Research on the Influencing Factors of Collaborative Innovation of Science and Technology in the Pearl River Delta Urban Agglomeration

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Abstract. This paper has measured the level of collaborative innovation of science and technology in the Pearl River Delta urban agglomeration from 2010 to 2018 by using the DEA-Malmquist index model. The empirical results show that the overall level of technological collaboration and innovation in the Pearl River Delta urban agglomeration is relatively high. The pure technical efficiency value of the Pearl River Delta urban agglomeration has hit its peak. In terms of its scale efficiency, that of Zhuhai and Jiangmen still has room for improvement, while that of other cities has reached the optimal level. Then, through the establishment of a panel data model of the Pearl River Delta urban agglomeration from 2009 to 2018, the influencing factors of technology collaborative innovation in the Pearl River Delta urban agglomeration was analyzed. Finally, this proposal was made.

1. Introduction

In the era of knowledge economy, with the increasingly prominent role of knowledge and technology in economic development and social progress, the trend of technology complexity and integration is enhanced. Under the new normal of economic development, China's economic development is changing from resource-driven to innovation-driven. The fundamental driving force of coordinated development lies in innovation-driven, and technological innovation is the core driving force to promote socioeconomic development.

The report of the 18th National Congress of the Party pointed out that scientific and technological innovation is the strategic support for improving social productivity and comprehensive national strength, and must be placed at the core of the overall situation of national development. Yao Yanhong and Du Menghua (2013) pointed out that the so-called science and technology collaborative innovation refers to the process of different innovation subjects based on the goal interest, through the organic cooperation and interaction of innovation elements. Under the constraints and coordination of innovation interaction mechanism, the process of improving resource utilization efficiency through complex non-linear interactions to produce an overall effect that cannot be achieved by a single element is horizontal collaborative innovation in form. Foreign scholars Kavita Surana et al. (2020) show that promoting the coordinated development of science and technology can well promote sustainable development. Li Jingwen and Li Jianling (2015) pointed out that the collaborative innovation of science and technology in Beijing, Tianjin and Hebei can provide long-term impetus for promoting the economic development and social change of the three places, which is also an important way to achieve the
coordinated sustainable development of the three places. This article will study the factors influencing the collaborative innovation of technology in the Pearl River Delta urban agglomeration.

The DEA method can easily deal with multi-input and multi-output problems. Because it is a non-parametric method, it is not necessary to determine the functional relationship between input and output in advance, so that the influence of subjective factors in the analysis can be effectively avoided. Wang Xiuli and Wang Lijian (2009) used the DEA model to evaluate the innovation efficiency of industry-university-research cooperation in 30 provinces and cities in my country. The results of the study show that the efficiency of innovation has not yet reached a level that is compatible with technological innovation capabilities and economic development. This article will use the DEA-Malmquist index model to measure technological innovation in the Pearl River Delta urban agglomeration from 2010 to 2018.

In addition, some scholars analyzed the influencing factors of technology collaborative innovation based on the panel data model. Tian Yipiao, Liu Mingyue, Zhang Weiguo (2018) pointed out that based on provincial panel data analysis, population urbanization is the main factor driving technological innovation and change. ARRAATT DG and others (2014) pointed out that capital opening will have an impact on the original regional technology innovation cooperation activities, break the existing space technology innovation cooperation activities, and promote the cooperation activities between the subjects in a larger space. Zhong Weizhou and Chen Chen (2018) conducted a study on trade openness, human capital threshold and regional innovation development. With the increase in human capital, trade openness will eventually promote China's patent application activities and regional innovation and development. Based on panel data, this paper studies the impact of R&D investment, human capital investment, industrial concentration, foreign trade dependence, and the proportion of actual foreign investment actually utilized on technology collaborative innovation in the Pearl River Delta urban agglomeration.

2. Measurement of technology collaborative innovation in the Pearl River Delta urban agglomeration based on the DEA-Malmquist index model

