EVOLUTION OF THE COUPLING COORDINATION RELATIONSHIP BETWEEN POPULATION STRUCTURE AND REGIONAL ECONOMY, AND THE DIAGNOSIS OF OBSTACLE FACTORS IN ULANQAB CITY, CHINA

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Key-words: population structure, regional economy, coupling coordination degree, obstacle degree, Ulanqab.

Abstract. Enhancing the capacity for the joint development of population structure and regional economy is crucial for promoting high-quality new-type urbanization in the modern development era. By integrating the PES (Population – Economy – Society) model with the coupled coordination model and the obstacle factor diagnostic model, a comprehensive evaluation index system for population structure and regional economy was established. This system was then employed to analyse the coupling relationship between population structure and regional economy, and to identify major obstacles in Ulanqab from 2000 to 2020. The findings indicate that (1) both the composite index of population structure and that of the regional economy exhibited a fluctuating upward trend, with population structure development preceding that of the regional economy; and that (2) the coupling degree and coupling coordination degree demonstrated an overall upward trajectory, reaching a stage characterized by high-quality coupling and favourable coordination. However, the coupling coordination degree lagged behind the coupling degree. (3) The urban-rural, employment, and cultural structures emerged as key impediments to urbanization. Specifically, major barriers included the number of primary and secondary school students, the number of full-time primary and secondary school teachers, the urban-rural income gap, and the urban Engel coefficient. (4) To address these challenges, it is essential to accelerate the transformation and upgrading of the industrial structure, gradually reduce the urban-rural income gap, improve the quality of basic education, and promote the coordinated development of population structure and regional economy.

1. INTRODUCTION

The relationship between population structure and regional economy is one of the most fundamental and critical issues in the development of human society. Both serve as key indicators for assessing the level of urbanization within a given region. The coordinated development of population structure and regional economy provides essential support for sustained economic growth and high-quality, sustainable regional development (Lin, Chen, 2013; Golley, Zheng, 2015). This relationship is inherently complex, characterized by intricate interconnections, mutual constraints, and reciprocal influences (Zhao *et al.*, 2019). While population urbanization can drive continuous regional economic growth, the impact of urbanization on economic development varies significantly across different stages of urbanization and regional economic phases (Zhao, 2019). Extensive research has been conducted both domestically and internationally on the relationship between population structure and regional economy. These studies primarily examine the effects of factors such as gender composition, age distribution, industrial structure, urban-rural dynamics, and cultural structure on economic development

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(Șerban, Tălângă, 2015; Șerban, Mitrică, 2024; Lindh, Malmberg, 1999; George, 2001; Andersson, 2001; Fougere, Mdrette, 1999; Chang, Brada, 2006; Peng, 2008; Bloom *et al.*, 2009, 2010; Prettner, 2013). Most of these analyses rely on qualitative methodologies, focusing on macro-perspective in population structure changes. However, relatively few studies quantitatively assess the coupling and coordination between population structure and regional economy (Li, Wang, 2017; Wu *et al.*, 2015, 2018; Xiong *et al.*, 2017; Xie, 2011). In China, research has predominantly been conducted from a macro perspective, encompassing national, provincial, and urban agglomeration levels (Bi, 2006; Yu *et al.*, 2018; Liu, 2012; Guo, Zhong, 2013; He *et al.*, 2013; Xiong *et al.*, 2017). Empirical studies at the microlevel, particularly those focusing on individual cities, remain rare. Moreover, systematic investigations that identify key obstructive factors between population structure and regional economy using the obstacle factor diagnosis model are even scarcer.

In summary, significant gaps remain in the depth and scope of existing research (1). First, studies on the relationship between population structure and economic development have primarily examined the influence of individual factors on the regional economy from a singular perspective. There is a lack of systematic and comprehensive research, with index factors not being thoroughly considered. (2) Previous studies have largely focused on analysing the coupling process between population structure and regional economy, yet empirical research on the obstacles hindering their coordinated development remains in short supply. (3) In the studied region, particularly in Ulanqab, there has been limited discussion on the quantitative analysis of the coupling effect between population structure and regional economy, as well as the identification of key obstructive factors.

