Research on Shanghai's Scientific and Technological Innovation Ability Based on Principal Component Analysis

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Abstract: The capacity for innovation in science and technology represents a city's potential and level of growth. This paper takes four municipalities (Shanghai, Beijing, Tianjin and Chongqing) as the research object. Evaluation indicators are created from the aspects of science innovation input and output. Based on the relevant data from 2017 to 2021, the innovation differences of the four municipalities are measured by principal component analysis using SPSS software. The research recommends that cooperation between universities and other institutions should be expanded to give full play to the advantages of universities. Also, foster scientific innovation capacity in high-tech industries more quickly. The innovation characteristics of Shanghai are compared and summarized in this empirical study, which serves as a guide for other regions planning scientific innovation work.

Keywords: Innovation ability; Evaluation system; Principal component analysis

1 INTRODUCTION

Regional competitiveness and sustainable economic development are impacted by the capacity for scientific and technical innovation in the region. Using the force of innovation, we can encourage the high-quality growth of the local economy. In previous studies, scholars have explored a variety of evaluation methods to discuss regional innovation capabilities from different perspectives.

Zhang et al. (2015) constructed a evaluation index system for scientific and technological innovation with first-level indicators of total volume, quality, speed and extra points. Zhu and Wang (2016), Liu et al. (2018) and Xiong et al. (2018) constructed evaluation models using the gray correlation analysis method, the Almond method and the factor analysis method, respectively. For analysis, some academics create indices from the input, output and environment (Gao et al., 2012; Wang et al., 2016; Wang and Yao, 2020; Liu and Yan, 2021). Besides, Zhang et al. (2021) adopted the weighted comprehensive evaluation method to evaluate from three dimensions: strength, efficiency and potential.

It can be seen that the evaluation index system of existing studies is inconsistent, and some studies lack data analysis. In order to scientifically and effectively monitor the current situation

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of scientific and technological innovation in Shanghai, this study builds an evaluation index system from the perspective of input and output using principal component analysis. The statistical yearbook data of four municipalities from 2017 to 2021 are selected for analysis and comparison, in order to contribute reference for further innovation planning.

2 EVALUATION METHOD

2.1 Index Construction

Based on the basic indicators in the China Science and Technology Statistical Yearbook, this study extends the evaluation index system. Which including 2 first-level, 8 second-level and 39 third-level indicators based on objective and operable scientific design principles (Table 1). Among them, the input indexes reflect the various resources required for innovation, output indexes capture the positive effects on the economy and society.

2.2 Evaluation Methods

Due to the extensive selection of evaluation indicators, this study applies the principal component analysis and quantitative analysis to improve the accuracy of the evaluation results. The quantitative methodology can capture the variations of technical and scientific development in various regions.

3 INPUT AND OUTPUT

3.1 Input Situation

3.1.1 R&D Project Application

Shanghai has a high number of R&D issues and has maintained growth in recent years (Table 2). From 2017 to 2021, the number of R&D topics in Shanghai ranked second among the four municipalities steadily, and the growth rate increased significantly after 2018. Beijing has always ranked first, far ahead of the other three municipalities. The number of R&D projects in Tianjin and Chongqing is relatively small, but it is also growing.

Table 1: Evaluation index system.

Level 1 indicators	Level 2 indicators	Level 3 indicators
Input	A. Number of R&D issues (projects)	A1. Number of R&D issues
		A2. Number of R&D topics for research and development institutions
		A3. Number of R&D topics in colleges and universities
		A4. Number of R&D projects in high-tech industries
	B. Full-time equivalent of R&D personnel	B1. Full-time equivalent of R&D personnel
		B2. R&D personnel in research and development institutions
		B3. R&D personnel in institutions of higher learning
		B4. R&D personnel in high-tech industries

	C. Internal expenditure of R&D funds	C1. R&D funding internal expenditures
		C2. Internal expenditures for research and development institutions
		C3. Internal expenditure for colleges and universities
		C4. Internal expenditure for high-tech industries
Output	D. Number of scientific papers	D1. The total amount of papers published by R&D institutions and universities
		D2. Number of papers produced by R&D institutions
		D3. Number of papers produced abroad by R&D institutions
		D4. Number of papers produced by institutions of higher learning
		D5. Number of papers produced abroad by institutions of higher learning
	E. Number of scientific and technical works	E1. The total amount of works published by R&D institutions and universities
		E2. Number of works produced by R&D institutions
		E3. Number of works produced by institutions of higher learning
	F. Number of patents	F1. Domestic patent applications
		F2. Number of domestic invention patent applications
		F3. Number of domestic patents granted
		F4. Number of domestic invention patents authorized
		F5. Number of domestic valid patents
		F6. Number of domestic valid invention patents
	G. Distribution of patents	G1. Number of patents filed by research and development institutions
		G2. Number of invention patents applied by research and development institutions
		G3. Valid invention patents in research and development institutions
		G4. Number of patents applied for by institutions of higher learning
		G5. Invention patent applications made by colleges and universities
		G6. Valid invention patents in colleges and universities
		G7. High-tech industry patent applications
		G8. Invention patents applied for in high-tech industries
		G9. Effective invention patents in high-tech industries
	H. Patent Value	H1. Transfer of patent ownership and licenses for R&D institutions
		H2. Patent ownership transfer and licensing income from R&D institutions
		H3. Transfer of patent ownership and licenses for institutions of higher learning
		H4. Patent ownership transfer and licensing income in institutions of higher learning

