

# GIS-Based Research on the Spatial Trajectory Migration of Shaanxi Province's Demographic, Economic and Industrial Centers of Gravity

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**Abstract:** This article analyzed the movement trajectory of population center of gravity, economic center of gravity, and industrial center of gravity of Shaanxi Province from 2000 to 2020 using GIS. The following are the key findings. (1) From 2000 to 2012, Shaanxi Province's economic center of gravity, population center of gravity, and industrial center of gravity shifted northeast. (2) After 2013, the economic and population centers of gravity shifted swiftly to the southwest, with the economic center of gravity moving more quickly than the population center of gravity. (3) The degree of longitude correlation between the center of gravity of the primary industry and the center of gravity of the economy and population was the highest, whereas the secondary and tertiary industries were the primary cause of the economic development gap between the north and south of Shaanxi Province, and the tertiary industry was the leading factor for the North-South population migration in Shaanxi Province. (4) Population, economy, and the industrial core of Shaanxi Province were influenced by institutional change, industrial structure, urbanization, and public education.

**Keywords:** population gravity center; economic gravity center; industrial gravity center; center of gravity shift; coupling; variation consistency

**JEL Classification:** R12; J11; L10

## 1. Introduction

Regional development imbalance and lack of coordination have long been important issues in China's growth. Principal paradox in contemporary Chinese society is between imbalanced and inadequate development and the people's ever-increasing desire for a better living. In the current era, the implementation of the regional coordinated development strategy has become one of our most important national strategies. Consequently, studying regional development is of significant practical importance. The trend of economic and population development is an essential indicator of the condition of a region's economic development and a significant factor in formulating and adjusting development policies. Population movement is a significant component in determining the level of regional economic growth. The migration of people increases the labor force and the consumer market. Simultaneously, the development situation of regional economy responds to the flow

of population, and the robust momentum of regional economic development has become a significant factor in the flow of population.

Population center of gravity refers to the equilibrium point of population distribution in the spatial plane in the research region. It is typically used to measure the equilibrium state of population distribution in a region by comparing it to the geometric center of that region. As natural, socioeconomic, and regulatory circumstances change, population and economy are redistributed, and the demographic and economic gravitational centers will shift correspondingly. The study of the moving trajectory of the population and economic center of gravity can reveal the characteristics and causes of the spatial changes of population and economic distribution and provide a decision-making foundation for the formulation of population and economic development policies and regional socioeconomic development planning. Geographic information system (GIS) plays an increasingly vital role in regional population and economic distribution as a result of the rapid development and widespread use of geographic information technology. Numerous experts in the United States have effectively adapted GIS spatial analysis to population and economic studies. Therefore, this paper chooses to carry out further research based on GIS technology.

The center of gravity model can explain the spatial distribution characteristics and evolution law of social and economic phenomena, as well as the direction and equilibrium of regional development (Grether & Mathys, 2008) and is frequently employed to investigate the evolution of population and economic center of gravity. Numerous studies have been conducted using the center of gravity model. For instance, Walker (1874) was the first to utilize the center of gravity model to research social science issues. He investigated the movement and evolution of the American population's center of gravity under the effect of Western development and other causes. Later, Bellone and Cunningham (1993) enhanced the concept of economic center of gravity by defining the regional center of gravity as the mass center of people in a region. In China, Fan and Taupman (1996) were the first to utilize the barycentric model to examine the evolution trend of the level of provincial agricultural industrialization. Since then, researchers have employed the center of gravity model (Hu et al., 2011), standard deviation ellipse (Li et al., 2015), coupling model (Gao et al., 2018), geographic detector (Hu et al., 2019), and other research methods to analyze urban agglomeration (Wang et al., 2011), provincial region (Hu et al., 2011), municipal region (Wu, 2014), and river basin (Wang et al., 2013).

According to the available literature, the majority of studies concentrate on determining the evolution trend of national or regional demographic or economic factors. Therefore, the possible marginal contribution of this paper, beginning with a province, analyzes the evolution trend of population and economic factors of the center of gravity, as well as the influence factors of population and economy, in order to provide some development recommendations for local development.

