

# Study on the Coordinated Industrial Development of City Cluster in the Yellow River Basin

## -- Taking Guanzhong Plain as an Example

Haixin Huang

The University of Queensland, Brisbane, 4068, Australia

**Abstract.** Ecological protection and high-quality development in the Yellow River Basin, an important ecological shelter and economic zone in China, has become a priority during the 14th Five-Year Plan period. This study takes 11 municipalities in Guanzhong Plain city cluster in the Yellow River Basin as the research object. Location quotient, Krugman structural difference index, functional specialization index and improvement potential model have been used to calculate the indicators of coordinated industrial development of city cluster. The results show that: the development level within Guanzhong Plain city cluster is different, with a great difference in total economic volume and GDP growth rate. The spatial distribution of industries in Guanzhong Plain city clusters can be described as follow: Xi' an is the tertiary industry cluster area, Baoji, Xianyang, etc. are the secondary industry cluster area, and other cities are the primary industry cluster area. In terms of manufacturing and tertiary industry, municipalities in Guanzhong Plain city cluster demonstrate similar industrial structures, and the level of regional industrial specialization needs to be further improved. The division level of new industries in Guanzhong Plain city cluster is relatively low, and the regional industrial chain has not yet formed. According to the city potential value and geographical location, Guanzhong Plain city cluster is divided into three industrial functional areas: central area (Xi' an), intermediate area (Xianyang, Baoji, Weinan, Yuncheng, Shangluo, Tongchuan), and peripheral area (Tianshui, Qingyang, Pingliang, Linfen). In the end, based on the above conclusions, this study puts forward some suggestions to promote the coordinated industrial development in Guanzhong Plain city cluster.

**Keywords:** Yellow River Basin; Urban Agglomeration; Industrial Synergy; Industrial Functional Area; Industrial Chain.

### 1. Introduction

The yellow river basin, due to its wide coverage including Qinghai-Tibetan Plateau, Inner Mongolian Plateau, Loess Plateau and the Huanghuaihai Plain, owns rich natural resources and is densely populated. Thus, it is regarded as an important ecological reserve and economic zone in China, which is of great significance in well promoting our national economy and the construction of ecological environment. Compared with other areas, the Yellow River Basin has been bothered by the problems for long of lagging behind economic development, relatively large poor population, homogeneous pillar industries, water shortage, serious soil erosion, and poor living environment. Accordingly, Secretary-General Xi Jinping, on September 18, 2019, announced at the Symposium on Ecological Conservation and High-Quality Development of the Yellow River Basin that the protecting the Yellow River Basin has become a major national strategy. He also proposed that "protection should be a direct measure while improving governance is the fundamental way". He mentioned that "we should work together to protect the Yellow River and promote governance", and appealed to the people to "make the Yellow River a river for the benefit of the people"[1]. On October 8, 2021, the Central Committee of the Communist Party of China and the State Council issued the "Overall Plan for the Ecological Protection and High-Quality Development of the Yellow River Basin", which pointed out that we should put the environment first, remain committed to green development, save water, take water conservation as a priority, implement policies according to local conditions, and coordinate planning and promote collaborative efforts [2].

Although the ecological protection and high-quality development of the Yellow River Basin have achieved certain results driven by a series of national policies, the development of the Yellow River

Basin is unbalanced and insufficient between regions and cities due to different economic bases and resource endowments. Since industry is the primary factor to realize the coordinated development of cities and facilitate the flow of factors, promoting the synergistic development of industries in city clusters is the most important task to enhance their overall strength and realize ecological protection and high-quality development in the Yellow River Basin, which is the focus of China's work during the 14th Five-Year Plan. Guanzhong Plain City Group, one of the city clusters in the Yellow River Basin, is a pivot place due to its being near the Eurasian Continental Bridge. It is an important gateway for the western region to get to the east and central regions, and its comprehensive strength ranks second in China's inland regions. [3-5]. In this regard, this paper first took 11 prefecture-level cities in the Guanzhong Plain City Cluster in the Yellow River Basin as the research objects. Then, we measured the indicators of industrial synergistic development in the city cluster by adopting the location quotient, Krugman structural difference index, functional specialization index and an improved potential model. Next, we divided each area into three industrial functional areas based on the a value describing whether the potential for future development is huge or not. With the goal of building regional industrial chains, the division of labor and functional positioning of functional areas were clarified. Based on the findings of the study, countermeasures and suggestions for promoting the synergistic industrial development of the Guanzhong Plain Urban Agglomeration were proposed, so as to provide suggestions for achieving ecological protection and high-quality development in the Yellow River Basin.

The contribution of this paper lies in two aspects. First, it is an innovation in the research perspective. Compared with similar literature which studied individual cities, this paper took 11 prefecture-level cities in the Guanzhong Plain Urban Agglomeration in the Yellow River Basin as the research object, which ensures the hierarchy and integrality and help promote the synergistic development of regional industries. Second, it is an innovation in terms of research method. Compared with similar literature, this paper applied the location quotient, Krugman structural difference index, functional specialization index and improved potential model to measure the indicators of industrial synergistic development of urban clusters, which prevents the limitation of using a single method.

## 2. Literature Review

Industrial synergy provides fundamental support for regional synergistic development [6]. Generally, it refers to the spatial transfer of industries within a certain region caused by market forces or policy influences, and the orderly combination process of industries to achieve multi-level close collaboration in function (space). The industrial synergy, therefore, aims to promote industrial division of labor, which tends to be a vertical relationship between upstream and downstream [7]. That is, synergy and division of labor are unified. In other words, the synergy between elements is necessarily closely related to the division of labor.

Throughout the development process of China's regional industrial synergy policy, there are four stages of development. The first stage was the early stage of the founding of the country. In response to the situation that most of the industries at that time were distributed in the eastern coastal areas, which covered less than 12% of the land area, China formulated the "First Five-Year Plan", "Second Five-Year Plan", "Third Five-Year Plan" and "Fourth Five-Year Plan". The policy content mainly included balancing the industrial layout of coastal and inland areas, while implementing the "third-front movement" to relocate a number of key industrial enterprises to the inland third-tier regions [8].