As a central city in Inner Mongolia, Ulanqab has evolved into a key urban centre with significant competitiveness and influence within the Hohhot-Baotou-Ordos-Ulanqab urban agglomeration in central and western China. It plays a vital role in driving and supporting regional economic and social development. Currently, Ulanqab's regional economy is at a critical juncture, undergoing a transitional phase aimed at optimization and upgrading. However, in the later stages of urbanization, the city faces several social development challenges, including a weakening impetus for sustained economic growth, an imbalanced population structure, a slowdown in population growth, and a widening urban-rural disparity. The tensions between profound shifts in the population structure and the regional economic system have become increasingly pronounced, making it imperative to address these challenges to achieve high-quality and sustainable urbanization in Ulanqab during this new phase of development.

From a systematic perspective on population structure and regional economic development, this paper employs the coupling coordination model and the obstacle factor analysis model to quantitatively assess the evolutionary dynamics of the coupling and coordination between population structure and regional economy in Ulanqab from 2000 to 2020. It also identifies the primary obstructive factors at different stages of urbanization. This approach facilitates an objective analysis of the coupling mechanism between Ulanqab's population structure and regional economic system, as well as the key development priorities in the later stages of urbanization. Furthermore, it provides a theoretical scientific foundation and practical guidance for formulating macro-level regional economic and population development policies. By doing so, it aims to promote a coordinated and interactive development between population structure and regional economy, ultimately ensuring their sustainable and balanced growth.

2. MATERIALS AND METHODS

2.1. Study area

Ulanqab is situated in the central region of the Inner Mongolia Autonomous Region, between 39°37′ to 43°28′N and 109°16′ to 114°49′E. It extends approximately 458 km from east to west and 442 km from north to south, covering a total area of about 54,500 km^2. The city shares borders with Hebei Province to the east, XilinGol League to the northeast, Shanxi Province to the south, Hohhot to the

southwest, Baotou to the northwest, and Mongolia to the north, with a border length exceeding 100 km. Ulanqab has an average altitude ranging from 1,152 m to 1,321 m, and experiences an arid to semi-arid temperate continental monsoon climate, with an average annual temperature between 0 and 6° C. As of 2021, Ulanqab had a total population of 1.6595 million, including 1.0091 million urban residents and 650,400 rural residents, resulting in an urbanization rate of 60.81%. The regional GDP reached 90.36 billion Yuan, with the secondary industry contributing 41.5% and the tertiary industry accounting for 42%. The per capita GDP stood at 57,831 Yuan. Additionally, customs import and export trade amounted to 2.779 billion Yuan, while total retail sales of consumer goods reached 23.67 billion Yuan. The per capita disposable income was 35,915 Yuan for urban residents, and 14,427 Yuan for rural and pastoral residents.

2.2. Data Sources

To quantitatively assess the spatio-temporal evolution of the relationship between population structure changes and the coupling coordination of the regional economic system in Ulanqab, Inner Mongolia Autonomous Region, from 2000 to 2020, this study uses comprehensive data on population structure and regional economic development over the same period. The research data are primarily derived from the *Inner Mongolia Statistical Yearbook* (2001–2021) and the *Ulanqab Statistical Yearbook* (2001–2021), ensuring their authority, validity, and reliability. For indicators lacking direct data, indirect calculation methods were applied to maintain analytical accuracy.

2.3. Research Methods

2.3.1. Construction of the evaluation index system

The population structure system and the regional economic system are two complex, interdependent systems that interact and influence each other. Constructing a scientifically sound and comprehensive evaluation index system by integrating the PES model (Chu *et al.*, 2021) is a fundamental prerequisite for exploring the coupling and coordination between population structure changes and regional economic development in Ulanqab. This study adheres to the principles of scientific rigor, comprehensiveness, dynamism, and data availability. In alignment with the objectives of accelerating ecological civilization construction and promoting high-quality urbanization in Ulanqab, a comprehensive evaluation index system has been developed. This system comprises two major subsystems: the population structure and the regional economy. The population structure system is further categorized into four dimensions – urban-rural structure, population quality, employment structure, and cultural structure – encompassing a total of 16 indicators (Table 1). Similarly, the regional economic system is divided into four dimensions – economic aggregate, industrial structure, economic level, and economic resilience – comprising a total of 19 indicators (Table 2).

