ISSN 2616-5902 Vol. 7, Issue 10: 83-89, DOI: 10.25236/AJBM.2025.071013

Research on the Path of Coordinated Development of Population and Regional Economy in Shandong Province

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Abstract: *To explore the interaction mechanisms between population factors, economic systems and tackle regional development imbalances, this research adapts the entropy method and the coupling coordination degree model to analyze the coupling coordination characteristics of population - economic systems in the three major economic circles (Jiaodong, Provincial Capital, and Lunan) of Shandong Province. The research data encompasses 16 cities in Shandong Province from 2014 to 2023. The results suggest: 1) There are significant regional disparities in coordinated development. The Jiaodong Economic Circle exhibits the highest level of population - economic synergy and remains in the adjustment stage; 2) After administrative restructuring, the Provincial Capital Economic Circle has made phased progress, transitioning from an antagonistic phase to a coordinated one; 3) The Lunan Economic Circle has long been confronted with the contradiction of population - led development but economic lag. Its coupling coordination type has regressed to an antagonistic phase, and there is insufficient economic support for population growth. Based on these findings, this study proposes development paths for high - quality population - regional economic coupling by consolidating advantages, enhancing core effects, resolving structural contradictions, and establishing coordinated mechanisms, offering support for Shandong Province's objective of "leading the way and pioneering new horizons".*

Keywords: *Population-Economic Coupling, Coordinated Regional Development, Entropy Method*

1. Introduction

As a core element of regional economic and social development, the spatiotemporal distribution pattern and dynamic evolution of the population profoundly influence the level of coordinated regional development [1][2][3][4]. In the process of China's high-quality development, the interactive relationship between the population and the economy has become the central issue in addressing the problems of unbalanced and inadequate development [5]. Shandong Province bears the important mission of taking the lead and opening a new situation in the national development pattern [6].

Previous studies have predominantly focused on static analyses of single demographic, age, and economic dimensions, with insufficient exploration of the dynamic coupling mechanisms between regional clustering patterns, spatiotemporal population evolution, industrial upgrading, and regional disparities. In particular, there has been a lack of systematic analysis of long-term spatiotemporal characteristics [7][8][9]. Building on this gap, this study examines the 2014-2023 period by analyzing changes in population size and spatial distribution, while integrating economic growth metrics and regional development disparities to systematically reveal the interactive mechanisms between demographic factors and economic systems.

2. Data sources and methods

2.1 Data source

This study designated 16 prefecture-level cities in Shandong Province as the research area. The data were sourced from the statistical yearbooks of Shandong Province and its 16 cities spanning the period from 2014 to 2023. The administrative boundary data of cities in Shandong was acquired from Tian di tu. The research area encompassed Laiwu City.

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2.2 Research Methodology

The entropy method represents a prevalent approach for assessing the significance of diverse indicators, capable of circumventing the subjective biases induced by human intervention. Consequently, this research employs the entropy method to ascertain the weights of various indicators and compute the coupling coordination degree between the population system and the economic system of each urban agglomeration, the specific procedures are as follows:

Step 1: The data is standardized. Given that both population and economy are positive indicators, the positive indicators are calculated independently, the formula is presented as follows:

$$\mathrm{x}'_{\mathrm{ij}} = \frac{X_{ij} - \min X_{ij}}{\max X_{ij} - \min X_{ij}} \tag{1}$$

X_{ij} represents the original value of the j indicator in the i prefecture ; X_{ij}' denotes the standardized value (0 to 1); $MaxX_{ij}$ and $minX_{ij}$ indicate the maximum and minimum values of the indicator, respectively.

Step 2,The task is to calculate the weight using the entropy value method, and the formula is:

$$p_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{n} x'_{ij}} \tag{2}$$

$$e_{ij} = \frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \times \ln p_{ij} \tag{3}$$

$$g_j = 1 - e_j \tag{4}$$

$$\mathrm{w}_j = \frac{g_j}{\sum_{i=1}^{2} g_j} \tag{5}$$

In the formula p_{ij} , represents the proportion of the i sample data, e_{ij} is the entropy value for the j index, and w_j represents the weight of the j index.

