

# The Research on Coupling Level Difference and Path of Human Capital and Economic Growth in China's Five Urban Agglomerations

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**Abstract**—Based on the data of the China's five major urban agglomerations from 2007 to 2016, the coupling level and spatial difference between human capital and economic growth were calculated using the extended coupling degree model and Dagum gini coefficient decomposition method. Then, the coupling promotion path of human capital and economic growth of the five urban agglomerations is designed under the framework of subsection dynamics. The results show that: first, the coupling degree of the five major urban agglomerations shows a slow upward trend and polarization, and the hot spots did not change significantly from 2007 to 2016 and had diffusion effect; second, the spatial difference of coupling degree is significant and the difference between urban agglomerations is the main source of the overall difference; third, from the perspective of regional distribution dynamics, there is obvious dynamic disharmony between human capital and economic growth in the five urban agglomerations. The degree of solidification of the latter is greater than that of the former, and the low-level trap of regional economic growth is more serious.

**Keywords**—urban agglomeration; coupling; spatial difference; distribution dynamics; coupling path

## I. INTRODUCTION

In the context of new economic agglomeration, urban agglomeration is gradually replacing the traditional provincial economy and becoming the synonym of regional economy. In 2016, China's five state-level urban agglomerations<sup>1</sup> with 11% of the land and 40% of the population have created a GDP of 40.9 trillion yuan, accounting for 55% of the country's total GDP, which is an important growth pole of China's economy and shows an important direction for future development. However, behind the long-term rapid development are differences between and within urban agglomerations which cannot be ignored. From the previous development experience, the phenomenon of regional segmentation is common in China (Lu Ming, 2009), which is more prominent for urban agglomerations as the main subject of urbanization promotion. There are many reasons for regional differences, among which capital

accumulation plays a decisive role (Wang Xiaolu, 2004; Wan Guanghua, 2005). Human capital, as an important capital, plays an important role in economic growth and social development, which has been widely recognized (Romer, 1987; Lucas, 1988). Therefore, exploring the spatial difference between the coordinated development between human capital and economic growth and seeking an effective path of coordinated and sustainable development has become the focus of whether urban agglomerations can create a situation of "big cities drive small towns to develop", which is thus of great significance.

The construction of human capital theory originates from Schultz (1961) and Becker (1962)'s research on the problem that the economic growth rate is much higher than the factor consumption rate. Since then, the human capital theory has become one of the hot topics in academic circles. In recent years, specific to China's situation, scholars have expanded their research, and through empirical analysis, many scholars have studied the impact of human capital on economic growth, poverty trap, urban-rural income gap and other aspects (Dai Qian, 2006; Fleisher, 2010; Wang Dihai, 2012; and Chao Xiaojing, 2014). In addition, the role of human capital in promoting coordinated economic development and narrowing regional gaps is gradually attached importance to (Acemoglu, 2012). For example, Han Zhaozhou (2012) et al., through research on provincial economic development, found that no matter what stage, human capital has a significant positive impact on the coordinated development of regional economy; Zhang Xiaopei et al. (2014), through research, found that only by increasing investment in human capital can backward regions of China catch up with advanced regions and achieve balanced regional economic development; Liu Zhiyong (2018) et al., through comparative analysis of the impact of factor differences such as human capital structure upgrading on differences among central, eastern and western regions, found that human capital structure upgrading can better explain regional differences.

In addition, it is worth noting that human capital and economic growth are not a simple unidirectional action relation, but have a certain interactive relationship, and if this interaction is ignored, the effect of human capital on economic growth will be overestimated (Dong Zhihua, 2017).

<sup>1</sup> Refer to the Yangtze River delta, Pearl River delta, Beijing-Tianjin-Hebei Region, Chengdu-Chongqing and the middle reaches of the Yangtze River.

Based on this, when exploring the coordinated development among multiple subsystems, scholars mostly use the coupling model built by Liao Chongbin (1999) to calculate the degree of coordinated development. The advantage of this model is that it does not consider the causal relationship among variables and can comprehensively analyze the coordinated changes among different subsystems, which is very suitable for measuring the degree of coordinated development between human capital and economic growth. For example, Lu Jin (2013) et. al. used the coupling model to calculate and analyze the coupling change characteristics between human capital and economic growth in China; Ren Le (2014) studied and compared the different roles of homogeneous and heterogeneous human capital in promoting regional economic growth by combining with the correlation degree and coupling degree model. At present, although the academic circles have achieved abundant research results by adopting the coupling model, the research on human capital and economic growth of urban agglomerations is still rare, and the research on coupling promotion path is much less.

Based on this, this paper, taking five major urban agglomerations as research samples, calculates the coupling degree between human capital and economic growth, and uses Dagum gini coefficient and its subgroup decomposition method to conduct quantitative analysis on the source and size of spatial differences, and then designs targeted coupling promotion path by analyzing club convergence index. This paper intends to focus on solving the following two problems: What are the characteristics, source and size of spatial difference of coupling level between human capital and economic growth in the five major urban agglomerations? How to better improve the coupling level of each urban agglomeration while giving consideration to balanced development of the five major urban agglomerations? In addition to providing decision-making reference for the development of the five major urban agglomerations, this paper also provides a new research idea for the traditional coupling model.

## II. RESEARCH DESIGN

### A. Research Framework and Research Approach

Taking the five state-level urban agglomerations as the research object, this paper firstly explores the spatial distribution characteristic of the coupling degree between human capital and economic growth from the spatial perspective to see whether there is continuous distribution; whether there is polarization phenomenon within the urban agglomeration, as time goes by, and so on to provide a foundation for the paper research, further study the difference of urban agglomerations in coupling degree between urban human capital and economic growth and lay a foundation for the paper to put forward the coupling promotion path, which requires to give consideration to the coordination of coupling degree of urban agglomerations. In the end, based on the two-dimensional plan of human capital and economic growth, this paper proposes a path that can not only improve the spatial imbalance of the coupling level of

China's five major urban agglomerations, but also improve the coupling level between human capital and economic growth of each city. This paper puts forwards a coupling degree framework and coupling promotion path as follows:

#### 1) Construction of coupling model and its connotation:

Coupling is a concept in physics, which refers to the phenomenon where two or more systems or forms of motion cooperate and interact with each other. In the study of social and economic systems, the biggest difference between coupling analysis and traditional research approach is that coupling analysis can analyze the coordination changes among different subsystems without considering the causal relationship among variables, so it has been preferred by scholars in recent years (Wang Yi, 2015; Cui Muhua, 2015; Zhou Cheng, 2016). The connotation of coupling includes coordination and development, of which coordination embodies "quality improvement" process between and within systems, and development embodies "quantity expansion" process in system evolution. Based on the research results of Liao Chongbin (1999), the formula for calculating coordination degree in this paper is as follows:

$$C = \left[ \frac{4(f(x) \cdot g(y))}{(f(x) + g(y))^2} \right]^2 \quad (1)$$

Where,  $C$  indicates coordination degree;  $f(x)$  and  $g(y)$  are the comprehensive evaluation indexes of human capital and economic growth respectively.  $0 \leq C \leq 1$ ,  $C$  equals to  $0$ , indicating that there is no coordination relationship between the two systems; on the contrary,  $C$  equals to  $1$ , indicating that the two systems are in the state of optimal coordination. Coordination degree  $C$  is an important index that can well indicate the coordination between two subsystems, but it cannot reflect the comprehensive benefit level (or development level) between subsystems. For example, when human capital and economic growth are both at a low level, coordination degree between them is very high. For this reason, the coupling model should cover both development and coordination, as described above. This paper adopts the coupling degree calculation formula as follows:

$$D = \sqrt{CT} \quad (2)$$

$$T = \alpha f(x) + \beta g(y) \quad (3)$$

In formula (2),  $D$  is coupling degree;  $T$  is the comprehensive evaluation index of development level, which reflects the overall efficiency or level of human capital and economic growth; in formula (3),  $\alpha$  and  $\beta$  are weights to be determined, reflecting the contribution coefficient of human capital and economic growth. This paper argues that human capital and economic growth are equally important,

so both  $\alpha$  and  $\beta$  are 0.5 here. In addition, according to the requirements of the law of urban development itself, the coupling degree is divided into 5 levels: 0–0.30 for lower coupling; 0.3–0.45 for lower coupling; 0.45–0.60 for moderate coupling; 0.60–0.75 for high coupling; 0.75–1 for extreme coupling.

2) *Promotion path based on coupling connotation:* According to formulas (1) and (3), it can be defined as iso-coordination line and iso-development line in the two-dimensional plan of human capital and economic growth, as shown in “Fig. 1”. Thereinto, half-line  $C=1$  with slope of 1 is the optimal coordination line,  $C_1$  and  $C_2$  are iso-coordination lines that are symmetric about the optimal coordination line and have the same coordination level, and  $T$  is the iso-development line. Therefore, the plane can be preliminarily divided into four areas by iso-coordination lines  $C_1$  and  $C_2$  and iso-development line  $T$ : high coordination - high development area (A), high coordination - low development area (D), low coordination - high development areas (B1 and B2) and low coordination - low development areas (C1 and C2). In addition, the areas above the iso-coordination line represent cities with lagged human capital (human capital < economic growth), and on the contrary, the areas below the iso-coordination line represent cities with lagged economic growth. Based on this, the arrows in the figure show the coupling promotion path for cities in areas B and D. Taking B1 area characterized by low coordination and high development as an example, on the basis of high development level, cities in this area shall give priority to the coordination and interaction among subsystems, that is, give priority to improving human capital subsystems to make them reach a higher coordination level with economic growth, so as to realize the dynamic coordinated development of human capital and economic growth.

For  $C_1$  and  $C_2$  areas, there are two promotion paths as follows: First, the solidification degree of economic growth level is more serious than that of human capital. In this case, the government should focus on solving the solidification problem of economic development and give priority to supporting cities located in B2 and C2 areas to help them realize the jumping of development level, namely, the coupling promotion path  $C_2 \rightarrow A$  and  $B_2 \rightarrow A$ . The policy significance of this promotion path is mainly reflected as follows: First, through macro-control, the government shall give priority to alleviating the phenomenon of solidification of economic development level to avoid the regions falling into the low development trap, and promote sustainable and balanced development of urban agglomerations; second, through government targeted assistance to cities in  $C_1$  and  $C_2$  areas, they can play a demonstration role for D area and encourage it to break the current state of low coordination development to improve the development level of its subsystems in stages and step by step, realize the D -  $C_1$  or D - B1 coupling path optimization, get government support and then, with the driving effect within the urban agglomeration,

develop into an area characterized by higher development level and coordination degree; second, the solidification degree of human capital is more serious than economic growth level. In this case, the government should focus on solving the solidification problem of coordination degree and give priority to realizing the transition of coordination degree, that is, give priority to supporting cities located in B1 and C1 areas, especially those with low human capital level for a long time. The policy significance of this path is similar to the above, and will not be repeated here.

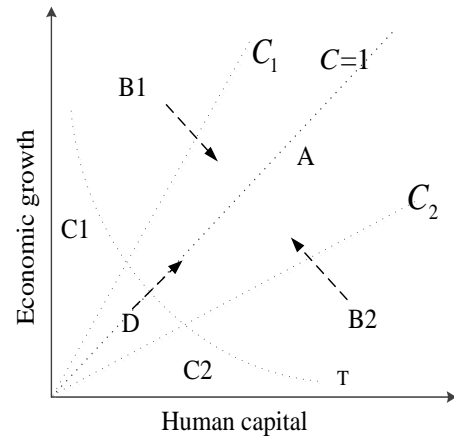


Fig. 1. Analytical diagram of coupling promotion path.

**B. Research Method**

1) *Coupling subsystem calculation — entropy weight TOPSIS method:* Before the calculation of the coupling degree, the two subsystems — human capital and economic growth shall be comprehensively evaluated. The entropy weight TOPSIS method adopted in this paper is a multi-attribute decision-making method improved based on the traditional TOPSIS method. The entropy weight method can effectively eliminate the influence of subjective factors and objectively reflect the importance of a certain index in the evaluation index system, and TOPSIS is a technique for order preference by similarity to an ideal solution. Assuming that  $m$  is the number of evaluated objects and  $n$  is the number of evaluation indexes for each evaluated object, a judgment matrix can be established as  $X = (x_{ij})_{m \times n}$  ( $i = 1, 2, \dots, m; j = 1, 2, \dots, n$ ). In order to avoid the problem that the information entropy cannot be calculated because the index value is 0, this paper adopts the standardized method as shown in formula (4), and other calculation steps are as follows:

$$x'_{ij} = \begin{cases} 0.1 + 0.9 \left( \frac{x_{ij} - X_{\min}}{X_{\max} - X_{\min}} \right) & \text{Positive index} \\ 0.1 + 0.9 \left( \frac{X_{\max} - x_{ij}}{X_{\max} - X_{\min}} \right) & \text{Negative index} \end{cases} \quad (4)$$

Calculating information entropy:

$$H_j = -\frac{1}{\ln m} \sum_{i=1}^m p_{ij} \ln \left( \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \right) \quad (5)$$

Defining the weight of index  $J$ ,

$$\omega_j = \frac{1-H_j}{\sum_{j=1}^n (1-H_j)}, \omega_j \in [0,1], \sum_{j=1}^n \omega_j = 1 \quad (6)$$

Calculating weighting matrix  $R$ :

$$R=(r_{ij})_{m \times n}, r_{ij} = \omega_j \square x_{ij} (i = 1, 2, \dots, m; j = 1, 2, \dots, n) \quad (7)$$

Euclidean distance between each scheme and the optimal solution and the worst solution:

$$\begin{cases} sep_i^+ = \sqrt{\sum_{j=1}^n (s_j^+ - r_{ij})^2}, S_j^+ = \max(r_{1j}, r_{2j}, \dots, r_{nj}) \\ sep_i^- = \sqrt{\sum_{j=1}^n (s_j^- - r_{ij})^2}, S_j^- = \min(r_{1j}, r_{2j}, \dots, r_{nj}) \end{cases} \quad (8)$$

Calculating comprehensive evaluation index  $C_i$ :

$$C_i = \frac{sep_i^-}{sep_i^+ + sep_i^-}, C_i \in [0,1] \quad (9)$$

Finally, the comprehensive evaluation indexes  $C_i$  of the two subsystems can be obtained respectively. The larger the value is, the better the evaluation object is.