Table 1

Evaluation index system of population structure

System layer	Subsystem layer	Entropy weight	Index layer	Unit	Index attribute	Entropy weight
Population structure	Urban-rural structure	0.0331	Year-end population	Person	+	0.1922
			Male population	Person	+	0.1978
			Female population	Person	+	0.1932
			Urbanization rate	%	+	0.4168
	Population quality	0.6464	Natural population growth rate	%	+	0.0958
			Per-capita education spending	Yuan/ Person	+	0.3604
			Number of health technicians	Person	+	0.2964

Table 1 (continued)

		Number of beds in health facilities	Bed	+	0.2474
Employment structure	0.2131	Ratio of employment in primary industry at the end of the year	%	-	0.3289
		Ratio of employment in the secondary industry at the end of the year	%	+	0.1406
		Ratio of employment in tertiary industry at the end of the year	%	+	0.4073
		urban registered unemployment rate	%	-	0.1232
Cultural structure	0.1074	Number of students in primary and secondary schools	Person	+	0.3752
		Number of students in colleges and universities	Person	+	0.1822
		Number of full-time teachers in primary and secondary schools	Person	+	0.2817
		Number of full-time teachers in colleges and universities	Person	+	0.1609

Table 2

Evaluation index system of regional economic system

System layer	Subsystem layer	Entropy weight	Index layer	Unit	Index attribute	Entropy weight
Economic system	Economic aggregate	0.2458	Gross regional product	Yuan	+	0.1800
			Regional GDP growth	%	+	0.1342
			GDP of primary industry	Yuan	+	0.0664
			GDP of secondary industry	Yuan	+	0.1751
			GDP of tertiary industry	Yuan	+	0.2103
			Total industrial output value above designated size	Yuan	+	0.2340
	Industrial structure	0.0591	Ratio of primary industry	%	-	0.3242
			Ratio of secondary industry	%	+	0.4797
			Ratio of tertiary industry	%	+	0.1961
	Economic level	0.0971	Per capita GDP	Yuan	+	0.2228
			Per capita disposable income of urban residents	Yuan	+	0.2575
			Engel coefficient of urban residents	–	-	0.1155
			Per capita disposable income of farmers and herdsmen	Yuan	+	0.2641
			Urban-rural income gap	Yuan	-	0.1401
	Economic resilience	0.598	Total retail sales of consumer goods	Yuan	+	0.1390
			Total amount of foreign trade	Yuan	+	0.5127
			Local fiscal revenue	Yuan	+	0.1303
			Local financial expenditure	Yuan	+	0.1247
			Investment in fixed assets	Yuan	+	0.0932

2.3.2. Comprehensive evaluation model

The deviation-standardized data processing method was employed to normalize the original data on population structure and regional economy in Ulanqab, eliminating unit and order-of-magnitude differences between the indicators. The following formulas were used to compute the indicators with varying properties (Xiong *et al.*, 2017).

Positive index formula:

$$X'_{ij} = \frac{X_{ij} - \min X_{ij}}{\max X_j - \min X_j}$$

Inverse index formula:

$$X'_{ij} = \frac{\max X_j - X_{ij}}{\max X_j - \min X_j}$$

Among them, $minX_j$ and $maxX_j$ represent the minimum and maximum values of the first ***j*** indicators, respectively; X'_{ij} is the index value after standardization, and X_{ij} is the original index value before standardization.

The weight of each subsystem and index factor is calculated using the entropy value method, with the calculation formula provided in Jiang *et al.* (2021) as follows:

$$P_{ij} = Y_{ij} / \sum_{i=1}^{n} y_{ij}, \quad E_j = -\ln(n)^{-1} \sum_{i=1}^{n} P_{ij} \ln P_{ij}, \quad w_i = \frac{1 - E_i}{n - \sum E_i}$$

Where, W_i represents the weight of the index, E_j denotes the information entropy of index ***j***, and P_{ij} is the ratio of index j in the ith city.

U(x) and *E(y)* are the comprehensive development indices, derived through the comprehensive linear weighting calculation of the subsystems. Here, *n* and *m* denote the concrete index number in the urbanization and ecological environment subsystems, respectively (Liang *et al.*, 2019; Wang *et al.*, 2021).

$$U(x) = \sum_{i=1}^{n} w_{ij} x_{ij}, \quad E(y) = \sum_{i=1}^{m} w_{ij} y_{ij}$$

2.3.3. Coupling degree model

The Coupling theory is referenced to construct a new model for the coupling of urbanization and the ecological environment (Liang *et al.*, 2019; Wang *et al.*, 2021). The computation formula is as follows:

$$C = \sqrt{\frac{U(X) \cdot E(y)}{\left(\frac{U(X) + E(y)}{2}\right)^2}}$$

The *C* value of the coupling degree refers to the degree of correlation and influence between systems. A shift in the *C* value from 0 to 1 indicates a favourable transition from disorder to order, reflecting the resonance between components within the system. Based on relevant research findings, the stages of coupling degree are divided into five levels (Table 3).