## 2. Research Methods and Data Sources

### 2.1. Research Methods

- Center of gravity model

The center of gravity model offers distinct advantages for examining the spatial variations of constituents. By analyzing the movement direction and distance of the center of gravity position of elements, it can intuitively and precisely reveal the distribution law and evolution characteristics of the elements in two-dimensional space. It is primarily used in center of gravity studies, such as population change and economic development. By creating a model of population and economic migration's center of gravity, this article analyzes the dynamic evolution characteristics and geographical matching relationship of population and economic center of gravity migration in Shaanxi Province during the past two decades.

Suppose that a large region consists of  $n$  small regions, that the geographical coordinate of the  $l$ -th region is  $(x_l, y_l)$ , and that  $m_l$  represents the quantity value of a certain attribute (such as economic aggregate) of the  $l$ -th region, then the calculation formula for the geographical coordinate of the center of gravity of a certain attribute in this region is:

$$\bar{x} = \sum m_l x_l / \sum m_l \quad (1)$$

$$\bar{y} = \sum m_l y_l / \sum m_l \quad (2)$$

- Distance of center of gravity

The moving distance of the center of gravity is an important metric for analyzing the center of gravity's evolution trajectory. The equation is as follows:

$$D_i = k \cdot \sqrt{(\bar{x}_i - \bar{x}_j)^2 + (\bar{y}_i - \bar{y}_j)^2} \quad (3)$$

$(\bar{x}_i, \bar{y}_i)$  and  $(\bar{x}_j, \bar{y}_j)$  in Formula (3) can only represent the geographical coordinates of the economic center of gravity as it changes over time, or they can represent the geographical coordinates of the economic center of gravity with different attributes, such as the industrial center of gravity and the population center of gravity. Where  $k$  ( $k = 111,111$  kilometers (km)) denotes the conversion coefficient from earth surface coordinate unit (degree) to plane distance (km).

- Analysis of coupling

In the spatial distribution of deviation, economic center of gravity and population center of gravity reflect primarily two aspects. First, their geographical locations do not intersect during the same time period; second, the direction of their trajectories in the time series is different. Therefore, this study focuses primarily on the coupling between the economic center of gravity and the population center of gravity in terms of their spatial distribution and the consistency of the direction of change.

- Spatial overlap

The spatial overlap is determined by the distance between the two objects. If the distance is great, the coupling is low; if it is short, it is high.  $E$  and  $P$  are coordinates of the same year that have distinct barycenters. Here is the formula for calculating:

$$S = d_{G_E G_P} = \sqrt{(x_E - x_P)^2 + (y_E - y_P)^2} \quad (4)$$

- o Consistency of variation

Consistency of variation refers to the Angle between two kinds of barycenter moving vectors relative to the time point, denoted by  $\theta$ , where the value range of  $\theta$  is  $[0,\pi]$ , and  $\cos C$  denotes the general exponent, which is identical to the property. The bigger C, the greater the variability; when  $C = -1$  or  $1$ , the variability is either consistent or inconsistent. Suppose the center of mass is located at a certain point in time and the change in latitude and longitude, respectively, is  $\Delta x$  and  $\Delta y$ . The formula for calculation is as follows:

$$C = \cos \theta = \frac{(\Delta x_E^2 + \Delta y_E^2) + (\Delta x_P^2 + \Delta y_P^2) - [(\Delta x_E - \Delta y_E^2) + (\Delta x_P^2 + \Delta y_P^2)]}{2\sqrt{(\Delta x_E^2 + \Delta y_E^2)(\Delta x_P^2 + \Delta y_P^2)}} = \frac{\Delta x_E \Delta x_P + \Delta y_P \Delta y_P}{\sqrt{(\Delta x_E^2 + \Delta y_E^2) + (\Delta x_P^2 + \Delta y_P^2)}} \quad (5)$$

## 2.2. Source of Data

This paper uses the gross domestic product (GDP), added value of the primary (secondary, tertiary) industry, and population of ten cities in Shaanxi Province since 2000. In order to avoid inconsistency from affecting the results of the industrial index calculation, the basic data are rectified prior to calculation. As the city's geographical coordinates, this paper selects the longitude and latitude of the province's center of gravity.