2) *Spatial difference of coupling degree — Dagum gini coefficient and its subgroup decomposition method:* What is different between the Dagum gini coefficient adopted in this paper and the traditional gini coefficient is that Dagum gini coefficient can be decomposed into: intra-regional gap, inter-regional gap and density of transvariation. Dagum gini coefficient definition is shown in formula (10):

$$G = \frac{\sum_{j=1}^k \sum_{h=1}^k \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{hr}|}{2n^2 \bar{y}} \quad (10)$$

Where,  $y_{ji}(y_{hr})$  represents the coupling degree of any city of  $j(h)$  urban agglomerations,  $\bar{y}$  is the average coupling degree of 76 cities,  $n$  stands for the number of all cities,  $k$  is the number of urban agglomerations, and  $n_j(n_k)$  is the number of cities in  $j(h)$  urban agglomerations.  $G$  can

be decomposed into three parts, that is, intra-regional gap  $G_w$ , inter-regional gap  $G_{nb}$ , and density of transvariation  $G_t$ , meeting  $G = G_w + G_{nb} + G_t$ . The detailed calculation method is relatively complicated, for which please see relevant literature (Dagum, 1997).

3) *Calculation of subsystem curing degree:* Step 1: Measurement of matrix of transition probability. To accurately calculate the solidification degree of coordination and development level, this paper, based on the distribution dynamic framework<sup>2</sup>, discretizes coordination degree and development level three categories: low, medium and high level (Zhou Di, 2018) to calculate the transition probability between different types. In the traditional distribution dynamic model, only one-step span is usually considered, so it is impossible to know the transition characteristics of the region after long-term accumulation. Bases on this, this paper makes expansion and obtain the results under different spans to make the conclusion more stable.

The Markov transition probability for  $d$  years is  $P_{ij}^{t,t+d} = P\{X_{t+d} = j | X_t = i\}$ , which shows the probability that a region with at poverty level  $i$  in the  $t$  year transitions to  $j$  level after  $d$  years. Considering all possible transition situations, we can obtain Markov transition probability  $P_{ij}^d$  in the  $T$  evaluation period. Calculation formula is as follows:

$$P_{ij}^d = \frac{\sum_{t=t_0}^{T-d} n_{ij}^{t,t+d}}{\sum_{t=t_0}^{T-d} n_i^t} \quad (11)$$

In formula (11), the number of regions that are  $i$  type in  $t$  year and transitions to  $j$  type in the  $t+d$  year is  $n_{ij}^{t,t+d}$ , where  $n_i^t$  represents the number of regions that belong to  $i$  type in terms of poverty level in  $t$  year. Through estimation according to the transition probability of different types, the Markov transition probability matrix within  $d$  year length can be obtained as follows, and the main diagonal is the degree of solidification at different levels.

<sup>2</sup> Distribution dynamics studies the dynamic evolution of the distribution of something in a region from the perspective of long-term dynamics, including overall distribution dynamics change (description of kernel density curve) and internal dynamic change (description of matrix of transition probability).



$$\begin{pmatrix} \frac{n_{11}^d}{n_{1\Box}^d} & \dots & \frac{n_{1j}^d}{n_{1\Box}^d} & \dots & \frac{n_{1k}^d}{n_{1\Box}^d} \\ \frac{n_{21}^d}{n_{2\Box}^d} & \dots & \frac{n_{2j}^d}{n_{2\Box}^d} & \dots & \frac{n_{2k}^d}{n_{2\Box}^d} \\ \dots & \dots & \dots & \dots & \dots \\ \frac{n_{k1}^d}{n_{k\Box}^d} & \dots & \frac{n_{kj}^d}{n_{k\Box}^d} & \dots & \frac{n_{kk}^d}{n_{k\Box}^d} \end{pmatrix} = \begin{pmatrix} p_{11}^d & \dots & p_{1j}^d & \dots & p_{1k}^d \\ p_{21}^d & \dots & p_{2j}^d & \dots & p_{2k}^d \\ \dots & \dots & \dots & \dots & \dots \\ p_{k1}^d & \dots & p_{kj}^d & \dots & p_{kk}^d \end{pmatrix} \quad (12)$$

Step 2: Construction of club convergence index. Considering the scale effect of the degree of solidification, this paper, on the basis of formula (12), comprehensively considers the scale effect and convergence degree to further constructs the overall club convergence index. The club convergence index within  $d$  years is calculated as follows:

$$CCL^d = p_{11}^d \times \frac{n_{1\Box}^d}{\sum n_{i\Box}^d} + p_{22}^d \times \frac{n_{2\Box}^d}{\sum n_{i\Box}^d} + \dots + p_{kk}^d \times \frac{n_{k\Box}^d}{\sum n_{i\Box}^d} \quad (13)$$

Where,  $p_{kk}^d$  is the element of the main diagonal in formula (12), representing the degree of convergence of the  $k$  class club in time duration  $d$ , and  $\frac{n_{k\Box}^d}{\sum n_{i\Box}^d}$  represents the scale proportion of the  $k$  class club.

C. Selection of Indexes

Considering the diversity and complexity of factors affecting human capital and economic growth, this paper, according to the principles of comprehensiveness, representativeness and comparability in selection of indexes, and based on data availability, refers to the research of scholars (Zhu Pingfang, 2007; Du Ting, 2014) and determines to use four aspects including education scale, cultural innovation, medical quality and life quality to reflect human capital level. In addition, economic growth is defined from four aspects: growth level, industrial structure, degree of openness and level of investment and consumption level. In order to eliminate the influence of factors such as population base, this paper adopts relative indexes. (See "Table I" for specific index system).

TABLE I. INDEX SYSTEM OF HUMAN CAPITAL AND ECONOMIC GROWTH

Objective Level	Criterion Level	Index Level
Human capital (X)	Education scale	Proportion of students in general institutes of higher education(%) Proportion of students in general middle schools (%) Proportion of students in primary schools(%)
	Cultural innovation	Library collection per hundred people (volume) Number of patents granted per 10,000 people(piece)
	Medical quality	Number of hospital and health center beds per 10,000 people (piece) Number of doctors per 10,000 people (medical practitioners + assistant medical practitioners) (person)
	Life quality	Natural population growth rate (%) (-)
	Economic growth (Y)	Growth level
Economic growth (Y)	Industrial structure	Proportion of added value of primary industry (%) (-) Proportion of added value of secondary industry (%) Proportion of added value of tertiary industry (%)
	Degree of openness	Dependence on trade (total export-import volume/GDP)(%) Actual utilization of foreign capital/GDP (%)
	Level of investment and consumption	Loan balance per capita(yuan)
		Fixed asset investment per capita (yuan) Per capital annual expenditure on consumption of urban citizens (yuan)

<sup>a</sup>. Notes: "-" indicates that the index is negative, that is, the smaller the value is, the better for the system; the others are all positive indexes, that is, the larger the value is, the better for the system; Proportion of students in schools refers to the proportion of students in schools of total population.