Table 3

Classification of coupling coordination degrees

Coupling degree ***C***	Coupling stage	Coupling coordination degree ***D***	Coupling coordination level
0.000<***C***≤0.300	Low level coupling	0.000<***D***≤0.300	Severe disorder
0.300<***C***≤0.500	Antagonistic stage	0.300<***D***≤0.500	Mild disorder
0.500<***C***≤0.700	Running-in stage	0.500<***D***≤0.700	Moderate coordination
0.700<***C***≤0.900	High level coupling	0.700<***D***≤0.900	Good coordination
0.900<***C***≤1.00	High quality coupling	0.900<***D***≤1.00	High quality coordination

2.3.4. Coupling coordination degree model

The degree of coupling only illustrates the level of interaction between the population structure system and the regional economic system, but it does not capture the total synergistic development impact between the two. Therefore, this research develops a coupling coordination model (Liang *et al.*,

2019; Wang *et al.*, 2021) based on the coupling degree model in order to assess the degree of coupling and coordinated development between the two systems. The calculation formula for scientifically determining the favourable status of the population structure and its alignment with economic coordination is as follows:

$$T = \alpha U(x) + \beta(y)$$
$$D = \sqrt{C \times D}$$

Where D represents the degree of coupling coordination, and T is the comprehensive coordinated development index between the two systems. Both α and β are undetermined coefficients, with $\alpha+\beta=1$. This paper assumes that population structure and regional economy are equally important for urban development, setting $\alpha=\beta=0.5$. Based on relevant studies, the degree of coupling coordination between population structure and regional economy is classified into five levels, as shown in Table 3.

2.3.5. Diagnosis model of obstacles

The diagnosis and analysis of the major impediments affecting changes in population structure and regional economy can effectively guide the development strategies for both population structure and regional economic growth in Ulanqab. The degree of impediment reflects the impact of each indicator on the subsystem, and the specific formula of the obstacle factor diagnosis model (Diao *et al.*, 2020; Lei *et al.*, 2016) is as follows:

$$O_j = \frac{I_j \times \omega_j}{\sum_{j=1}^{m} I_j \times \omega_j}$$

Where I_j represents the difference between the optimal target value and the actual value of each indicator, which can be expressed as $1\text{-}r_{ij}$ (the difference between the standardized value of each indicator and 1); ω_j is the weight of the j index.

3. RESULTS AND ANALYSIS

3.1. Time sequence analysis of the population structure change and the regional economic comprehensive level

3.1.1. Time series analysis of the comprehensive level of population structure change

The comprehensive index of Ulanqab's population structure system demonstrated a reasonably stable and modest growth trend from 2000 to 2019, increasing from 0.1419 in 2000 to 0.9390 in 2019. This growth was influenced by fluctuations in the population and employment quality, and cultural structure indices (Fig. 1). There were three minor variations in 2003, 2006, and 2008. Long-term regional economic development has lagged, with a particularly severe population outflow. However, fluctuations in urban-rural structure, employment structure, and cultural structure indicators showed a declining trend. In contrast, the composite quality index exhibited strong growth, increasing year by year after 2000. In 2013, it rose to first place, with a growth rate of 0.8455. The comprehensive index of the population structure system increased steadily, with an average annual growth rate of 1.877% from 2000 to 2019, providing crucial economic support for the region's long-term development. The following reflects the order of index increase in Ulanqab's population structure system: > employment structure index (0.7252) > cultural structure index (0.3919) > urban-rural structure index > population quality index (0.8455) (0.2347). Education funding rose from 19,014 yuan in 2000 to 410,633 yuan in

2020, an increase of 21.6%. Medical, health, and education activities have advanced rapidly in recent years, with education entering an era of high-quality and rapid development.

3.1.2. Time series analysis of the regional economic comprehensive level

The comprehensive index of Ulanqab's regional economic system has fluctuated upward, increasing from 0.0516 in 2000 to 0.7685 in 2020, with an average annual growth rate of 3.414% (Fig. 2). Despite this growth, the overall increase rate remains relatively low. The regional economic composite index can be further divided into three distinct fluctuation growth phases: 2000 to 2004, 2005 to 2016, and 2017 to 2020. In 2020, the total economic performance showed a decline, largely due to the impact of the COVID-19 outbreak. This decline aligns with the regional economic growth pattern observed in Ulanqab over the past 21 years.

