Industrial Agglomeration, Human Capital Structure Evolution and High-quality Economic Development ——An Empirical Study Based on the Collaborative Agglomeration of Financial Industry and Manufacturing Industry

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Abstract: It is of great practical significance to explore the relationship among industrial agglomeration, human capital structure evolution and high-quality economic development to maintain the steady progress of China's economy. Based on the provincial panel data from 1997 to 2020, this paper uses the spatial econometric model and the mediating effect model to empirically analyze the relationship among industrial collaboration, human capital structure evolution and high-quality economic development. The results show that there is a significant inverted "U" -shaped relationship between the collaborative industrial agglomeration and the development of high-quality economic index, and there is obvious regional heterogeneity in the eastern, central and western regions. Collaborative industrial agglomeration indirectly affects high-quality economic development through the evolution of human capital structure, and human capital has a significant mediating effect. The findings of this essay suggest that policy makers should strengthen the positive externality of industrial agglomeration and reduce its negative externality to promote the high-quality development of economy, as well as increase the investment in education to promote the evolution of human capital structure from low level to high level.

Keywords: Industrial collaborative agglomeration; Evolution of human capital structure; High-quality economic development; Space measurement; The mediation effect

1. Introduction

China's economic development has made remarkable achievements since the reform and opening up, basically achieving volume accumulation and speed catching up. In that case, the extensive growth model that mainly rely on input of various kinds of resources and demographic dividend is no longer suitable for the long-term development goals. The report of the 19th National Congress of the Communist Party of China stressed that "under the new normal of the economy, we should earnestly promote changes in the quality, efficiency and driving force of economic development". Therefore, high-quality development is not only a summary of the current economic situation, but also an active choice to adapt to the new normal economic development.

Collaborative agglomeration, proposed by Ellison and Glaeser (1997), refers to the phenomenon of high correlation and spatial interdependence among heterogeneous industries [1]. Most of this

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agglomeration results from the three factors highlighted by Marshall: intermediate commodity inputs, labor sharing, and knowledge and technology spillover [2]. And collaborative agglomeration development has become an inevitable choice for most countries to achieve sustainable development. As the main force in promoting China's economic development, manufacturing industry is the driving force to support China's economic growth [3]. The financial industry, as a heterogeneous industry highly related to the manufacturing industry, synergistic agglomeration with the manufacturing industry can promote the stripping of low-value manufacturing industry from the core region, and promote the agglomeration of high-end manufacturing industry, thus promoting the progress of China's manufacturing industry [4]. Under the background of the synergistic development strategy, the synergistic agglomeration trend of Chinese manufacturing industry and financial industry has become increasingly prominent.

In addition, the report of the 19th National Congress also pointed out that "efforts should be made to build an industrial system with coordinated development of the real economy, modern finance and human resources". Therefore, it is urgent to optimize the structure of human capital to match the pace of economic development under the new normal as demographic dividend is fading. The optimization of human capital structure is a dynamic evolution process. With the development of education and the improvement of population's education level, the structure of human capital gradually evolves from low level to high level, which changes synchronously with China's economic growth [5]. Therefore, the mechanism of human capital should also be considered in the discussion of the collaborative agglomeration of manufacturing and financial industry affecting high-quality economic development.

By reviewing the literature, it is found that most scholars mainly focus on the study of the impact of single industrial agglomeration on a certain dimension of economic development. For example, Qian J and Wang Y believe that financial agglomeration can promote the optimization of industrial structure and drive economic development by providing technical support and optimizing technological innovation [6-7]. According to the research of Yen Ngoc Nguyen et al. (2019), different stages of financial development have different promoting effects on economic growth [8]. In the early stage of agglomeration, due to the threshold benefit and profit-seeking of finance, the inverted "U-shaped" relationship between financial development and urban and rural residents' income will be caused, which will affect the coordinated development of regional economy to a certain extent [9-10]. The study of Yuan Huaxi (2019) showed that the improvement of regional financial agglomeration can improve the green development efficiency of neighboring regions, but such spatial spillover effect has obvious spatial attenuation [11]. Kukalis (2010) found that financial industry agglomeration is more significant in the later stage of industrial growth, and can trigger external economies of scale, thereby promoting regional economic development [12].

Manufacturing agglomeration plays a significant role in promoting regional economic growth [13]. In the manufacturing industry agglomeration areas, enterprises can enjoy lots of convenient, such as sharing labor resource, reducing transportation cost, enjoying the preferential policy, and getting more market opportunities, and all of these will push themselves to enhance their competitiveness, so as to make the region economy development form a virtuous cycle [14]. In addition, industrial agglomeration can promote the improvement of regional innovation capability, but there is obvious industry and regional heterogeneity [15-16]. At the same time, the spillover of knowledge and green technology brought by manufacturing agglomeration will promote the growth efficiency of green economy in this region [17].

It is only in recent years that the research on collaborative industrial agglomeration and high-quality economic development has been gradually enriched. As for the relationship between them, scholars mainly form three kinds of arguments. The first one is promotion theory. Some scholars believe that industrial collaborative agglomeration can promote economic development by optimizing industrial structure [18-19]. At the same time, collaborative industrial agglomeration can promote the improvement of local innovation efficiency, and exert positive spillover effect on the innovation efficiency of surrounding regions through interaction with research talents [20]. Chen Jianjun et al. also found that collaborative industrial agglomeration could promote the improvement of production efficiency in local and surrounding areas, but the spillover effect on the improvement of urban production efficiency would decline with the increase of distance [21]. The second is the theory of inhibition. The research of Wu Zhenhua (2020) found that collaborative industrial agglomeration has a significant negative effect on the quality of economic development, especially in the central regions [22]. The third theory is nonlinearity. According to the research of Ma Yu et al. (2020), the agglomeration of high-tech industries has a threshold effect on both the quantity and quality of economic development, and the effect before and after the threshold value is respectively inhibiting and promoting [23].