In the second stage, after the reform and opening up, China formulated the "Fifth Five-Year Plan", "Sixth Five-Year Plan" and "Seventh Five-Year Plan" as well as the "Guangdong Province Special Economic Zone Regulations" etc. The policies mainly included the promulgation of preferential policies on foreign capital utilization, foreign exchange retention and taxation. In addition, the advantageous location and industrial base of the eastern region were used to promote the transfer of

key industries from the inland areas to the eastern coastal areas, and the degree of coordination of China's regional industries gradually deteriorated during this stage [9].

In the third stage, since the 1990s, the worsening of regional economic disparities and the gradual weakening of regional industrial coordination seriously affected the steady development of China's national economy and society. Regional coordinated development and industrial synergy gradually became the focus of China's work at this stage. Based on this, the government formulated a series of policies such as the Decision of the State Council on Current Industrial Policies, the National Industrial Program for the 1990s, the Basic Guidelines for the National Tertiary Industry Development Plan, the Interim Provisions on the Direction of Foreign Investment and the Outline of the Ninth Five-Year Plan and Vision 2010 for National Economic and Social Development to support and regulate the coordinated industrial development of the less developed regions in the central and western regions. These policies were issued in the hope of forming a pattern of national, regional and local industries in a hierarchical and synergistic development [10].

The fourth stage starts from the 21st century. Although the level of regional economic development and regional industrial coordination has been improved to a certain extent, the disparity among regions is still very large. Besides, China has entered the stage of rapid development of industrialization and urbanization, so the rough economic growth model is no longer suitable for the requirements of sustainable economic and social development in China. On this basis, China proposed a series of strategies including the Strategy for Large-Scale Development of Western China in 2000, the Strategy to Revitalize the Old Industrial Bases in Northeast China in 2003, the Strategy for the Rise of Central China in 2004, the Strategy for Coordinated Development in the Yangtze River Delta in 2010, the Strategy for Coordinated Development of the Beijing-Tianjin-Hebei Region in 2014, the Strategy for Development of Yangtze River Economic Belt in 2016, the Strategy for Construction of Guangdong-Hong Kong-Macao Greater Bay Area in 2016, the Strategy for Construction of the Yellow River Basin in 2019, and the Strategy for the Development of the Yellow River Basin Ecological Zone in 2019. These policies aim to build a new pattern of east-west, north-south, longitudinal and horizontal regional industrial development to form a regional economic pattern of coordinated development and complementary advantages [11].

Also, industrial synergy is a comprehensive industrial symbiosis network involving synergistic effects of many industries, which has the potential to improve the efficiency of industrial resources and provide economic benefits at the same time.[12]. By introducing concepts such as Green Social Network (GSN) and proximity, foreign scholars promoted industrial symbiosis and the formation of industrial synergy [13-14], and studied the synergistic effect of product innovation, process innovation, marketing innovation and organizational innovation [15]. As for domestic scholars, there are more research perspectives on the collaborative industrial development of urban clusters, including the following four aspects. (1) **Industrial spatial pattern**. Industrial spatial pattern includes two types: static and dynamic, both of which can provide a basis for industrial layout planning of urban agglomerations. Among them, static analysis can understand the current industrial spatial pattern status of city clusters, such as in which areas a certain industry or sector is mainly concentrated; while dynamic analysis can clarify the spatial transfer trend of industries in a certain time period [16-21]. (2) **Industrial division of labor theory and empirical analysis**. The former summarizes the general rule of industrial division of labor evolution in urban agglomerations, i.e., the transformation from the traditional regional division of labor stage to the new regional division of labor stage, which specifically refers to the transformation from inter-sector or inter-industry to intra-product division of labor, and then to industrial chain division of labor. Meanwhile, the division of labor content of each functional area is outlined. For example, the core area mainly focuses on tertiary industry, and the industrial chain links mainly focus on R&D, design and marketing, etc. [22-24]. The latter categorizes industries based on the industrial chain or value chain, and different cities are given different functional positioning [25] (3) **Industrial isomorphism**. With the help of industrial structure similarity coefficient, industrial structure difference index, structural overlap index, local specialization index, etc. [26], the regional specialization level and the degree of industrial

isomorphism among regions can be measured [30]. It has been shown that there is a negative relationship between industrial isomorphism and industrial efficiency [27], and the level of specialization of the area is reduced [28] (4) **Industrial synergy influencing factors, paths and mechanisms**. By analyzing the current situation of industrial synergy, we identify the factors that hinder or affect the development of synergy, and proposed ways and mechanisms to solve these problems [29-31]. Chu's research was representative. Based on symbiotic thinking and industrial planning, he proposed that the planning perspective of "industry = location + layout + structure + cluster" should be established for the Beijing-Tianjin-Hebei city cluster, and outlined the laws and influencing factors of Beijing-Tianjin-Hebei industrial synergy development [32]. Li et al. applied the models like Spatial Dubin to propose that there is spatial heterogeneity in the effects of five major mechanisms( echnological innovation, basic investment, financial services, fiscal expenditure, and "Internet+") on different types of sub-regions in the Yangtze River Delta.

In summary, the research on industrial synergistic development of the Yellow River Basin urban agglomerations is still in the exploratory stage. The current research mainly focuses on theoretical and empirical studies on the industrial spatial pattern of urban agglomerations, industrial division of labor, industrial isomorphism, industrial synergistic influencing factors, paths and mechanisms, and industrial synergistic degree and effects. Theoretical and empirical studies on the synergistic development of industries in the Yellow River Basin city cluster are lacking. At the same time, most of the similar literature still focuses on a certain city, which lacks hierarchy and integrity and makes the implementation of industrial synergistic development planning more difficult. In this paper, based on the absorption of existing studies, we use the location quotient method, Krugman structural difference index method, functional specialization index and improved potential model to measure the level of industrial synergistic development of 11 prefecture-level cities in the Guanzhong Plain city clusters in the Yellow River basin, and propose countermeasures to promote the industrial synergistic development there.

### 3. Research Methodology and Data Source

#### 3.1 Data Source

The research in this paper focuses on the current degree of industrial synergistic development of the Guanzhong Plain city cluster in the Yellow River basin and the division of three industrial functional areas (the core radiation area, the intermediate support area and the peripheral linkage area). Due to the availability and uniformity of data, this paper calculated the results of various indicators of industrial synergy development of Guanzhong Plain city clusters in 2019 or 2020. The data used are mainly from the documents related to the statistical bulletin on national economic and social development of 11 prefecture-level cities in Guanzhong Plain City Cluster in 2020 and China Statistical Yearbook (2020), China Statistical Yearbook on Population and Employment (2020), China Statistical Yearbook on Cities (2020) and statistical yearbooks of each city. In addition, since the data of Pingliang City in 2019 were missing, the trend line was deduced using the statistical yearbook data of the region from 2012-2018, and finally the relevant industry data were obtained.