D. Research Objects and Data Sources

In this paper, the research objects are the five urban agglomerations, which include 76 prefecture-level cities according to The Outline of the Plan for the Reform and Development of the Pearl River Delta, The Outline of the Regional Planning for Yangtze River Delta, Regional Planning for Beijing-Tianjin-Hebei Metropolis Circle,

Regional Planning for Chengdu-Chongqing Economic Zone, Development Planning for Urban Agglomerations in Middle Yangtze River and other relevant documents. Among urban agglomerations in Middle Yangtze River, Xiantao, Qianjiang and Tianmen are county-level cities, and only some districts and counties in Fuzhou and Ji'an are included in the urban agglomerations of Middle Yangtze River, so these five cities are not considered.

This paper selects 2007, 2010, 2013 and 2016 as investigation years, and the data are collected from China City Statistical Yearbook, China Statistical Yearbook on Science and Technology, China Rural Statistical Yearbook, Almanac of China's Population and Statistical Communique on National Economic and Social Development of each city.

### III. EMPIRICAL RESULTS AND ANALYSIS

#### A. Spatial Distribution Characteristics of Coupling Degree

After synthetically calculating the coupling degree of each city, in order to further study the spatial distribution characteristics of coupling degree of five urban agglomerations, it is selected with the coupling data of two time sections in 2007 and 2016 in this paper. The spatial distribution of coupling degree discrimination grade is plotted by using ArcGIS tools. The results are shown in "Fig. 2" and "Fig. 3".

Overall, the coupling degrees among urban agglomerations are obviously different. The average coupling degrees of the Pearl River Delta and the Yangtze River Delta urban agglomerations are higher, while the coupling degrees of the middle reaches of the Yangtze River

and Chengdu-Chongqing urban agglomerations in the central and western regions are generally low. Spatially, the distribution trend is gradually decreasing from east to west. In 2007, most cities were at a low coupling degree, and only Shenzhen and Shanghai were at an extreme coupling degree. By 2016, most cities have achieved the transition of coupling degree. All urban agglomerations have highly coupled cities, and their development in the future can be shown as good examples for the surrounding area.

From the inside of the urban agglomeration, we can see that there is the polarization in the coupling degree of each urban agglomeration, presenting a centralized distribution of fragmentation. The hot spots (such as Beijing and Shenzhen) have developed rapidly and opened a gap with other cities, which did not change much from 2007 to 2016. It shows that the coordinated development of urban agglomeration is still imbalanced. In addition, this phenomenon of regional hot spot polarization has a certain diffusion effect in space. The cities with higher coupling level promote the coordinated development of adjacent areas, which reflects the co-development phenomenon of "big cities driving small towns" in urban agglomeration.

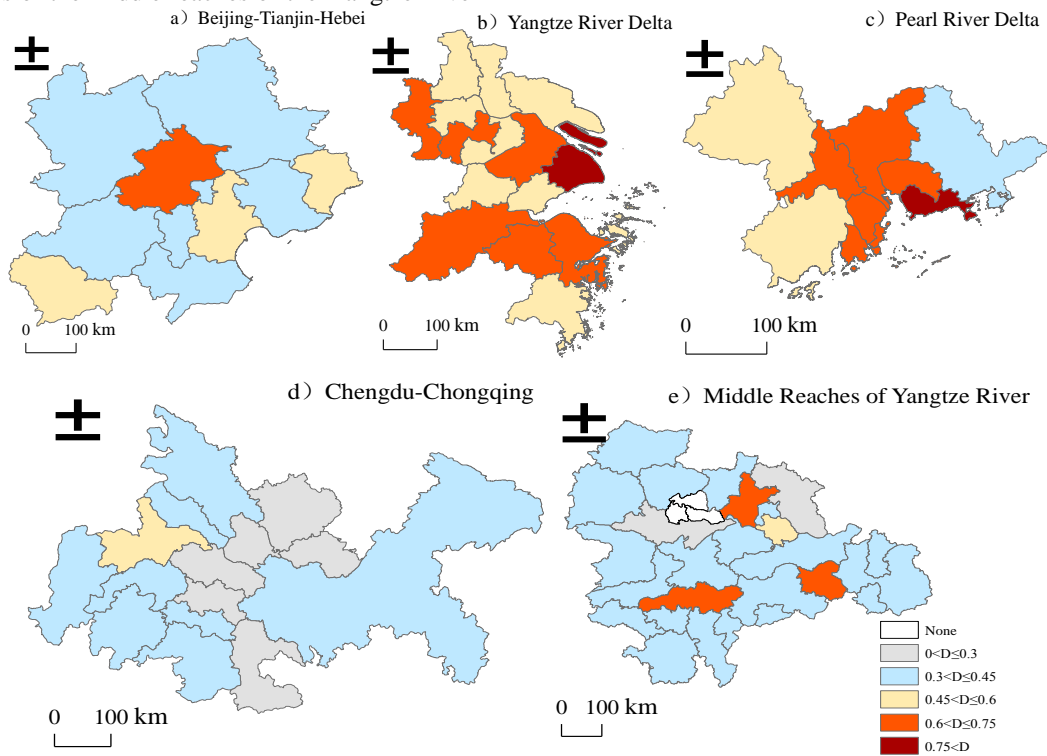


Fig. 2. Spatial Distribution Pattern of Coupling Degree of Five Urban Agglomerations in 2007.