To sum up, current studies mainly focus on the impact of single industry agglomeration of financial industry or manufacturing industry agglomeration on a certain dimension of high-quality economic development, while systematic studies on the impact of collaborative agglomeration of financial industry and manufacturing industry on high-quality economic development are relatively scarce. Secondly, in terms of research methods, most of them use ordinary panel data, which do not fully consider the spatial impact and ignore the differences in economic development among regions. Moreover, there is little literature on the mediating role of the evolution of human capital structure in promoting high-quality economic development. Therefore, it is of great importance to explore the relationship between industrial collaborative agglomeration, evolution of human capital structure and high-quality economic development. This paper will systematically analyze the influence of industrial agglomeration on high-quality development and examine the mediating effect of the evolution of human capital structure, and put forward relevant policy suggestions based on the research conclusions.

2. Influence mechanism and research hypothesis

2.1 Coordinated industrial agglomeration and high-quality economic development

High-quality economic development under the new normal is guided by the new development concept of "innovation, coordination, green development, opening up and sharing". Therefore, this paper analyzes the impact of the collaborative agglomeration of financial industry and manufacturing industry in five aspects: innovation-driven, coordinated development, green development, economic opening and economic sharing. Furthermore, the paper analyzes the mechanism of human capital structure as the mediating effect of two industries' synergistic agglomeration on high-quality economic development.

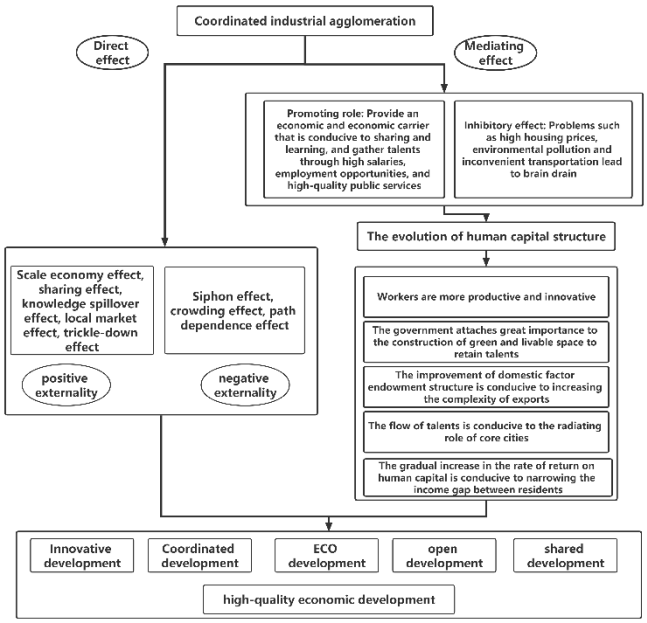

Fig. 1 Mechanism diagram of industrial synergistic agglomeration influencing high-quality economic development

2.1.1 Positive external effects

The collaborative agglomeration of financial industry and manufacturing industry will produce five positive external effects on high-quality economic development: First, the effect of scale economy. Financial agglomeration can bring sufficient capital flow and provide financial support for the technological R&D and innovation activities of manufacturing enterprises in the region. In the meanwhile, it also can provide financing services to meet diversified financing needs of manufacturing enterprises, broaden the financing channels and effectively reduce the cost for financing, thus promoting enterprises' innovation ability. The second is the sharing effect. The collaborative industrial agglomeration improves the utilization efficiency of labor market. Therefore, enterprises can reduce the cost of labor and can improve labor productivity, thus significantly improving labor mismatch problems [24]. In turn, it is conducive to shared economic development. Third, knowledge spillover effect. The agglomeration of enterprises promotes the rapid exchange of information and technology diffusion. The shortening of geographical distance provides employees with face-to-face communication opportunities. Through the exchange and sharing of information, technology and complex tacit knowledge, the ability of innovation subjects to imitate, absorb and transform can be improved [25]. Fourth, the local market effect. The regions with large demand for products will have a higher proportion of output and are likely to become net exporters. In the industry agglomeration areas, enterprises and population agglomeration generate more physical product demands and financial service requirements, both of which enable enterprises to increase profits by expanding its scale, thus promoting the development of open economy. The fifth is the trickle-down effect. The industrial collaborative agglomeration area that has achieved the first development through the

agglomeration effect can further benefit the poor areas through different forms of consumption, labor absorption, tax transfer and industrial transfer, promote their development and prosperity, and realize the coordinated economic development.

2.1.2 Negative external effects

The collaborative agglomeration of financial industry and manufacturing industry will also have three negative external effects on high-quality economic development: first is the siphon effect. Industry cluster district continuous development will continue to attract talent from surrounding disadvantage areas. Resources such as capital, technology, on the one hand, improve the industrial scale and the regional competitiveness of the industry agglomeration area, while on the other hand, lead to loss of resources of inferior regions. Thus, it is not conducive to regional coordinated development and shared economic development. The second is the crowding effect. When the agglomeration level exceeds the critical value, the crowding effect will occur. On the one hand, it is difficult to produce the scale effect, and the innovation factors in the agglomeration area cannot play an effective role, and the development of economic innovation is inhibited. On the other hand, it will highlight the negative environmental externalities. A large number of industrial production activities will bring pressure to the ecology, which goes against the green development of economy. The third is the path-dependent effect. The agglomeration will attract a large number of production factors to gather rapidly and increase the inertia of industrial development, which will lock the industrial development level at the middle and low value end and inhibit technological innovation [3].

2.2 Industrial synergistic agglomeration and evolution of human capital structure

Industrial synergistic agglomeration can promote the evolution of human capital structure through human capital inflow and human capital self-improvement. From the perspective of individuals, they seek for better monetary income and non-monetary income including living environment, education, health care and other public facilities. Industrial cooperative agglomeration zone can attract high-quality talents from other places through high salary, full employment opportunities and high-quality public service supply. Therefore, human capital structure of these regions can be optimized. From the perspective of enterprises, the same type of enterprises is clustered in the same area, so that they are faced with the pressure of competition as it is easy to compare product price, quality and product differentiation between peers. In order to survive in the competition, enterprises must vigorously introduce a large number of specialized talents, develop new products through the advantages of human capital, improve the efficiency of enterprise management, and enhance the competitiveness of enterprises [26].

The self-promotion of human capital is another channel through which industrial agglomeration promotes the evolution of human capital structure. Its modes are as follows: On the one hand, a large number of excellent talents in the industrial agglomeration area brings competition pressure to individuals. The employees with good performance can get the honor of success and rich remuneration return, while the employees with poor performance are faced with the pressure of being dismissed by the enterprise. Based on this pressure, individuals have the tendency to continuously improve their work efficiency and innovation through self-learning. On the other hand, the formation of human capital needs the input of physical capital, enterprises, organizations and other economic carriers. There are a large number of economic carriers in the industrial

collaborative agglomeration area, which provide opportunities for labor to learn skills and exchange experience [27].