Step 3: Calculating the comprehensive evaluation index of population system and economic system of each city in Shandong Province according to the required weight, and the formula is as follows:

$$U_{\mathrm{i}} = \sum_{j=1}^{n} x'_{ij} w_j$$

Step 4: Coupling Coordination Model

The coupling degree gauges the intensity of interaction between the urban population and the economy, whereas the coordination degree quantifies their collaborative alignment throughout the development process. When the urban population and the economy exhibit effective coordination and balanced growth, this phenomenon is referred to as coordinated coupling; conversely, it is denoted as uncoordinated coupling. The coupling coordination model can assess the mutual influence and interaction between the population and the economy in Shandong Province, as shown in Equations (6) to (8).

$$C = \frac{\sqrt{F \times G}}{(F+G)/2} \tag{6}$$

$$\mathrm{T}=\alpha F+\beta G \tag{7}$$

$$D = \sqrt{C \times T} \tag{8}$$

In the formula, C denotes the coupling degree; T represents the comprehensive coordination function;

ISSN 2616-5902 Vol. 7, Issue 10: 83-89, DOI: 10.25236/AJBM.2025.071013

D indicates the coupling coordination degree. The values of C and D range from 0 to 1, where higher values signify stronger coupling and coordinated development among elements. α and β are weight coefficients, both set to 0.5 as the two systems are considered equally important. U_1 and U_2 represent population and economic indicators respectively.

This study categorizes coupling coordination into four types: (0,0.3) indicates low-level coupling, [0.3,0.5) denotes antagonistic phase, [0.5,0.8) signifies integration phase, and [0.8,1.0] represents high-level coupling [10][11].

3. Results Analysis

The analysis of the population system comprehensive evaluation index (U_1) and economic system comprehensive evaluation index (U_2) using the entropy method reveals that from 2014 to 2023, the coordinated development of population and economic systems in Shandong's three major economic circles exhibited distinct regional differentiation, closely aligned with the province's urbanization and economic growth trajectories.

Research indicates that the Jiaodong Economic Circle has become the region with the highest population-economic synergy in the province, driven by the virtuous cycle of industrial agglomeration and population attraction in cities like Qingdao, Yantai, and Weifang. From 2014 to 2023 (in Table 1), the U_1 ratio decreased from 0.504 to 0.487, the U_2 dropped from 0.447 to 0.419, demonstrating a narrowing gap that reflects dynamic adaptation between population and economic development. As the core city of the Jiaodong Economic Circle, the Qingdao accounted for 17.12% of the province's GDP in 2023, with an urbanization rate of 78.30% for its permanent residents. The dual reinforcement of industrial upgrading and population inflow has further consolidated the region's systemic coupling advantages. The provincial capital economic circle has shown phased growth characteristics. From 2014 to 2018, U_1 consistently exceeded U_2, reflecting the stage-specific feature where population concentration preceded economic development. After Laiwu's integration into Jinan in 2019, both population scale and economic output grew concurrently, with the gap narrowing from 0.116 to 0.165 by 2023, indicating continuous optimization of the economic system's population support. This transformation stems not only from resource integration through administrative adjustments but also from industrial upgrading under Jinan's provincial capital strategy. In 2023, Jinan's GDP surpassed 1.2 trillion yuan, with a permanent population of 9.437 million, significantly enhancing its core driving role.