Calculating the demographic center of gravity, economic center of gravity, and industrial center of gravity requires geographic and attribute data. Shaanxi Province's administrative map is vectored using ArcGIS 10.3 and GeoDa, and its coordinate system is a projection coordinate system. The source of the attribute data is the Shaanxi Provincial Statistical Yearbook, which primarily consists of the total population data, economic data, and industrial data for each urban area in Shaanxi Province at the end of 2020.

## 3. Analysis of the Evolution and Migration Trajectory of the Population Center of Gravity, Economic Center of Gravity, and Industrial Center of Gravity

### 3.1. Evolution of the Population's Center of Gravity in Space and Time

By adopting the calculation method of gravity center and utilizing GIS platform to calculate the population data of prefecture-level cities in Shaanxi Province, the geographical coordinates of population center of gravity of prefecture-level cities in Shaanxi Province from 2000 to 2020 and the spatial dynamic migration and change rule of population center of gravity from 2000 to 2020 are obtained. As shown in Figure 1, the population center of Shaanxi Province remained in Jingyang County, Xianyang City from 2000 to 2020. Since the year 2000, the population center of Shaanxi Province has moved between 108.75- and 108.78- degrees east longitude and 34.63- and 34.66- degrees north latitude. The population center of gravity in Shaanxi Province changed to the northeast from 2000 to 2015, to the southeast from 2016 to 2020.

From the standpoint of the movement direction and distance of the center of gravity, the geographical distribution of the population exhibited two stages of change. The first stage: from 2000 to 2015, the population moved approximately 5.43 km northeast at a sluggish pace. The second phase: from 2015 to 2020, the township was moved approximately 5.29 km to the southeast. In instance, the moving distance in 2018 and 2020 was 1.50 km and 1.78 km,

respectively, and was the greatest in these two years. Possible causes include the development and utilization of various coal, oil, natural gas, and other energy sources in northern Shaanxi in recent years, the development of red tourism to drive the economy, and the improvement of the environment, causing more people to settle in northern Shaanxi, and the population series promoting the population center of gravity to shift to the northeast.

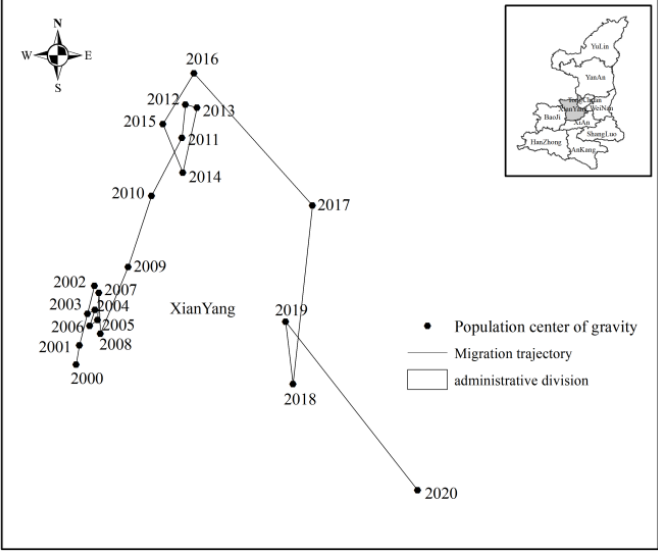


Figure 1. Migration trajectory of the population's gravitational center in Shaanxi Province

3.2. Evolution of the Economic Center of Gravity in Space and Time

The economic center of gravity and its displacement are dependent on the geographical distribution and adjustment of economic activities, and its evolution track reflects the alterations in the spatial distribution of economic activity. Figure 2 shows that since the year 2000, the economic center of Shaanxi Province has moved from the coordinates of 108.75-108.78 degrees east longitude and 34.63-34.66 degrees north latitude. In terms of administrative divisions, it was located in the Jingyang County from 2000 to 2003, the Sanyuan County from 2004, and the Tongchuan City from 2005 to 2020. Overall, the economic center of gravity shifted to the northeast, but from 2012 to 2015 it shifted to the southwest and from 2016 to 2019 it shifted back to the northeast. Based on an examination of the statistics, it can be inferred that the rate of economic contribution to the northeast is rising steadily.