However, collaborative industrial agglomeration also causes problems such as high housing prices, environmental pollution and inconvenient transportation, which will lead to the outflow of talents, offset the income effect of collaborative industrial agglomeration, and further inhibit the optimization of human capital structure [28].

2.3 Evolution of human capital structure and high-quality economic development

The evolution of human capital structure influences high-quality economic development through the following mechanisms: first, a high level of human capital is an important support of innovation. With the improvement of laborer quality, there will be higher productivity and innovation ability, which can promote the industry value chain upgrade, from capital or Labor intensive to technology and knowledge intensive. Secondly, the accumulation of human capital in China has a strong spatial correlation, and has a radiation effect on the surrounding areas [29]. By driving the evolution of human capital structure in relatively backward areas, the regional development gap can be reduced and the coordinated development of regions can be promoted. Thirdly, people who have received a higher level of education tend to have a higher income, so they pay special attention to the living environment in addition to meeting their basic needs. In order to retain talents, the government will formulate environmental regulations and policies to create a green and livable living space, which will promote green economic development. Finally, with the continuous improvement of the domestic income distribution and the increasing rate of return on human capital, the continuous optimization of human capital structure will help narrow the income gap of residents [30].

Based on the above mechanism, the following hypotheses are proposed in this paper:

Hypothesis 1: Under the influence of positive and negative externalities, there is a nonlinear relationship between the co-agglomeration of financial industry and manufacturing industry and high-quality economic development.

Hypothesis 2: Under the influence of positive and negative externalities, there is a nonlinear relationship between the co-agglomeration of financial industry and manufacturing industry and the evolution of human capital structure.

Hypothesis 3: The evolution of human capital structure can promote high-quality economic development, and the evolution of human capital structure plays a mediating effect on the impact of industrial collaborative agglomeration on high-quality economic development.

3. The empirical analysis

3.1 Model construction and data description

3.1.1 Spatial panel econometric model

To explore industry agglomeration effect on the high-quality economic development and measure the possible existence of space effect, this paper uses a more general spatial econometric model, the Spatial Dubin Model (SDM) as a basic empirical model, at the same time, considering the industry collaborative agglomeration possible nonlinear effect on high-quality economic

development, the quadratic term of collaborative agglomeration level was added as explanatory variable, and the model was set as:

$$\mathrm{Heco}_{it} = d_1 + \delta_1 \sum_{m=1}^{n} w_{im}\, Heco_{mt} + a_1 FM\_agg_{it} + a_2 FM\_agg_{it}^{\ 2} + a_3 \mathrm{Hstruc}_{it} + z_x con_{xit} + \alpha_4 \sum_{m=1}^{n} w_{im}\, FM\_agg_{it} + \alpha_5 \sum_{m=1}^{n} w_{im}\, FM\_agg_{it}^{\ 2} + \alpha_6 \sum_{m=1}^{n} w_{im}\, \mathrm{Hstruc}_{it} + \mathrm{z}_{x1} \sum_{m=1}^{n} w_{im}\, con_{xit} + \mathrm{u_i} + \mathrm{v_t} + \varepsilon_{it} \quad (1)$$

Heco_{it},FM_agg_{it}, $Hstruc_{it}$ and con_{xit} respectively represent the high-quality economic development index, the co-agglomeration index of financial industry and manufacturing industry, the evolution index of human capital structure and the X [th] control variable of region i in year t; w_{im} is the spatial weight matrix. The geographical distance matrix and geographical adjacent matrix (01 matrix) are selected to fit the model. The regression structure obtained from the geographical distance matrix structure is taken as the benchmark analysis result, and the results obtained from the geographical adjacent matrix are taken as the robustness test. $\mathrm{u_i}$ and $\mathrm{v_t}$ represent the unobservable region and time fixed effects respectively, ε_{it} is random error term.

3.1.2 Mediating effect model

In order to further explore whether collaborative industrial agglomeration can have an indirect impact on high-quality economic development through the evolution of human capital structure, this paper draws on the stepwise regression method proposed by Baron & Kenny to test the mediating effect of the evolution of human capital structure, and constructs a stepwise regression equation of mediating effect based on the spatial econometric model. Equations (1), (2) and (3) are used to test whether the evolution of human capital structure plays a mediating effect.

$$\mathrm{Hstruc}_{it} = d_2 + \delta_2 \sum_{m=1}^{n} w_{im}\, \mathrm{Hstruc}_{mt} + b_1 FM\_agg_{it} + \gamma_x con_{xit} + \mathrm{b}_2 \sum_{m=1}^{n} w_{im}\, FM\_agg_{it} + \gamma_{x1} \sum_{m=1}^{n} w_{im}\, con_{xit} + \mathrm{u_i} + \mathrm{v_t} + \varepsilon_{it} \quad (2)$$

δ_2 is the spatial autoregressive coefficient, $d_2, b_1,\ b_2, \gamma_x\ and\ \gamma_{x1}$ are the regression coefficient,$w_{im}\ is\ the\ spatial\ weight\ matrix,$ $\mathrm{u_i}$ and $\mathrm{v_t}$ respectively represent the unobservable region and time fixed effects, ε_{it} is random error term.

$$\mathrm{Heco}_{it} = d_3 + \delta_3 \sum_{m=1}^{n} w_{im}\, Heco_{mt} + c_1 FM\_agg_{it} + c_2 FM\_agg_{it}^{\ 2} + \sigma_x con_{xit} + \mathrm{c}_3 \sum_{m=1}^{n} w_{im}\, FM\_agg_{it} + \mathrm{c}_4 \sum_{m=1}^{n} w_{im}\, FM\_agg_{it}^{\ 2} + \sigma_{x1} \sum_{m=1}^{n} w_{im}\, con_{xit} + \mathrm{u_i} + \mathrm{v_t} + \varepsilon_{it} \quad (3)$$

$\delta_3$is the spatial autoregressive coefficient, $d_3\ \ c_1, c_2, c_3, c_4, \sigma_x\ and\ \sigma_{x1}$ are regression coefficients, w_{im} is spatial weight matrix, $\mathrm{u_i}$ and $\mathrm{v_t}$ represent unobservable region and time fixed effects respectively, ε_{it} is random error term.

