

## **The Research on Connotation and Measurement of Technology innovation capability of city**

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### **Abstracts**

At present, the topic of technology innovation capability of city is very popular. There are many research papers about innovation capability in the world, but what is innovation capability? Different people have different viewpoints, having failed to reach a unified view. One important reason is that there have no core connotations of innovation ability. In the paper, Firstly, we give a new definition of the core content of the technology innovation capability of city, to propose five core elements of architecture of innovative capacity, to establish the indicator system of innovative capacity; Secondly, we establish two types of indicators of the technology innovation capability of city, which are the total amount indicators and structure indicators. Finally, according to a new measurement index system, using the statistical methods such as factor analysis and cluster analysis, we have made comparative study of technology innovation capability of city in 15 cities such as Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou, Nanjing, Tianjin, Chengdu and so on, exploring the gaps and problems of technology innovation capability of city, finding the new road of technology innovation capability of city, building an innovation-oriented country. The study results show that: On the terms of a single city, Beijing and Shanghai at the forefront of innovation capability, is a leader Group. On the terms of the four regions, the eastern region of technology innovation capability of city is significantly better than the others. On the terms of five dimensions, the institutional framework and the social framework are more important than others.

Keywords : Technology innovation capability of city ; Cluster analysis ; factor analysis ; Comparative Study

### **1. Introduction**

Recently, the whole society have paying homage to to innovation, research on innovation is voluminous. What is innovation? What is innovation capability? A tall buildings where they stand around ; A huge amounts of money spent into the Science and Technology Parks? Yes, Because innovation requires material foundation. No, because the Science and Technology Park is not equal innovation capability, more does not equal innovative achievements .

What is innovation? What is innovation capability? This is a problem.

The definition of innovation recorded in "Book of Rites": " if you can make things better for one day, you should make them better every day and never stop doing this." Jobs, To create the myth of innovation, said: "The difference in the leader and a follower lies in the innovation " Schumpeter, who is known as the father of the technological innovation, said: "Innovation is the creative destruction of innovation," so, Speaking of innovation , The benevolent see benevolence and the wise see wisdom -- different people have different views.

The 3T theory <sup>[1-5]</sup> which is found by Richard Florid of American, thought that the core elements of the urban innovation capability was talent, technology and tolerance. The 5C creativity index <sup>[6,9]</sup> thought that the core elements of the urban innovation capability was

human, cultural, social, institutional and creative capital. The Shanghai urban creativity index <sup>[7]</sup> believed that, the core elements of the urban innovation capacity is the scale of the industry, science and technology research and development, culture, environment, human environment and social environment. Cultural and creative index <sup>[8]</sup> hold the views that, the core elements of urban innovation capability was that, the contribution, achievements, environment, investment and talent. However, 5C and 3T did not consider economic factors, which does not fully correspond to the China, a developing country. Shanghai city creative index is comprehensive, but it does not consider the system factor, which is an important prerequisite condition for innovation in China, is also one of the most important factors needed by attention. Beijing cultural and creative index has logical problems, which put the indicators of the contribution of outputs, outcomes, environment as parallel to the Input indicators. In fact, there is a similar problem a lot of innovative research.

On the basis of the above analysis and literature research, expert interviews, we have re-conceptualization of the innovation capability from five factors which is more perfect than the existing research. We believe that the core content of the innovation capacity can be defined from five dimensions of factors:

The innovation of this paper is mainly reflected in the following:

Firstly, the research perspective the conceptualization of scientific and technological innovation capability innovation. Learned from the theory and ideology of "3T", put forward by Richard Florida, we combine with the actual situation in China, logically defining the concept of scientific and technological innovation capability in China, giving the formation of the corresponding "5F" index system, and to measure the index and method of research.

Secondly, we build innovative index system about scientific and technological innovation capacity. We put forward the evaluation and measure indicators of tolerance and inclusiveness; we view the indicators of the number of patents, scientific papers as the conditions of technology accumulation and the starting point which support innovation activities, rather than as an innovation output indicators.

Thirdly, the innovative methods and ideas of scientific and technological innovation capacity measurement. We would quantitative empirical research for the newly created index system of urban technological innovation capacity, and make a comparative study of the horizontal city technological innovation capacity, make correlation and regression analysis among the core elements of the innovation capacity. In this thesis, we pursue the best measurement methods, selecting regression analysis, econometric model, a combination of factor analysis and cluster analysis method based on the core conception of innovation capability, the actual situation and data condition in China.