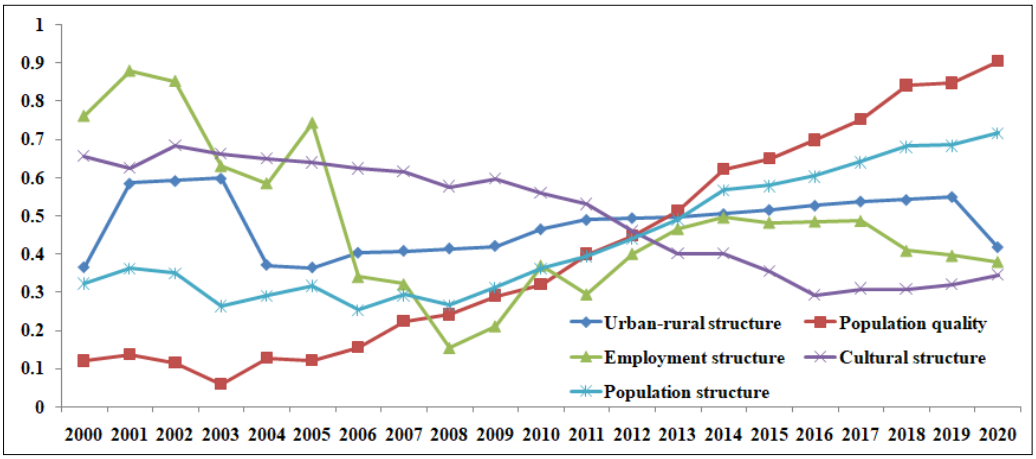

Fig. 1 – The changing trend of the comprehensive index of the population structure system in Ulanqab.

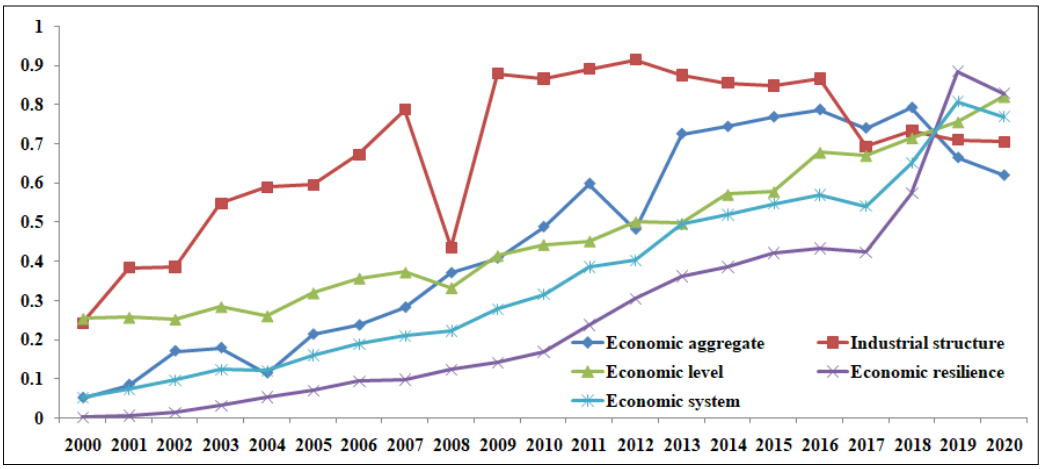

Fig. 2 – Ulanqab's comprehensive index of the variation trend of regional economic system.

The economic structure in Ulanqab has experienced stronger fluctuations in its composite index. Urban transformation and the gradual upgrading of the industrial structure, alongside sustained growth in industries such as modern logistics, big data, and the port economy, have contributed significantly to economic development. This trend accelerated after 2013, in response to national supply-side structural

reforms, and was marked by the ongoing transformation and upgrading of the industrial structure. Within the regional economic system, the economic aggregate, economic level, and economic resilience indices have consistently risen. Additionally, per capita GDP, disposable income, and average employee salaries have shown steady growth, signalling a positive trend in regional economic development. For instance, the fiscal resilience index exhibited significant fluctuations. It rose gradually from 2000 to 2010, saw a sharper increase post-2010, and entered a phase of rapid development in 2017. Prior to 2018, the index remained at a low point, but in 2019, it experienced a dramatic rise, reaching the top and remaining there through 2020.

3.2. Time series analysis of coupling degree between population structure change and regional economy

The population structure of Ulanqab and the composite index of the regional economic system are regarded as two independent systems. Using the coupling theory model, a quantitative analysis is conducted on the coupling degree (C) and the coupling coordination degree (D) between the population structure system and the regional economic system. The results are presented in Table 4. As shown in Table 4 and Figure 3, from 2000 to 2020, the coupling between Ulanqab's population structure system and regional economic system evolved in three distinct stages: an initial coupling stage from 2000 to 2003, followed by a high-quality coupling phase, and then maintaining a long-term trend of high-quality coupling and stable development through 2020.