3.2 Variable description

a) Explained variable: High Quality Economic Development Index (Heco). Based on the concept of the new development, this paper constructs evaluation index system of high-quality

economic development from six dimension including the output growth, innovation development, coordinated development, green development, open development, sharing development.

In order to ensure the consistent impact of various indicators on high-quality economic development, the positive and negative indicators are standardized, and the information entropy weight method is used to comprehensively evaluate the high-quality economic development. As can be seen from Table 1, the level 2 indicators of innovation development, sharing development and open development accounted for 36.0%, 23.0% and 22.2% respectively, which is consistent with China's recent situation. It can be seen from Figure 2 that the high-quality economic development index of China has achieved a significant increase during 1997-2020, and the spatial distribution difference of the high-quality economic development index in eastern China is higher than that in central and western China as a whole.

Table 1 Evaluation index system of high-quality economic development

Level 1 indicators	Level 2 indicators	The weight	Level 3 indicators	Attribute	Unit	The weight
High Quality Economic Development Index	Output growth	6.7%	GDP/value added	+	Billion Yuan	3.71%
			GDP per capita	+	Yuan	2.65%
			Regional GDP index	+	%	0.17%
			Regional GDP per capita index	+	%	0.22%
	Innovation development	36.0%	Number of authorized applications for invention patents	+	Unit	8.42%
			Number of authorized applications for utility model patents	+	Unit	8.04%
			Number of patent applications for design	+	Unit	9.66%
			Technical market turnover	+	Million Yuan	9.88%
	Coordinate development	1.5%	Proportion of secondary and tertiary industries	+	%	0.34%
			The proportion of the urban population	+	%	0.89%
			Urban-rural income ratio	-	-	0.20%
			Urban-rural consumption ratio	-	-	0.08%
	Green development	10.6%	Sulfur dioxide emission	-	Million tones	0.27%
			Industrial solid waste production	-	Million tones	0.14%
			Quantity of utilization of industrial solid waste	-	Million tones	0.20%
			Number of nature Reserves	+	Piece	2.90%
			Area of nature reserve	+	Hectares	7.10%
	Open development	22.2%	Import and export	+	Dollars	7.92%
			Foreign direct investment	+	Dollars	6.84%

			Foreign registered capital	+	Dollars	7.40%
	Sharing development	23.0%	Per capita consumption of rural households	+	Yuan	2.64%
			Per capita consumption of urban households	+	Yuan	2.23%
			Per capita net income of rural households	+	Yuan	2.79%
			Per capita net income of urban households	+	Yuan	2.40%
			Unemployment rate	-	%	0.15%
			Illiteracy as a percentage of the population aged 15 and above	-	%	0.09%
			Consumer price index	-	%	0.22%
			Mobile phone year-end users	+	-	3.59%
			Length of road	+	Kilometer	1.88%
			Health workers in total	+	Number	1.78%
			Number of people participating in urban basic endowment insurance at the end of the year	+	Number	2.88%
			Number of people participating in unemployment insurance at the end of the year	+	Number	2.32%

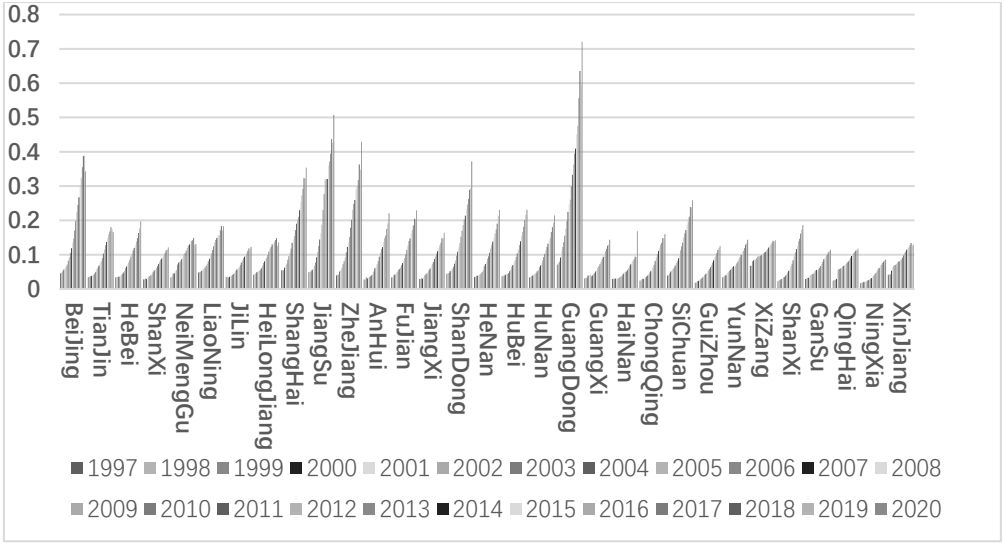

Fig 2 Bar chart of high-quality economic development index of 31 Chinese provinces (autonomous regions and municipalities) from 1997 to 2020

b) Key explanatory variable: manufacturing agglomeration (M-agg), which is measured by the locational entropy of manufacturing industry, which is the ratio of the number of manufacturing employees to the total employment. Financial industry agglomeration (F-agg) is measured by financial industry location entropy, which is the ratio of the number of financial industry employees to the total employment. The co-clustering index of financial Industry and Manufacturing industry (FM-agg) can be calculated as follows:

$$FM_{agg} = \left[1 - \frac{\left| M_{agg} - F_{agg} \right|}{M_{agg} + F_{agg}} \right] + M_{agg} + F_{agg} \tag{4}$$

c) Intermediate variable: Hstruc (Human Capital Structure Evolution Index). This paper uses vector Angle computing to measure human capital index structure evolution, the data can be divided into five grades: human capital has not been to school (illiterate and semi-literate belong to this category), primary school, middle school, high school, college and above.

$$\phi_j = \arccos\left\{ \frac{\sum_{i=1}^{5} (x_{j,i} \cdot x_{0,i})}{\sqrt{\sum_{i=1}^{5} x_{j,i}^2} \cdot \sqrt{\sum_{i=1}^{5} x_{0,i}^2}} \right\} \tag{5}$$

$x_{j,i}$ represents the i[th] component of the reference vector x_j (j=1,2,3,4,5); $x_{0,i}$ represents the component of the vector x_0. After calculating the influence of other people's capital at all levels ϕ_j, the evolution index of human capital structure can be obtained by weighted sum.

$$Hstruc = \sum_{j=1}^{5} (w_j \cdot \phi_j) \tag{6}$$

d) Control variables

Fixed investment: Fixed asset investment plays an important role in boosting economic growth, and the dependence of the economy on investment also affects the level of economic development. This paper measures this index by per capita fixed asset investment. This paper uses per capita public finance expenditure to measure this indicator.