The population-economy system of the Southern Shandong Economic Circle has long been in an imbalanced phase characterized by population dominance and economic lag. In 2014 (in Table 1), the region's U_1 ratio stood at 0.688 while U_2 was 0.181, with a gap of 0.507. Although U_1 dropped to 0.347 and U_2 rose to 0.167 in 2023, narrowing the disparity to 0.180, the structural contradiction of strong population concentration coupled with weak economic support remains unresolved. Taking Linyi and Heze as examples: Linyi, the most populous city in Southern Shandong, had a permanent population exceeding 11 million in 2023, yet its tertiary industry accounted for only 43.2%. The population magnetism of traditional commerce and logistics failed to effectively translate into high-quality economic growth momentum. While Heze's GDP growth rate consistently ranked among the province's top, its per capita GDP in 2023 still lagged approximately 30% below the provincial average, revealing insufficient economic capacity to "feed back" population growth.

From a macro perspective, the development trends of the three major economic circles align closely with Shandong Province's overall urbanization and economic growth. Between 2014 and 2023, the province's urbanization rate rose from 55.01% to 64.07%, with an average annual GDP growth of 6.5%. The Jiaodong Economic circle maintained a stable GDP share above 40%, while the Provincial Capital Economic Circle increased its contribution from 23% to 28%. The Lunan Economic circle sustained a share around 20%, demonstrating a dynamic balance between regional stability and strategic adjustments.

In summary, future strategies should be customized according to the unique characteristics of the three economic circles. The Jiaodong Economic circle ought to reinforce its dual - core radiation via Qingdao and Yantai, facilitate industrial synergy between Weihai and Rizhao, and further solidify the balanced advantages of its population - economy system. The Provincial Capital Economic circle is required to deepen the core driving function of Jinan by capitalizing on industrial cooperation with cities such as Zibo and Tai'an, thereby magnifying the synergistic effects of administrative restructuring. The Lunan Economic circle should concentrate on industrial upgrading to improve its economic support capacity for population growth, gradually reducing the development disparity with the Jiaodong and

ISSN 2616-5902 Vol. 7, Issue 10: 83-89, DOI: 10.25236/AJBM.2025.071013

Provincial Capital Economic circles. Only through these coordinated endeavors can Shandong Province attain comprehensive synergy and high - quality development in its population - economy system.

Table 1 Comprehensive evaluation results of population system (U_1) and economic system (U_2) in major years of three economic circles in Shandong Province

Region	Indicator	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Provincial Capital Economic Circle	U_1	0.378	0.378	0.376	0.376	0.38	0.427	0.372	0.372	0.371	0.37
	U_2	0.262	0.259	0.257	0.257	0.247	0.231	0.229	0.213	0.212	0.205
Jiaodong Economic Circle	U_1	0.504	0.483	0.482	0.481	0.483	0.488	0.499	0.497	0.497	0.487
	U_2	0.447	0.441	0.447	0.451	0.451	0.453	0.461	0.413	0.418	0.419
Lunan Economic Circle	U_1	0.504	0.483	0.482	0.481	0.483	0.488	0.499	0.497	0.497	0.487
	U_2	0.447	0.441	0.447	0.451	0.451	0.453	0.461	0.413	0.418	0.419

From 2014 to 2023（in Table 1）, the three major economic Circles have maintained consistently high and steadily increasing coupling degrees between population and economic systems, reflecting deepening regional interactions without systemic disconnection. The Jiaodong Economic Circle consistently leads with the strongest system interaction. The provincial capital economic Circle demonstrated accelerated growth in coupling degree during the mid-term period, highlighting the strengthening effects of key policy adjustments on systemic connectivity. Although the Lunan Economic Circle shows the lowest coupling degree, it has also exhibited a gradual upward trend, demonstrating continuously enhanced mutual interactions.

Unlike the stability of coupling degree, the comprehensive coordination function and coupling coordination degree exhibit a pattern of gradient increase with differences becoming increasingly fixed. According to Table 1, the Jiaodong Economic Circle has long maintained the highest comprehensive coordination function among the three major economic circles, demonstrating significant advantages in population-economic system development. The provincial capital economic circle achieved a phased leap in its comprehensive coordination function during the mid-term period, followed by steady growth. In contrast, the Lunan Economic Circle has remained at a low level for an extended period, revealing obvious weaknesses in its overall system strength.

