

Game theory: central government should regulate the development of dual-nuclei cities

Xiang Chen^{1*}

¹ School of Management and Economics, The Chinese University of Hong Kong (Shenzhen Campus), Shenzhen, Guangdong, 518172, China

Abstract. The dual-nuclei structure, which means two considerable cities in one region, is typical in urban agglomerations. However, relevant studies have long lacked exploration of the game relationship between two cities. Studies about dual-nuclei structure from game theory may offer some suggestions for the healthy development of dual-nuclei regions. This article will focus on building simplified models of dual-nuclei structure by using Guangzhou and Shenzhen as examples. In the study, cities are divided into two types, which are the center city and the port city. By using game trees to explore the fitness relationship of dual-nuclei cities, the study has found that the overall benefit is not always optimal when the dual-nuclei cities compete for their own benefit though it is harmful to the overall interests of the region in trading areas. It may approach the optimal benefit in the education area, but there still exists the risk of vicious competition. Therefore, governments need to regulate the differential development of dual-nuclei cities by adopting different economic and educational policies for different cities.

1 Introduction

According to Lu Yuqi, the dual-nuclei structure model indicates that in some areas there exist two significant cities, which include a regional central city and a port city. Regional central city is the political, cultural and transportation center. At the same time, the port city has a finance and trade advantage. Each city performs different functions.

However, the division of urban functions in the Greater Bay Area (GBA) has been relatively confusing in recent years due to historical reasons. Guangzhou, the central city in GBA, also plays an important role in foreign trade. The Canton Fair was an important function after 1997. Therefore, Guangzhou and Hong Kong (Shenzhen) have to compete in the foreign trade area. Some scholars have predicted the negative impact of the multi-cities in the GBA and recommend that these cities carry out differentiation development [3].

At the same time, the Shenzhen government is actively promoting the development of higher education (HE). According to Xie et al., the development of HE in STEM is conducive to strengthening the innovation capability of Shenzhen. Shenzhen has improved its HE

* Corresponding author: 23020063@linkuhk.edu.cn

level by introducing universities in other cities, such as Guangzhou and Hong Kong. However, the major settings of the Shenzhen branch campuses have a high degree of overlap with the parent campuses, which causes negative competition between the campuses. In recent years, the admissions scores of non-local colleges such as Harbin Institute of Technology (Shenzhen), have once exceeded Sun Yat-sen University, the local prestigious college [9].

The reason for the above problems may be that the division of city functions is not clear enough. In order to help governments better divide the functions of each city, research can analyze the relationship between dual-nuclei cities through game theory. However, studies from the perspective of game theory are relatively lacking. Scholars focus on the division of dual-nuclei structure model types, while ignoring the study of the optimal relationship between the two cities [6]. The study of dual-nuclei structure model may further develop the recent studies and provide suggestions for the development of the twin cities represented by Guangzhou and Shenzhen. This article will build a simplified model of dual-nuclei cities by setting two kinds of cities, which are the center city and the port city. Through Guangzhou and Shenzhen, the article explores the optimal combination of dual-nuclei cities by using game trees. The result shows that cities tend to compete for their own benefits which may affect the overall benefit of the region in the trading area. At the same time the higher education area also has a risk of negative competition. Therefore, governments need to regulate the development of the twin cities.

2 Methodology

2.1 Data source

The annual reports of Guangzhou Port and Shenzhen Port are used to assign values to their operational costs and revenues. In the HE area, the influence and operational costs are estimated through the average rankings and funding of the top five universities in each city. Taking Guangzhou and Shenzhen as examples can better explore the game relationship between dual-nuclei cities. If cities like Chengde or Chongqing were used as an example, the relative lack of port freight in Chengde might lead to an incomplete discussion. Therefore, Guangzhou and Shenzhen, which competes in both trade and education, can better illustrate the prevalent issues faced by dual-nuclei cities.