Fiscal expenditure: Fiscal expenditure not only reflects the level of regional economic development, but also reflects the size of the macro-control role played by the government.

Transportation construction: Transportation is the link between regions and plays a guiding role in economic development. This paper measures this index by per capita highway mileage.

3.3 Data description

The research object of this paper is 31 provinces (autonomous regions and municipalities directly under the central government) in mainland China except Hong Kong, Macao and Taiwan. The sample span is from 1997 to 2020. The data used in this paper are all from China Labor Statistical Yearbook, China Statistical Yearbook, China Regional City Yearbook, China Internet Development Statistical Report, as well as the statistical yearbooks and statistical bulletins of

various regions. In order to solve the problem that there is no data in some regions in a certain year, this paper uses methods such as average filling and growth rate filling to fill in a few missing data. Descriptive statistics of all variables are shown in Table 2 below. Tables 3 and 4 show that there is no serious collinearity problem among the indicators.

Table 2 Descriptive statistics of variables

Variable	Sample size	The mean	The standard deviation	The minimum	The maximum
High Quality Economic Development Index	744	0.106	0.087	0.017	0.721
Financial industry agglomeration	744	1.021	0.228	0.507	1.843
Manufacturing agglomeration	744	0.857	0.345	0.094	1.828
Coordinated industrial agglomeration	744	2.668	0.461	1.042	3.895
Human capital structure evolution index	744	17.256	0.638	15.656	20.042
Investment in fixed assets	744	2.13	1.954	0.061	8.398
Transportation construction	744	33.398	37.182	2.656	323.055
Fiscal expenditure	744	0.738	0.806	0.03	6.06

Table 3 Correlation test between independent variables and mediating variables

Coordinated industrial agglomeration	Human capital structure evolution index	Investment in fixed asset	Transportation construction	Fiscal expenditure
1.000				
0.251	1.000			
-0.053	0.419	1.000		
-0.653	-0.335	0.289	1.000	
-0.280	0.314	0.736	0.613	1.000

Table 4 Variance inflation factors of independent variables and mediating variables

Variable	Coordinated industrial agglomeration	Human capital structure evolution index	Investment in fixed asset	Transportation construction	Fiscal expenditure	The mean
VIF	4.79	4.66	2.45	2.27	1.86	3.2
1/VIF	0.209	0.215	0.408	0.441	0.538	

3.4 Regression analysis

3.4.1 Spatial correlation analysis

The regional Moran's I index was used to measure the economic high-quality development index of 31 provinces (autonomous regions and municipalities directly under the central government) from 1997 to 2020. The key to the measurement of the global Moran's I index lies in the setting and selection of the spatial weight matrix. Considering the comprehensiveness of the measurement, this paper constructs two kinds of matrices: geographical adjacent matrix. If two regions are adjacent, the diagonal element is 1, and if they are not adjacent, it is 0. Geographical distance matrix, whose diagonal element is the reciprocal of the geographical distance between two provincial capitals. The main diagonal elements of the spatial weight matrix are all 0.

The results show that the Moran's I index of high-quality economic development under the two spatial weight matrices is positive on the whole, but it fails to pass the significance test between 1997 and 2010, and passes the significance test at least at the level of 10% after 2011. It can be found that before 2011, the local agglomeration of high-quality economic development in China was strong, the transmission in geographic space was low, and the spatial correlation was weak. However, after 2011, this situation has been significantly improved, the economic ties between regions have been strengthened year by year, and the spatial correlation of the high-quality development index of Chinese economy has been rapidly improved.

Table 5 Moran's I Index of high-quality economic development from 1997 to 2020

Years	Geographically adjacent matrix		Geographical distance matrix	
	Moran’s I	P values	Moran’s I	P values
1997	0.034	0.258	0.003	0.165
1998	0.019	0.304	-0.004	0.213
1999	-0.037	0.487	-0.012	0.282
2000	-0.014	0.423	-0.012	0.285
2001	0.05	0.204	-0.029	0.453
2002	0.046	0.21	-0.03	0.468
2003	0.006	0.344	-0.028	0.439
2004	-0.006	0.388	-0.027	0.427
2005	0.009	0.333	-0.023	0.387
2006	0.016	0.306	-0.017	0.317
2007	0.037	0.231	-0.005	0.212
2008	0.052	0.19	0.001	0.167
2009	0.064	0.163	0.005	0.143
2010	0.087	0.111	0.01	0.112
2011	0.114	0.07	0.018	0.075
2012	0.122	0.06	0.021	0.064

2013	0.111	0.073	0.021	0.067
2014	0.112	0.073	0.022	0.061
2015	0.131	0.051	0.029	0.041
2016	0.134	0.048	0.031	0.037
2017	0.115	0.066	0.021	0.063
2018	0.118	0.061	0.023	0.057
2019	0.149	0.033	0.033	0.033
2020	0.189	0.011	0.047	0.011

The results of spatial autocorrelation test show that the high-quality economic development index has spatial correlation. Therefore, the regression results obtained by the traditional panel model are biased, which cannot accurately reflect the impact of coordinated agglomeration of financial industry and manufacturing industry on the high-quality economic development. According to the LM test results in Table 6, both SAR (spatial lag model) and SEM (spatial error model) models pass the significance test above 5% level under the two spatial matrices, indicating that the relationship between the collaborative agglomeration of financial industry and manufacturing industry and high-quality economic development needs to consider the influence of spatial factors. In this paper, both SAR and SEM models can be used for analysis, and a more general form of SDM (Spatial Dubin Model) model can be further considered for analysis. According to the LR test results in Table 8, the P-value is significant at the level of 1%, indicating that the SDM model will not degenerate into SAR and SEM models. Therefore, this paper constructs the SDM model to analyze the impact of the collaborative agglomeration of the two industries on high-quality economic development based on the geographical distance matrix and geographical adjacency matrix. In this paper, the estimation results of the geographical distance matrix are used as the benchmark analysis, and the results of the geographical adjacent matrix are used as the comparative analysis and robustness explanation. Finally, this paper further determines that the spatial econometric model should adopt two-way fixed effects of individual and time through Hausman test and LR test.

