Spatial-Temporal Pattern of Scientific and Technological Talent Agglomeration and Its Influencing Factors in Chengdu-Chongqing City Cluster

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Abstract. The study of change and influencing factors in the Chengdu-Chongqing city cluster may contribute to science and technology innovation, as well as enrich existing population geography theories, expand the scope of application of multivariate statistical analysis by exploring factors that influence the agglomeration of science and technology talent. Statistical data from 2010 to 2019 was utilized in this study to apply location quotient theory, cluster analysis and fixed-effect regression model to research objectives. The results indicate that the Chengdu-Chongqing city cluster has a stable or increasing agglomeration of scientific and technological talent and is mainly divided into four categories; economic factors such as regional GDP, R&D expenditure investments in science, bed capacity per 10,000 people, teacher-student ratios in compulsory education, and road density have significant positive impacts on social factors.

Keywords: Chengdu-Chongqing City Cluster · Scientific and Technological Talent Agglomeration · Location Quotient · Cluster Analysis · Fixed-effect Regression Model

1 Introduction

It has become increasingly apparent that the degree of scientific and technological talent concentration is one of the most important indicators of a nation's and regional science and technology innovation capacity [1, 2]. In order to develop a western science city and a center of innovation in science and technology with national influence, it is imperative to encourage the concentration of scientific and technological talent within the Chengdu-Chongqing city cluster. As well as providing a reference for achieving strategic goals and improving the accuracy of policies, exploring the evolutionary trends and influencing factors of the Chengdu-Chongqing city cluster provides essential information for optimizing current population geography theory.

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In scientific and technological agglomeration, scientific and technological talents are flowed or migrated to achieve a concentration and combination in space. There has been significant interest in this topic from both practice and academia alike. In one study, representative indicators of scientific and technological talent concentration levels are examined [3, 4, 5]. While in the other study, factors influencing such talent concentration are examined [6, 7]. Scholars have yet to develop a systematic understanding of scientific and technological talent aggregation in the context of Chengdu-Chongqing city cluster, despite an abundance of literature on the subject.

We used Location Quotient (LQ) and cluster analysis to analyze the development trend of scientific and technological talent agglomeration in Chengdu-Chongqing city cluster and its influencing factors. It is structured as follows: the second section discusses theory and methodological considerations; the third section discusses factors influencing agglomeration of science and technology talent in the Chengdu-Chongqing city cluster; and the fifth section concludes the article.

2 Materials and Methods

2.1 Definition

Scientific and technological talents are currently defined broadly and specifically. Scientific and technological talents include all individuals associated with scientific and technological activities, including both R&D personnel who are directly involved in scientific research activities as well as those who provide support and security for scientific and technological research activities, even if they do not participate directly in scientific and technological research activities [8]. The current narrow view equates scientific and technological personnel with R&D personnel, namely those involved in R&D and those who provide direct services to them, including managers, administrators, and administrative personnel. This paper equates scientific and technological talent with research and development personnel as the central component of scientific and technological research activities and the availability and reliability of data.

2.2 Study Area

Linked to *the master plan for the construction of the Chengdu-Chongqing economic circle* by The Communist Party of China Central Committee and the State Council, the Chengdu-Chongqing city cluster consists of 16 cities, including Chengdu, Zigong, Luzhou, Deyang, Mianyang, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Guang'an, Dazhou, Ya'an, Ziyang, and Chongqing.

2.3 Data Sources

The majority of the data in this paper come from the 2010–2019 Sichuan Science and Technology Statistical Yearbook and Chongqing Science and Technology Statistical Yearbook, the 2010–2019 China City Statistical Yearbook, the 2010–2019 China National Economic and Social Development Statistical Bulletin of 16 cities and relevant government work reports. Some of the data represent the outcomes of self-directed calculations.

2.4 Method Description

2.4.1 Location Quotient

It is currently possible to measure the concentration of scientific and technological talent using two primary methods. The first relates it to the level of education and considers the proportion of employed people with a certain degree or higher as the degree of agglomeration of scientific and technological talent [9]; the second uses an indicator based on industrial concentration which is reflected through the location quotient [10, 11]. Consequently, this paper employs the second method for measuring the concentration of scientific and technological talent by eliminating the scale difference between regions. As a consequence, the concentration of scientific and technological talent is measured using the second method in this paper.