Table 2: Number of R&D issues.

Region \ Year	2017	2018	2019	2020	2021
Beijing	136969	135387	147141	156681	177259
Tianjin	37267	39415	43312	44494	45342
Shanghai	75575	75608	83060	90084	99596
Chongqing	30181	34864	40925	47135	53992

It can be seen from the number of R&D projects in 2021 by various institutions (Figure 1), and universities account for the majority of project applications (Table 3). Among the four municipalities with the largest number of R&D topics, Shanghai has the most, about 69.60%, followed by Beijing, about 65.20%. In terms of quantity, the number of R&D topics in Beijing universities has 115571, ranking first.

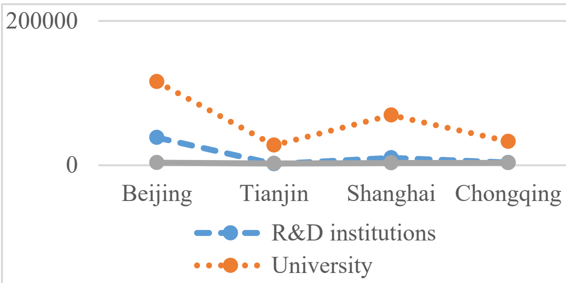

Figure 1: Comparison of the amount of R&D issues.

Table 3: Proportion of R&D topics in universities in 2021.

Region	Beijing	Tianjin	Shanghai	Chongqing
Proportion	65.20%	60.20%	69.60%	60.77%

3.1.2 Researcher Input

In 2021, R&D staff full-time equivalent in Shanghai fell 198646 person-years short of Beijing (Table 4). Therefore, the pool of scientific research expertise retains a lot of space for growth. Figure 2 shows that institutional R&D staffing varies by region. Experts from R&D institutions and colleges in Shanghai make up a sizable component of the workforce, whereas Tianjin's R&D experts make up the majority of the same colleges, while Beijing R&D institutions account for the largest proportion of personnel, Chongqing is a high-tech industry personnel accounted for more.

Table 4: Full-time equivalent of R&D personnel in 2021.

Region	Beijing	Tianjin	Shanghai	Chongqing
Equivalent	313986	92502	198646	97602

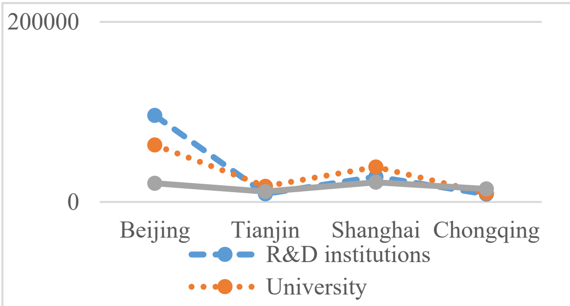

Figure 2: R&D personnel in each agency in 2021.

3.1.3 Research Fund Input

In recent years, all four regions have increased internal spending on R&D funding. Shanghai's internal R&D expenditure far exceeds that of Tianjin and Chongqing, and although it lags behind Beijing (Table 5). The financing for scientific research has expanded dramatically, indicating that Shanghai has given the subject a high priority. According to Table 6, Shanghai is the city with the highest spending on R&D institutions, and all types of institutions have seen a surge in recent years, notably in 2021.

Table 5: Internal expenditure (10000 yuan).

Year / Region	Beijing	Tianjin	Shanghai	Chongqing
2017	13840231	5101839	9361439	2470012
2018	14845762	5373223	10493187	3021830
2019	15796512	4587227	12052052	3646309
2020	18707701	4923997	13592023	4102094
2021	22335870	4629716	15245534	4695714

Table 6: Internal expenditure of various institutions.

