Research on Spatial Heterogeneity of Regional Innovation Convergence

Yong Gang Xue(✉)

Medical Business School, GuangDong Pharmaceutical University, Guangzhou, China
xueyonggang@gdpu.edu.cn

Abstract. Regional coordinated development is an important goal of current economic development. Based on the spatial econometric model, this paper analyzes the convergence and variation characteristics of regional innovation, and studies the influence of spatial related factors on the convergence of regional innovation. It is found that regional innovation in Guangdong Province has convergence and spatial heterogeneity, and spatial related factors have an important impact on innovation convergence. On the basis of considering spatial related influencing factors and spatial heterogeneity, it is proposed to formulate regional innovation related policies, drive economic development through innovation, and finally achieve convergence to a higher level of economic state.

Keywords: spatial correlation · spatial econometrics · regional economies

1 Introduction

Since the reform and opening up, China's economy has achieved rapid development, but it still faces the severe problems of unbalanced regional economic development and low quality of economic development. Realizing the coordinated development of regional economy has become an important goal of China's economic development in recent years. The "Pearl River Delta (PDR)" region of Guangdong province attaches importance to the role of capital and talents and enhances the driving force of regional innovation on economic growth, so that the regional economy has achieved rapid development and improved its competitive advantage; On the contrary, other regions in Guangdong Province failed to make full use of resource endowments and other reasons, and economic growth was in a disadvantageous position. The difference of regional innovation ability is an important factor causing this result, because innovation is the fundamental driving force to improve economic growth and achieve high-quality economic development. Innovation is affected by many factors such as human, capital investment and regional economic environment. Therefore, it is necessary to study the spatial characteristics of regional innovation convergence.

2 Literature Review

Some scholars have studied the spatial spillover of regional innovation. Andrea, F (2019) studied the regional spatial spillover of EU from 2008 to 2012, and found that the regional

Z. Zeng et al. (Eds.): ECIT 2022, AHE 11, pp. 419–426, 2023.
https://doi.org/10.2991/978-94-6463-005-3_41

innovation input has spatial correlation, and the innovation output is affected by the spatial spillover effect [1]; Qiu, J (2020) studied whether there is spatial knowledge spillover effect among regions. The empirical results show that there is regional innovation convergence, and developing developed regions obtain more benefits from innovation spillover than developed regions [2]; Yang, X (2021) studied the impact of high-speed railway on regional innovation convergence based on endogenous economic growth model. The results show that high-speed railway significantly improves regional innovation convergence, and the regional innovation spillover range of central cities exceeds 300 km [3]; Wang, Y (2021) used Moran index and spatial econometric model to analyze the change trend and spillover effect of regional innovation output, and found that regional innovation has spatial correlation, regional innovation output has positive spillover effect, and environmental regulation promotes regional innovation [4]; Erdil, E (2021) studied the change process of knowledge innovation and whether it has convergence, and found that the European region has the convergence characteristics of knowledge innovation, and the convergence is more obvious in underdeveloped regions [5]; Li, G (2021) studied the differences and causes of regional innovation by using panel data and stochastic frontier analysis method, and found that there are essential differences between different provinces of regional innovation and there is no stochastic convergence [6]; Gao, X (2021) analyzed the spatial mechanism of regional innovation within the province by using patent data. The research shows that regional innovation capability is a dynamic economic phenomenon, and there are spatial instability and heterogeneity in the relationship of innovation capability between different province regions [7]; Xu, y (2022) calculated the efficiency of green innovation based on the stochastic frontier analysis model, and found that R&D expenditure is still the main positive influencing factor of innovation, the overall efficiency and lasting efficiency have a decentralized trend in the local distribution, and there is a certain club convergence effect [8]; Lee, C (2018) studied the impact of science and technology convergence effect on innovation, found that science and technology convergence has a positive nonlinear impact on innovation, and found that organizational capacity, regional science and technology spillover and other factors have a positive impact on the relationship between convergence and innovation [9].

It can be concluded that although scholars have studied the causes and influencing factors of regional innovation convergence, there is insufficient research on the regional heterogeneity of convergence. Due to the differences of spatial geographical location and natural endowment, there should be differences in innovation between different regions of Guangdong Province, especially between the “Pearl River Delta” region and other regions. Under the background of implementing the economic development strategy of innovation driven development, in order to achieve the goal of coordinated development of regional economy, it is necessary to study the spatial heterogeneity of regional innovation convergence.