As a fundamental concept in regional economics, location quotient is the ratio between the output value of a particular industrial sector in a region and the total regional output value and the national output value of that sector to the total national output value [12], and its mathematical expression is:

$$LQ_{ij} = \frac{X_{ij} / \sum_{i=1}^{m} X_{ij}}{\sum_{j=1}^{n} X_{ij} / \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij}} \tag{1}$$

According to the Eq. (1), i denotes the ith industry (i = 1, 2, 3,……, m); j denotes the j-th region (j = 1, 2,……, n). X can adopt different meanings according to the content of the research, such as total output value, employment, sales revenue, etc. This industry is more likely to have a regional specialty when the location quotient is greater. LQ $>$ 1 indicates that the distribution of an industry in a region is more concentrated and has a greater comparative advantage than the national average, indicating the industry is somewhat competitive; LQ = 1 indicates that the distribution of the industry in the region is equal to the national average and has no obvious advantage; LQ $<$ 1 indicates that the distribution of the industry in the region is more dispersed than the national average [12].

Taking into account the previous definitions, this paper determines the location quotient of scientific and technological talent as the ratio of the number of R&D personnel in a given region to the number of talents employed there. There is a proportional relationship between R&D personnel and the total number of employees in Chengdu-Chongqing city cluster agglomeration.

$$TLQ = \frac{T_j / E_j}{\sum_{j=1}^{16} T_j / \sum_{j=1}^{16} E_j} \tag{2}$$

As demonstrated by Eq. (2), where j denotes the region, including cities in the Chengdu-Chongqing city cluster (j = 1, 2,……, 16), T represents the number of scientific and technological talent, T_j denotes the number of scientific and technological talent in region j, E denotes the number of employed persons, E_j denotes the total number of employed persons in region j, $\sum_{j=1}^{16} T_j$ means the total number of scientific and technological talent in Chengdu-Chongqing city cluster, $\sum_{j=1}^{16} E_j$ denotes the total number of employed persons in Chengdu-Chongqing city cluster.

2.4.2 Influencing Factor Model Construction

Researchers have examined the factors influencing the aggregation of scientific and technological talent using a variety of analytical frameworks. They can be divided into three main categories: economic, scientific, and social. Various stages of urban economic development are characterized by a combination of economic and social factors that play a significant role in the aggregation of scientific and technological talent. Wen et al. conducted a comparative study which concluded that financial strength increases a city's competitiveness, increasing its ability to attract scientific and technological talent [13]. According to Cowling and Lee [14], cities that are home to a greater number of physicians and research institutions are likely to attract higher levels of scientific and technological talent.

This paper develops the following econometric model based on Eq. (2). The corner labels indicating regions and years have been omitted from the following equation for the sake of brevity.

$$\ln TLQ = \sum_{i=1}^{2} \alpha_{1i} \ln X_{1i} + \sum_{i=1}^{2} \alpha_{2i} \ln X_{2i} + \sum_{i=1}^{4} \alpha_{3i} \ln X_{3i} + \beta + \mu. \tag{3}$$

As shown in Eq. (3), X_{1i} represents the i-th element in economic factors, X_{2i} represents the i-th element in scientific factors, X_{3i} represents the i-th element in social factors, α_{1i} represents the influence coefficient of i-th element in economic factors, α_{2i} represents the i-th element in scientific factors, α_{3i} indicates the influence coefficient of the i-th element in social factors, $\alpha_{1i} \ln X_{1i}$ indicates the influence level of the i-th element in economic factors, $\alpha_{2i} \ln X_{2i}$ indicates the influence level of the i-th element in scientific factors, $\alpha_{3i} \ln X_{3i}$ indicates the influence level of the i-th element in social factors, $\sum_{i=1}^{2} \alpha_{1i} \ln X_{1i}$ indicates the influence level of economic factors, $\sum_{i=1}^{2} \alpha_{2i} \ln X_{2i}$ indicates the influence level of scientific factors, $\sum_{i=1}^{4} \alpha_{3i} \ln X_{3i}$ indicates the influence level of social factors, β is the constant term while μ is the error term.