Year / Region	R&D institutions	University	High-tech industry
2017	2647025	866479	1282252
2018	2793983	936117	1338172
2019	3204862	1091950	1449217
2020	3475742	1249132	1273159
2021	3788421	1548140	1635419

3.2 Output Situation

3.2.1 Publication of Literature

Shanghai has an important position in the contribution of scientific and technological literature, and its publication volume has been growing from 2017 to 2021. Moreover, the majority of universities that publish scholarly literature contribute to it, because Shanghai is home to several colleges with a vibrant academic culture. In 2021, the output of scientific and technological papers in Shanghai universities was 97,943, and 2,900 works were published, while R&D institutions were not good at this, publishing 11,787 scientific papers and 220 monographs.

3.2.2 Patent Application

Beijing received 226,100 patent applications in 2021, while Shanghai received 113,600, placing it second among the four areas directly and increasing by 15.54% from 2020 (Table 7). This indicates that Shanghai's capacity to produce patent rights is expanding. As shown in Figure 3, patent filings by different institutions in different regions have their own characteristics. Among the main innovators in Shanghai and Chongqing, there are more patent applications from universities and high-tech industries; The great bulk of Beijing's patent applications come from colleges and R&D centers; Tianjin's R&D institutions and high-tech industries have few patent applications, and university patent applications occupy the main force.

Table 7: Domestic patent applications.

Year / Region	2017	2018	2019	2020	2021
Beijing	156312	189129	185928	211212	226113
Tianjin	79963	106514	86996	99038	96045
Shanghai	100006	119937	131740	150233	173586
Chongqing	82791	59518	64648	72121	67271

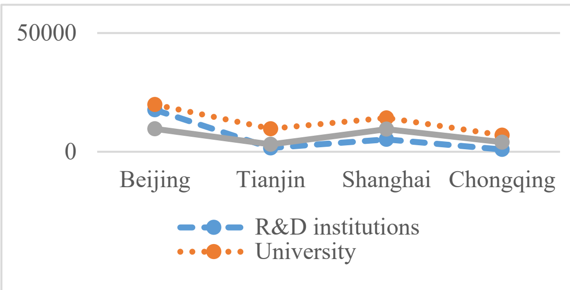

Figure 3: Patent applications by various institutions.

3.2.3 Patent Authorization

Shanghai received roughly 100,600 patent authorizations in 2021 (Figure 4), placing it second among the sample cities in terms of this metric. Of these, 22,700 invention patents—or 22.60%

of the total—were authorized. Beijing has both the most patents permitted and the most invention patents permitted. Also, the ratio of invention patents permitted, which accounts for 40.33%, is significantly higher than that of Shanghai.

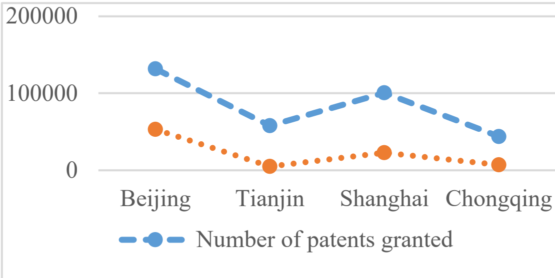

Figure 4: Patent authorization status in 2021 (cases).

3.2.4 Valid Invention Patents

In Shanghai, there were 129,768 valid invention patents and 443,510 active patents in 2021 (Table 8). Without a doubt, far more than Tianjin and Chongqing. Beijing continues to have the most patents that are still in force, nevertheless.

Table 8: Valid invention patents in 2021.

Region	Beijing	Tianjin	Shanghai	Chongqing
patents in force	653053	198946	443510	158176
invention patents	284288	34726	129768	32443

3.2.5 Patent Assignment and Licensing

Shanghai has been working hard to translate patents into real productivity. As shown in Tables 9 and 10, the quantity of patent transfers and permits granted to R&D institutions in Shanghai rose between 2017 and 2020. In particular, the growth rate is rising in 2020. The number didn't start to drop until 2021, although it was still high. Due to Beijing's strong patent ownership transfers and licensing, Tianjin and Chongqing's R&D institutions have experienced very little patent ownership transfers and permits. Beijing and Shanghai are the two cities with the highest amount of intellectual rights permitted and transferred to higher education institutions. Shanghai surpassed Beijing in 2021 to take the top spot among the four regions.

Table 9: Transfer and licensing by R&D institutions.

Year / Region	2017	2018	2019	2020	2021
Beijing	368	758	874	745	1357

Tianjin	71	21	22	23	43
Shanghai	114	175	190	338	245
Chongqing	7	15	41	34	12

Table 10: Transfer and licensing by the universities.