Table 1 presents the three major economic Circles have formed a tiered structure: Jiaodong leads the pack, the provincial capital is catching up, while Lunan remains lagging behind. The Jiaodong Economic Circle has consistently been in a phase of coordination refinement, with collaborative quality continuously improving. The provincial capital's economic Circle has transitioned from the antagonistic phase to coordination refinement during its mid-term development, maintaining stable synergy thereafter. Conversely, the Lunan Economic Circle has long remained in the antagonistic phase, failing to break through critical thresholds in systemic coordination, and urgently requires enhanced development momentum.

Table 2 Coupling index of population and economic system in the three major economic circles of 2014-2023 Shandong Province

Region	Index	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Provincial Capital Economic Circle	C	0.984	0.982	0.981	0.981	0.977	0.964	0.979	0.975	0.974	0.972
	T	0.22	0.219	0.217	0.217	0.214	0.329	0.301	0.293	0.292	0.288
	D	0.469	0.468	0.465	0.465	0.46	0.565	0.544	0.535	0.533	0.526
	Type	A	A	A	A	A	I	I	I	I	I
Jiaodong Economic Circle	C	0.969	0.966	0.968	0.97	0.97	0.971	0.973	0.966	0.967	0.965
	T	0.476	0.462	0.465	0.466	0.467	0.471	0.48	0.455	0.458	0.453
	D	0.676	0.668	0.671	0.673	0.674	0.678	0.682	0.659	0.661	0.657
	Type	I	I	I	I	I	I	I	I	I	I
Lunan Economic Circle	C	0.748	0.75	0.752	0.756	0.754	0.883	0.894	0.834	0.829	0.826
	T	0.435	0.435	0.436	0.439	0.436	0.293	0.299	0.261	0.258	0.257
	D	0.569	0.572	0.574	0.578	0.576	0.508	0.515	0.466	0.462	0.46
	Type	I	I	I	I	I	I	I	A	A	A

Note: A represents antagonistic phase; I represents integration phase

From 2014 to 2023, the coupling degree (C) between population and economic systems in the three major economic circles maintained high levels with periodic fluctuations, reflecting dynamic adjustments in regional interaction intensity as development progresses. The Jiaodong Economic circle consistently led with the strongest system interaction. The Provincial Capital Economic circle showed slight fluctuations but remained at a high level, demonstrating how administrative adjustments influence systemic connectivity. The Lunan Economic circle exhibited an upward trend followed by stabilization, with continuously strengthening system interactions.

ISSN 2616-5902 Vol. 7, Issue 10: 83-89, DOI: 10.25236/AJBM.2025.071013

As shown in Table 2, unlike the fluctuating coupling degree, the Comprehensive Coordination Function (T) and Coupling Coordination Degree (D) exhibit distinct gradient patterns and stage-specific differentiation. The Jiaodong Economic Circle has consistently maintained the highest Comprehensive Coordination Function among the three major economic circles, demonstrating significant advantages in population-economic system development. The Provincial Capital Economic Circle achieved a phased leap in Comprehensive Coordination Function in 2019, followed by steady adjustments. In contrast, the Lunan Economic Circle has remained at a low Comprehensive Coordination Function level for an extended period, with subsequent declines indicating notable weaknesses in systemic comprehensive strength.

In terms of coordination patterns, the three major economic circles have formed a tiered structure: Jiaodong maintains a stable integration phase with continuously improving collaboration quality, the provincial capital circle achieved a transition from antagonism to integration in 2019 and has maintained stable coordination since, while Lunan remained in the integration phase initially and stayed in antagonism after 2021. The system-wide coordination capability has failed to surpass the critical threshold, with development momentum requiring urgent reinforcement（in Table 2）.