Table 4

Evaluation results of coupling coordination degree between population structure and regional economy in Ulanqab

Year	Coupling degree	Coupling type	Coupling Coordination degree	Coordination type	Year	Coupling degree	Coupling type	Coupling Coordination degree	Coordination type
2000	0.6898	Running-in stage	0.3590	Mild disorder	2011	0.9999	High quality coupling	0.6239	Moderate coordination
2001	0.7410	High level coupling	0.4003	Mild disorder	2012	0.999	High quality coupling	0.6487	Moderate coordination
2002	0.8224	High level coupling	0.4274	Mild disorder	2013	1.000	High quality coupling	0.7015	Good coordination
2003	0.9301	High quality coupling	0.4231	Mild disorder	2014	0.999	High quality coupling	0.7363	Good coordination
2004	0.9094	High quality coupling	0.4308	Mild disorder	2015	0.9996	High quality coupling	0.7498	Good coordination
2005	0.9436	High quality coupling	0.4737	Mild disorder	2016	0.9996	High quality coupling	0.7655	Good coordination
2006	0.9891	High quality coupling	0.4669	Mild disorder	2017	0.9964	High quality coupling	0.7671	Good coordination
2007	0.9864	High quality coupling	0.4971	Mild disorder	2018	0.9997	High quality coupling	0.8158	Good coordination

Table 4 (continued)

2008	0.9963	High quality coupling	0.4921	Mild disorder	2019	0.9966	High quality coupling	0.8622	Good coordination
2009	0.9983	High quality coupling	0.5412	Moderate coordination	2020	0.9994	High quality coupling	0.8614	Good coordination
2010	0.9976	High quality coupling	0.5804	Moderate coordination					

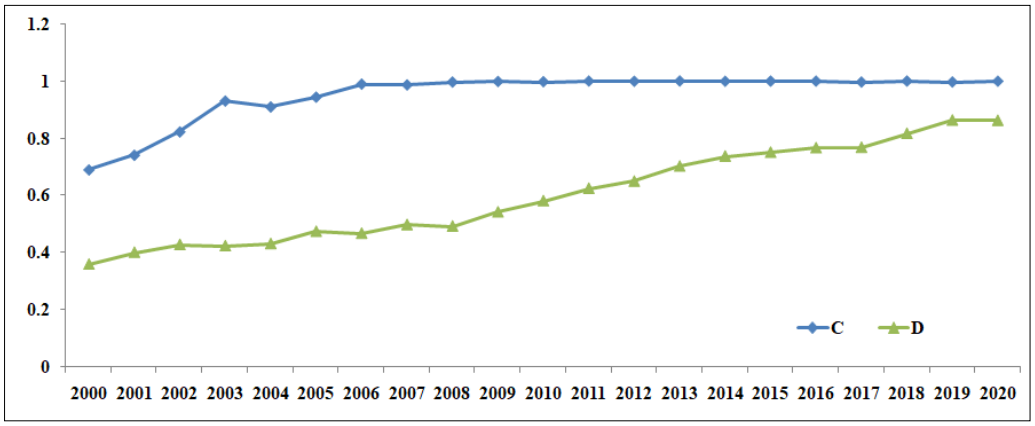

Fig. 3 – Variation trend of comprehensive evaluation index, coupling degree and coupling coordination degree of population structure and regional economic system in Ulanqab.

This coupling evolution process suggests that Ulanqab's population structure and regional economic systems have consistently integrated and expanded in a harmonious manner. The transformation of the population structure has contributed positively to regional economic development. It is crucial to fully recognize the long-term sustainability and stability of the social regional economy. With the annual increase in fixed-asset investments in urban infrastructure, the ongoing upgrading of public services such as social medical care, healthcare, and education, and the continuous optimization of the overall social environment during the rapid urbanization process, the population structure and regional economic systems have maintained a long-term, high-quality synergistic relationship.

The coupling coordination degree between the population structure system and the regional economic system in Ulanqab increased from 0.3590 in 2000 to 0.8614 in 2020, showing an increment of 0.6526, with an annual growth rate of 0.0311 (Table 4 and Fig. 3). The trend in the coupling coordination degree indicates a gradual progression. The coupling coordination types evolved from mild dissonance to moderate coordination and, finally, to a good coordination. Inflection points in the coupling coordination degree occurred in 2000 (mild dissonance), 2009 (moderate coordination), and 2013 (good coordination). This evolution reflects the continuous optimization and adjustment of the coupling coordination between Ulanqab's population structure system and regional economic system over time.