## **2.the operationalization of the innovation capability**

The operationalization of the innovation capability means that we make some necessary measure indicators to evaluate innovation capability. In the operation of innovation capacity, we put forward two types of indicators of the capital and the structure, including quantitative and qualitative indicators, which is more comprehensive than the existing research of urban innovation capability.

Each architecture designed to measure the indicators from the capital and structure especially. Including five-level indicators, 10 secondary indicators and 30 three indicators.

Table 1 innovation capability index system<sup>[11]</sup>

Talent factor	talent Capital	The number of resident population
		the number of University and above number
		the number of R&D personnel number
	talent structure	Percentage of employment personnel employed in knowledge-intensive service sector in Society(%)
		The number of doctors and masters in R&D personnel
		The number of scientists and engineers per million people
Technology factor	technology capital	R & D Internal Expenditures
		R & D intensity
		The number of scientific papers
		The effective number of patents
		R & D Institutions
	technology structure	Invention patent applications per million people
		the proportion of funding for basic research in R & D expenditures
		the proportion of new product development expenses in R & D expenditures
		the proportion of enterprise funds and foreign funds in R & D expenditures
		the proportion of Invention patent applications accounted for patent applications
Industry factor	Industry capital	GDP
		Local fiscal revenue
		The number of balance of various loans in Financial institutions at the end of year (\$ billion)
	Industry structure	the proportion of the services industry in GDP (%)
		million GDP energy consumption
		The number of per capita financial income
System factor	System capital	Proportion of government investment in R & D expenditure (%)
		External expenditure of R & D expenditure
	System structure	Proportion of number of employees of the public administration and social organizations in the society as a whole employment staff
		Proportion of employment of non-state-owned economy in total employment in cities and towns
		Proportion of the government allocation in GDP allocation
society factor	society factor	the ratio of new immigrants (fusion index)
	society structure	Divorce ratio (%)
		The average age of the urban population

In the social architecture(fator), the ratio of new immigrants is a indicator that measures a city of tolerance and inclusiveness. For example, Shenzhen is a city of immigrants, where tolerant and inclusiveness is higher than other cities. From the view of the social structure, according to the research by Mr. Zhao Hongzhou<sup>1</sup>, the peak of creative age is 33.5 years old, approximately normal distribution (Weibull distribution). The best age domain area of innovation activities is roughly between the ages of 25-45. The optimal age curve of the scientists made important scientific contributions to science means that there is the maximum probability of success within the best age. In other words, scientists in the best age domain area have the biggest possibility to make a significant contribution.

### 3. The empirical analysis of innovation capability

#### (1).The factor score analysis of innovation capability

The talent architectures factor F1 , technology architecture factor F2, industry structure factor F3 , system architectures factor F4 and social architecture factor F5 we has been score and ranking by factor analysis as following.

Next, how to get the total factor score of the city innovation capability, there are two ideas: First, we take expert scoring method. Second, we view five architectures factor as weight, based on the ratio of the size of the cumulative variance contribution rate for each architecture, avoiding the drawbacks of subjective weighting method. Expert scoring method would bring large errors. The second method used here to determine the weights. As a result, we get the score and ranking of the five dimensions of innovation capability factor, and an integrated factor F score in descending order, the table below shows that urban innovation capability comprehensive score came in the first place is Beijing, the second place is Shanghai, the third place is Guangzhou, the fourth is Shenzhen which is higher than other cities; innovative capacity is ranked in the last four cities are Changsha, Zhengzhou, Qingdao and Chongqing .

From the overall factor score of innovation capability, the top five is Beijing, Shanghai, Guangzhou, Shenzhen and Hangzhou. Beijing is the first place in talent, technology, industrial and institutional framework ,which social structure factor is the third. The system framework factor of Shanghai, located in the fourth, the rest of the architecture factor rank at the second. The overall factor score ranking of Guangzhou is located in the third, which industry architecture fator located the third. Shenzhen's social architecture factor is located the first place, which the city has best tolerance and inclusiveness that support innovation activities, Shenzhen has a very good performance in tolerance and inclusiveness,which is a younger city of immigrants. However, the system architecture fator is in 14, which need pay more attention to be further strengthened. The five architecture fators of Hangzhou rankings are located in the forefront, which the five architecture fators of supporting for innovation activities development is more balanced, neither obvious "expertise", nor "short board".