#### 3.2 Research Methodology

##### 3.2.1 Location Quotient (L.Q.)

Location quotient is an indicator used to measure the degree of industrial agglomeration and indicates the level of specialization of industries in a given area [27]. The basic formula is as follows.

$$LQ_{ij} = \frac{q_{ij}/q_j}{q_i/q} \quad (1)$$

In this formula,  $q_{ij}$ ,  $q_i$ ,  $q_j$ , and  $q$  denote the total output value of city industry, the national output value of industry, the total output value of city, and the national output value respectively.  $LQ_{ij}$

is the specialization index of the industry  $i$  of city  $j$ . If the index value is greater than 1, it means that the industry has a high degree of concentration and national specialization in the city; Else, it means that the industry has a relatively low degree of concentration in the city and does not have specialization.

### 3.2.2 Krugman Index

The index is mainly used to measure the degree of variation in the industry among cities [24], which can be described as follows.

$$KI_{ij} = \sum_{k=1}^n |X_{ik} - X_{jk}| \quad (2)$$

$X_{ik}$  and  $X_{jk}$  here stand for the proportion of industry  $k$  in city  $i$  and  $j$ .  $KI_{ij}$  is the sign of Krugman index (0~2). The larger the index, the greater the industry differentiation and higher the specialization level among cities; and vice versa. In the paper, the Krugman index of manufacturing industry is calculated mainly using the annual data of main business income of industrial enterprises above the scale, while the Krugman index of tertiary industry is measured by the number of urban units employed at the end of the year.

### 3.2.3 Functional Specialization Index

With the deepening of regional integration, the division of labor among cities gradually changes from traditional to modern, i.e., the competitiveness of regional industries is enhanced, not only by focusing on the industrial specialization of cities, but also by making the positioning of cities clear and their functions complementary. The basic formula of measurement is as follows [41].

$$FS_i = (L_{i \text{enterprise managers}} / L_{i \text{production personnel}}) / (L_{N \text{enterprise managers}} / L_{N \text{production personnel}}) \quad (3)$$

In this formula,  $L_i$  stands for the employment status of region  $i$ ,  $L_N$  for that of the whole nation. The number of urban rental and business services employees for enterprise managers, and the number of urban manufacturing, mining and electricity, heat, gas and water production and supply employees for production personnel. If  $FS > 1$ , it means that the regional management sector is more concentrated and the level of functional specialization is high; If  $FS$  tends to 0, it means that the regional production sector is more concentrated and the level of functional specialization is low; If  $FS$  tends to 1, the new regional division of labor is not obvious.

### 3.2.4 Improved Potential Model

The potential model is able to measure the energy level of each region in the region. The basic steps are as follows: first, we got the gravity value by calculating the interrelations and interactions between regions in the region through the gravity model; then we calculated the weights, i.e. the contribution of a region in the urban agglomeration to the gravity value; finally, we can get the regional potential value. The basic formula is as follows.

$$I_r = \kappa_{rs} \sum_{s=1}^n X_{rs} \quad (4)$$

$\kappa_{rs}$  here represents the contribution of region  $r$ , which can be calculated by

$$\kappa_{rs} = \frac{Y_r}{Y_r + Y_s} \quad (5)$$

The gravity model is the basis of the potential model, which is a measure of the degree of interaction between regions. Since its introduction into the field of urban cluster research, it has been continuously revised and improved. The article has drawn on the research experience of other scholars in the process of applying the model [42-43], and revised the formula shown below.

$$X_{rs} = C_{rs} \frac{\gamma_r^\alpha \gamma_s^\beta}{d_{rs}^\delta} (r \neq s; r, s = 1, 2, \dots, n) \tag{6}$$

$$C_{rs} = \sum_{k=1}^n (E_{rk} - E_{sk}) \tag{7}$$

$$E_{rk} = \frac{Z_{rk}}{\sum_{r=1}^n Z_{rk}} \tag{8}$$

$$Z_{rk} = (L_{r\text{enterprise managers}}/L_{r\text{production personnel}})/(L_{N\text{enterprise managers}}/L_{N\text{production personnel}}) \tag{9}$$

Here,  $X_{rs}$  represents the gravity between two countries (r, s).  $Y_i$  (i = r, s) stands for the city quality of city i. Based on studies conducted by Wang and Niu, [33], Luo and Feng [34], Xiang [35], Zou, [36], The regional quality evaluation index system is constructed from five dimensions, including the level of economic development, infrastructure, social development level, environmental quality and regional communication status (see Table 1 for details);  $d_{rs}$  Indicates the straight-line distance between two regions.  $\alpha$  and  $\beta$  are usually set as 1, and distance decay index  $\delta$  as 2 [33-34].  $C_{rs}$  is the industry coefficient, indicating the complementarity of the two regions.  $E_{rk}$  and  $E_{sk}$  refer to the share of the city group in the outward functional volume of the industry  $k$  in the two regions, respectively.  $Z_{rk}$  is the city function specialization index.

**Table 1.** Regional Quality Evaluation Index System

Target layer	Primary index	Sub-categories	Unit
City quality	level of economic development	General budget revenue	10 thousand
		Total fixed assets investment	100 million
		Industrial value added	100 million
		Gross Regional Product	10 thousand
		Value-added ratio of tertiary industry	%
	infrastructure	Public Library Collection	10 thousand
		Urbanization rate	%
		Number of Hospitals	buildings
	social development level	Per capita disposable income of urban residents	yuan
		General higher education students	10 thousand
		Total retail sales of social consumer goods	10 thousand yuan
	regional environmental quality	Comprehensive utilization rate of general industrial solid waste	%
		Greening coverage of built-up areas	%
		Harmless disposal rate of domestic waste	%
	regional communication status	Revenue from postal services	10 thousand yuan
Number of Internet users		10 thousand households	
Number of cell phone subscribers		10 thousand households	