4. Development paths

Based on the differentiated characteristics of the three economic circles, it is necessary to build a development path of precise policy and comprehensive coordination to promote the high-quality coupling of population and regional economic system.

4.1 Jiaodong Economic Circle: Consolidate the advantages of balance and strengthen the coordination of the whole region

To enhance dual-core radiation capabilities, with Qingdao and Yantai as hubs, the Jiaodong Economic Circle will focus on advantageous industries such as marine economy, high-end equipment manufacturing, and digital economy. This strategy will extend industrial chains to high-value-added segments, continuously attract high-skilled talent, and reinforce the positive feedback loop of "economic strength driving population concentration." Leveraging platforms like Qingdao West Coast New Area and Yantai Bohai New Area, the circle aim to establish regional industrial innovation poles, thereby enhancing technological and talent radiation to neighboring cities.

Enhance the regional division of labor and cooperation by leveraging the port advantages of Weihai and Rizhao to foster the growth of industries with distinctive features, such as marine fisheries and green petrochemicals. Concurrently, Weifang should focus on the development of high-end chemicals and sophisticated manufacturing to circumvent competitive uniformity. Local governments of Shandong's three major economic circles shall establish inter-city industrial coordination mechanisms to facilitate the seamless flow of talent, technology, and capital. The Jiaodong Economic Circle's administrative coordination body shall develop a talent-sharing platform for the Jiaodong Economic Circle to achieve a balance between labor supply and demand in core cities and smaller towns, thereby diminishing internal development disparities.

4.2 Provincial capital economic circle: magnify the core effect and promote the linkage of circles

To bolster Jinan's central driving force, the city will persist in advancing the "Strong Provincial Capital" initiative, prioritizing the development of strategic emerging industries such as the digital economy, biomedicine, and high-end equipment manufacturing. This strategic focus aims to enhance the dual-core capabilities of GDP growth and population concentration. By capitalizing on Jinan's New and Old Kinetic Energy Conversion Pilot circle, the goal is to establish a regional economic growth pole that draws industrial chain support and population influx from neighboring cities, including Zibo, Tai'an, and Dezhou, ultimately forming a "1-hour commuting circle".

To optimize the benefits of administrative integration, post-Laiwu's incorporation, the city will deepen resource convergence, promoting integrated development between Jinan and Laiwu in industrial layout, public services, and infrastructure. This includes coordinated planning for rail transit and the sharing of educational and medical resources, thus avoiding the "administrative merger-functional fragmentation" dilemma. Additionally, establishing industrial linkage mechanisms between Jinan and cities such as Zibo, Tai'an, and Liaocheng will transform the provincial capital economic circle into a

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core platform for population and economic synergy in central Shandong.

4.3 Lunan Economic Circle: Solving structural contradictions and improving supporting capacity

Driving industrial upgrading and transformation, Linyi is focusing on digital transformation in trade and logistics, building regional logistics hubs and e-commerce industrial bases to convert its demographic advantages into momentum for high-quality economic development. Heze leverages clusters in biomedicine and high-end chemicals to cultivate leading enterprises and enhance industrial value-added. Zaozhuang and Jining are accelerating green transitions in traditional coal and coking industries, developing new energy and cultural tourism sectors to optimize industrial structures while strengthening their capacity to absorb and support population growth.

Enhancing population-industry alignment, Leveraging Lunan's large population and abundant labor resources, targeted vocational training programs are implemented to meet local industrial demands and curb labor outflow. Through the integrated development plan for the Lunan Economic Circle, coordinated industrial collaboration among the four cities is being advanced. For instance, Jining focuses on high-end equipment manufacturing while Zaozhuang develops lithium battery industries, creating a synergistic pattern of "specialized industries driving population concentration". This approach gradually narrows the gap with the Jiaodong region and the provincial capital economic circle.