2.2 Index selection

The following table shows the relevant parameter settings and their descriptions. According to Liang, China has been facing the problem of overcapacity in recent decades [7]. The performance of overcapacity is oversupply. Therefore, the increase in export profits due to competition is ignored in this research. Assume that the total profit of trade equals W_0 .

The operating cost of China Merchants Port in 2023 is 13.471 billion yuan, while Guangzhou Port is 11.993 billion yuan (data from their annual report or port authority board). Both ports have branches in other places. When taking the operating costs of the companies in their own city into account, the operating expenses of both ports are similar. Therefore, the operating costs are uniformly represented by C_1 .

Table 1. Guangzhou6 KHQ]KHQ ¶V , QGH[6HOHFWLRQ

6 \ PER	'HVFULSWLRQV	5HODWLRQ
W_0	7RWDO SURILW RI UHJLR	
W_1	3URILW RI ¶HQLWUHQHFLW	
ΔW	LQFUHDVH WUDGH SURILWV E	$< \Delta W < W_1$
C_0	3RUW RSHUDWLQJ RPSHWLQLRQ	$C_0 < C_1$
C_1	3RUW RSHUDWLQJ FRVW XQGI	
F_1	%HQHILW RI +(FHQWHL	$F_1 > F_2 \approx F_3$
F_2	7KH %HQHILW RI +(SRUW ¶LW\	
F_3	7KH %HQHILW RI +(SRUW ¶LW\	$M_i < F_j$
ΔF	7KH LQIOXHQFH RI VHW¶LQWHEU	
M_i	7KH 0DQDJHPHQW FRVW F	

2.3 Method introduction

In urban management both economic parameters and political factors can be described by the basic rules of game theory [6]. Therefore, this article will set benefit and cost parameters for different decisionmaking. By drawing game trees, the search will focus on finding the Nash equilibrium points under the natural competition of the dual cities. In this study, Guangzhou is divided as the center city, and Shenzhen is the port city. The research data is primarily sourced from relevant information collected in Guangzhou and Shenzhen over the past decade.

3 Results and discussion

3.1 Center city's analysis as challenger

From the game tree, it shows that when $W_1 > C_1 - C_0$, the port city will choose to compete with the center city (Figure 1) When $\Delta W < C_1 - C_0$, it will give up competing with the center city to gain its own benefit. When the center city chooses strategy 1, the total benefit of the whole region would be less than $W_0 - C_0$. However, it is also difficult to restrict the development of trade in the center city. In this example, Guangzhou is the capital of Guangdong province and Shenzhen is the port city. The Guangdong Development Plan (ODP) to coordinate their respective interests [8]. In this case, the port is both exclusive and competitive, which is similar to the private product. When both cities have shipping capabilities, there will be competition between them. Guangzhou's recent "Three-Year Action Plan Report" confirms that it will continue to intensify competition in foreign trade [9]. Therefore, the central government needs to minimize the proportion of trade in the center city in the entire region due to the formula of $W_t = (W_1 - C_1 - \Delta W) \div a$, where a is the profit. This requires coordination and division of interests between the two cities. However, the coordination between the two cities still has a limited impact on the overall region but on their own [10]. The two cities should always avoid competing in the same areas, which is the most efficient way. Even in the most extreme case, export-oriented cities can focus on export freight, while central cities can serve as domestic trade centers.

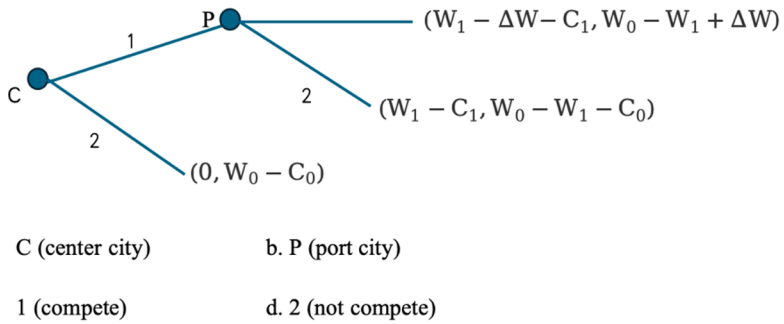


Fig. 1. Game Tree of trading area.