The geographical distribution of the population exhibited two stages of change based on the direction and distance of the center of gravity. The initial phase: from 2000 to 2012, it migrated approximately 426.32 km to the northeast. During the second phase, from 2013 to 2020, the township was moved 569.83 km to the southwest. In particular, the travelling distance in 2017 was 164.68 km and in 2018 it was 166.67 km. The greatest moving distance was two years. In recent years, the northern region of Shaanxi has become rich in coal, oil, natural gas, rock salt, and other resources that can be exploited under favorable conditions. Future national energy and chemical industry center of importance. At the same time, the economic belt along the Great Wall has been viewed as a new economic growth point and breakthrough point for Shaanxi Province, as well as the development focal point. It provides

favorable transportation conditions for the rapid development of northern Shaanxi, the construction of an energy and chemical industry base, and the growth of tourism, and indirectly encourages the development of northern Shaanxi and the growth of the GDP. The regional economic gravitational center will ultimately shift to the northeast as a result of such a large amount of economic input.

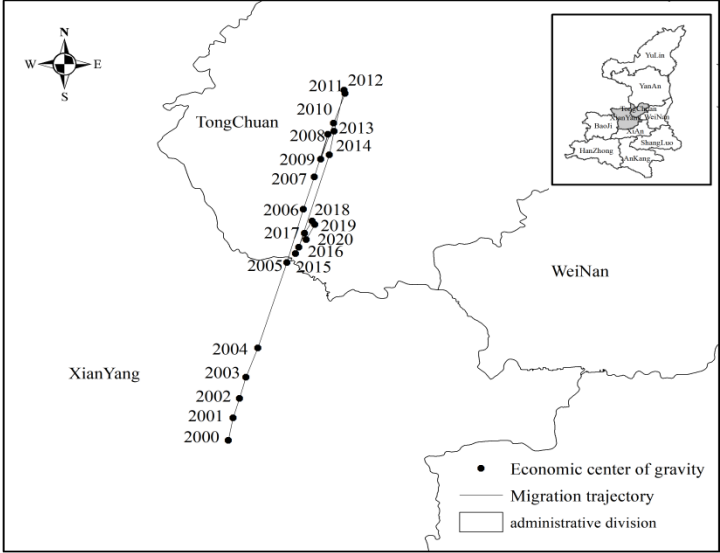


Figure 2. Migration trajectory of the economic gravitational center in Shaanxi Province

3.3. Evolution of the Industrial Gravity Centre in Space and Time

- Spatial-temporal evolution of the primary industry's gravitational center

Figure 3(a) illustrates the dynamic evolution of Shaanxi Province's key industry gravitational center. Since 2000, the center of gravity of primary industry in Shaanxi Province has changed to the northeast, with a deviation range of 108.69-108.77 degrees east longitude and 34.51-34.85 degrees north latitude. Since Jingyang County of Xianyang City in 2000, Liquan County of Xianyang City in 2002, and Chunhua County of Xianyang City in 2010, the geographical location has shifted. This indicates that the development of the primary industry in Shaanxi Province has not altered significantly over time.

From the standpoint of the center of gravity's moving distance and direction, its spatial dispersion can be classified into four stages. (1) From 2000 to 2002, this stage traveled 7.22 km to the northeast. (2) From 2003 to 2006, this stage shifted 11,26 km to the southwest. (3) From 2007 to 2014, this stage shifted 29.97 km to the northeast. (4) From 2015 to 2020, this stage migrated 0.41 km to the northwest over a somewhat narrow span.