Despite the overall increase in the coupling coordination degree, a discernible gap remains before achieving high-quality coordination. Furthermore, a comparative analysis based on comprehensive indexes of the population structure system and the regional economic system in Ulanqab from 2000 to 2020 reveals that the coupling coordination type, characterized by an advanced population structure, has predominated over the past 21 years. This also indicates that, from 2000 to 2020, the sustainable development of the population structure has been a crucial driver of regional economic growth in Ulanqab. The capacity of the population structure system, therefore, serves as a key impetus for driving regional economic growth in Ulanqab.

3.3. Changes in population structure and regional economic obstacle factor diagnosis

Using the obstacle degree diagnosis model, an in-depth analysis was conducted on the population structure system and the regional economic system in Ulanqab from 2000 to 2020. The study examined the subsystems and index factors that influence the coordinated development between the population structure and regional economy, and a trend chart of the obstacle factors was generated (Fig. 4).

Based on the trend chart of obstacle factors for the population structure system and the regional economic system, the obstacle degree of each system to the coordinated development of the population structure and regional economy in Ulanqab generally showed a fluctuating downward trend. Notably, the main obstacle subsystems exhibited significant dynamic differences at various stages of the urbanization development.

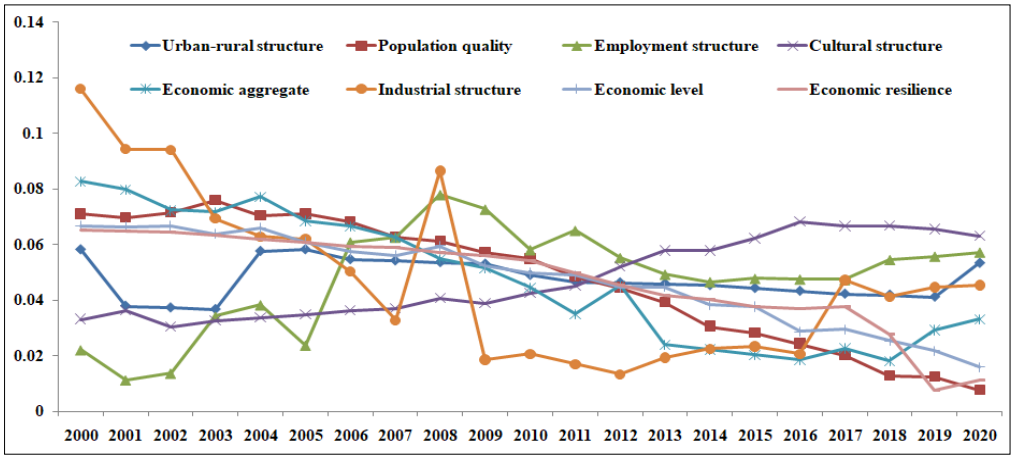

Fig. 4 – Changing trend of population structure system and obstacle factors of regional economic system in Ulanqab.

Based on the changing trends in the population structure system and the barrier components of the regional economic system, the population structure and regional economic systems in Ulanqab over the past 21 years can be divided into two distinct phases. From 2000 to 2011, the primary obstacles were population quality, economic aggregate, and economic structure. In contrast, from 2011 to 2020, the key barriers shifted to the urban-rural structure, employment structure, and cultural structure.

From 2000 to 2010, the trends in the obstacles within the subsystems of the population structure and regional economy indicated that Ulanqab had a weak economic foundation, with a dominant agricultural economy and a significant lag in the development of the industrial economy. During this period, regional economic development was characterized by extensive growth. The primary constraints on the degree of system coupling and coordination were the GDP of the secondary industry, the ratio of the primary industry, and per capita GDP.

From 2010 to 2020, as the regional economic structure gradually transformed and upgraded, accompanied by continuous growth in the regional economic aggregate and improvements in the overall economic development level, the urban-rural development gap expanded. The regional economy exhibited limited capacity to absorb labour resources, while the development level of basic education in primary and secondary schools remained relatively underdeveloped. Additionally, there was a significant surplus of rural labour. In recent years, Hohhot has experienced a notable outflow of elementary and secondary school students, along with full-time teachers. The key obstacles during this period were the urban-rural financial gap, the urban Engel coefficient, the availability of full-time teachers in primary and secondary schools, and the number of primary school pupils.