Table 6 LM test results

LM Test	Geographically adjacent matrix		Geographical distance matrix	
	Statistical value	P value	Statistical value	P value
Spatial error model				
Lagrange multiplier	5.153	0.023	6.150	0.013
Robust Lagrange multiplier	20.238	0.000	23.794	0.000
Spatial lag model				
Lagrange multiplier	20.075	0.000	60.201	0.000

Robust Lagrange multiplier	35.161	0.000	77.846	0.000

Table 7 LR test results

LR Test	Geographically adjacent matrix		Geographical distance matrix	
	Statistical value	P value	Statistical value	P value
The SDM model degenerates into the SAR model	96.82	0.000	104.52	0.000
The SDM model degenerates into the SEM model	94.36	0.000	105.34	0.000

The regression results show that the spatial autoregressive coefficient (rho) under the two matrices passes the significance test at least at the level of 10%, which is significantly positive under the geographical adjacent matrix and negative under the geographical distance matrix, indicating that the high-quality economic development index has a significant spatial correlation among regions. Therefore, it is correct to choose spatial econometric model for analysis in this paper.

Table 8 Regression results of spatial model at the national level

variables	Geographical distance matrix	Geographically adjacent matrix
	Model 1	Model 2
Coordinated industrial agglomeration	0.134***	0.231***
	-0.0513	-0.0498
The square term of industrial cooperative agglomeration	-0.0271***	-0.0446***
	-0.00873	-0.00858
Investment in fixed assets	0.00174	-0.000338
	-0.00196	-0.00197
Transportation construction	-0.00109***	-0.000913***
	-0.000166	-0.000192
Fiscal expenditure	0.0206***	0.0256***
	-0.00513	-0.00576
rho	-0.401***	-0.0746*
	-0.155	-0.0409
sigma2_e	0.00104***	0.00107***
	-0.0000541	-0.0000553
Extreme value point	2.472	2.590
Observations	744	744
R-squared	0.191	0.381

In terms of the core explanatory variables, under the two matrices, the coefficient of the primary term of industrial collaborative agglomeration is positive, and the coefficient of the quadratic term is negative, both of which are significant at least at the level of 1%, indicating that there is a significant "inverted U-shaped" curve relationship between the collaborative agglomeration

of financial industry and manufacturing industry and high-quality economic development. And its critical value is 2.472 under the geographical distance matrix, while it is 2.590 under the geographical adjacency matrix. With the continuous improvement of the level of industrial collaborative agglomeration, the role of collaborative agglomeration on high-quality economic development is gradually obvious. However, when the level of industrial collaborative agglomeration reaches the threshold of 2.472 to 2.590, the improvement of the level of industrial collaborative agglomeration will hinder the high-quality economic development. The reason for the inverted U-shaped relationship between industrial collaborative agglomeration and high-quality economic development is that it will bring positive spillover effects such as matching effect, learning effect and sharing effect in the early stage of industrial agglomeration, which are specifically shown as follows: First, enterprises can recruit employees with matching ability at the lowest price as the matching efficiency between employees and enterprises is high, which can reduce labor costs. The free flow of employees will force enterprises to compete among talents and promote the sharing of information among enterprises. Secondly, spatial agglomeration can reduce the cost of information acquisition. In the meanwhile, enterprises improve the core competitiveness of enterprises in the whole region by learning technology and management experience from each other. Moreover, sharing infrastructure among enterprises can reduce production costs, and industrial agglomeration areas are more likely to obtain policy support from local governments.

However, with the industrial agglomeration to a certain extent, it will bring crowding effect that hinders the high-quality development of the economy. Specifically, it is shown as follows: Firstly, industrial agglomeration will bring land tension, and the rise of land price and rent in the core areas will increase the labor cost and land cost of enterprises; Secondly, industrial agglomeration will bring a large number of labor force, less land and increasing number of people will lead to traffic congestion, shortage of public facilities and social welfare; Thirdly, the agglomeration of manufacturing and other heavy industries brings environmental pollution. All above analysis verify hypothesis 1.

In terms of control variables, the coefficients of fixed investment are all negative, but they do not pass the significance test, indicating that the increase of fixed asset investment to a certain extent will reduce the level of high-quality economic development. The reason may be that regional economic development relies excessively on investment to drive economic growth. Instead of paying attention to the quality of investment it pays more attention to the scale of investment, and does not optimize the investment structure, resulting in inefficient investment. Therefore, it is not conducive to high-quality economic development. The coefficients of fiscal expenditure are all positive and pass the significance test at the level of 1%, indicating that the moderate expansion of fiscal expenditure will improve the level of high-quality economic development. The reason is that the level 2 indicators such as innovative development, green development, coordinated development and sharing development account for a large proportion in the evaluation system, and whether these indicators can achieve good results rely on the financial support from government. For example, the government's appropriate support for the innovation of small and medium-sized enterprises is conducive to improving the integration efficiency and quality of innovation resources. The government can effectively protect green resources, promote the equalization of public service facilities, and reduce the gap between the rich and the poor around the country. The traffic construction coefficients are all negative and pass the significance test at the level of 1%, indicating that the continued expansion of the scale

of traffic infrastructure construction will be detrimental to the high-quality economic development. The possible reasons are as follows: first, the regional layout of transportation facilities is not conducive to the coordinated development among regions. The transportation in the eastern region is more developed, while the central and western regions are relatively backward, but the government still invests in the construction of transportation in the eastern region. Second, the transportation industry has high energy consumption and serious pollution, and the rapid growth of its scale is often at the cost of resource destruction and environmental pollution. Third, transportation construction, measured by per capita highway mileage, has limited impact on high-quality regional economic development.