Shaanxi Province's agriculture and aquaculture industries have gradually shifted toward northern Shaanxi, i.e., the industry's principal focus is in the northeast, as a result of the national government's ongoing policy shifts. The fundamental reasons for the evolution of the core industry's center of gravity exhibiting the aforementioned features are as follows: (1) The land resources of northern Shaanxi are abundant, and the agriculture and breeding industries are becoming increasingly concentrated. (2) The provincial government of Shaanxi actively promotes the strategic adjustment of the agricultural and rural economic structure.

Strengthen the input and development of agriculture, the fruit industry, and animal husbandry through the modification of industrial structure, economic structure, and agricultural variety structure, and develop other cash crops according to local requirements. (3) The province of Shaanxi increased the production of cash crops by bolstering high-standard farmland development, land consolidation, agricultural water conservation projects, and soil improvement, as well as other initiatives. (4) The infrastructure is imperfect, the development of agriculture is significantly influenced by natural causes, natural disasters have a large impact on agriculture, but their frequency is considerable, and there is unpredictability regarding time and location. There is no evident pattern in the frequency with which these circumstances cause the principal industry to shift its concentration.

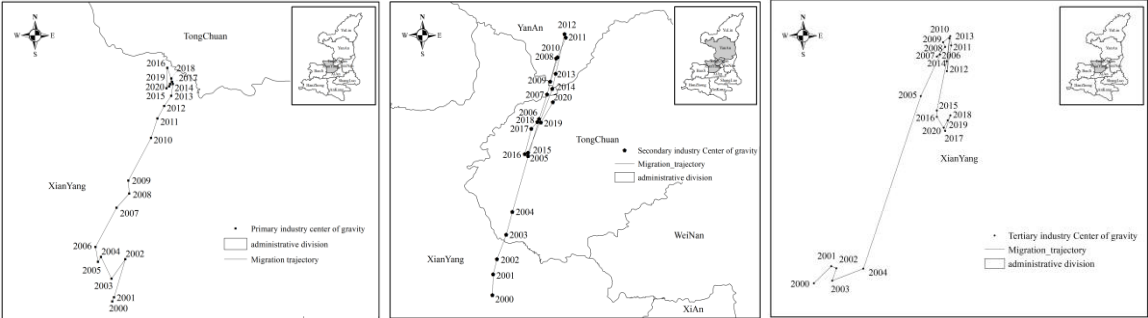


Figure 3. Migration trajectory of the industrial gravity centre

- Spatial-temporal evolution of the principal industry's gravitational center

Figure 3(b) illustrates the dynamic nature of the evolution of the secondary industry's gravitational center in Shaanxi Province. Since 2000, the center of gravity of primary industry in Shaanxi Province has changed to the northeast, with a deviation range of 108.66-108.90 degrees east longitude and 34.70-35.51 degrees north latitude. The center of gravity changed from Jingyang County of Xianyang City in 2000, to Chunhua County of Xianyang City in 2001, to Yaozhou District of Tongchuan in 2004, to Xunyi County of Xianyang City in 2007, to Huangling County of Yan'an City in 2012, to Xunyi County of Xianyang City in 2014, and to Yaozhou District of Tongchuan between 2015 and 2020.

From the standpoint of the center of gravity's moving distance and direction, its spatial distribution can be separated into two stages. (1) From 2000 to 2012, this stage traveled 109.05 km to the northeast. (2) From 2013 to 2015, this stage travelled 11.09 km to the southwest. Gradually decreasing movement distance and a relatively concentrated center of gravity. (3) From 2016 to 2020, it moved to the northeast, with a travel distance of 38.32 km.

The primary factors for the evolution of the secondary industry's center of gravity are as follows: The development of Shaanxi Province's primary industries is primarily centered in the province's northern region. In northern Shaanxi Province, Yulin City is the epicenter of the coal industry. Prior to the year 2000, coal exploration and development was increased, and the Shenmu coal base was also constructed. Pull the secondary industry's center of gravity directly to the north. With the expansion of oil and gas in Yan'an, the establishment

of the Yanchang oil base, and the acceleration of metal mining in Shangluo City, however, the secondary industry's center of gravity has shifted to the southwest. The industrialization level of each region has significantly increased, the secondary industry focus is relatively balanced and concentrated, but the mineral resources of the northern Shaanxi region are superior and provide a solid foundation for development, whereas the industrial development of southern Shaanxi is relatively lagging, resulting in a greater north-south development gap than east-west.