Combining previous studies and adhering to the principles of comprehensiveness and data availability, Table 1 lists the factors that influenced this study. In order to account

Table 1. List of influencing factors.

Classification of factor	Influencing factors
Economic Factors	Regional Gross Domestic Product [11]
	The proportion of tertiary industry output value [13]
Scientific Factors	R&D investment [14]
	Share of effective inventions [15]
Social factors	Regional urbanization rate [11]
	Number of beds per 10,000 people [15, 17]
	Teacher-student ratio in compulsory education [6, 18]
	Road Density [6, 19]

for both the cross-sectional and time-trend gaps, a fixed-effects regression model is used to distinguish samples with fixed relative observations or time periods.

3 Results and Discussion

3.1 The Change of Scientific and Technological Talent Agglomeration in the Chengdu-Chongqing City Cluster

Over the period 2010–2019, the 16 regions of Chengdu-Chongqing city cluster have experienced significant increases in scientific and technological talent. The location quotient of scientific and technological talents in Chengdu-Chongqing has generally remained stable or increased. Relative significance of observations.

According to Table 2, there was a decrease in the talent location quotients for Zigong, Deyang, Mianyang, Neijiang, Zigong, and Chongqing between 2010 and 2019. First, this can be attributed to the growth of Chengdu-Chongqing city clusters, which have impacted these regions' data; second, the scope of statistics has changed since Jianyang moved to Chengdu in May 2016. Furthermore, scientific and technological talents have been lost to varying degrees as a result of the tainted environment. This paper presents an in-depth analysis of the agglomeration of scientific and technological talents in each region. As a result, the conclusions above are based on relative advantage, namely Chengdu-Chongqing's relative position within its regional labor force.

In Fig. 1, Tableau2022.2 is utilized in order to calculate a map of talent concentration locational advantage distribution within the Chengdu-Chongqing city cluster. In light

Table 2. Scientific and Technological Talent Aggregation in Chengdu-Chongqing City Cluster, 2010–2019

Region	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average
Chengdu	1.9967	2.4421	2.5378	2.5292	2.6737	2.7773	2.5142	2.4950	2.4319	2.2946	2.4692
Zigong	0.6173	0.6979	0.5804	0.5516	0.4981	0.3982	0.6583	0.5226	0.4858	0.4721	0.5482
Luzhou	0.2755	0.4036	0.3560	0.3404	0.3847	0.4119	0.3697	0.3530	0.3167	0.3843	0.3596
Deyang	1.4152	1.4541	1.5834	1.4314	1.1981	1.0826	1.1456	1.1065	1.0512	1.1346	1.2603
Mianyang	3.4849	2.4689	1.8473	2.0639	1.7212	1.8576	1.8254	1.8643	1.8434	1.7815	2.0759
Suining	0.0562	0.0967	0.3236	0.3584	0.4555	0.2173	0.2322	0.2681	0.3214	0.4077	0.2737
Neijiang	0.7567	0.2110	0.6313	0.7662	0.4670	0.6044	0.3437	0.2815	0.3611	0.3520	0.4775
Leshan	0.2197	0.4237	0.4737	0.4922	0.4634	0.4799	0.5087	0.4588	0.3595	0.4425	0.4322
Nanchong	0.1363	0.2053	0.4011	0.3157	0.3298	0.2592	0.2664	0.2565	0.2809	0.3149	0.2766
Meishan	0.0184	0.1276	0.3740	0.1940	0.2929	0.2224	0.2575	0.2203	0.2040	0.1895	0.2101
Yibin	0.4074	0.5022	0.6978	0.4291	0.7404	0.5795	0.5475	0.4719	0.4655	0.5093	0.5350
Guang'an	0.0604	0.1074	0.0721	0.0600	0.0800	0.0663	0.0844	0.0947	0.0794	0.1387	0.0843
Dazhou	0.0297	0.1538	0.1290	0.1495	0.1706	0.1340	0.1586	0.2324	0.1775	0.2108	0.1546
Ya'an	0.2151	0.3801	0.2649	0.3451	0.3772	0.3191	0.4360	0.4183	0.3878	0.5428	0.3686
Ziyang	0.0827	0.1219	0.1379	0.1249	0.1400	0.0860	0.0546	0.0899	0.0870	0.0780	0.1003
Chongqing	1.4541	1.2669	1.1650	1.1785	1.1580	1.1872	1.2297	1.2687	1.3427	1.3519	1.2603