3.2 Port city's analysis as challenger

In HE area, when $F_3 - M_2 < F_2 - M_2$, the optimal structure is (a, f) , which will maximize the return (Figure 2). Universities in GBA have different development levels and distribute off-balance [11]. The cities where universities are located may restrict their development. + R Z H Y H U H V W D E O L V K L Q J E U D Q F K F D P S X V H V P D \ H D V H high-tech enterprises D Q F R R S H U D W H Z L W K R W K H U F L W L H V \ X Q L Y transformation capability of the universities and to finally develop the HE in the GBA [12]. In this situation, HE is a quasi-public good, which can be shared in the region. The subgame perfect Nash equilibrium is the overall optimal benefit. Therefore, establishing branch campuses in the dual-nuclei structure region is a positive-sum game. However, when $F_3 - M_2 > F_2 - M_2$ WKH SRUW FLW \ PD \ FKRRVH WR L Q V S L W G X F H R V but may have a negative effect on the region when $M_2 < F_2 - M_2 + \Delta F$. In this case, WKH LP S D F W R I L Q W U R G X F L Q J R W K H W_2 > F_2 - M_2 + \Delta F, U H V R X U which means the marginal benefit of introducing a provincial university is higher than that of a local university, greater benefits will be obtained. However, in actual operation, the marginal benefit of operating a provincial university does not always exceed that of a local university. This requires port cities to carefully consider regional interests when introducing educational resources. Therefore, the central government should further regulate the cross-provincial operation of universities and encourage the cooperation of HE in the region.

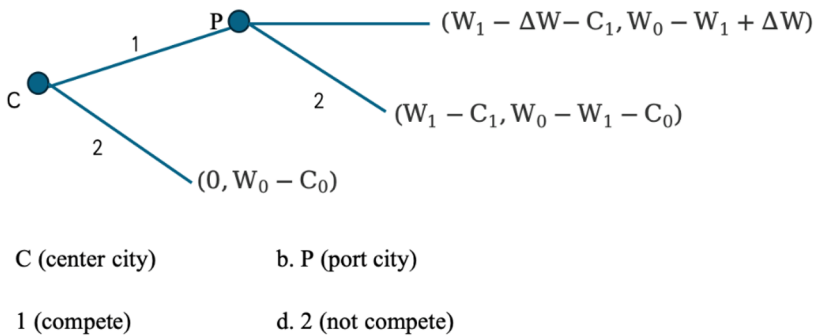


Fig. 2. Game Tree of education area.

3.3 Discussion

In the trading area, the center city and port city may have negative competition. Some scholars suggest building cluster management of ports in GBA, while others indicate that the cooperation among ports is useless to the overall benefit [2]. In this paper, the model also shows that lower proportion of center cities in trading area can benefit the whole region. However, it is impossible for the center city to give up the development of trade. Therefore, Fu et al point out that cities in GBA should have differential development in the field of trade [3]. For example, the port city should focus more on international trading and increasing product added value. At the same time, the center city can mainly manage domestic trade. It is hard for the local governments to reach an agreement. The cities would always fight for their own benefits in the trading area, which would cost deadweight loss. Therefore, the central governments can encourage cities to engage in different types of trade by providing different tax policies.