## 4. Status Quo of the City Clusters' Coordinated Development in Guangzhong Plain

### 4.1 Overview

The Guanzhong Plain City Cluster, with a "new first-tier" city Xi'an being its center, spans three provinces: Shaanxi, Shanxi and Gansu. The regional scope includes six cities in Shaanxi Province (Xi'an, Xianyang, Baoji, Weinan, Tongchuan and Shangluo), two cities in Shanxi Province (Linfen and Yuncheng), and three cities in Gansu Province (Tianshui, Pingliang and Qingyang). Guanzhong Plain City Cluster is the starting point of the ancient Silk Road, an important pivot point of the Asia-Europe Continental Bridge, and an important gateway for the western region to the east and central regions. Its comprehensive strength ranks the second inland region in China. Since Guanzhong Plain City Cluster links the east and west, and north and south, taking its advantages in location into account will facilitate its development. Not only is it beneficial to promote the western development strategy and support the development of the northwest region, but it is also conducive to promoting national economic growth and market space from east to west and from south to north, and even to the continued promotion of China's "Belt and Road" strategy.

### 4.2 Development Status

Regional development levels within the city cluster vary, with large differences in total economic volume and GDP growth rates. The GDP of Xi'an is about 26 times greater than that of Tongchuan.

**Table 2.** Industrial Output Value and Industrial Structure of Guanzhong Plain City Cluster in 2020

Region	Structure (%)	Industry value added and growth rate					
		Primary Industry		Secondary Industry		Tertiary Industry	
		value added (100 million)	growth rate(%)	value added(100 million)	growth rate(%)	value added(100 million)	growth rate(%)
Xi'an	3.1:33.2:63.7	312.75	3.00	3328.27	7.40	6379.37	4.20
Xianyang	15.4:44.1:40.5	339.51	3.10	972.00	-1.10	893.31	0.40
Baoji	9.0:55.4:35.6	205.14	3.40	1261.18	4.30	810.63	1.70
Weinan	20.0:34.9:45.1	373.69	3.70	651.54	-1.20	841.04	-0.10
Tongchuan	8.1:34.9:57.0	30.76	4.00	133.34	2.30	217.65	7.10
Shangluo	15.5:36.0:48.5	114.49	2.90	265.94	-24.20	359.02	-1.00
Linfen	7.5:42.9:49.6	113.4	4.00	645.6	6.20	746.2	1.70
Yuncheng	16.3:34.1:49.6	267.9	4.10	561	7.50	814.7	4.10
Tianshui	18.9:24.3:56.8	126.01	5.60	161.82	4.90	379.06	5.10
Pingliang	23.1:24.5:52.4	109.85	5.60	116.70	1.20	249.61	4.00
Qingyang	12.9:47.2:39.9	97.62	5.50	356.36	5.60	300.75	1.90

Data source: compiled based on the 2020 National Economic and Social Development Statistical Bulletin documents of each municipality.

Regions with the largest value added in the primary industry include Weinan, followed by Xianyang, Xi'an and Yuncheng, while other regions have smaller value added, especially Tongchuan, which is only 30.76. As for the growth rate of value added in the primary industry, Tianshui and Pingliang come the first, followed by Qingyang, Tongchuan and Weinan, and the slowest growth rate is seen in Shangluo, which is 1.9 times lower than that of Tianshui. In the secondary industry, the regions with the highest value added include Xi'an, Baoji and Xianyang, with the lowest value added in Pingliang; the fastest growth rate is seen in Xi'an (7.4%), while Xianyang, Weinan and Shangluo decrease. When it comes to the growth rate of tertiary industry, it is high in general, with an average

growth rate of 2.65% for the whole region; however, the gap in value added of industry is large, 25.56 times, which is much higher than the other two industries.

From the perspective of the structure of the three industries, the regional average ratio is 12.72:45.03:42.25; the gap between the secondary and tertiary industries is small, and the structure shows an olive-shaped trend. Xi'an, Yuncheng, Pingliang and Tianshui are dominated by tertiary industries, among which Xi'an has entered the post-industrialization stage with a 63.7% share of tertiary industries; Yuncheng and other three regions account for a high share of tertiary industries, but the share of primary industries is all above 14%. The industrial structure of Xianyang, Baoji, Weinan, Tongchuan, Shangluo and Qingyang is "2-3-1" type, with the proportion of the secondary industry above 35%, which means that the secondary industry is the main driving force of economic development (See Table 2 for details).

The above description of the Guanzhong Plain City Cluster shows that there are obvious differences in the industrial gradient within the region, which is conducive to the complementary industries and reasonable division of labor between regions.

### 4.3 Regional Industry Spatial Pattern

The synergistic development of industries has distinct spatial characteristics. The spatial distribution pattern of industries in the Guanzhong Plain City Cluster is analyzed via the location quotient calculation of the degree of industrial agglomeration in each region. By substituting the data into equation (1), the location quotients of the secondary and tertiary industries in each region of the Guanzhong Plain city cluster are obtained, and the spatial distribution is shown in Figure 1a and Figure 1b.

**Table 3.** Location Quotient Value of Secondary and Tertiary Industries in Guanzhong Plain City Cluster in 2020

Region	LQ of secondary industry	Rank	Region	LQ of tertiary industry	Rank
Baoji	1.46	1	Xi'an	1.17	1
Qingyang	1.25	2	Tongchuan	1.05	2
Xianyang	1.17	3	Tianshui	1.04	3
Linfen	1.13	4	Pingliang	0.96	4
Shangluo	0.95	5	Linfen	0.91	5
Tongchuan	0.92	6	Yuncheng	0.91	6
Weinan	0.92	7	Shangluo	0.89	7
Yuncheng	0.90	8	Weinan	0.83	8
Xi'an	0.88	9	Xianyang	0.74	9
Pingliang	0.65	10	Qingyang	0.73	10
Tianshui	0.64	11	Baoji	0.65	11

Overall, the industrial distribution of the Guanzhong Plain City Cluster presents a spatial pattern in which the tertiary industry gathering in Xi'an, the secondary industry gathering in Baoji and Xianyang, and other regions are where the primary industries are densely distributed. In Table 3, the areas with secondary industry LQ greater than 1 include Xianyang, Baoji, Linfen and Qingyang, which are mainly concentrated in the middle of the region. The tertiary industry is mainly concentrated in Xi'an, Tongchuan and Tianshui, while the LQ of other regions is less than 1, and no specialization has been formed. From the perspective of specific industries, the dominant industries in the secondary industry cluster are mainly food manufacturing, wine, beverage and refined tea manufacturing, petroleum processing, coking and nuclear fuel processing, pharmaceutical

manufacturing and non-metallic mineral products, etc.; while the dominant industries in the tertiary industry are transportation, storage and postal services, accommodation and catering, finance, scientific research, technical services and geological exploration, water conservancy, environment and public facilities management, etc. Management industry and other industries have obvious advantages.