Fig. 1. Distribution of scientific and technological talent agglomeration in the Chengdu-Chongqing city cluster

of the spatial distribution of scientific and technological talent within the Chengdu-Chongqing cluster, it is evident that the cluster is spatially divergent. As a result of agglomerating scientific and technological talent, Chongqing, Deyang, Mianyang, and Chengdu are clearly advantages. The talent location quotient for each of these cities is always above one, indicating a relatively advantageous location. Chengdu's talent location quotient is 2.4692, while Guang'an's talent location quotient is 0.0843.

In order to better analyze the level of talent agglomeration, this paper uses stata for cluster analysis. From the cluster analysis results, we can see that the agglomeration degree of the Chengdu-Chongqing city cluster is divided into four categories: the first category is Chengdu and Mianyang; the second category is Zigong, Yibin, Neijiang, Leshan, Luzhou, Ya'an, Suining, Nanchong; the third category is Meishan, Dazhou, Guang'an, Ziyang; the fourth category is Deyang, Chongqing. From the above analysis, the agglomeration of scientific and technological talents presents regional similarities (see Fig. 2).

3.2 Influencing Factors of Science and Technology Talent Agglomeration in Chengdu-Chongqing City Cluster

To examine the influencing factors affecting the agglomeration of scientific and technological talents in the Chengdu-Chongqing city cluster, the study constructed a panel database of 16 regions from 2010 to 2019 and applied a fixed-effect regression model. According to Table 3, the goodness-of-fit for all sample groups (within-group R2) is 0.5135 and the F-value test indicates that the regression model is significant. As a whole, the statistical analysis based on this panel database has a good fit and is able to provide a strong explanation for the locational advantage of science and technology talent agglomeration in Chengdu and Chongqing.

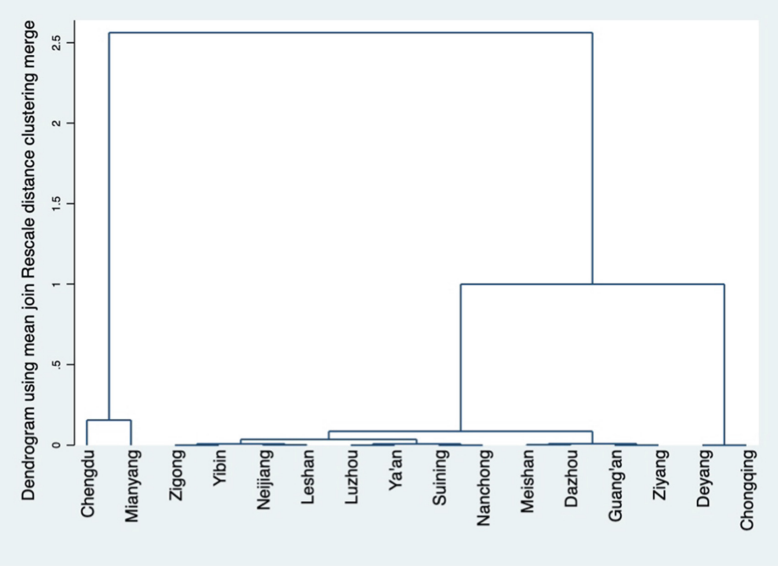

Fig. 2. Cluster dendrogram of scientific and technological talent agglomeration in the Chengdu-Chongqing city cluster