Year / Region	2017	2018	2019	2020	2021
Beijing	302	745	429	514	402
Tianjin	40	47	111	92	165
Shanghai	243	312	381	332	409
Chongqing	102	84	113	124	236

4 PRINCIPAL COMPONENTS

Principal component analysis was employed in this study to assess Shanghai's capacity for innovation in science and technology. First, the actual data for Shanghai from 2017 to 2021 were normalized using SPSS program, as well as four major components were identified. Then, the indicators are separated into these four primary components based on the correlation, and the principal component scores from 2017 to 2021 are computed using this methodology.

Table 11 shows the principal component composition and associated coefficients. Table 12 shows the score of the principal components in Shanghai. It can be found that the principal component 1 has occupied an absolute advantage, and the score continues to improve. Moreover, it includes the majority of the indicators (such as the number of R&D topics, internal R&D spending, patent applications, etc.). The score of component 2 has basically increased in recent years. Some of its indications are the volume of academic publications, and universities' revenue through licensing. Component 3 contains few indicators and low scores, but has maintained steady growth in recent years, including indicators such as the number of effective invention patents in high-tech industries. However, few indicators, such as the number of articles produced by R&D institutions, are included in component 4. Its score is increasing year by year, but it is all negative.

Table 11: Principal component composition.

Index	Ingredient 1	Ingredient 2	Ingredient 3	Ingredient 4
C3	0.998	0.030	0.001	-0.046
D4	0.996	0.048	0.000	-0.080
F5	0.994	-0.105	-0.010	-0.013
D5	0.993	-0.101	-0.004	-0.060
D1	0.992	0.084	0.008	-0.097
F1	0.991	-0.108	0.004	0.081
C1	0.989	-0.138	-0.051	-0.005
A1	0.989	-0.005	-0.012	-0.150

A3	0.983	-0.010	0.029	-0.180
C2	0.982	-0.140	-0.110	-0.059
F2	0.982	-0.062	0.144	0.105
F6	0.980	-0.179	-0.072	0.046
G9	0.976	-0.010	-0.088	0.200
F3	0.970	-0.177	0.082	-0.142
G7	0.970	0.158	-0.149	0.112
G4	0.966	-0.060	0.244	0.063
G3	0.963	-0.241	-0.039	0.111
B4	-0.957	-0.035	0.147	0.247
B1	0.948	-0.044	0.072	0.306
B3	0.947	0.271	0.167	-0.049
G5	0.942	-0.045	0.280	0.178
G2	0.936	0.129	0.279	0.171
G6	0.932	-0.276	-0.027	0.232
G1	0.931	0.251	0.229	0.130
F4	0.930	-0.185	-0.075	0.310
D3	0.917	0.323	-0.169	-0.160
B2	0.869	0.244	0.313	-0.297
D2	0.868	0.419	0.085	-0.253
H2	0.851	0.330	0.297	-0.280
H3	0.837	-0.004	-0.420	0.349
A4	0.826	0.167	-0.537	0.034
A2	0.791	-0.482	0.015	-0.376
C4	0.752	0.546	-0.272	0.249
H1	0.700	-0.697	0.135	-0.082
E3	-0.009	0.938	0.346	0.019
E1	-0.048	0.878	0.457	0.134
H4	0.538	-0.811	0.145	-0.179
G8	0.558	0.727	-0.361	0.176
E2	-0.208	-0.564	0.512	0.614

Table 12: Shanghai principal component scores.

Index	2017	2018	2019	2020	2021
1	1.241	1.280	1.315	1.329	1.376
2	1.017	1.085	1.051	1.195	1.206
3	1.002	1.004	1.034	1.107	1.120
4	-0.678	-0.627	-0.551	-0.410	-0.333

5 CONCLUSIONS

Shanghai's capacity is typically characterized by the following traits. First, there is a significant and growing investment in R&D overall. Second, it has advantages in patent application and authorization, and effective invention patents. Third, there is a significant capacity for producing articles and works in science and technology. Fourth, universities perform well in scientific and technical innovation, while high-tech industries need to raise the level.

So we should fully utilize Shanghai's strengths in colleges, establish partnerships with organizations that do research in other regions. Then, Shanghai needs to reinforcing the capabilities of high-tech industries. Especially for core technologies, high-tech enterprises should be encouraged to strive for technological talents and invest sufficient funds.

Also, in the environment of open innovation, Shanghai should further utilize the global innovation network, carry out international cooperation, and introduce outstanding foreign experts.

In conclusion, by creating 39 subdivision indices for principal component analysis, this study enriches the dimension of measurement of scientific and technical innovation capability and serves as a guide for Shanghai's innovation strategy. Moreover, The level of regional scientific and technological innovation and the causes of disparities must also be thoroughly discussed in future studies, and researchers must use more novel methods and data to develop empirical investigations for confirmation.

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