#### 4.4 City-to-city Industry Discrepancy

Industrial specialization is an important aspect of studying regional industrial coordination, which can reflect the characteristics of division of labor and complementarity between industries within urban clusters. In this paper, the Krugman index is applied to measure the status of industry division of labor level among urban cluster regions. Since the development of mining industry in primary and secondary industries requires higher natural factors, the industries selected were mainly manufacturing and tertiary industries to measure the regional industry division of labor index, as shown in Table 4.

**Table 4.** Table of Typical Industries for Measuring the Krugman Index

Industry	
Agricultural and sideline food processing industry	Food Manufacturing
Wine, beverage and refined tea manufacturing	Tobacco products industry
Textile industry	Textile and apparel industry
Leather, fur, feathers and their products and footwear industry	Wood processing and wood, bamboo, rattan, palm, grass products industry
Furniture Manufacturing	Paper and paper products industry
Printing and recording media reproduction industry	Culture, education, industry, sports and recreational goods manufacturing
Petroleum processing, coking and nuclear fuel processing industry	Chemical raw materials and chemical products manufacturing
Pharmaceutical manufacturing	Chemical fiber manufacturing
Rubber and plastic products industry	Non-metallic mineral products industry
smelting and pressing of ferrous metals	Non-ferrous metal smelting and rolling processing industry
metal product industry	General Equipment Manufacturing
Special equipment manufacturing	Automotive Manufacturing
Railroad, ship, aerospace and other transportation equipment manufacturing	Electrical machinery and equipment manufacturing
Computer, communications and other electronic equipment manufacturing	Instrument manufacturing
Other Manufacturing	Comprehensive utilization of waste resources industry
Metal products, machinery and equipment repair industry	Electricity, heat production and supply industry
Gas production and supply industry	Water production and supply industry
Accommodation and catering industry	Information transmission, computer services and software industry
Financial Industry	Real Estate
Leasing and business services	Scientific research, technical services and geological prospecting industry
Water, environment and public facilities management industry	Residential services, repairs and other services
Wholesale and retail trade	Transportation, storage and postal industry

According to the formula (2), the diversity degree of each industry among the regions of Guanzhong Plain City Cluster can be calculated. From Table 5, it can be seen that the average value

of Krugman index of manufacturing industry in Guanzhong Plain City Cluster is 1.02, which indicates that the discrepancy degree of industrial structure among city cluster regions is low and the level of regional industrial specialization needs to be further improved. Among them, Tianshui has the largest mean value of Krugman index, which indicates that the industrial structure difference between this area and other cities in the region is relatively large and its industrial specialization level is high. The Krugman index of Tongchuan, Xianyang and Weinan is about 0.9, demonstrating that the level of industrial specialization in these areas is low and the industrial isomorphism is strong. In terms of tertiary industries, the industry Krugman indices are all relatively low among cities (See Table 6 for details). In other words, the tertiary industry categories are relatively complete among the regions within the Guanzhong City Cluster, but the degree of industry specialization is not high.

**Table 5.** Krugman Structural Difference Index of Manufacturing Industries among the Guanzhong Plain City Cluster Regions in 2019

Region	Xi'an	Tongchuan	Baoji	Xianyang	Weinan	Shangluo	Yuncheng	Linfen	Tianshui	Pingliang	Qingyang
Xi'an		1.0852	1.0327	1.0488	1.2265	1.1647	1.3979	1.4246	1.0072	1.2470	1.3072
Tongchuan	1.0852		0.9567	0.9424	0.8740	0.7716	1.0948	0.9779	1.0320	0.5283	0.8450
Baoji	1.0327	0.9567		0.9364	1.0692	0.7072	1.0021	1.1962	1.3079	1.0185	1.1738
Xianyang	1.0488	0.9424	0.9364		0.7663	0.8150	0.9841	0.9986	1.1574	0.9044	0.9160
Weinan	1.2265	0.8740	1.0692	0.7663		0.9950	0.5607	0.6179	1.2759	0.8673	0.8789
Shangluo	1.1647	0.7716	0.7072	0.8150	0.9950		1.0705	1.2510	1.0324	0.8272	1.0555
Yuncheng	1.3979	1.0948	1.0021	0.9841	0.5607	1.0705		0.5085	1.5705	1.2277	0.9237
Linfen	1.4246	0.9779	1.1962	0.9986	0.6179	1.2510	0.5085		1.4580	1.1033	0.5797
Tianshui	1.0072	1.0320	1.3079	1.1574	1.2759	1.0324	1.5705	1.4580		0.9874	1.2896
Pingliang	1.2470	0.5283	1.0185	0.9044	0.8673	0.8272	1.2277	1.1033	0.9874		0.9203
Qingyang	1.3072	0.8450	1.1738	0.9160	0.8789	1.0555	0.9237	0.5797	1.2896	0.9203	
Average	1.1941	0.9107	1.0401	0.9469	0.9132	0.9690	1.0341	1.0116	1.2118	0.9631	0.9890

Note: The data are calculated and compiled according to the relevant formula.