Based on the DEA-Malmquist index model (output-oriented), this article measures the technological cooperation innovation of the Pearl River Delta urban agglomeration from 2010 to 2018. The output variables are the output of new products of industrial enterprises above the scale of the Pearl River Delta urban agglomeration (10,000 yuan), the amount of patent application and the amount of patent authorization. The input variables include the local general public budget expenditure of science and technology in the Pearl River Delta urban agglomeration, the number of scientific and technological activities personnel in R&D institutions, the number of industrial enterprises R&D activities personnel above the scale, the internal expenditure of the R&D funds of industrial enterprises above the scale, the number of students in ordinary institutions of higher learning in schools, and the general public budget expenditure in education places, etc. Judging from the overall average level of the Pearl River Delta urban agglomeration, the overall level of scientific and technological collaborative innovation of the Pearl River Delta urban agglomeration in 2010-2018 is relatively high. From the perspective of pure technical efficiency value, the Pearl River Delta urban agglomeration have reached the optimal value. From the scale efficiency value, Zhuhai and Jiangmen need to be further strengthened, and other cities have reached the optimal level. In addition, the Pearl River Delta urban agglomeration has reached the optimal level from the pure technical efficiency value in 2018. From the scale efficiency value, Zhuhai, Jiangmen and Zhaoqing are in the stage of increasing scale expansion, and other cities are at the best level. There is still room for improvement in the scale of science and technology collaborative innovation in Pearl River Delta urban agglomeration. The main results of the empirical study are detailed in Table 1-3.

| year | Pure technical efficiency (1) | Scale efficiency (2) | Technical efficiency (3) = (1) × (2) | Skill improved (4) | TFP = (3) × (4) |
|------|-------------------------------|---------------------|----------------------------------------|-------------------|-----------------|
|      |                               |                     |                                        |                   |                 |

Table 1 2010-2018 Pearl River Delta Technology Collaborative Innovation
3. Research on the influencing factors of collaborative innovation of science and technology in the Pearl River Delta Urban Agglomeration

Based on the panel data from 2009-2018, this paper analyzes the influence of R&D input, human capital input, industrial concentration, foreign trade dependence, actual utilization of foreign capital ratio on scientific and technological collaborative innovation in the Pearl River Delta urban agglomeration. The selection of indicators and variables is shown in Table 4, and the data are derived from the Guangdong
Statistical Yearbook.

Through the establishment of panel data model, analysis of the Pearl River Delta urban agglomeration science and technology collaborative innovation factors, panel data regression model as follows:

\[
Z_{Lt} = \alpha_{t} + \beta_{1}RD_{it} + \beta_{2}ZXS_{it} + \beta_{3}JZD_{it} + \beta_{4}YCD_{it} + \beta_{5}IFDI_{it} + \epsilon_{it}
\]

Among them, the meaning of each variable is shown in Table 4, \(\alpha_{t}, \beta_{1}, \beta_{2}, \beta_{3}, \beta_{4}, \beta_{5}\) They are the parameter to be estimated. \(\epsilon_{it}\) is the random disturbance term of iid.

| Indicators                                      | Variables | Name of variable | Variable definition                                                                 |
|------------------------------------------------|-----------|------------------|-------------------------------------------------------------------------------------|
| Science and Technology Collaborative Innovation | ZL        | Patents per billion | Number of domestic patent application authorizations (pieces)/GDP(100 million yuan) |
| R&D inputs                                     | RD        | R&D percentage   | Internal expenditure on R&D expenditure of the whole society (100 million yuan)/GDP(100 million yuan)*100% |
| Human capital investment                       | ZXS       | Percentage of college students | Number of college students (ten thousand)/resident population at the end of the year (ten thousand) *100% |
| Industrial concentration                       | JZD       | Concentration index | \(\sum_{j=1}^{J} \left( \frac{GDP_{ij}}{GDP_{i}} \right)^2\)                        |
| Foreign Trade Dependence                       | YCD       | Percentage of actual utilization of foreign capital | Total imports and exports (100 million US dollars)/GDP (100 million yuan) |
| Percentage of actual utilization of foreign capital | IFDI     | Actual utilized foreign capital (100 million US dollars)/GDP (100 million yuan) |

| Indicators | ZL  | RD   | ZXS  | JZD  | YCD  | IFDI   |
|------------|-----|------|------|------|------|--------|
| ZL         | 1   | 0.496292 | -0.14493 | 0.376195 | 0.227123 | -0.35598 |
| RD         | 0.496292 | 1     | -0.14493 | 0.376195 | 0.227123 | -0.35598 |
| ZXS        | -0.14493 | 0.01999 | 0.01999 | 0.567298 | 0.439094 | -0.29653 |
| JZD        | 0.376195 | 0.567298 | 0.271728 | 1     | 0.248953 | -0.27524 |
| YCD        | 0.227123 | 0.439094 | 0.033217 | 0.248953 | 1     | 0.417881 |
| IFDI       | -0.35598 | -0.29653 | 0.296189 | -0.27524 | 0.417881 | 1  |