3 Data and Method

There are obvious differences in the level of economic development in different regions of Guangdong Province. In recent years, the government has been committed to the

coordinated development among regions. According to the economic development level and spatial geographical location, Guangdong Province is divided into Pearl River Delta (PDR) region, eastern region, northern region and western region. The number of patent applications in various regions is used as the measurement index of regional innovation. The data sample is the innovation data of cities from 2006 to 2020, and the data source is GUANG DONG STATISTICAL YEARBOOK from 2007 to 2021.

3.1 Spatial Correlation

In spatial econometric analysis, spatial correlation refers to the spatial relationship between variables, which is expressed as the correlation degree between random variables that obey a specific spatial location distribution.

Moran's I test is a classical method of spatial correlation test. Its original assumption is that there is no spatial correlation in any form between variables, and the alternative assumption is that there is at least some form of spatial correlation between variables. The calculation method of Moran's I statistics is shown in (1):

$$Moran's\ I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}(y_i-\overline{y})(y_j-\overline{y})}{s^2\sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}} \tag{1}$$

Where $S^2 = \frac{1}{n}\sum_{i=1}^{n}(y_i-\overline{y})^2$, $\overline{y} = \frac{1}{n}\sum_{i=1}^{n}y_i$

y_i represents the innovation index of region i, n is the number of regions, ω_{ij} represents spatial weights of region i and region j, W represents spatial weight matrix.

3.2 Spatial Econometric Model

The convergence model was first used to measure whether there is convergence or divergence in the income gap between countries or regions, and later extended to the fields of consumption, trade, innovation and so on. σ-convergence and β-convergence method are often used in convergence model, σ-convergence method measures whether the regional variables have a convergence trend from the spatial dimension, β-convergence method measures whether the regional variables have the convergence trend from the time dimension.

When studying the σ-convergence of regional innovation, model (2) is used to estimate the convergence.

$$\ln y_{it} = \overline{\ln y_t} + \varepsilon_{it} \tag{2}$$

Where y_{it} represents the innovation index of region i at period t, $\overline{\ln y_t}$ represents the mean value of $\ln y_{it}$ in period t. The residual term of model is σ-convergence.

β-convergence refers to the faster growth rate of innovation production in regions with backward innovation level, resulting in the narrowing trend of innovation gap among regions. It is studied on regional innovation β-convergence based on model (3).

$$\frac{\ln(y_{it}/y_{it_0})}{T} = \alpha + \beta \ln y_{it_0} + \varepsilon_i \tag{3}$$

Where $\ln y_{it_0}$ and $\ln y_{it}$ represent the innovation level at the beginning and end of the period of region I respectively, T represents the number of periods, and β is the convergence coefficient. When β is less than 0, it indicates that the innovation level of each region will reach the same stable state, that is, there is β-convergence, otherwise there is no β-convergence.

Although the model (3) has endogenous problems, the endogenous problems decreases gradually with the increase of the number of periods. At the same time, β-convergence is to investigate the phenomenon of long-term economic change. Therefore, 2006 is set as the base period in the paper, and the number of periods is 15.

Because the innovation activities between regions may affect each other due to the flow of factors and knowledge spillover, the traditional model deviates from the assumption that the innovation activities in each region are independent of each other. Therefore, it is necessary to modify the traditional model under the influence of spatial correlation, as shown in (4) and (5) respectively.

$$\ln y_{it} = \alpha_i + \lambda \sum_{j=1, j\neq i}^{n} W_{ij} y_{jt} + \varepsilon_{it} \tag{4}$$

$$\frac{\ln(y_{it}/y_{it_0})}{T} = \alpha + \beta \ln y_{it_0} + lag_j + \varepsilon_i \tag{5}$$

Where $lag_j = \lambda \sum_{j=1, j\neq i}^{n} W_{ij} \frac{\ln(y_{jt}/y_{jt_0})}{T}$, W represents spatial weight matrix.

The convergence rate can be calculated separately based on models (3) and (5), and the calculation method is shown in (6).

$$Con\_rate = -\frac{1}{T} \ln(1 + T \times \hat{\beta}) \tag{6}$$

4 Empirical Results

4.1 Empirical Results of Spatial Correlation

Moran's I index is used to measure the spatial correlation of regional economy in Guangdong Province. The results are shown in Fig. 1.

As can be seen from Fig. 1, Moran's I increased year by year from 2006 to 2010, fluctuated up and down from 2011 to 2018, and decreased after 2018. During the sample period, the Moran's I index of regional innovation was greater than zero and passed the significance test. This shows that regional innovation in different regions of Guangdong Province has a positive spatial correlation, that is, regional innovation will be significantly affected by adjacent regions. When studying regional innovation, we must consider the impact of this spatial correlation.