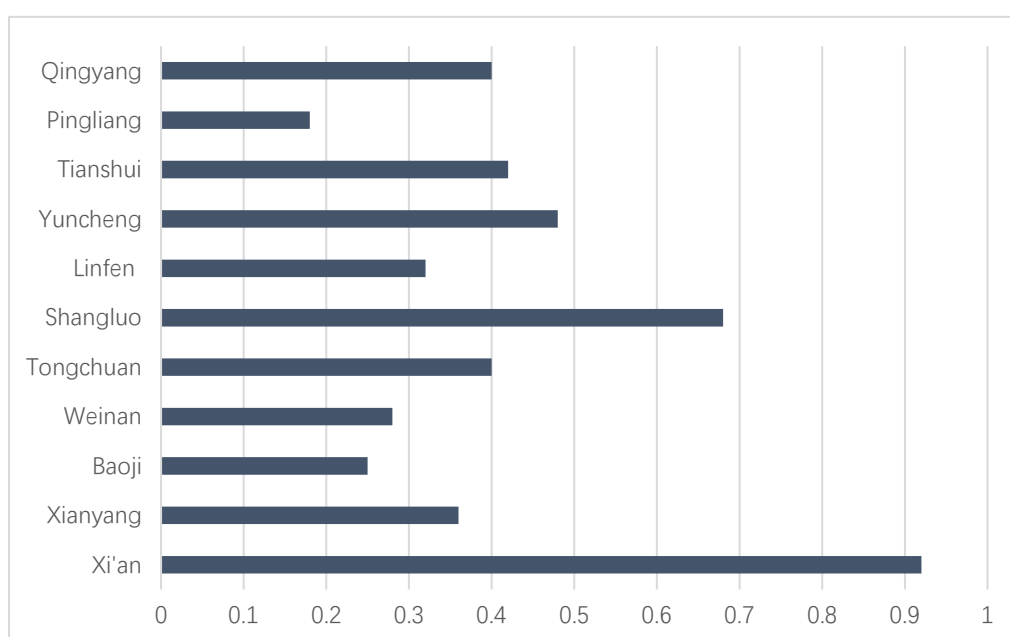
**Table 6.** Krugman Structural Difference Index of Tertiary Industry among Guanzhong Plain City Cluster Regions in 2019

Region	Xi'an	Tongchuan	Baoji	Xianyang	Weinan	Shangluo	Yuncheng	Linfen	Tianshui	Pingliang	Qingyang
Xi'an		0.2308	0.2397	0.2692	0.2540	0.2729	0.2903	0.2198	0.2479	0.2948	0.2447
Tongchuan	0.2308		0.0775	0.0749	0.0911	0.0570	0.1504	0.1886	0.0485	0.0977	0.0747
Baoji	0.2397	0.0775		0.0777	0.0802	0.0942	0.1554	0.1654	0.0901	0.1010	0.0675
Xianyang	0.2692	0.0749	0.0777		0.0585	0.0527	0.1084	0.1322	0.1861	0.0401	0.0597
Weinan	0.2540	0.0911	0.0802	0.0585		0.0937	0.1490	0.1582	0.0945	0.0774	0.0743
Shangluo	0.2729	0.0570	0.0942	0.0527	0.0937		0.1229	0.1519	0.0525	0.0650	0.0481
Yuncheng	0.2903	0.1504	0.1554	0.1084	0.1490	0.1229		0.1083	0.1632	0.1236	0.1404
Linfen	0.2198	0.1886	0.1654	0.1322	0.1582	0.1519	0.1083		0.1951	0.1236	0.1356
Tianshui	0.2479	0.0485	0.0901	0.1861	0.0945	0.0525	0.1632	0.1951		0.1022	0.0677
Pingliang	0.2948	0.0977	0.1010	0.0401	0.0774	0.0650	0.1236	0.1236	0.1022		0.0745
Qingyang	0.2447	0.0747	0.0675	0.0597	0.0743	0.0481	0.1404	0.1356	0.0677	0.0745	
Average	0.2564	0.1091	0.1148	0.1059	0.1130	0.1010	0.1511	0.1578	0.1247	0.1099	0.0987

Note: The data are calculated and compiled according to the relevant formula.

#### 4.5 Functional Specialization Level

With the constant improvement of division of labor, the spatial division of labor in city clusters gradually transits to the industrial chain division of labor. That is, the new industrial division of labor keeps developing. The degree of division of labor in urban agglomerations can be measured by the functional specialization index (equation 3). As can be seen in Figure 1, the functional specialization index of the Guanzhong Plain City Cluster is 0.42, indicating that the new industrial division of labor in the region is low and the regional industrial chain has not yet been formed. Among the prefecture-level cities, only Xi'an has the largest functional specialization index of 0.92, which tends to be 1, demonstrating that it will be in the upstream of the industrial chain in the new industrial division of labor in the urban agglomeration; the FS of other regions is mostly less than 1 and tends to be 0, indicating that the production sectors are more concentrated and will be in the middle and lower reaches in the process of building the regional industrial chain.



**Figure 1.** Functional Specialization Index of Guanzhong Plain City Cluster and each city in 2019

### 5. Development Directions of Industrial Synergy in Guanzhong Plain City Cluster

The current situation and problems of regional industrial synergy development have been analyzed above. Then, how to solve these problems and promote regional industrial synergy development is the focus of this section. Firstly, by calculating the potential value of each region through the potential model, we can clarify the spatial structure of the city cluster and divide the Guanzhong Plain City Cluster in the Yellow River Basin into three industrial functional areas including core zone, intermediate support zone and peripheral linkage zone based on the spatial geographic location of each region. Then, based on each region's own advantages, we explored the industrial development direction of each industrial functional area based on its function or position and role in the regional industrial chain division of labor system.

#### 5.1 Division of Functional Zone

By substituting the data into equations (3)-(8), the potential values of each region can be obtained. According to Table 7, it can be seen that there is a large difference in the potential values of the Guanzhong Plain urban agglomeration regions, and the spatial structure shows a typical monocentric development pattern. Xi'an city enjoys the largest potential value and is at the absolute core; followed

by Xianyang and Weinan, while Pingliang and Tianshui have the smallest potential value, with a significant difference of 227 and 138 times from Xi'an city, respectively. Drawing on the research done by Xiang[35], Zou et al.,[36], Li [37] and Liu[38], together with the potential value of each region and its spatial location, the city cluster can be divided into three different levels of industrial functional areas. First, the core radiation zone – Xi'an. Xi'an has the highest regional potential value, indicating that the region has strong gathering effect and attractiveness to other regions, and is the pivot that determines the economic growth of the city cluster. It is in the center of spatial geographic location, which facilitates the development of other regions in the region by radiation. The second is the intermediate support zone, which includes Weinan, Baoji, Yuncheng, Xianyang, Shangluo and Tongchuan. These six areas have relatively high potential values, well-developed secondary industries and a good industrial base; they are in the middle of the three industrial functional areas and can serve as a development base for advanced manufacturing industries and a place to undertake industrial transfer from the core zone, as well as a major driving zone for the development of peripheral zone. The third is the peripheral zone, covering Qingyang, Tianshui and other 4 surrounding areas. These areas have low potential value, high proportion of primary and tertiary industry output value, high potential for tourism development, and good ecological and environmental protection, and can be taken as peripheral zone of urban clusters.