Table 5 shows the correlation coefficient matrix between variables. From the perspective of simple correlation coefficients, the simple correlation coefficients between variables are not high, so a preliminary estimation model of OLS is established, as shown in Table 6. At a significance level of 10%, RD and YCD have a significant positive effect on ZL; IFDI has a significant negative effect on ZL; ZXS and JZD have insignificant effect on ZL. There may be multiple collinearities between explanatory variables, and the irrelevant variables in the preliminary model are eliminated and re-modeled.
Table 6 Preliminary OLS estimation of the model (1)

| Variable | Coefficient | Std. Error | t-Statistic | Prob.  |
|----------|-------------|------------|-------------|--------|
| C        | 0.42774     | 2.144893   | 0.199423    | 0.8424 |
| RD       | 0.447724*   | 0.257821   | 1.736572    | 0.0861 |
| ZXS      | -0.06053    | 0.067117   | -0.90182    | 0.3697 |
| JZD      | 4.86615     | 4.677851   | 1.040253    | 0.3012 |
| YCD      | 4.133008*   | 2.39628    | 1.72476     | 0.0882 |
| IFDI     | -201.021**  | 86.60799   | -2.32104    | 0.0227 |

Note: In Table 6, $R^2$ is 0.34257; Adjusted $R^2$ is 0.303437; F value is 8.754051; P value corresponding to F test is 0.000001. AIC value is 3.637644;

Table 7 Preliminary OLS estimation of the model (2)

| Variable | Coefficient | Std. Error | t-Statistic | Prob.  |
|----------|-------------|------------|-------------|--------|
| C        | 2.593641*** | 0.59241    | 4.378117    | 0.0000 |
| RD       | 0.497921**  | 0.237365   | 2.097701    | 0.0389 |
| YCD      | 4.9878**    | 2.255957   | 2.210947    | 0.0297 |
| IFDI     | -247.989**  | 74.66785   | -3.32123    | 0.0013 |

Note: In Table 7, $R^2$ is 0.332080; adjusted $R^2$ is 0.308780; F value is 14.25262; P value corresponding to F test is 0.000000; AIC value is 3.609030.

After eliminating the insignificant variables, OLS modeling was conducted again, and it was found that the adjusted $R^2$ value became higher and the AIC value was lower, and the coefficients of the selected explanatory variables were all significant at the 0.05 significance level. However, for the explanatory variable YCD, observing the significance of the coefficient, we can find that RD and YCD have a significant positive effect on ZL, and IFDI has a significant negative effect on ZL.

Considering that our sample data is panel data, we use F test and Hausman test to choose between the mixed model of panel data, individual random effect model and individual fixed effect model.

Table 8 Model F test

| Effects Test | Statistic | d.f.  | Prob.  |
|--------------|-----------|-------|--------|
| Cross-section F | 30.36993  | (8,78) | 0.0000 |
| Cross-section Chi-square | 127.3145 | 8      | 0.0000 |

F test: $H_0: \beta_j = \alpha$, the intercept term under each individual regression is equal to the intercept term for the overall regression, and there is no individual fixed effect. Because the P value corresponding to the F test is less than 0.05, the null hypothesis should be rejected and an individual fixed effect model should be established, as shown in Table 8.

Table 9 Hausman test

| Test Summary | Chi-Sq. Statistic | Chi-Sq. d.f. | Prob.  |
|--------------|-------------------|--------------|--------|
| Cross-section random | 10.51734 | 3          | 0.0146 |

Hausman test: $H_0: \text{cov}(X_{it}, \alpha_i)$, for each individual regression. The covariance between the explanatory variable and the intercept term is 0. There is no individual fixed effect. The corresponding
P value of the Hausman test is less than 0.05, it should also reject the null hypothesis and establish an individual fixed effect model, specifically refer to Table 9.

Table 10 Panel data individual fixed effect model results

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|----------|-------------|------------|-------------|-------|
| C        | 4.267044*** | 0.888969   | 4.799990    | 0.0000|
| RD       | 0.651205*** | 0.258855   | 2.515710    | 0.0139|
| YCD      | -9.47694*** | 2.432475   | -3.89601    | 0.0002|
| IFDI     | -192.118*** | 53.27654   | -3.60605    | 0.0005|

Note: ***, **, * indicate significance at 0.01, 0.05, and 0.1 significance levels, respectively.