4.4 Provincial level: Establish a coordination mechanism to promote regional coordination

Establishing a cross-regional coordination platform, At the provincial level, a Leading Group for Population-Economic Synergy Development in three major economic circles will be established to coordinate industrial planning, resource allocation, and public services. A targeted collaboration mechanism will be implemented between Jiaodong, the provincial capital, and Lunan, enabling Jiaodong's economic circle to transfer technological and industrial projects to Lunan while sharing innovation resources with the provincial capital's economic circle. This initiative aims to transform regional disparities from passive reduction to proactive collaboration.

Strengthening the Element Support System, Optimize the household registration system and public services. For instance, relax settlement restrictions for residents from the Lunan Economic Circle migrating to Jiaodong and the Provincial Capital Economic Circle. Simultaneously, advance cross-regional settlement of public services such as education and healthcare to reduce institutional barriers to population mobility. Increase fiscal and policy support for the Lunan Economic Circle, focusing on industrial upgrading and infrastructure development. This will ensure coordinated population-economic development, ultimately achieving comprehensive collaboration and high-quality growth across Shandong Province's population and regional economic systems.

Acknowledgments

Project Funding: 2021 Shandong Provincial Social Science Planning Project: Research on the Trends, Characteristics, and Socioeconomic Impacts of Population Development in Shandong in the New Era (21CPYJ34).

References

[1] Hou Li, A Ruhuan. Analysis of the spatiotemporal evolution and driving factors of population changes in China's regions [J]. Journal of Demography, 2025,47(03):1-18.
[2] Du C, Yang S, Song X. Study on the Coupling Mechanism of Regional Economy and Regional Population Mobility in Less Developed Regions Based on AHP-CRITIC Coupling Perspective[J]. BCP Business & Management, 2022, 33: 284-295.
[3] Xing L. Evaluation of the impact of artificial intelligence and intelligent Internet of Things on population mobility on regional economic differences[J]. Soft Computing, 2023, 28(23-24): 13977-13988.
[4] Yin Y, Tong J, Gu J, et al. Socio-hydrology pathway of grain virtual water flow in China[J]. Agricultural Water Management, 2024, 292: 108658.
[5] Yuan Xin, Golden Bull. Supporting Chinese-style Modernization through High-quality Population Development: Context, Strategy, and Pathways [J]. Social Policy Research, 2025(02):3-14+132.
[6] Yang Tongtong, Zhao Qiuli, Feng Fan. Shandong: Building a Pioneer circle for Green, Low-Carbon,

ISSN 2616-5902 Vol. 7, Issue 10: 83-89, DOI: 10.25236/AJBM.2025.071013

and High-Quality Development [N]. Guangming Daily, 2024-04-11 (004).
[7] Li Xiaoqing, Zhang Qiang. Population Development Trends and Response Strategies in Shandong under High-Quality Development [J]. Shandong Macroeconomic, 2025, (03):24-29.
[8] Cui Shuyi. Promoting High-Quality Economic and Social Development in Shandong Through Proactive Population Policy Responses [J]. Shandong Human Resources and Social Security, 2024, (11):8-10.
[9] Wang Zhiyu, Lu Chang, Cai Xueqin et al. Carbon intensity and ecological impacts of the 'space-economy-population' model in the Shandong section of the Yellow River Basin The spatiotemporal interaction of system services [J]. Environmental Science, 2025,46(03):1573-1584.
[10] Fan Liyu, Gao Feng. Spatiotemporal Evolution Characteristics and Prediction Analysis of Coupling Coordination of Population, Resources, Economy and Environment (PREE) System in China Province [J]. Ecological Economics, 2023,39(03):168-176.
[11] Liu Qingfang, Li Mengqi, Song Jinping et al. Population-Socioeconomic-Resource-Environment Synergy and Interactive Responses in the Qinghai-Tibet Plateau Region [J]. Economic Geography, 2025,45(09):32-43.