**Table 7.** Potential Values for the Guanzhong City Cluster Regions in 2019

Region	Potential Value	Region	Potential Value	Region	Potential Value
Xi'an	135.5483	Yuncheng	3.4698	Qingyang	1.0001
Xianyang	60.7632	Baoji	2.0069	Pingliang	0.9811
Weinan	10.7823	Shangluo	1.8573	Tianshui	0.5972
Tongchuan	5.9863	Linfen	1.4999		

Note: The data are calculated and compiled according to the relevant formula.

## 5.2 The Direction of Industrial Development in Different Industrial Functional Areas

The development of different industrial functional areas is based on the regional industrial division of labor, and only a reasonable division of labor can promote the synergistic development of industry, which in turn makes the region form a reasonable division of labor and a pattern of staggered development. According to the position and functions of different industrial functional areas in the regional industrial division of labor, and with reference to the experience of the Yangtze River Delta, Beijing-Tianjin-Hebei and other city groups in industrial cooperative development, the industrial development direction of industrial functional areas is explored.

On the whole, (1) The core zone focuses on the development of the economy of central areas and assumes the functions of industrial chain division of labor such as scientific and technological research and development, marketing and training. It is able to develop strategic emerging industries, further enhance modern service industry and high-tech industry. The details are as follows. (2) Intermediate support zone, which accelerates the pace of development of advanced manufacturing and high-tech industries, while focusing on the production and processing of key components and services, optimizes the industrial structure and accelerates the transformation and upgrading of traditional manufacturing industries. (3) Peripheral zone, mainly for general manufacturing, focuses on general parts manufacturing, product assembly and testing and other links, and develop tourism and other advantageous industries according to local conditions. The details are as follows.

**The core zone.** On the whole, the core zone is the economic growth pole in the region, which has the role of radiating the economic development of the surrounding areas. Xi'an is the only central city of national level in the Guanzhong Plain City Cluster and is located at the center of the city cluster, so it has advantages that cannot be matched by other regions and can play a strong role in radiation.

Compared with other cities in this cluster, Xi'an has more research institutions, colleges and universities, richer research and education resources, stronger historical and cultural deposits, and more diversified culture; it has rather complete infrastructure (convenient transportation) and more available access to information.

Therefore, on the one hand, based on these advantages mentioned above, we should attract more influential international and domestic enterprises to settle in the city and accelerate the economy development of the core zone, take advantage of resources such as technology and talents to improve the innovation ability of industrial functional areas and engage in the production of high value-added parts of products. Meanwhile, we should actively participate in the international industrial division of labor and enhance the position of Xi'an in the international value chain division of labor.

On the other hand, we should make more innovation in key areas of advantageous industries and continue to grow high-tech industries and advanced manufacturing industries such as automobile manufacturing, railroad, ship, aerospace and other transportation equipment manufacturing, electrical machinery and equipment manufacturing, computer, communication and other electronic equipment manufacturing and instrumentation manufacturing. In addition, it is necessary to transfer the energy-consuming industries to the intermediate support zone and peripheral zone, which includes petroleum processing, coking and nuclear fuel processing industry, non-ferrous metal smelting and rolling processing industry and ferrous metal smelting and rolling processing industry. In this way, we can not only radiate and drive the development of other industrial functional areas, but also reduce the regional pressure on water, electricity and other energy sources.

**Intermediate support zone.** It is in the middle of the other two industrial functional areas, with the function of "linking the upper zone and the lower one". "Linking to the upper zone" refers to the industrial interface and cooperation with the core radiation. It provides the core area with supporting facilities and services required for industrial development. "Linking the lower zone" refers to the driving effect on the development of industries and technologies in the peripheral linkage areas. Six regions, including Weinan, Baoji, Tongchuan, Shangluo and Xianyang, can serve as the component units of the intermediate support zone of the city cluster because of their high regional potential values and good industrial foundation. The industrial structure of this area is dominated by secondary industries, and it will take advantage of the regional advantages to create an automotive industry cluster consisting of Xi'an-Baoji-Yuncheng-Xianyang-Weinan, as well as to form Xi'an-Shangluo-Yuncheng-Qingyang-Tianshui pharmaceutical manufacturing industry. However, the development of high-tech industries and advanced manufacturing industries is relatively slow, while the industrial structure differs greatly from the core zone, which has certain restrictions on the extension of the regional industrial chain.

Therefore, on the one hand, based on the good industrial foundation, low cost and other advantages, this zone should undertake some industries transferred from the core area. Meanwhile, it needs to transform and upgrade the overcapacity industries and make full use of the construction of Silk Road to accelerate the pace of de-capacity; transfer the general manufacturing industries that do not have advantages to the peripheral linkage area, and provide them with technical and financial support. On the other hand, it should focus on high-tech industries and advanced manufacturing industries, speed up the construction of industrial parks and create a superior environment in order to cultivate and attract high-end talents. Also, it should accelerate the development of tertiary industries such as transportation, finance and insurance, and optimize the industrial structure of industrial functional areas.

**Peripheral zone.** The potential value of all four areas in this zone is small, which indicates that the attractiveness to other areas is low. Moreover, it is far away from the core zone and is in the outskirts of the urban cluster. Thus, the communication between the two industrial functional areas is hindered, and the possibility of enjoying an associated benefits from the core zone is low.

This industrial functional area, while formulating its own development plan, should be based on its own advantages. It is not wise to develop industries without comparative advantages merely for improving the industrial system. For example, in the process of regional industrial division of labor,

it can engage in the middle and low-end part of the industry as well as give priority to the development of general manufacturing industries, such as agricultural and sideline food processing industry, tobacco products industry, textile industry, etc. Specifically, the primary industry in the four regions has relatively high output value and good agricultural foundation, but the accessibility among regions is poor, so the agricultural products offered to other industrial functional areas should be those in shortage and easy to preserve. In terms of industry, the advantageous industries of the four regions are more concentrated in wine and beverage manufacturing and agro-food processing industries, while other industries are lacking and have not formed advantageous industries, so they can further expand these industries. Moreover, they can take advantage of lower costs to undertake industries transferred from other industrial functional areas and drive the economic development of these industrial functional areas. As for service industry, the region's natural advantages are used to build special tourist scenery and accelerate the development of tourism.