Table 10 shows the regression results of individual fixed-effect models. The corresponding P value of the F test is 0.000000, it is less than 0.05, and the overall model is significant. The coefficients of the three explanatory variables are significant at the 5% significance level. And the adjusted R2 is 0.814790. It reaches 0.8, and the AIC value is 2.372202. It is less than the OLS model, indicating that the model's interpretation has been greatly improved. Considering the individual fixed effect, R&D investment has a significant positive impact on the collaborative innovation of the Pearl River Delta urban agglomeration. The dependence of foreign trade and the proportion of actual use of foreign capital (IFDI) have a significant negative impact on the coordinated innovation of the Pearl River Delta urban agglomeration.

4. Conclusions and countermeasures

4.1. Conclusion

This article first uses the DEA-Malmquist index model to measure the level of technology collaborative innovation in the Pearl River Delta urban agglomeration from 2010 to 2018. The results show that the overall level of technology collaborative innovation in the Pearl River Delta urban agglomeration is relatively high in terms of the overall average level in this area. From the perspective of pure technical efficiency value, the Pearl River Delta urban agglomeration has reached the optimal level. From the perspective of scale efficiency value, Zhuhai and Jiangmen still need to be further strengthened, and other cities have reached the optimal level. In addition, the Pearl River Delta urban agglomeration has reached the optimal level in terms of pure technical efficiency in 2018. From the perspective of scale efficiency, Zhuhai, Jiangmen and Zhaqing are in the stage of increasing scale, and other cities have achieved the optimal level. There is still room for improvement in the scale of technological collaborative innovation in the Pearl River Delta urban agglomeration.

This paper studies the panel data of the Pearl River Delta urban agglomeration from 2009 to 2018. Through model construction, correlation analysis, model preliminary OLS estimation, F test and Hausman test, the individual fixed effect model of panel data is finally selected. Empirical research results show that at a 5% significance level, (1) Human capital investment and industry concentration index have no significant impact on technology collaborative innovation; (2) R&D investment, foreign trade dependence and actual use of foreign capital have a significant impact on technology collaborative innovation, of which R&D investment’s impact on the collaborative innovation of science and technology is positive, while the impact of the dependence on foreign trade and the proportion of actual use of foreign capital on the collaborative innovation of science and technology is negative. R&D proportion of enterprises and other entities on independent innovation significantly promotes the technological innovation collaboration of the Pearl River Delta urban agglomeration. As a relatively active technological innovation subject, enterprises have a higher proportion of R&D in the process of collaborative development of the Pearl River Delta urban agglomeration, indicating that the enterprise is more innovative in the long run, as companies digest and absorb imported technologies, their independent innovation capabilities will also improve. The established enterprise technology R&D
centers will meet the market demands more closely and speed up the commercialization of technological innovation achievements. The dependence of foreign trade on YCD and the actual utilization of foreign capital accounted for IFDI have significantly hindered technology collaborative innovation in the Pearl River Delta urban agglomeration. With the continuous improvement of the opening up in the capital market, the financial support environment has been optimized to provide financing support for innovation entities. This can effectively solve the problem of insufficient funding for innovation or rely solely on government financial support to form a systematic supporting environment surrounded by technology, research and development as well as finance. In this paper, the study of regional technological innovation synergy is more focused on the interactive activities between innovation entities. When the funds required for the innovation activities of the entities are adequately guaranteed, the entities will be accelerated to seek more high-quality innovation resources outside the region, which is bound to sway the decision towards the collaborative behaviour of technological innovation, especially to reduce the opportunities for synergy of technological innovation in the region.

4.2. countermeasures and suggestions

(1) Establish a collaborative innovation development model that takes the enterprise as the core and actively interacts with other innovation entities.

(2) Take government supervision and management measures to reduce the technological monopoly and contradiction of the innovation main body of the Pearl River Delta city group.

(3) The government intensifies its support for technological innovation of enterprises and allocates resources reasonably.

(4) Strengthen R&D investment and talent exchange and cooperation.

Acknowledgments

This work was financially supported by (1) the Zhuhai City's 2019-2020 Annual Philosophy and Social Sciences Planning Project “Research on Influencing Factors and Spatial Spillover Effect of Collaborative Innovation of Science and Technology in Pearl River Delta Urban Agglomeration” (2019ZC145) (2) School-level scientific research project of Beijing Institute of Technology, Zhuhai. "Research on the Influencing Factors and Spatial Spillover of Collaborative Innovation of Science and Technology in the Pearl River Delta urban agglomeration” (XK-2019-09).

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