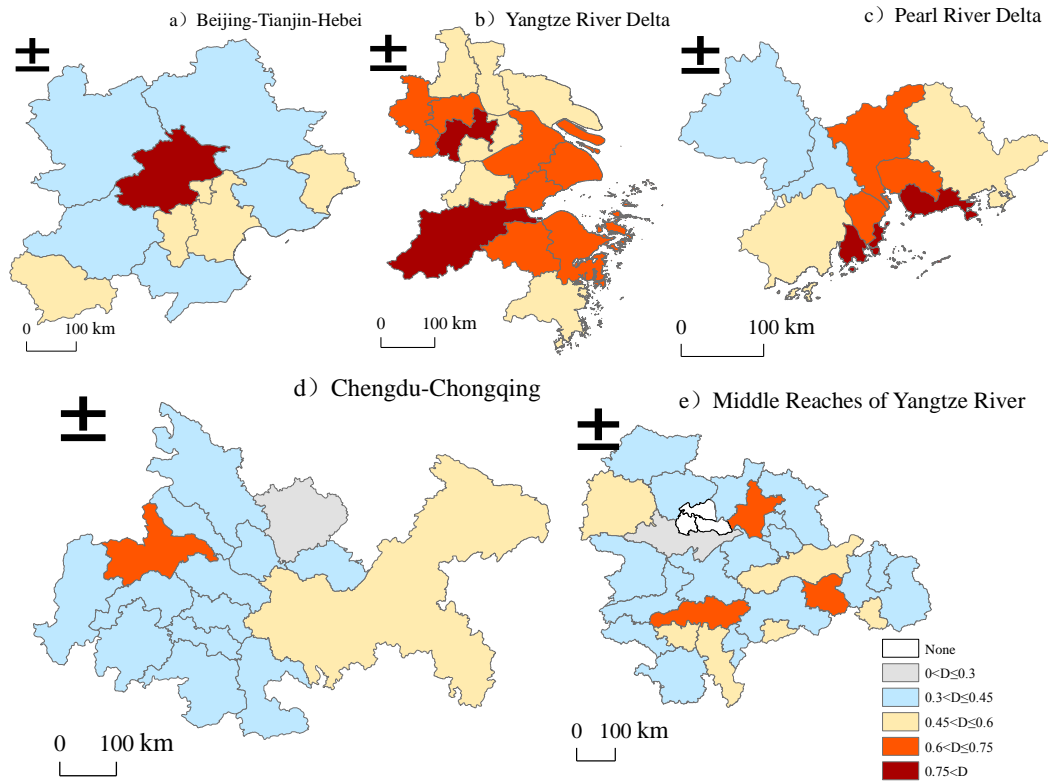


Fig. 3. Spatial Distribution Pattern of Coupling Degree of Five Urban Agglomerations in 2016.

**B. Size and Source of Spatial Difference of Coupling Degree**

1) Overall difference of coupling degree and internal difference of five urban agglomerations: The evolution trend of the overall difference of coupling degree and internal difference of five urban agglomerations during the sample investigation period are shown in “Table II”.

Overall, the coupling degrees between human capital and economic growth of the five urban agglomerations are quite different. The overall gini coefficient is in the range from 0.149 to 0.175. The difference shows a downward trend in the fluctuation, which indicates that the overall gap of coupling level of five urban agglomerations is narrowing. From the perspective of the evolution trend, it declined by 0.017 from 2007 to 2010, with a large extent. Taking 2007 as the base period, the overall difference of coupling degree of the five urban agglomerations decreased by 1.25% per year as of 2016.

The gini coefficient within each urban agglomeration also shows a trend of fluctuation and eventual decline. It is

most significant in Chengdu-Chongqing urban agglomeration, which decreased by 0.028 from 2007 to 2010. In the observed years, the difference decreased by 22.58%, and the average annual declining rate was 1.35%. In addition, the decline of the Yangtze River Delta urban agglomeration is also significant, with the average annual decline rate of 1.37%. Except that the gini coefficient in the urban agglomeration of the Yangtze River Delta and the middle reaches of the Yangtze River goes through a process of "rise-decline", other urban agglomerations are experiencing a process of "decline-rise". Finally, except the urban agglomerations in the Pearl River Delta and the middle reaches of the Yangtze River, the differences of the coupling degree between the five urban agglomerations and each urban agglomeration show a downward trend. In terms of the mean value, the coupling difference of Beijing-Tianjin-Hebei urban agglomeration is the biggest; followed by the middle reaches of the Yangtze River urban agglomeration; the Pearl River Delta and Chengdu-Chongqing urban agglomerations are at the middle level, and that of the Yangtze River Delta urban agglomeration is the smallest.

TABLE II. OVERALL GINI COEFFICIENT AND INTRA-REGIONAL GINI COEFFICIENT OF COUPLING DEGREE OF THE FIVE MAJOR URBAN AGGLOMERATIONS

Year	Overall	Pearl River Delta	Yangtze River Delta	Beijing-Tianjin-Hebei Region	Chengdu-Chongqing	middle reaches of Yangtze River
2007	0.175	0.109	0.082	0.130	0.124	0.118
2010	0.158	0.093	0.086	0.101	0.102	0.119
2013	0.149	0.095	0.084	0.104	0.094	0.107

Year	Overall	Pearl River Delta	Yangtze River Delta	Beijing-Tianjin-Hebei Region	Chengdu-Chongqing	middle reaches of Yangtze River
2016	0.159	0.139	0.071	0.129	0.096	0.118
Mean value	0.160	0.109	0.081	0.116	0.104	0.115

2) *Coupling differences among the five major urban agglomerations:* The difference of coupling degree of “human capital-economic growth” among the five urban agglomerations and its evolution trend are shown in “Table III”. The difference of coupling degree among urban agglomerations generally shows a trend of “decline-rise”. Taking the urban agglomeration of the Pearl River Delta and the Yangtze River Delta as the examples, the difference between the two urban agglomerations was 0.110 in 2007, while 0.091 in 2010, remaining a downward trend. But from 2010 to 2016, it showed an upward trend, rebounding from 0.089 to 0.116. The trend of variation of differences among other urban agglomerations is similar, which appears to be a downward trend in fluctuations in an overall view. Only the gini coefficients between the Pearl River Delta and Yangtze

River Delta, Pearl River Delta and Chengdu-Chongqing urban agglomerations eventually showed an enlarged trend, rising from 0.110 and 0.160 in 2007 to 0.116 and 0.173 in 2016, respectively. In addition, the declines of differences between the Pearl River Delta and the middle reaches of the Yangtze River, the Yangtze River Delta and the middle reaches of the Yangtze River is the most obvious. In the observed years, the declines are 20.58% and 19.25% respectively, with the annual average decline rate of about 1.35%. In terms of the mean value, the difference between the Pearl River Delta and the middle reaches of the Yangtze River is the biggest, ranging from 0.243 to 0.306. The difference between the Pearl River Delta and Yangtze River Delta urban agglomerations is the smallest, ranging from 0.091 to 0.116.

TABLE III. INTERREGIONAL GINI COEFFICIENT OF COUPLING DEGREE OF FIVE URBAN AGGLOMERATIONS

Year	1 and 2	1 and 3	1 and 4	1 and 5	2 and 3	2 and 4	2 and 5	3 and 4	3 and 5	4 and 5
2007	0.110	0.187	0.160	0.306	0.275	0.180	0.239	0.209	0.140	0.138
2010	0.091	0.178	0.177	0.248	0.247	0.125	0.205	0.204	0.114	0.123
2013	0.092	0.166	0.165	0.249	0.248	0.137	0.180	0.178	0.107	0.127
2016	0.116	0.178	0.173	0.243	0.253	0.147	0.193	0.192	0.127	0.128
Mean value	0.102	0.177	0.169	0.262	0.255	0.147	0.204	0.196	0.122	0.129

a. Note: “1-5” respectively represents Pearl River Delta, Yangtze River Delta, Beijing-Tianjin-Hebei, Chengdu-Chongqing and the middle reaches of Yangtze River.