4. DISCUSSIONS

The objective of this study was to investigate the interaction between Ulanqab's population structure and regional economy. By applying the coupling model and the obstacle factor diagnosis model, the coupling relationship between the two systems was analysed, and key obstacle factors were identified. The study aimed to demonstrate that there is a significant coupling effect in cities between the population structure and regional economy at different stages of development, with a particular focus on the coordination between the two.

The regional economic growth pattern in Ulanqab has gradually shifted, transitioning from an extensive economic development model to a green and energy-efficient circular economy model, emphasizing transformation and upgrading. At the same time, with the rapid adaptation and development of the population structure, the new urbanization development phase represents an inevitable trend in China's social evolution. The challenge of achieving high-quality coupling and sustainable development between the population structure and regional economy is both complex and pressing. To effectively realize the high-quality and sustainable development of both the population structure and regional economy, the following measures should be implemented:

(1) In the process of regional economic development, emphasis should be placed on advancing clean energy industries, such as wind and solar energy storage, as well as hydrogen storage. The tourism and healthcare sectors should be actively promoted. Additionally, industrial clusters focused on graphite-based new materials should be nurtured and expanded. The production of high-quality, green agricultural and livestock products, such as potatoes and oats, should be increased. The development of data centres should also be prioritized to foster extended growth. Furthermore, industries like high-end building materials and the manufacturing of wind power and photovoltaic equipment should be steadily developed.

(2) Capitalize on the advantages provided by the geographical location, convenient transportation networks, high-quality livestock products, favourable ecological environment, and proximity to the port hinterland; systematically integrate these diverse advantages to foster the development of an open-economy model; initiate the construction of central freight train services and comprehensive goods collection centres; establish a new development zone dedicated to green livestock product brands, cultivate a well-recognized graphite materials production base, develop a tourism and leisure destination, establish a green data centre, and create key nodes within the national logistics hub network.

(3) Consolidate the achievements in ecological civil engineering and new-type urbanization initiatives. Expedite the high-quality development of the regional economy, thereby gradually reducing the income disparity between urban and rural populations. Strengthen the infrastructure and enhance the quality of basic education in primary and secondary schools, while promoting the advanced development of local higher education institutions. Raise the overall educational standards and significantly increase the capacity for talent development. Additionally, undertake a comprehensive and systematic exploration of an innovative model that fosters high-quality urban-rural integrated development. Continuously drive the sustainable and progressive optimization of the urban-rural population structure, aiming to promote long-term, harmonious social and economic development.

5. CONCLUSIONS

In recent years, the urbanization process in Ulanqab has accelerated, and the gap between the population structure and the regional economic system has become increasingly evident. This study developed a comprehensive evaluation index system for the population structure and regional economy, integrating it with the PES model. Using the entropy weight method, coupling the coordination degree and the obstacle factor diagnostic model, this paper thoroughly examines the overall development level, the evolution of coupling coordination, and the key obstacles impacting the coordinated development of Ulanqab from 2000 to 2020. The following are the main conclusions:

(1) From 2000 to 2020, the population structure and regional economic development levels in Ulanqab exhibited an upward trend with fluctuations, reflecting the overall development of the system. For a prolonged period, the comprehensive index of population structure consistently outpaced that of the regional economy, indicating that the regional economy's capacity for sustainable expansion still requires improvement.

(2) The evolution of the coupling between population structure and regional economy has progressed through two phases toward high degrees of coupling and high-quality coordination. The relationship between the population structure and regional economy has continuously developed in a collaborative manner, as evidenced by the transition to a high-level coupling phase in 2001 and the sustained high-quality coupling since 2003.

(3) The evolution of the coupling coordination degree between population structure and regional economy shows a gradual progression from a lower stage to a higher stage. The coupling coordination type has transitioned through three stages: from mild disorder to moderate coordination, then to good coordination. However, there remains a substantial gap before reaching the high-quality coordination phase.

(4) The subsystem's scores and index barriers have been progressively reduced year after year. The focus of the subsystem's development process has shifted from factors such as population quality, economic aggregate, and economic structure to aspects including urban-rural structure, employment structure, and cultural structure. Among the main challenges in Ulanqab's later stages of urbanization are the income disparity between urban and rural areas, the Engel coefficient for urban residents, the number of full-time teachers in primary and secondary schools, the number of students in primary and secondary schools, and other related factors.

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