Table 2 The five dimensions factor score and Comprehensive factor score

	Talents factor		technology factor		Industry factor		System factor		Social factor		Comprehensive fator	
	Score	rank	Score	rank	Score	rank	Score	rank	Score	rank	Score	rank
Beijing	2.304	1	2.342	1	2.533	1	1.834	1	0.654	3	1.814	1
Shanghai	0.845	2	0.889	2	1.527	2	0.688	4	1.522	2	1.084	2
Guangzhou	0.177	4	-0.002	5	0.564	3	0.469	6	0.447	4	0.349	3
Shengzhen	-0.145	9	-0.19	9	0.309	5	-1.641	14	2.393	1	0.177	4
Hangzhou	-0.113	8	-0.128	8	0.066	6	0.458	7	0.009	7	0.085	5
Nanjing	0.109	5	0.341	3	-0.221	10	0.756	3	-0.588	10	0.082	6
Tianjin	-0.198	10	-0.42	12	-0.203	9	0.575	5	-0.044	8	0	7

<sup>1</sup>Zhao Hongzhou, the law of scientific discovery age is a Weibull distribution [M], 1991.

Chengdu	-0.449	12	-0.199	10	0.392	4	-0.285	9	0.071	6	-0.114	8
Wuhan	0.23	3	-0.022	6	-0.076	7	-0.335	12	-0.955	14	-0.291	9
Xi'an	-0.096	7	0.148	4	-0.979	14	-0.308	10	-0.687	13	-0.393	10
Shenyang	-0.017	6	-0.407	11	-0.786	11	0.777	2	-1.636	15	-0.397	11
Changsha	-0.364	11	-0.043	7	-0.951	13	-0.348	13	-0.612	11	-0.462	12
Zhengzhou	-0.85	15	-0.895	15	-1.178	15	-0.083	8	-0.237	9	-0.561	13
Qingdao	-0.711	13	-0.727	14	-0.827	12	-0.319	11	-0.631	12	-0.613	14
Chongqing	-0.723	14	-0.689	13	-0.17	8	-2.239	15	0.294	5	-0.76	15
East average <sup>2</sup>	-0.372	10.1	-0.354	10	-0.572	10.5	-0.393	10	-0.549	10.6	-0.449	11.5
Middle average	-0.602	12.4	-0.59	12	-0.523	10.2	-0.984	12	-0.295	9.2	-0.607	13.5
west average	-0.566	12.2	-0.544	12	-0.422	9.6	-1.205	12.3	-0.183	8.3	-0.605	13.3
northeast average	-0.017	6	-0.407	11	-0.786	11	0.777	2	-1.636	15	-0.397	11

From the five factors, the first three cities of talent factor are Beijing, Shanghai and Wuhan; the first three cities of technology factors are Beijing, Shanghai and Nanjing; the first three cities of industrial factor are Beijing, Shanghai and Guangzhou; the first three cities of system factor are Beijing, Shenyang and Nanjing; the first three cities of social architecture are Shenzhen, Shanghai and Beijing; the first four cities of composite score factor are Beijing, Shanghai, Guangzhou and Shenzhen.

Now, let us see innovation capability factor score in four regions.

From the four economic regions, the highest average composite score in four regions (here only analyze the innovation capacity of the three regions) is the east (0.37), the second is the west (-0.42), the third is the middle (-0.44), but the difference about factor score is not very large. 8 cities in the eastern cities, Beijing and Shanghai is above the regional's average level, and much higher than the average level, and the remaining six cities is below the regional average.