- Spatial-temporal evolution of the tertiary industry's gravitational center

Figure 3(c) illustrates the dynamic nature of the evolution of the Shaanxi Province tertiary industrial center of gravity. Since 2000, the center of gravity of tertiary industry in Shaanxi Province has changed generally to the northeast, with a deviation range of 108.68-108.79 east longitude and 34.50-34.69 north latitude, and the spatial position being Jingyang County, Xianyang City.

Based on the moving distance and direction of the center of gravity, its spatial dispersion can be split into three stages: (1) From 2000 to 2010, this stage traveled 27.26 km to the northeast at a relatively rapid rate. (2) From 2011 to 2012, this stage shifted 2.89 km to the southwest over a relatively limited span. (3) From 2013 to 2020, this stage migrated southwestward by 14.15 km.

The evolution track of the tertiary industry exhibits the aforementioned features primarily due to the fact that the development of the tertiary industry is accompanied by rapid economic expansion. The center of gravity of Shaanxi's GNP indicates a shift from the southwest to the northeast, as does the center of gravity of the tertiary industry. In recent years, the investment structure of the service industry in Shaanxi Province, which has a low urbanization rate, has been unreasonable, and the poor investment and low labor productivity of certain industries have hampered the development of the tertiary sector. Northern Shaanxi has maintained a high rate of development, and the process of industrialization has been accelerated, which promotes the rapid development of finance, information, trade, logistics, and other related industries in the region, resulting in the center of Shaanxi's tertiary industry gradually shifting to the northeast and converging. Nonetheless, the progress of industrialization and urbanization in southern Shaanxi is generally lagging, and industries such as banking and trade are underdeveloped, causing the regional disparities in the development of tertiary industry in Shaanxi to grow continuously.

In general, the tertiary industry expands swiftly alongside economic expansion. The gross product center of Shaanxi Province demonstrates a southwest-to-northeast trend, which is mirrored by the tertiary industry. The continuous acceleration of the development of the primary and secondary industries has facilitated the rapid development of finance, information, trade, transportation, logistics, and other related industries in Shaanxi Province, thereby widening regional disparities in the development of the tertiary industry in Shaanxi Province.



### 3.4. Coupling Analysis of the Population and Economic Gravitational Centers

The distance between the population and economic centers of gravity in Shaanxi Province increased gradually from 0.08 km in 2000 to 0.48 km in 2013. There are two stages to the change in distance between the population and economic centers of gravity. In the first stage (2000-2011), the distance between the population and economic centers of gravity in Shaanxi Province increased from 0.08 km in 2000 to 0.48 km in 2011. During the second stage (2012-2020), the distance between Shaanxi Province's population and economic centers of gravity was essentially maintained at 0.30 km. During this time period, the population and economic centers of gravity in Shaanxi Province moved rather consistently, and the distance between them stayed constant.

Table 1. Coupling analysis of the population and economic gravitational centers in Shaanxi Province

Year	Population center of gravity		Economic barycenter		Spatial distance
	East Longitude	North Latitude	East Longitude	North Latitude	
2000	108.752298	34.633781	108.677403	34.594695	0.08
2001	108.752545	34.635242	108.683995	34.628759	0.07
2002	108.753668	34.639715	108.692882	34.658203	0.06
2003	108.753154	34.637603	108.701883	34.690329	0.07
2004	108.753707	34.637908	108.718401	34.734718	0.1
2005	108.753316	34.636695	108.758771	34.864368	0.23
2006	108.753902	34.637149	108.781681	34.945055	0.31
2007	108.754012	34.639183	108.79705	34.994036	0.36
2008	108.754116	34.636105	108.815992	35.058789	0.43
2009	108.756215	34.641123	108.805934	35.020729	0.38
2010	108.75797	34.646465	108.823665	35.075401	0.43
2011	108.760254	34.650824	108.839832	35.12066	0.48
2012	108.76051	34.653328	108.838275	35.125626	0.48
2013	108.761393	34.653099	108.824639	35.063434	0.42
2014	108.76032	34.648209	108.817814	35.027594	0.38
2015	108.75882	34.651869	108.775379	34.88757	0.24
2016	108.761165	34.655675	108.770776	34.877906	0.22
2017	108.77007	34.645744	108.78346	34.90855	0.26
2018	108.768612	34.632323	108.793879	34.927002	0.3
2019	108.768054	34.637006	108.79768	34.921783	0.29
2020	108.777986	34.624345	108.785602	34.899021	0.27