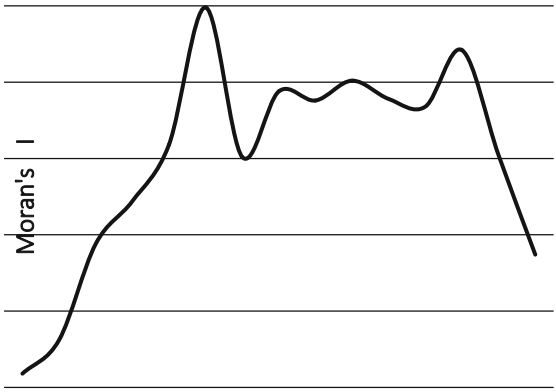

Fig. 1. Regional innovation Moran's I

4.2 Empirical Results of σ-Convergence

The empirical results of σ-convergence are shown in Table 1. The smaller the σ-value, the stronger the convergence of regional innovation. On the contrary, it indicates that the convergence is weakened. From the perspective of the whole province, The σ-value has a gradual downward trend, indicating that the difference of innovation ability in different regions of Guangdong Province has a decreasing trend with time, that is, it has σ-convergence.

There are obvious differences in σ-value size in different regions. The σ-value of PDR and eastern region is greater than in the western and northern regions. From 2006 to 2014, the σ-convergence of PDR region showed an increasing trend, and the σ-convergence decreased from 2015 to 2020. In contrast to the PDR region, the σ-convergence in the eastern region showed weakening trend from 2006 to 2012 and increased from 2013 to 2020. The western region shows the characteristics of multiple fluctuations. From 2006 to 2009, the convergence gradually weakened, and then from 2010 to 2013, the convergence gradually increased. From 2014 to 2018, it gradually weakened and finally increased. From 2006 to 2015, the convergence of the northern region gradually weakened, and there was a continuous strengthening trend from 2016 to 2020.

4.3 Empirical Results of Spatial σ-Convergence

The empirical results of spatial correlation test show that regional innovation in Guangdong Province has spatial correlation, so it is necessary to further analyze the convergence of regional innovation in Guangdong Province under the influence of spatial correlation. The empirical results of spatial σ-convergence are shown in Table 2.

Comparing the results of Tables 1 and 2 it is found that from the perspective of the whole province, the convergence of regional innovation in Guangdong Province is enhanced after considering the spatial related influencing factors. However, considering the spatial related factors, the convergence changes are different in different regions and years. The convergence is enhanced in some years and weakened in some years. The

Table 1. σ-Convergence

Year	PDR	East	West	North	ALL
2006	1.386	1.204	0.400	0.467	1.660
2007	1.449	1.173	0.478	0.475	1.666
2008	1.464	1.339	0.494	0.356	1.716
2009	1.420	1.441	0.449	0.422	1.676
2010	1.367	1.348	0.405	0.479	1.663
2011	1.212	1.447	0.367	0.492	1.566
2012	1.117	1.498	0.193	0.519	1.565
2013	1.120	1.077	0.169	0.526	1.507
2014	1.111	0.921	0.304	0.549	1.435
2015	1.128	1.132	0.336	0.603	1.495
2016	1.142	0.971	0.392	0.526	1.427
2017	1.127	0.992	0.594	0.329	1.427
2018	1.088	0.735	0.419	0.324	1.396
2019	1.108	0.647	0.239	0.552	1.382
2020	1.134	0.732	0.116	0.372	1.374

Table 2. Spatial σ-Convergence

Year	PDR	East	West	North	ALL
2006	1.432	1.112	0.411	0.486	1.510
2007	1.530	1.056	0.593	0.531	1.509
2008	1.562	1.466	0.597	0.411	1.506
2009	1.476	1.439	0.488	0.419	1.460
2010	1.371	1.565	0.469	0.534	1.429
2011	1.132	1.768	0.294	0.568	1.313
2012	1.070	1.828	0.105	0.597	1.278
2013	0.987	1.272	0.188	0.606	1.215
2014	0.981	0.745	0.156	0.624	1.209
2015	0.989	0.494	0.145	0.662	1.295
2016	1.032	0.347	0.321	0.586	1.220
2017	1.043	0.495	0.649	0.354	1.183
2018	0.986	0.353	0.392	0.348	1.132
2019	1.107	0.445	0.230	0.599	1.111
2020	1.165	0.746	0.144	0.426	1.146

Table 3. β-Convergence

Variable	PDR	East	West	North	ALL
$\hat{\beta}$	−0.0037	−0.0061	−0.0111	−0.0121	−0.0042
Con_rate	0.38	0.64	1.21	1.34	0.43
spatial $\hat{\beta}$	−0.0038	−0.0065	−0.0148	−0.0118	−0.0044
Con_rate	0.39	0.68	1.67	1.30	0.46

change presents Matthew Effect, that is, those with strong convergence become stronger, while those with weak convergence become weaker.