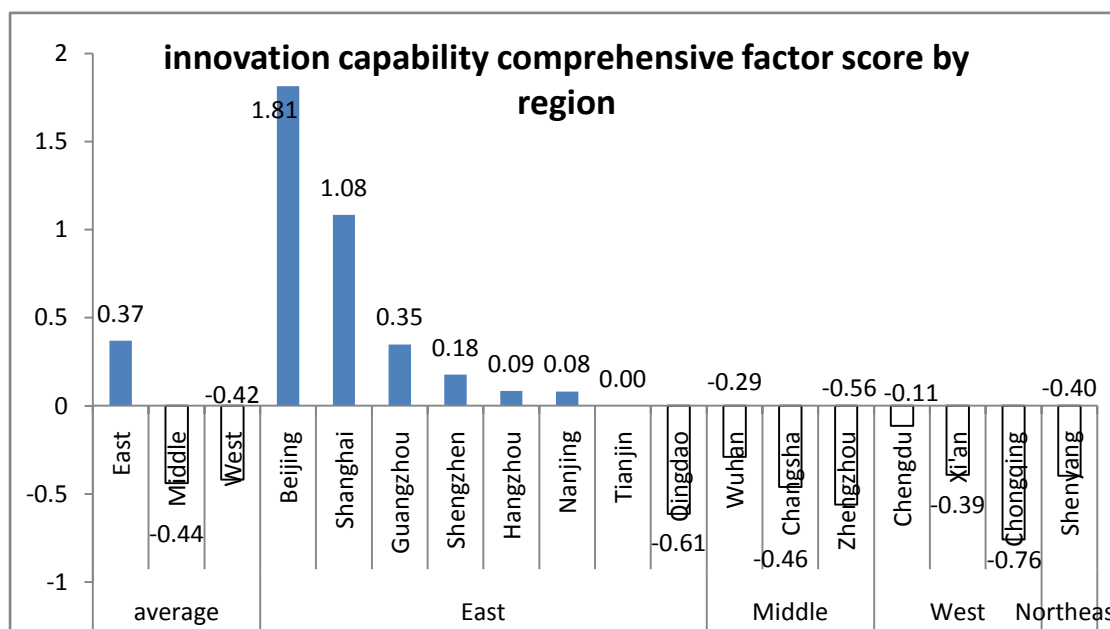


Figure 1 innovation capability comprehensive factor score by region

Now, we would classify "good" and "bad" cities according to the five architectures technology innovation capacity of 15 cities, where the standard "good" is views as factor

<sup>2</sup> Decimal places in order to distinguish between the rankings before and after.

score above average level , and the standard "bad" is under average level. Let us look at the following Table 3.

**Table 3 the Classification of City innovative capability**

Talent good	Talent good	Talent good	Talent good	Talent bad	Talent bad
technologygood	technologygood	technology bad	technology bad	technology bad	technologygood
industry good	industry bad	industry bad	industry good	industry bad	industry bad
instituion good	instituion good	instituion bad	instituion good	instituion good	instituion bad
society good	society good	society bad	society bad	society good	society bad
<b>Beijing</b>	<b>Nanjing</b>	<b>Wuhan</b>	<b>Guangzhou</b>	<b>Shenyang</b>	<b>Xi'an</b>
<b>Shanghai</b>					
Talent bad	Talent bad	Talent bad	Talent bad	Talent bad	Talent bad
technology bad	technology bad	technology bad	technology bad	technology bad	technology bad
industry good	industry good	industry bad	industry bad	industry good	industry bad
instituion good	instituion bad	instituion good	instituion bad	instituion bad	instituion bad
society bad	society good	society bad	society bad	society bad	society good
<b>Hangzhou</b>	<b>Shengzhen</b>	<b>Tianjin</b>	<b>Changsha</b>	<b>Chengdu</b>	<b>Chongqing</b>
			<b>Qingdao</b>		<b>Zhengzhou</b>

Note:good is better than the average level,bad is lower than the average.

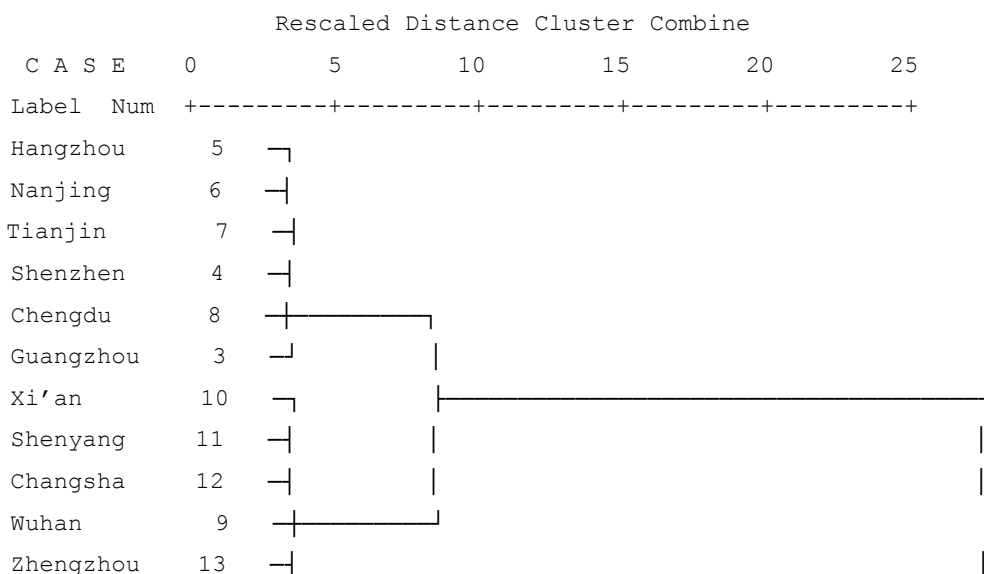
According to the average level of classification, its scientific and rational of results in the table 3, we need to pend further exploration. Next,we would classify the cities technological innovation capability by clustering method. However, the classification on the table 3 is helpful for us to find our specific cities about "specialty" and "short board" , to provide advice and thinking.