3) *Decomposition of the sources of overall differences in coupling degree of five urban agglomerations:* “Table IV” shows the three sources and contribution rates of overall difference in the coupling degree between human capital and economic growth of five metropolitan agglomerations. It can be seen that the contribution value of difference from urban agglomeration fluctuates slightly and remains unchanged from 2007 to 2016. However, the difference contribution rate increased slightly, with an average of 14.64%. The difference contribution between urban agglomerations is always at the highest level, with the contribution rate ranging from 65.82% to 71.63%. From 2007 to 2010, it had a big fluctuation, which is decreased by 3.97%. The contribution rate of intensity of transvariation was in the middle, ranged from 14.29% to 18.86%. The contribution rate of differences between urban agglomerations is the lowest, ranging from 13.92% to 14.97%. It is also known that the average contribution rate of transvariation density is slightly larger than the difference contribution rate in urban agglomerations, but no obvious difference. Above all, it can be seen that the difference of coupling degree between human capital and economic

growth in the five urban agglomerations is mainly due to the difference between urban agglomerations, which declined slowly and steadily from 2007 to 2016, but always accounted for more than 65% of the total difference contribution rate.



TABLE IV. DECOMPOSITION OF CONTRIBUTION VALUE AND CONTRIBUTION RATE OF OVERALL DIFFERENCE IN COUPLING DEGREE OF FIVE URBAN AGGLOMERATIONS

Year	Within the Urban Agglomerations		Between Urban Agglomerations		Intensity of Transvariation	
	Contribution value	Contribution rate (%)	Contribution value	Contribution rate (%)	Contribution value	Contribution rate (%)
2007	0.024	13.92	0.125	71.63	14.45	14.29
2010	0.023	14.84	0.107	67.66	17.49	17.29
2013	0.022	14.83	0.101	67.61	17.56	17.47
2016	0.024	14.97	0.105	65.82	19.22	18.86
Mean value	0.023	14.64	0.109	68.18	17.18	16.98

### C. Coupling Promotion Path

1) *Dynamic coordination analysis of human capital and economic growth in five urban agglomerations:* In order to improve the coupling degree of urban agglomeration, in this paper, it will be started from the internal perspective of its distribution dynamics, is adopted with club convergence index to investigate the solidification of human capital and economic growth in five cities, so as to improve the coupling degree of cities on the basis of narrowing the differences between cities. Specifically, this paper divides

cities into three types of clubs by using 75% and 125% of the mean value and median as the demarcation points respectively. In order to reflect the time accumulation effect of the transfer of human capital and economic growth level, Markov model with variable duration is used to study the transfer of coordination and development level among different types of cities, with the duration of 3, 6 and 9 years. The calculation results of club convergence indices are shown in "Table V".

TABLE V. CLUB CONVERGENCE INDICES OF HUMAN CAPITAL AND ECONOMIC GROWTH IN DIFFERENT SPANS AND LENGTHS

Duration (Year)	Mean Value Partition			Median Partition		
	Human capital	Economic growth	Difference	Human capital	Economic growth	Difference
3	0.763	0.917	-0.154	0.803	0.917	-0.114
6	0.697	0.875	-0.178	0.711	0.895	-0.184
9	0.724	0.882	-0.158	0.684	0.921	-0.237
Mean value	0.728	0.891	-0.163	0.732	0.911	-0.178

As can be seen from "Table V", by either means or median criteria are classified club types; the club convergence indices of economic growth of the five urban agglomerations are larger than the club convergence indices of human capital in different span and length. The difference between them is between 0.154-0.178 and 0.114-0.237 (absolute value), and the difference tends to increase with the accumulation of time. It shows that, from the perspective of distribution dynamics, the five urban agglomerations have more serious solidification characteristics of high and low levels of economic growth, while the mobility of human capital level is higher. That is, as time goes on, "disadvantaged areas" can catch up with and surpass in the level of human capital, but easily fall into the "low development trap" of the economy.

Above all, there is obvious inconsistency between human capital and economic growth in the five urban agglomerations, and the regional solidification degree of the latter is significantly greater than that of the former. The "low-level trap" phenomenon of regional economic growth

and the "Matthew Effect" that strong get stronger are more serious. The enlightenment is that the government should pay more attention to the balance of regional economic growth when reversing the spatial imbalance of the coupling level of the five major urban agglomerations, giving priority to supporting cities with long-term lagging economic growth. First, the government should make a "unilateral breakthrough" in its subsystem of economic growth, and then provide the corresponding material basis for the accumulation of human capital. Next, the two aspects can further promote the coordinated development of internalization in the region, and gradually reverse the spatial imbalance between urban agglomerations and within urban agglomerations.

2) *Coupling promotion path from the perspective of coordination and development:* Classification of region types. In order to design a more targeted path of coupled improvement, this paper divides the regions of coupling characteristics according to the two-dimensional scatter diagram of human capital and economic growth of each city.

All regions are divided into four types: high coordination and high development region (A), low coordination and high development region (B1, B2), low coordination and low development region (C1, C2), and high coordination and low development region (D). In addition, the region is further divided into human capital lag type and economic growth lag type based on the optimal coordination line with the origin slope of 1, as shown in "Fig.4".

It can be seen that, from the distribution of scatter points in the diagram, most of the five urban agglomerations are concentrated in high-coordination and low-development areas. This indicates that there may be a low development trap of "false coordination" in some areas, which is consistent with the conclusion above that the solidification degree of development level is more serious.

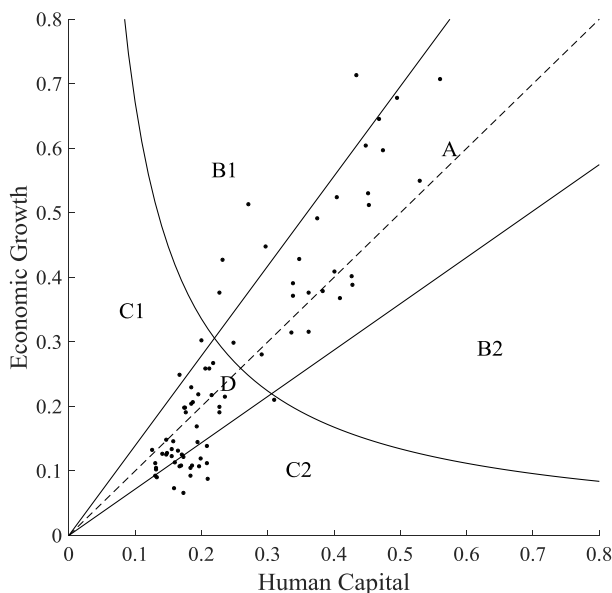


Fig. 4. Regional distribution map of five urban agglomerations.

The curve in "Fig. 4" is the average development line of each city, and the two symmetric lines across the 45 degree line of the original point are the average coordination line. It can be seen that, from the distribution of scatter points in the figure, most of the five urban agglomerations are concentrated in D region with high coordination and low development and C2 with low coordination and low development. It indicates that some cities may have a low development trap of "false coordination". In addition, it can be found that in the cities with low coordination, the cities with high development belong to the human capital lagging type, while in the vast majority of the cities with low level of development belong to the economic growth lagging type. This means that the government should take different ways to help cities with different levels of development, when providing targeted assistance.