4.4 Empirical Results of β-Convergence

The empirical results of β-convergence are shown in Table 3. The estimated values of the β-coefficients of basic model are less than zero, which indicates that the regional economic innovation in Guangdong Province exists.

β-convergence trend when the spatial correlation is not considered. Comparing the empirical results of basic model and spatial econometric model, it can be found that the introduction of spatial effect affects the regional economic innovation of Guangdong Province β-Convergence characteristics, that is, the economic cooperation of regional economy plays an important role in the β-convergence of regional economic innovation. The convergence rate of Western and northern regions is higher than that of PDR and eastern regions. The convergence rate of northern region is the fastest, while that of PDR region is the slowest.

5 Conclusions

In view of the imbalance of regional economic development in Guangdong Province, the paper calculates the regional economic innovation in Guangdong Province σ-Convergence and β-convergence firstly, and then studies the heterogeneity of convergence of different regional innovation, and finally analyzes the spatial correlation of regional innovation and its influence on regional innovation convergence. Based on the empirical analysis, the following conclusions can be drawn:

1) Regional innovation in Guangdong Province has σ-convergence and *β-convergence*: the empirical results show that although the innovation convergence of the four regions in Guangdong Province has volatility, it has σ-convergence and *β-convergence trend on the whole.*
2) There is spatial heterogeneity in regional innovation convergence: the results show that there are differences in the size, speed and change process of regional innovation.
3) Spatial correlation has an important impact on regional innovation Convergence: The results show that considering spatial correlation factors, σ-convergence has different changes and presents Matthew Effect, and *β-convergence is obviously accelerated.*

We should pay attention to the change process of regional innovation convergence and its spatial heterogeneity, formulate innovation related policies according to each region's own endowment and geographical advantages, so as to improve the driving effect of innovation on economic development, and finally realize the convergence of regional economy to a higher level of stability.

Acknowledgment. Funding: Guangdong Education Science Planning Project: Research on behavior characteristics and promotion ways of innovative Population & Community in Colleges and Universities in Guangdong Province from the perspective of Ecology (2019GXJK167).

References

1. Furková A (2018) Spatial spillovers and European Union regional innovation activities. Cent Eur J Oper Res 27(3):815–834. https://doi.org/10.1007/s10100-018-0581-4
2. Qiu J, Liu W, Ning N (2019) Evolution of regional innovation with spatial knowledge spillovers: Convergence or divergence? Netw Spat Econ 20(1):179–208. https://doi.org/10.1007/s11067-019-09477-2
3. Yang X, Zhang H, Lin S, Zhang J, Zeng J (2021) Does high-speed railway promote regional innovation growth or innovation convergence? Technol Soc 64:1–13
4. Wang Y, Zhang F, Zheng M, Chang C (2021) Innovation's spillover effect in China: incorporating the role of environmental regulation. Environ Model Assess 26:695–708
5. Erdil E, Akçomak İS, Çetinkaya UY (2021) Is there knowledge convergence among european regions? Evidence from the European Union framework programmes. J Knowl Econ 5:1–25. https://doi.org/10.1007/s13132-021-00754-5
6. Li G, Zhou Y, Liu F, Tian A (2021) Regional difference and convergence analysis of marine science and technology innovation efficiency in China. Ocean Coast Manag 205:105581
7. Gao X, Zhai K (2021) Spatial mechanisms of regional innovation mobility in China. Soc Indic Res 156(1):247–270. https://doi.org/10.1007/s11205-021-02638-2
8. Xu Y, Zhang Y, Lu Y, Chen J (2021) The evolution rule of green innovation efficiency and its convergence of industrial enterprises in China. Environ Sci Pollut Res 29(2):2894–2910. https://doi.org/10.1007/s11356-021-15885-0
9. Lee C, Park G, Kang J (2016) The impact of convergence between science and technology on innovation. J Technol Transf 43(2):522–544. https://doi.org/10.1007/s10961-016-9480-9