**(2). cluster analysis of the innovation capacity factor score**

Cluster analysis is more scientific,which could avoid the subjective arbitrariness of human qualitative analysis classification. The purpose of Cluster analysis is to make the distance as far as possible among the various types, to make the distance as close as possible in midpoint, and the classification results have a convincing explanation.

**Figure 2 clustering analysis of innovation ability score factor**

Dendrogram using Ward Method





Type 1 : Xi'an Shenyang Changsha Wuhan Zhengzhou Qingdao Chongqing  
 innovation capacity is the general

Type 2 : Hangzhou Nanjing Tianjin Shenzhen Chengdu Guangzhou  
 innovation capability is a litter better

Type 3 : Shanghai  
 innovation capability is better

Type 4 : Beijing  
 innovation capability much better

Cluster analysis results show that, due to various cities under the combined effect of the core elements of the talent architecture, technology architecture, industry architecture, system architecture, and social architecture, besides there are some differences in urban history and culture, the natural environment, economic base, technological resources, technological innovation capacity shows a certain regularity.

Firstly, Eastern cities are better than other parts, the Yangtze River Delta, Pearl River Delta and the Beijing-Tianjin region city have more scientific and technological innovation capacity. Secondly, there has some correlation among five factors. For example, the city which the technology architecture is good is also good at talent architecture. We can illustrate this problem from the statistical sense. Let us look at the correlation of five architecture, and we often use three measured method: Pearson Correlation, Kendall's tau\_b and Spearman's rho.

Based on the clustering classification tree results, we will divided 15 cities into three scientific and technological innovation capability group. Which is specifically shown in the following table.

**Table 4 innovation capability Group classification of 15 cities in China**

Group	city
Leader Group	Beijing、 Shanghai
Challenges or catch up Group	Hangzhou、 Nanjing、 Tianjin、 Shenzhen、 Chengdu、 Guangzhou
The latecomer Type Group	Xian、 Shenyang、 Changsha、 Wuhan、 Zhengzhou、 Qingdao、 Chongqing

**4. The relevant recommendations to improve the scientific and technology innovation capability**

we put forward relevant decisions, recommendations and reference according to some conclusions above, in order to improve the city technology innovation capability when we seek for the road to innovation:

First of all, from social factor of the city technology innovation capability, innovation requires social and culture environment of tolerance and inclusion. Innovation culture to create a tolerant spirit, tolerance of failure <sup>[11]</sup>, which will help attract more technology talent. Then, creative talents in the social and cultural environment of tolerance and

inclusiveness are easier to produce innovation results. Silicon Valley in the United States has a strong culture and atmosphere of tolerance and inclusiveness, a gathering place of innovation.

Secondly, From the system architecture of city technology innovation, we establish and improve the mechanism of market competition, which is conducive to carry out innovation activities smoothly. We establish the mechanisms of the core enterprises, universities and research institutes to work closely. We should not only play the role of good government support and guide to innovation activities, but also balance forces between the government and market, to reduce administrative activities, to increase the openness of the market.

Thirdly, From the talent architecture of the city scientific and technological innovation capacity, what we need to do is to strengthen the urban agglomeration of technological innovation talent and the ability of attraction, reserving a certain population size and highly educated R&D talent, cultivating creativity, creative talents, which is one of the key ways to improve innovation capability. We not only pay attention to the quality of the innovation talents, but also pay attention to the quality of creative talents.

Fourth, from the industry architecture of the city technology innovation capability, the level of economy, financial strength, and financial capital which provide financial support and protection for innovation activities. We would create diversification of the sources of funding of innovation activities, especially financial institutions on innovation activities, to support the formation of multi-level and wide range of scientific and technological innovation funding mechanisms. We developed the preferential fiscal and taxation policies in order to accelerate the optimization and transformation of industry structure, to enhance the awareness of energy saving and emission reduction, which have a fundamental guarantee for the smooth progress of the innovation activities and sustainable economic development.

Fifth, from the technical architecture of technology innovation capability, it is an important for us to pay more attention to the existed size and structure of technology accumulation that is helpful to carry out innovation activities. We not only make full use of the advantages of the existing capital accumulation, but also pay attention to the irrational allocation problem in the structure of technology accumulation. We not only pay more



attention to the number of R&D funding for the investment, but also need pay more attention to the R&D funding allocation structure and structure of sources. We are concerned about the number of existed patents, but we are also concerned about the proportion of invention patent. We are not only concerned about the number of scientific papers, but also the frequency of scientific papers cited, in order to achieve the city original innovations ,to improve the capability of urban technology innovation independently, to accelerate the pace of building an innovation-oriented country.

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