Moreover, after the introduction of spatial factors, the collaborative industrial agglomeration will also have an impact on the high-quality economic development of surrounding areas. Therefore, the partial differential decomposition method proposed by Elhorst (2014) [32] will be used to decompose the effects calculated by the SDM model into direct effects and indirect effects to estimate the spatial relationship. The direct effect refers to the influence of explanatory variables in the region on the explained variables in the region. Indirect effect refers to the influence of the change of explanatory variables in the local region on the explained variables in other regions. The results of spatial effect decomposition are shown in Table 9 below.

Table 9 Effect decomposition results of national spatial econometric model

Variables	Geographical distance matrix			Geographically adjacent matrix		
	Model 1			Model 2		
	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
Coordinated industrial agglomeration	0.159***	0.627**	0.748***	0.234***	-0.050	0.184
	-0.0523	-0.26	-0.276	-0.0511	-0.111	-0.12
The square term of industrial cooperative agglomeration	-0.0315***	-0.0999**	-0.125***	-0.0453***	0.0198	-0.0255
	-0.00895	-0.0432	-0.0456	-0.00884	-0.0192	-0.0205
Investment in fixed assets	0.000505	0.0375***	0.0386***	-0.000426	0.0186***	0.0182***
	-0.00198	-0.00775	-0.00814	-0.00191	-0.0034	-0.00396
Transport construction	-0.0016***	-0.0031***	-0.0041***	-0.0009***	-0.0012***	-0.0021***
	-0.000165	-0.000875	-0.000851	-0.000185	-0.000405	-0.000338
Fiscal expenditure	0.0339***	-0.102***	-0.0792**	0.0259***	-0.00663	0.0193*
	-0.00529	-0.032	-0.0315	-0.0056	-0.0131	-0.0112

Note: ***, ** and * indicate significance at 1%, 5% and 10% levels, respectively.

It can be seen from Table 9 that under the geographical distance matrix, the coefficient of the direct effect and indirect effect of industrial collaborative agglomeration is positive, and the coefficient of the quadratic effect is negative, and all pass the 5% significance level test, indicating that the collaborative agglomeration of the two industries will not only affect the high-quality development of the local economy, but also affect the high-quality development of the surrounding areas. But this effect depends on the degree of agglomeration, below the threshold

it is a positive effect, while above the threshold, it will bring negative effects. The direct effect of threshold value is 2.64, and the indirect effect of threshold value is 3.14, which is greater than the former. This is mainly due to the fact that when the level of industrial collaborative agglomeration reaches the local threshold, spillover effects will occur. Some financial and manufacturing enterprises will migrate to neighboring provinces and cities, which will improve the coordinated agglomeration level of financial industry and manufacturing industry in neighboring provinces and cities. However, when the level of industrial collaborative agglomeration in neighboring provinces and cities reaches a certain level, it will inhibit the high-quality development of local economy.

In terms of control variables, the indirect effect of fixed asset investment is positive and highly significant, indicating that the increase of local fixed asset investment is conducive to the high-quality economic development of surrounding areas. The indirect effect of transportation construction and fiscal expenditure is negative and reaches a highly significant level, indicating that the increase of local transportation construction and fiscal expenditure will have a negative impact on the high-quality economic development of surrounding areas. The above results show that when taking measures to promote high-quality economic development, not only the local internal factors should be considered, but also the possible impact of related factors in adjacent areas should be taken into account.

3.4.2 Analysis of regional regression results

Table 10 Regression results of spatial model at regional level

Variables	Geographical distance matrix			Geographically adjacent matrix		
	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	Eastern region	Central region	Western region	Eastern region	Central region	Western region
Coordinated industrial agglomeration	0.309**	0.412***	0.124***	0.243*	0.274***	0.0982***
	-0.124	-0.0874	-0.0348	-0.132	-0.0795	-0.0349
The square term of industrial cooperative agglomeration	-0.0570***	-0.0773***	-0.0221***	-0.0480**	-0.0522***	-0.0224***
	-0.0199	-0.0166	-0.00709	-0.0213	-0.015	-0.00734
Control variables	Control	Control	Control	Control	Control	Control
Extreme point	2.711	2.665	2.805	2.531	2.625	2.188
rho	-1.067***	-1.049***	-0.310**	-0.0934	0.0361	-0.354**
	-0.137	-0.137	-0.134	-0.0573	-0.0758	-0.143
sigma2_e	0.00114***	0.00119***	3.04e-05***	0.00137***	3.41e-05***	0.0001***
	-0.000109	-0.000113	-0.0000030	-0.00012	-0.000003	-0.000008
Observations	264	192	288	264	192	288
R-squared	0.338	0.324	0.368	0.717	0.346	0.386

Note: ***, ** and * indicate significance at 1%, 5% and 10% levels, respectively.

This paper divides 31 provinces (autonomous regions and municipalities directly under the central government) except Hong Kong, Macao and Taiwan into three major regions: eastern,

central and western regions, and constructs corresponding geographical adjacent matrix and geographical distance matrix respectively. The Spatial Dubin Model is used for empirical analysis and plays the role of robustness test at the same time. The regression results are shown in Table 10.

As can be seen from Table 10, the relationship between collaborative industrial agglomeration and high-quality economic development in the eastern, central and western regions shows a significant inverted "U-shaped" curve. The extreme points under the geographical distance matrix are 2.711, 2.665 and 2.805 respectively, which are similar to the results obtained at the national level, further enhancing the previous conclusions.