In the education area, the introduction of local HE in the port city can enhance the total benefit of the region. However, emerging port cities tend to introduce schools, which are not always the HE in the local area, as much as possible. Take Shenzhen as an example, of its nine nonlocal HE institutions, six are from other areas [4]. Although it can also enhance the overall HE resources in the region, its benefit may be relatively low compared to introducing local universities. These branch campuses of local universities have had a strong impact on local universities especially for universities in the center city. Therefore, port cities need to strengthen the cooperation with the HE institutions in their own regions. For instance, LQVWHDG RI EULQJLQJ LQ RWKHU FLWLHV + (RUJDQLJ D DQG *XDQJJKRX V XQLYHUVLVWLHV)URP WKLW SHUVSHF crossprovincial education by universities meets the common interest regional development.

4 Conclusion

Research shows that in dual-core structural regions, the central city should minimize trade competition with the port city as much as possible. However, considering its own benefits, the center city would not give up the trading area. In the development of education, Port cities need to introduce educational resources from central cities. In this case, the maximization of regional interests can be achieved. However, it should be noted that the introduction of external resources into port cities for other considerations may undermine the overall interests. All in all, it is difficult to achieve optimal results in the region when cities pursue their own interests. Therefore, the central government needs to reach regional development of the cities by formulating different tax policies and strengthening the management of local schooling.

The research results are not only applicable to GuangShenzhen, but also have reference value for other dual-core structure regions, such as Nanjing Suzhou and ChengduChongqing. It preliminarily explores the optimal combination of urban relationships and their development patterns within the dual-core structure model. The combination of game theory and the regional dual-core structure can provide new insights for urban management. In future research, it is necessary to optimize parameters by strengthening data processing. It can reduce errors through statistical methods such as hypothesis testing. At the same time, the study ignores the situation where cities can take actions simultaneously and have repeated games between them. In the next research, further research needs to be conducted through incomplete information game theory and repeated games.

References

1. Y. Q. Lu, Y.H. Wei, The natural basis of the formation of the double structural model. *Journal of Geographical Sciences* 15(3), 85-96 (2003).
2. Y.M. Sang, L. Xiao, The evolution and location of Guangzhou applying the double structural model. *Journal of South China Normal University (Nature Science Edition)*, 121 (2003).
3. F. Yu, L. Qin, J.S.L. Lam, H.X.Feng, Investigating the evolution of the Guangdong Hong Kong Macao Greater Bay Area (GBA) multi-port system: The multifaceted perspectives. *Ocean & Coastal Management* 260 (2023).
4. X. Xie, Q. Huang, J. Jung, Higher education and regional development of Shenzhen. *International Journal of Chinese Education* 11(3), (2022).
5. R. Axelrod, W.D. Hamilton, The evolution of cooperation. *Science* 211(4489), 1390-1396 (1981).
6. Y.M. Liang & K.L.QD. *Journal of Jiangnan University (Social Sciences Edition)*, 102-116 (2024).
7. & /L 0 . 1J < 7DQJ 7)XQJ)URP 1D 1/2R/U \$UGH DD F\$A review of the outline of the development plan for the Guangdong Hong Kong Macao Greater Bay Area. *Planning Theory & Practice* 23(2), 310-314 (2021).
8. X.J. Ma, Research on the coordinated development of the central ports in the Guangdong and Shenzhen Ports as example. *Logistics Engineering and Management* 45(6), 103-107 (2023).
9. M. Zhang, L.L. Cai, A study on the complementarity and cooperation of universities in the Guangdong Hong Kong Macao greater bay area. *Journal of Higher Education* 23(1), 23-26 (2021).
10. J. Li, H. Liu, The logic of higher education integration in Guangdong Hong Kong Macao Big bay area and its approach. *Journal of Higher Education* 39(10), 31-36 (2018).
11. H. R. Xiong, Exploring the Development Trend of Ports in the Guangdong Hong Kong Macao Greater Bay Area (GBA) Based on the Intermodal Transport Development of Guangzhou Port. *Business & Management* 42(1), 61-68 (2023).
12. Y. Fang, X. Liu, Urban higher education development with Chinese characteristics: The case of Shenzhen. *International Journal of Chinese Education* 10(2023).