## 6. Conclusion and Policy Proposals

Promoting the collaborative industrial development of the city clusters in the Yellow River Basin is the focus of China's 14th Five-Year Plan period. This paper employed the location quotient, Krugman structural difference index, functional specialization index and improved potential model to measure the indicators of the urban clusters, and divided them into three industrial functional areas based on the spatial geographic location of each area, aiming at building a regional industrial chain and clarifying the division of labor and functional positioning of the functional areas. The study found that:

Firstly, the development levels of regions within the city cluster are different, especially in total economic volume and GDP growth rates. The GDP of Xi'an is about 26 times greater than that of Tongchuan. The largest value added of primary industry is seen in Weinan, and the fastest growing cities are Tianshui and Pingliang. The regions with the highest value added of secondary industry include Xi'an, Baoji and Xianyang, and the fastest growing city is Xi'an. The growth rates of tertiary industry are all high, and the average growth rate of the whole region is 2.65%. Among them, Xi'an, Yuncheng, Pingliang and Tianshui are dominated by tertiary industry, and Xianyang, Baoji, Weinan, Tongchuan, Shangluo and Qingyang are dominated by the secondary industry.

Secondly, the spatial distribution of industries in the Guanzhong Plain City Cluster is analyzed by the location quotient. On the whole, the spatial distribution of industries in the Guanzhong Plain City Cluster shows a spatial pattern in which Xi'an is a tertiary industry cluster, Baoji and Xianyang are secondary industry clusters, and other areas are primary industry clusters.

Thirdly, with the help of Krugman index, the status of industry division of labor among city cluster regions was measured. It is found that the average value of industry Krugman index of Guanzhong Plain City Cluster is 1.02 in terms of manufacturing industry, which indicates that the degree of industrial structure difference among different regions is low and the regional industrial specialization needs to be further improved. Among them, the average value of Krugman index in Tianshui City is the largest, so its industrial specialization level is higher; the Krugman index in Tongchuan, Xianyang and Weinan is smaller, so its industrial specialization level is lower. From the viewpoint of tertiary industry, the Krugman index of industries among cities is relatively low, that is, the industry categories of tertiary industry among regions within the Guanzhong City Cluster are relatively complete, but the degree of industry specialization is not high.

Fourthly, the functional specialization index of the Guanzhong Plain City Cluster is 0.42, which means that the level of new industrial division of labor in the region is low and the regional industrial chain has not yet been formed.

Fifthly, by improving the potential model to measure the potential value of each region in the city cluster, it is found that there is a large difference in the potential value among these regions. The spatial structure there shows a typical monocentric development pattern. Xi'an has the highest potential value and is in the absolute core, followed by Xianyang and Weinan, while Pingliang and

Tianshui show the lowest potential value. Combining the potential values of each region and their spatial locations, the city cluster can be divided into three different levels of industrial functional areas: core radiation area (Xi'an), intermediate support area (Xianyang, Baoji, Weinan, Yuncheng, Shangluo, Tongchuan), and peripheral linkage area (Tianshui, Qingyang, Pingliang, Linfen).

Based on these findings, we made the following policy proposals.

**First of all, the government should play a guiding role and establish a sound institutional mechanism.**

Reasonable government's guidance is the prerequisite to realize the regional industrial synergistic development. The construction of Guanzhong Plain City Cluster is in its initial stage, and the three provinces have not yet issued and formulated unified industrial synergy policy, so the industrial development of each region is still in a scattered state. Therefore, forming a synergy and thus promoting coordinated regional development is the primary task for the three provinces. The three governments play their planning-oriented role from the strategic perspective of the high-quality development of the Yellow River Basin, and draw up strategies for the collaborative development of industries in the three provinces to guide the reasonable division of industries and avoid duplication of construction among regions and prevent disorderly competition within the cluster. The establishment of institutional mechanisms such as innovation, talent cooperation and interest coordination is the guarantee for collaborative industrial development. We should insist on innovation-driven development and explore new development modes and paths of industries by improving S&T innovation level.

**The second one is to create a regional industrial chain and establish a modern industrial system.**

The construction of modern industrial system in urban clusters mainly depends on the development of regional industrial chain. As globalization and regional integration gradually deepen, especially the construction of "the Belt & Road Initiatives", the original international and regional division of labor has changed from the initial inter-industry division of labor to intra-industry division of labor, and then to industrial chain division of labor, which gradually becomes the main development trend. Traditional industries still occupy a large proportion of the advantageous industries in the Guanzhong Plain City Cluster in the Yellow River Basin, while the development of strategic emerging industries and modern service industries is relatively slow. Therefore, according to the requirements of the industrial chain division of labor, the basin must develop water-saving industries, promote the transformation and upgrading of traditional industries. With the development opportunities of the "Belt and Road", the government should accelerate the pace of going out, clarify the regional division of labor positioning, play its function and role in the industrial chain. Also, it should reasonably adjust the industrial layout, and the water-consuming industries that do not have regional advantages should be transferred to other areas. Meanwhile, efforts should be made to develop modern service industries and strategic emerging industries such as energy conservation and environmental protection, new information technology, high-end equipment manufacturing, etc. to promote the optimization and upgrading of industrial structure, and then establish a modern industrial system.

**The third is to plan transportation networks rationally and accelerate infrastructure construction.**

The synergistic development of city cluster industries is linked by transportation networks and other infrastructure. By reasonably planning the transportation network of city clusters in the basin, the cluster can build a comprehensive and hierarchical transportation network, accelerate regional transportation integration, enhance the accessibility of transportation among regions, and thus promote the intensity of industrial exchanges and cooperation among regions.

The city cluster should focus on promoting the construction of civil aviation between Xi'an-Xianyang International Airport and important node cities such as Baoji, Qingyang and Linfen. In addition, it should make full use of international national transportation lines such as the Longhai Line to build a number of local transportation lines that are important for promoting regional interconnection and enhancing exchanges among regions along the line. The construction of

infrastructure within the city cluster should also focus on the construction of post and telecommunications, environmental governance and other infrastructure. Moreover, it is essential to build a high-speed shared information network for urban clusters, promote networking and informatization, and facilitate regional industrial division of labor.

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