As can be seen from Table 2, the demographic and economic centers of gravity in Shaanxi Province moved in different directions each year from 2000 to 2020. During the years 2000-2001, 2001-2002, 2003-2004, 2005-2006, 2006-2007, 2008-2009, 2009-2010, 2010-2011, 2013-2014, and 2015-2016, the Population center of gravity and the economic center of gravity essentially maintained the same direction of change. However, during the years 2002-2003, 2004-2005, 2007-2008, 2011-2012, 2014-2015, 2016-2017, 2017-2018, and 2018-2019, the two changes reversed course. In 2012-2013, 2019-2020 the spatial variability was 0.12 and 0.02, and the direction of the two shifts was essentially immaterial. In Shaanxi Province, the consistency of the change of population center of gravity and economic center of gravity was 0.78 from 2000 to 2020, suggesting that the direction of change between the two was extremely consistent.

Table 2. Consistency between Shaanxi Province's population and economic gravitational centers

Year	Population center of gravity		Economic barycenter		Change consistency
	$\Delta Y(E)$	$\Delta X(E)$	$\Delta Y(P)$	$\Delta X(P)$	$C=\cos\theta$
2000					
2001	0.0002	0.0015	0.0066	0.0635	1.00
2002	0.0011	0.0045	0.0089	0.0616	0.99
2003	-0.0005	-0.0021	0.009	0.0765	-0.99
2004	0.0006	0.0003	0.0165	0.1740	0.56
2005	-0.0004	-0.0012	0.0404	0.2103	-0.99
2006	0.0006	0.0005	0.0229	0.1297	0.74
2007	0.0001	0.0020	0.0154	0.1137	1.00
2008	0.0001	-0.0031	0.0189	0.0267	-0.80
2009	0.0021	0.005	-0.0101	0.0166	0.59
2010	0.0018	0.0053	0.0177	0.0999	0.99
2011	0.0023	0.0044	0.0162	0.0502	0.99
2012	0.0003	0.0025	-0.0016	-0.0572	-1.00
2013	0.0009	-0.0002	-0.0136	-0.098	0.12
2014	-0.0011	-0.0049	-0.0068	-0.1759	0.98
2015	-0.0015	0.0037	-0.0424	-0.1497	-0.79
2016	0.0023	0.0038	-0.0046	0.0210	0.72
2017	0.0089	-0.0099	0.0127	0.0491	-0.55
2018	-0.0015	-0.0134	0.0104	0.0132	-0.85
2019	-0.0006	0.0047	0.0038	-0.0052	-0.87
2020	-0.0009	-0.0181	0.0066	0.0184	0.29

In conclusion, following a period of growth, the distance between Shaanxi's population and economic centers of gravity has stayed largely steady. Not only did the direction of the population center of gravity and economic center of gravity remain the same for the most of the period from 2000 to 2020, but the overall direction of movement was also highly consistent.

#### 4. Evolution of the Population, Economic and Industrial Gravitational Center: An Analysis of Affecting Elements

##### 4.1. Economic Growth-Related Variables

The evolution of Shaanxi Province's economic center of gravity is strongly tied to the province's economic expansion. When the economy is expanding rapidly, the efficiency can be enhanced, but the two degrees of differentiation, the economic center of gravity shifts, and regional economic discrepancies grow. In addition, rapid economic growth reduces social poverty and raises resident income and employment; that is, the greater the economic growth rate, the less poverty, the higher the per capita GDP, and the smaller the regional economic disparities. The evolution of the economic center of gravity in Shaanxi Province is influenced by economic growth.

