football type" mode of "few high-low provinces and more intermediate provinces" is presented. High quality coupling coordination has not yet appeared in a large area.

From the perspective of time distribution, in the past two decades, the number of provinces with unbalanced and antagonistic coupling and coordination between scientific and technological innovation and common prosperity has been decreasing, while the number of provinces with running in and coupling coordination has been increasing gradually, while the number of coordinated provinces has been very small since 2015, only Beijing. It can be seen that the coupling and coordination level of China's provincial scientific and technological innovation and common prosperity is increasing year by year, but there is still much room for improvement.

Table 2: The degree of coupling and coordination between scientific and technological innovation and common prosperity.

Province	2000	2005	2010	2015	2019	average
BJ	0.623	0.703	0.730	0.811	0.888	0.742
TJ	0.482	0.589	0.617	0.702	0.691	0.622
HE	0.243	0.272	0.368	0.427	0.486	0.353
SX	0.240	0.286	0.362	0.436	0.498	0.359
NM	0.192	0.278	0.362	0.419	0.455	0.342
LN	0.344	0.416	0.503	0.542	0.586	0.478
JL	0.308	0.373	0.473	0.526	0.572	0.446
HL	0.266	0.342	0.433	0.490	0.554	0.411
SH	0.549	0.653	0.660	0.718	0.778	0.669
JS	0.352	0.429	0.557	0.649	0.697	0.531
ZJ	0.345	0.420	0.530	0.622	0.699	0.512
AH	0.241	0.293	0.391	0.487	0.566	0.386
FJ	0.343	0.395	0.452	0.510	0.575	0.445
JX	0.231	0.279	0.377	0.460	0.552	0.370
SD	0.280	0.343	0.475	0.547	0.566	0.442
HA	0.220	0.262	0.358	0.459	0.515	0.354
HB	0.317	0.340	0.447	0.536	0.601	0.437
HN	0.260	0.323	0.441	0.521	0.583	0.416
GD	0.352	0.433	0.546	0.622	0.691	0.525
GX	0.224	0.267	0.367	0.416	0.457	0.339
HI	0.209	0.221	0.349	0.420	0.458	0.346
CQ	0.296	0.368	0.479	0.570	0.622	0.454
SC	0.280	0.328	0.427	0.511	0.568	0.418
GZ	0.241	0.239	0.348	0.389	0.462	0.324
YN	0.224	0.245	0.327	0.391	0.452	0.324
SN	0.333	0.373	0.479	0.543	0.613	0.460
GS	0.236	0.288	0.375	0.456	0.520	0.365
QH	0.241	0.284	0.341	0.398	0.474	0.344
NX	0.228	0.268	0.350	0.429	0.489	0.344
XJ	0.197	0.236	0.346	0.423	0.465	0.324

3.3 Obstacle Factor Diagnosis of Coupling Coordination

Table 3 shows the top three obstacle factors of scientific and technological innovation level from 2000 to 2019. It can be seen that the proportion of added value of high-tech industry, R&D investment intensity and R&D personnel per 10000 people before 2015 are the top three influencing factors, which are mainly concentrated in innovation input. This is because China is in the initial stage of innovation and development, the input in innovation and R&D is seriously insufficient, and the innovation environment needs to be improved. From 2015 to 2019, Proportion of added value of high-tech industry, Proportion of new product sales revenue and R&D expenditure intensity ranked among the top three, mainly focusing on innovation output, indicating that China's innovation driven development is in the transformation stage from quantity catching up to quality surpassing. Improving the transformation rate of innovation resources and enhancing innovation benefits are the focus of future development.

Table 3: Main obstacle factors and degree of scientific and technological innovation.

Ranking		1	2	3
2000	Obstacle factor	Proportion of added value of high-tech industry	R&D expenditure intensity	R&D personnel per 10000 people
	Obstacle degree (%)	21.857	21.054	19.271
2005	Obstacle factor	Proportion of added value of high-tech industry	R&D expenditure intensity	R&D personnel per 10000 people
	Obstacle degree (%)	21.959	20.904	19.656
2010	Obstacle factor	Proportion of added value of high-tech industry	R&D expenditure intensity	R&D personnel per 10000 people
	Obstacle degree (%)	22.538	20.554	19.594
2015	Obstacle factor	Proportion of added value of high-tech industry	Proportion of new product sales revenue	R&D expenditure intensity
	Obstacle degree (%)	22.523	19.869	18.797
2019	Obstacle factor	Proportion of added value of high-tech industry	Proportion of new product sales revenue	R&D expenditure intensity
	Obstacle degree (%)	25.028	19.918	18.441

Table 4 shows the top three obstacle factors of common prosperity from 2000 to 2019. It can be seen that the main obstacle factors of common prosperity during the investigation period are concentrated in the degree of achievement sharing, including Per capita expenditure on basic public services, Per capita education expenditure, Per capita GDP, Number of beds in medical institutions per capita, Participation rate of basic endowment insurance, Public transport vehicles per 10000 people. It shows that there is still a certain gap in infrastructure construction, residents' living standards and welfare benefits in different regions of China. Improving the degree of sharing is the focus of promoting common prosperity in China in the future.

Table 4: Main obstacle factors and degree of common prosperity.

Ranking		1	2	3
2000	Obstacle factor	Per capita expenditure on basic public services	Per capita education expenditure	Per capita GDP
	Obstacle degree (%)	14.544	13.807	12.993
2005	Obstacle factor	Per capita expenditure on basic public services	Per capita education expenditure	Per capita GDP
	Obstacle degree (%)	14.003	13.533	12.949
2010	Obstacle factor	Per capita education expenditure	Number of beds in medical institutions per capita	Per capita expenditure on basic public services
	Obstacle degree (%)	13.486	12.854	12.744
2015	Obstacle factor	Per capita GDP	Participation rate of basic endowment insurance	Per capita expenditure on basic public services
	Obstacle degree (%)	12.987	12.808	12.802
2019	Obstacle factor	Public transport vehicles per 10000 people	Participation rate of basic endowment insurance	Per capita GDP
	Obstacle degree (%)	14.503	13.287	12.716

4 CONCLUSIONS

This paper constructs the evaluation index system of provincial scientific and technological innovation and common prosperity, calculates the comprehensive index and coupling co scheduling of the two systems from 2000 to 2019, and reveals the main obstacle factors affecting the development of the two systems. The results show that China's scientific and technological innovation level and common prosperity level have continuously improved during the investigation period, and there is a large gap between different provinces. At the same time, through the calculation and analysis of the coupling and coordination model, it can be seen that the coupling and coordination degree of scientific and technological innovation and common prosperity in various provinces is constantly improving. Among them, Beijing has entered the state of coordinated development since 2015.According to the main obstacle factors of the two systems, the main obstacle to the progress of scientific and technological innovation lies in the low quality of innovation output, and the main obstacle to the construction of common prosperity lies in the low degree of achievement sharing.

Scientific and technological innovation is not only the creation power of social wealth, but also has an impact on the distribution of wealth creation and rational distribution of wealth. In the future, we should give better play to the leading and supporting role of scientific and technological progress in building a modern industrial system, pay more attention to quality and efficiency, advanced industrial foundation, etc., promote the construction of urban and rural infrastructure in different regions, increase financial expenditure, and effectively improve the living standards of residents.

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