### 3) Coupling promotion path of urban agglomerations:

For any region, enhancing the coupling degree can start from two directions: to improve economic growth under the set level of human capital and to enhance human capital

under the set level of economic growth. Each region can improve its coupling level by implementing the targeted improvement its own region. For example, the Coupling promotion path of low coordination and high development cities (B1, B2) should focus on the improvement of coordination level, and the same is true of region C. In addition, through the previous analysis, the solidification degree of economic growth level of the five major urban agglomerations is more serious. Therefore, the state should focus on supporting the areas in C2 region and promote the improvement of their development levels, so as to take a C→B→A Coupling promotion path. This measure has two meanings: First, through the previous analysis, the solidification of inter-regional economic growth is more serious, requiring regulation of external force, especially for these areas caught in the "low-level trap" of development. Therefore, the state should focus on supporting the development level of these areas in order to promote the coordinated development of the region. Secondly, under the condition of limited resources, key support should be given to the areas with a low level of coordination and development, which can embody the principle of fairness. Thirdly, it can stimulate the regions in D region, which often lack efforts to break their "false coordination" state. Because their efforts may fail and they may step back to the low coupling state of development and coordination and enter C region. However, the adoption of this "precise support" by the state can produce a backstop effect, mobilize the enthusiasm of these regions and make them adopt a step-by-step path of promotion. That is, they shall break through the impasse by breaking through a subsystem of human capital or economic growth, so as to achieve the improvement of coupling degree. So, which cities are specifically included in each region? According to the detailed partition of "Table VI", it can be found that these cities with low coordination and low development are mainly located in the urban agglomerations of Chengdu-Chongqing and the middle reaches of the Yangtze River.

The above is the Coupling promotion path proposed based on the national level and the overall perspective, but for each urban agglomeration, how to adjust the coupled path? Combined with "Table VI", it can be seen that, in the overall adjustment of urban agglomeration, we also need to prescribe the right remedy, and choose the optimal Coupling promotion path according to the specific situation of each city. Most of the urban agglomerations in the Pearl River Delta and the Yangtze River Delta are in Area A, while most of the urban agglomerations in Beijing-Tianjin-Hebei Region, Chengdu-Chongqing and the middle reaches of the Yangtze River are in Area C2 and D. Therefore, in the urban agglomerations, the focus of adjustment should not be the same. The urban agglomerations of Pearl River Delta and Yangtze River Delta should actively mobilize the exemplary driving role of highly coordinated development cities under their own geographical advantages, and support cities in B1 and D regions. The urban agglomerations of Beijing-Tianjin-Hebei Region, Chengdu-Chongqing and the middle reaches of the Yangtze River should pay more attention to improving the level of development, especially starting from the subsystem of economic growth, continuously improving the

economic level, and then continuously promoting the regional development with the endogenous driving force of interaction with human capital. In addition, it is also

necessary to pay attention to the diffusion effect of hot cities and strive to achieve the goal of "big cities driving small towns" for joint development.

TABLE VI. LIST OF REGIONAL DIVISION

	Pearl River Delta	Yangtze River Delta	Beijing-Tianjin-Hebei Region	Chengdu-Chongqing	Middle Reaches of Yangtze River
A	Guangzhou, Shenzhen, Zhuhai, Dongguan and Zhongshan	Nanjing, Wuxi, Suzhou, Nantong, Yangzhou, Hangzhou, Ningbo, Jiaxing, Huzhou, Shaoxing and Taizhou		Chengdu	Wuhan, Changsha and Nanchang
B1	Foshan and Huizhou	Shanghai and Zhoushan	Tianjin	None	None
B2	None	None	None	None	None
C1	None	None	Tangshan	None	Xinyu
C2	None	None	Baoding	Zigong, Luzhou, Mianyang, Suining, Nanchong, Yibin, Guang'an, Ya'an and Ziyang	Jingzhou, Huanggang, Xianning, Xiangtan, Hengyang, Yiyang and Loudi
D	Jiangmen and Zhaoqing	Taizhou	Shijiazhuang, Qinhuangdao, Zhangjiakou, Chengde, Cangzhou, Langfang	Chongqing, Neijiang, Leshan, Meishan	Huangshi, Yichang, Xiangyang, Deyang, Ezhou, Jingmen, Xiaogan, and Zhuzhou, Yueyang, Changde, Jingdezhen, Pingxiang, Jiujiang, Yingtan, Yichun and Shangrao

IV. CONCLUSION

The human capital and economic growth of five urban agglomerations are comprehensively evaluated by the entropy weight TOPSIS method. The coupling degree of the two is calculated by the system coupling model. And the spatial distribution characteristics and differences of coupling degree are analyzed by drawing spatial distribution of coupling degree by ArcGIS and using Dagum gini coefficient and its subgroup decomposition method. Finally, based on the Markov transition probability matrix, the club convergence index of the two subsystems is constructed to design the Coupling promotion path properly, which can provide some reference for the government to reverse the spatial unbalanced situation of the coupling level of the five urban agglomerations. The specific conclusions are as follows:

Firstly, the coupling level of urban agglomerations shows a fluctuating upward trend, but still low. The coupling degree is decreasing from east to west in the space and is at a low level coupling. There is no significant change in hot spots from 2007 to 2016. It reflects the phenomenon of hot spot polarization in regional coupling level. In addition, the hot spots also have a certain diffusion effect. It can be seen that there is a certain coordination and interaction in the coupling of urban agglomerations in China.

Secondly, the coupling degrees of the five urban agglomerations have significant spatial differences. The overall differences and the differences within urban agglomerations show a downward trend in fluctuations over time. Except the Pearl River Delta and Chengdu-Chongqing urban agglomerations, the differences among other urban agglomerations are gradually narrowing. As of 2016, the biggest intra-regional difference is the Pearl River Delta urban agglomeration, and the biggest inter-regional

difference is the Yangtze River Delta and Beijing-Tianjin-Hebei urban agglomeration. The difference between urban agglomerations is the main source of the overall difference, which always maintains a difference contribution rate of more than 65%. It can be seen that the coupling between urban agglomerations in China is lack of coordination and interaction, and priority should be given to solving the unbalanced problem among urban agglomerations in macro-control.

Thirdly, in the coupling subsystems of the five urban agglomerations, there are obvious differences in the solidification of regional differences between human capital and economic growth level. Regional economic growth has a more serious solidification at high and low levels, and some regions have fallen into the "low-level trap" of false coordination. And as time goes on, the solidification of regional economic growth has always been more serious. This shows that there is a more serious "Matthew effect" phenomenon in the economic growth of the five urban agglomerations in China, and the liquidity of intercity economic growth level is worse.

In order to reverse the spatial imbalance of the coupling level of the five major urban agglomerations and enhance the coupling level of human capital and economic growth in different regions, based on the above analysis conclusions, this paper puts forward the following countermeasures and suggestions:

First is to strengthen the inter-regional and intra-regional linkages of urban agglomerations, and strive to achieve the goal of "big cities driving small towns" for common development. The Pearl River Delta, the Yangtze River Delta and the Beijing-Tianjin-Hebei Urban Agglomeration are located in the eastern coastal areas with good location and abundant resources, which should give full play to the demonstration role of the central cities, promote the rational

flow of resources, and make full use of the spatial spillover of hot spots. Relatively speaking, Chengdu-Chongqing and the middle reaches of the Yangtze River located in the central and Western regions have not obvious advantages. They should actively explore the multi-channel cooperation within and between urban agglomerations in accordance with our own actual situation, form a complementary and mutually beneficial development model, and strive to narrow the regional gap.