##### 4.2. Economic Institutional Change Factors

The economic system is the introduction and execution of behavioral limitations into economic operations. Residents' mutual relationships and range of options are defined by

laws, property rights are safeguarded, transaction costs are decreased, the stability of the transaction environment is increased, and economic growth is robust. China is transitioning from a planned economy to a market-based economy, and the market mechanism is strengthening progressively. In a planned economy, economic progress is equalized, whereas in a market economy, regional division is exacerbated and economically developed regions become more economically developed. The evolution of the economic center of gravity is affected by the transformation of the economic system in Shaanxi.

#### *4.3. Industrial Structure Factors*

Industrial structure relates primarily to the economic relationship and quantity relationship between the three industries in the social production process. Industrial structure differs at different economic levels. Reasonable industrial structure is the foundation for regionally healthy and sustainable development. A reasonable industrial structure can facilitate coordination between the economic center of gravity and the demographic center of gravity, thereby decreasing regional economic disparities.

#### *4.4. Factors Related to Urbanization*

The evolution of the population center of gravity is influenced by the degree of urbanization and the proportional distribution of capital income. The greater the urbanization rate, the more people a city can handle, the more people migrate from economically depressed areas to economically prosperous cities, and the population center of gravity shifts. The share of distribution of capital income is connected. The overly high share of capital income distribution reduces the income of workers with low capital amounts who rely on labor, hence promoting a shift in the population's center of gravity.

#### *4.5. Factors related to education*

Public education is beneficial to raising the human capital of the work force, enhancing the income of the labor force, and decreasing the deviation between the population and economic centers of gravity, hence minimizing regional economic disparities. Due to an increase in education expenditures and an improvement in the penetration rate, the human capital pool of disadvantaged inhabitants has increased, hence promoting migration to economically developed regions. Additionally, the development of transportation, communications, and other infrastructure has aided the migration of underdeveloped inhabitants to developed regions.

### 5. Conclusions and Recommendations

#### *5.1. Conclusions*

This paper analyzes the spatial migration trajectory, moving distance, direction, spatial coupling, and related influencing factors of population center of gravity, economic center of gravity, and industrial center of gravity in Shaanxi Province from 2000 to 2020 using GIS, and draws the following conclusions: (1) Economic expansion, industrial development, and

demographic change in Shaanxi Province are interdependent and mutually beneficial. (2) From 2000 to 2012, Shaanxi Province's economic center of gravity, population center of gravity, and industrial center of gravity shifted northeastward. (3) After 2013, the economic and population centers of gravity shifted swiftly to the southwest, with the economic center of gravity migrating more quickly than the population center of gravity. (4) The degree of longitude correlation between the center of gravity of the primary industry and the center of gravity of the economy and population is the highest, while the secondary and tertiary industries are the primary cause of the economic development gap between the north and the south of Shaanxi Province and the tertiary industry has become the leading factor for the north-south population migration in Shaanxi Province. (5) Institutional change, industrial structure, urbanization, and public education influence Shaanxi's population, economy, and industrial concentration.

## 5.2. Recommendations

On the basis of the preceding findings, the following policy recommendations are made: First, we should encourage the merger of Xi'an and Xi'an and the economic development of Shaanxi Province through the expansion and reinforcement of the provincial capital. Second, actively support the southern Shaanxi region's adaptation to local conditions, develop an appropriate agriculture industry cluster, and propel the province's overall primary industry's high-quality, rapid expansion. Third, enhance the economic vitality of eastern Shaanxi by capitalizing on the distinctive assets of each county. Relevant industrial policies have been implemented to support Yulin, Yan'an, and Tongchuan, reduce backward production capacity, restructure their own economic development mode, delve deeper into tourism resources, and improve investment attractiveness for high-tech businesses. For Shaanxi Province's economic development to be coordinated, it is required to further apply industrial strategies to address the issue of uncoordinated regional development. Fifth, boost the rate of urbanization, encourage population mobility, expand public education, and enhance the level of human capital.

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Conflict of interest: none.

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