3.4.3 Mediating effect test

Table 11 Mediating effect test results

Variables	Geographical adjacent matrix		Geographical distance matrix	
	Model 9	Model 10	Model 11	Model 12
	Human capital structure evolution index	High quality economic development index	Human capital structure evolution index	High quality economic development index
Coordinated industrial agglomeration	0.954***	0.121**	0.843***	0.206***
	-0.207	-0.0521	-0.197	-0.0503
The square term of industrial cooperative agglomeration	-0.148***	-0.025***	-0.138***	-0.040***
	-0.0352	-0.00885	-0.034	-0.00866
Human capital structure evolution index		0.0188**		0.0221**
		-0.00913		-0.00928
Investment in fixed assets	-0.0047	0.00187	-0.0134*	0.000347
	-0.00786	-0.00196	-0.00782	-0.00198
Length of road	-0.00741***	-0.00094***	-0.0079***	-0.00080***
	-0.000664	-0.000179	-0.000763	-0.000205
Fiscal expenditure	0.193***	0.0174***	0.200***	0.022***
	-0.0207	-0.00542	-0.0228	-0.00603
rho	0.268**	-0.383**	0.250***	-0.082**
	-0.114	-0.154	-0.0509	-0.041
sigma2_e	0.0169***	0.00104***	0.0167***	0.00105***
	-0.000875	-0.0000538	-0.000872	-0.0000547
Observations	744	744	744	744
R-squared	0.574	0.271	0.476	0.242

According to the stepwise test of mediating effect, the estimation results of Model 10 and Model 12 show the following results: first, there is a significant relationship between the synergistic agglomeration of the two industries and high-quality economic development. And there is a significant relationship between the evolution of human capital structure and high-quality economic development; The estimation results of models 9 and 11 show that the synergistic

agglomeration of the two industries and the evolution index of human capital structure also show a relationship of promotion first and then inhibition, which indicates that the evolution of the evolution structure of human capital plays a mediating effect.

Specifically, the spatial autoregressive coefficients (rho) of Model 9 and 11 are 0.268 and 0.250, respectively, indicating that the optimization of human capital structure have a positive spatial spillover effect, which may be attributed to the following two aspects: First, when a region achieves higher quality economic development through the evolution of human capital structure, other neighboring regions will copy and imitate the behavior of improving human capital in this region due to the pressure of widening gap. Second, geographically adjacent provinces have more opportunities to exchange human capital, through which their human capital structure can be optimized. The coefficient of the primary term of industrial collaborative agglomeration is positive, and the coefficient of the quadratic term is negative. This inverted "U-shaped" curve indicates that the influence of industrial collaborative agglomeration on the optimization of human capital structure is promoting first and then inhibiting. The reason is that industrial collaborative agglomeration provides human capital with more job vacancy, higher salaries and more efficient exchange and learning opportunities. Thus, it can continuously attract talent inflow and improve the local human capital structure. However, when the agglomeration reaches a certain level, the disadvantages of agglomeration gradually appear, leading to the outflow of high-level human capital. Hypothesis 2 is proved.

The estimation results of model 10 and 12 show that the coefficients of the evolution index of human capital structure under the two matrices are 0.0188 and 0.0221, indicating that the optimization of human capital structure has a significant role in promoting high-quality economic development. There is an inverted "U" shaped relationship between industrial collaborative agglomeration and high-quality economic development, with the threshold values of 3.025 in the geographical adjacency matrix and 2.562 in the geographical distance matrix, which are higher than the thresholds of 2.590 and 2.472 in Model 1 and Model 2 respectively, indicating that after considering the mediating effect of human capital structure, the promoting effect of industrial cooperative agglomeration on high-quality economic development will be delayed, which verifies the mediating effect of the evolution of human capital structure again. Hypothesis 3 is verified.

4. Conclusions and policy recommendations

The main conclusions are as follows: First, in addition to Hong Kong, Macao and Taiwan, the high-quality economic development index of 31 provinces in mainland China has achieved substantial increase and their economic development level exists significant spatial heterogeneity, namely the average level in the east is greater than the Midwest, but the spatial correlation becomes significant year by year. Second, the relationship between industrial collaborative agglomeration and high-quality economic development shows an inverted "U" shape. When the agglomeration level exceeds the threshold, the positive externalities such as sharing effect, matching effect and learning effect brought by industrial agglomeration will be offset or even exceeded by the negative externalities such as high housing prices, high pollution and traffic congestion, thus suppressing the high-quality economic development. From the perspective of mechanism, there are direct and indirect mechanisms of synergistic industrial agglomeration on

high-quality economic development. On the one hand, collaborative industrial agglomeration has a direct impact on high-quality economic development through agglomeration effect and scale effect. On the other hand, industrial cooperative agglomeration also has an indirect effect through its influence on the evolution of human capital structure, in which the evolution of human capital structure plays a mediating effect. Third, the evolution of human capital structure is conducive to improving the level of high-quality economic development, and talent is an important support for high-quality economic development. At the same time, the evolution of human capital has a positive spillover effect. In addition, there is a relationship between industrial co-agglomeration and the evolution of human capital structure, that is, first promotes and then inhibits.

Based on the above research conclusions, the following three suggestions can be put forward:

To begin with, under the "two-wheel drive" effect of the collaborative agglomeration of manufacturing and financial industry, the eastern and western regions should constantly optimize the industrial structure in combination with their regional advantages, improve the level of economic development within the region, and narrow the inter-provincial development differences. At the same time, we should pay attention to strengthen the coordination division of labor and resource sharing among regions to reduce the regional polarization.

In addition, there is an inverted "U" shaped relationship between industrial collaborative agglomeration and high-quality economic development, which is characterized by promoting first and then inhibiting, but this does not mean that the level of industrial collaborative agglomeration should be controlled below the threshold. The continuous improvement of the degree of industrial collaborative agglomeration is the performance of the market mechanism, while the negative externality brought by industrial collaborative agglomeration is the performance of market failure. The government should take measures to improve the positive externality and reduce the negative externality to make up for the market defects, and delay the inhibitory effect of industrial collaborative agglomeration on the high quality of the economy. For example, the government can promote cross-industry knowledge spillover and technology coupling between financial industry and manufacturing industry through functional industrial policies, and enhance the positive externality of collaborative agglomeration of these two industries. In addition, high technology and advanced management can also be used to reduce the negative externality of industrial agglomeration and make regional economic operation more effective. For example, macro-control should be used to control the improving housing prices, new transportation such as subway and smart travel technologies can be used to alleviate congestion, and appropriate environmental regulations can be made to eliminate backward and heavily polluting production capacity.

What is more, government should attach great importance to the promoting effect of human capital on high-quality economic development, pay attention to the training of talents at different levels to optimize the structure of human capital, enhance the internal driving force of high-quality economic development by optimizing the structure of human capital, and release the indirect promoting effect of industrial synergistic agglomeration on high-quality economic development. In this process, the government should play a leading role in implementing the "education priority strategy" proposed by the 19th National Congress, give priority to cultivate local talents, and attract and retain high-end talents by creating a good talent development environment and improving the talent incentive mechanism. By combining these measures together, the

human capital structure can be optimized, thus promoting the high-quality economic development.

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