According to Table 3, economic factors play an important role in the agglomeration of scientific and technological talents. The industrial structure of the region is not technologically advanced, but R&D investments have a significant positive impact on the agglomeration of scientific and technological talents. As a region invests more in R&D, it is likely that it will receive greater support for the development of scientific and technological skills. In addition, the easier it is to gather scientific and technological talents. However, the percentage of effective inventions does not significantly affect the concentration of scientific and technological talents. Possibly this is because effective inventions do not always translate into productivity or economic promotion effects due to certain obstacles or time delays. Furthermore, there are limited immediate incentives to attract scientific and technological talent. As well, the gathering of scientific and technological talents takes time. As far as social factors are concerned, the number of beds per 10,000 people, the teacher-student ratio at compulsory education, and the density of roads have a positive and significant impact on the concentration of scientific and technological talents. When choosing a place of employment, scientific and technological talents do not only consider economic income, but also take medical care into account. Scientific and technological talents are directly affected by these social factors as to whether or not they are able to relocate a family and then care for them. In addition, it is important to note that the concentration of scientific and technological talents does not significantly increase with an increase in regional urbanization. In tandem with Zhang Meili & Li Baizhou research [11], this may be due to the fact that Chengdu-Chongqing is still in the initial stages of scientific and technological talent agglomeration and regional urbanization. Currently, the ratio does not have a significant effect on the agglomeration of scientific and technological talent.

Table 3. Results of panel data based on fixed effects model

Classification of factor	Influencing factors	Coefficient	P-value
Economic Factors	Regional Gross Domestic Product	1.276597	0.065*
	The proportion of tertiary industry output value	-0.8031964	0.271
Scientific Research Factors	R&D investment	0.5916004	0.000***
	Share of effective inventions	-1.917044	0.845
Social factors	Regional urbanization rate	-0.590973	0.158
	Number of beds per 10,000 people	-0.234986	0.026**
	Teacher-student ratio in compulsory education	20.32232	0.001***
	Road Density	-0.3678364	0.097*
	F	4.19	0.000***
	within-group R^2	0.5149	

Note: "*" marks the significance of the coefficient, "***" is significant at the 1% level, "**" is effective at 5% level, "* " is significant at the 10% level

4 Conclusions

Taking 16 regions within the Chengdu-Chongqing city cluster from 2010 to 2019, this paper analyzes the temporal and spatial divergence dynamics of the agglomeration degree of scientific and technological talents and its driving forces.

First of all, a series of scientific and technology talent agglomeration policies issued since 2010 have played a certain role in promoting the Chengdu-Chongqing urban agglomeration. Chengdu-Chongqing generally had a stable and rising trend in scientific and technological talent from 2010 to 2019. Secondly, there are significant spatial differences in the agglomeration of scientific and technological talents in the Chengdu-Chongqing urban agglomeration. Chengdu, Deyang, Mianyang, and Chongqing are the cities with a relatively high degree of agglomeration of scientific and technological talents in the region. There are no obvious cluster effects of scientific and technological talent in the two central cities of Chengdu and Chongqing. Furthermore, when choosing a place of work, scientific and technological talents don't just take into account the region's economic development level and research and development investments that affect their development, but also take into account other social factors that influence elderly family members, children, and other medical and educational factors.

A summary of the contributions of this paper is provided below: First, by using the talent location quotient, we have been able to gain a comprehensive understanding of the agglomeration and changing trends of scientific and technological talents in the 16 cities of the Chengdu-Chongqing urban agglomeration from 2010 to 2019, laying the foundation for further research into the agglomeration of scientific and technological talents. At the same time, the cluster analysis results show that the existing types of scientific and technological talent agglomeration are mainly divided into four categories,

represented by Chengdu, Zigong, Meishan and Deyang.In addition, Tableau2022.2 can be utilized to create a spatial distribution map of the concentrations of scientific and technological talents within the Chengdu-Chongqing urban agglomeration, which provides an overview of the location distribution characteristics of scientific and technological talent within the Chengdu-Chongqing urban agglomeration. Finally, we are conducting a study of the influencing factors of scientific and technological talent agglomeration in Chengdu-Chongqing urban agglomeration using a fixed effect regression model. This will serve as a reference for improving scientific and technological talent policy in the region and optimizing the business environment for scientists and technologists.

Compared to previous research, new findings have been obtained. Nonetheless, there are also the following limitations. Firstly, the definition of scientific and technological talents in this paper is somewhat one-sided because it equates scientific and technological talents with R&D talents, future studies can define it in a broader sense and analyze its concentration degree. Secondly, in terms of factors influencing the concentration of scientific and technological talents, this paper is limited by the avowed purpose of the study, the future research should select as many factors as possible to reveal the factors influencing the concentration of talents more comprehensively and provide more powerful theoretical support.

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