Second, according to the level of human capital and economic growth, each region can be divided into four types, and be adopted with a targeted Coupling promotion path. B and C regions should strive to make up for their shortcomings and strive to enter a region as soon as possible, and the state should focus on supporting the development of C2 region and promote it to take a C2→B2→A coupling path. This is due to more serious solidification of the level of inter-regional economic growth. Especially, for the development of low-level regions, it is necessary for the state to take macro-control measures and give them priority of precise assistance, so as to avoid them falling into the "low-level trap" of long-term economic growth and promote coordinated regional development. At the same time, these areas need to improve their development level according to the lag of subsystems. In addition, based on the urban agglomerations, the Pearl River Delta and Yangtze River Delta urban agglomerations should give priority to adjusting the coordination of their subsystems, so as to realize the "quality promotion" of human capital and economic growth. However, Beijing-Tianjin-Hebei, the middle reaches of the Yangtze River and Chengdu-Chongqing urban agglomerations should put the development in the first place, constantly improve the integration of market economy, and realize the "volume expansion" of human capital and economic growth.

#### REFERENCES

- [1] Lu Ming, Chen Zhao. Fragmented Growth: Why Economic Opening May Worsen Domestic Market Segmentation? [J]. *Economic Research*, 2009, 44(03): 42-52. (in Chinese)
- [2] Wang Xiaolu, Fangang. Changing Trend and Influencing Factors of Regional Gaps in China [J]. *Economic Research*, 2004, (01): 33-44.
- [3] Wan Guanghua, Lu Ming, Chen Zhao. Globalization and Interregional Income Gap: Evidence from China [J]. *Chinese Social Sciences*, 2005 (3): 17-26. (in Chinese)
- [4] Romer P M. Growth based on increasing returns due to specialization [J]. *The American Economic Review*, 1987, 77(2): 56-62.
- [5] Lucas R E. On the mechanics of economic development[J]. *Journal of Monetary Economics*, 1988, 22(1): 3-42.
- [6] Schultz T W. Investment in human capital[J]. *The American economic review*, 1961, 51(1): 1-17.
- [7] Becker G S. Investment in human capital: A theoretical analysis [J]. *Journal of political economy*, 1962, 70(5, Part 2): 9-49.
- [8] Fleisher B, Li H, Zhao M Q. Human capital, economic growth, and regional inequality in China[J]. *Journal of development economics*, 2010, 92(2): 215-231.
- [9] Qian Xiaojing, Shen Kunrong. Urban-Rural Income Gap, Labor Quality and China's Economic Growth [J]. *Economic Research*, 2014, 49 (06): 30-43. (in Chinese)
- [10] Hao Nan, Li Jing. Technological Progress, "Erosion Effect: of Human Capital and International Technology Gap — Empirical Analysis Based on Cross-border Panel Data of 2001-2015 [J]. *Economist*, 2018 (07): 55-62. (in Chinese)
- [11] Ma Ying, He Qing, Li Jing. Human Capital Mismatch among Industries and Its Impact on Output [J]. *China's Industrial Economy*, 2018 (11): 5-23. (in Chinese)
- [12] Acemoglu D. What does human capital do? A review of Goldin and Katz's *The race between education and technology*[J]. *Journal of Economic Literature*, 2012, 50(2): 426-463.
- [13] Han Zhaozhou, An Kang, Gui Wenlin. Empirical Study on the Coordinated Development of Regional Economy in China [J]. *Statistical Research*, 2012, 29 (01): 38-42. (in Chinese)
- [14] Zhang Xiaobei, Li Zihao. Does the difference in human capitals aggravate regional economic imbalance [J]. *Economist*, 2014, (04): 14-21. (in Chinese)
- [15] Liu Zhiyong, Li Haizheng, Hu Yongyuan, Li Chenhua. Advanced Human Capital Structure and Economic Growth — Also on the Formation and Reduction of the Regional Gap between the East, the Mid and the West [J]. *Economic Research*, 2018, 53 (03): 50-63. (in Chinese)
- [16] Dong Zhihua. Interaction between Human Capital and Economic Growth — Empirical Analysis Based on China's Human Capital Index [J]. *Macroeconomic Research*, 2017 (04): 88-98. (in Chinese)
- [17] Liao Zhongbin. Quantitative Evaluation and Classification System of Harmonious Development of Environment and Economy: Taking Pearl River Delta Urban Agglomeration as an Example [J]. *Tropical Geography*, 1999, (02): 76-82. (in Chinese)
- [18] Qu Jin, Zhou Huimin. Empirical Analysis of Coupling Relationship between Provincial Human Capital and Economic Growth in China [J]. *Journal of Quantitative & Technical Economics*. 2013, 30(09): 3-19+36. (in Chinese)
- [19] Ren Le. Analysis of the Relationship between Heterogeneous Human Capital and Regional Economic Coupling — Data Testing Based on 18 Cities in Henan Province [J]. *Economic Management*, 2014, 36 (07): 31-38. (in Chinese)
- [20] Wang Yi, Ding Zhengshan, Yu Maojun, Shang Zhengyong, Song Xiaoyu and Chang Xijie. Quantitative Analysis of Coordination Relationship between Modern Service Industry and Urbanization Based on Coupling Model — Take Changshu City of Jiangsu Province as an Example [J]. *Geographical Research*, 2015, 34 (01): 97-108. (in Chinese)
- [21] Cui Muhua. Coupling Coordinating Relation between Urbanization and Eco-environment in 9 Cities of Central Plains Urban Agglomeration [J]. *Economic Geography*, 2015, 35 (07): 72-78. (in Chinese)
- [22] Zhou Cheng, Feng Xuegang, Tang Rui. Analysis and Prediction of Coupling Coordinating Development of Regional Economy — Eco-environment — Tourism Industry: Taking the provinces and cities along the Yangtze River Economic Belt as an example [J]. *Economic Geography*, 2016, 36 (03): 186-193. (in Chinese)
- [23] Dagum C. A New Approach to the Decomposition of the gini Income Inequality Ratio [J]. *Empirical Economics*, 1997, 22(4): 515-531.
- [24] Zhou Di, Zhou Fengnian. Testing, Measuring and Explaining the Convergence of China Water Resources Use Efficiency Club: 2003-2015 [J]. *Journal of Natural Resources*, 2018, 33 (7): 1103-1115. (in Chinese)
- [25] Zhu Pingfang, Xu Dafeng. Estimation of Human Capital in Chinese Cities [J]. *Economic Research*, 2007, (09): 84-95. (in Chinese)
- [26] Du Ting, Xie Xianjian, Liang Haiyan, Huang'An and Han Quanfang. Comprehensive Evaluation and Spatial Analysis of County Economy in Chongqing City Based on Entropy Weight TOPSIS and GIS [J]. *Economic Geography*, 2014, 34 (06): 40-47. (in Chinese)