Postprint: Spatiotemporal Differentiation Characteristics of Coupled Coordinated Development Between Land Ports and Carrier Towns in Xinjiang

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Abstract

Promoting the coordinated development of border ports and their carrier towns constitutes an important element in the high-quality development of the "port economic belt." This study employs the entropy weight method and coupling coordination model to measure the spatiotemporal evolution characteristics of the coupling coordination level between Xinjiang' s land ports and their carrier towns from 2009 to 2019. The results demonstrate: (1) The comprehensive development level of Xinjiang' s major land ports and their carrier towns has exhibited a steady upward trend overall. Since 2015, the driving force for the integrated development of the two systems has gradually shifted from port-led to carrier town-led, with excessive dependence on import and export volumes representing the primary cause for the slowdown in port economic growth. (2) The coupling coordination level between Xinjiang' s major land ports and their carrier towns is generally optimizing, which can be categorized into three types: well-coordinated ports exemplified by Alashankou Port, primarily-coordinated ports exemplified by Bakhtu Port, and barely-coordinated ports exemplified by Takeshiken Port. (3) Spatially, Xinjiang' s land port economic development pattern is evolving toward a configuration that balances Alashankou Port and Horgos Port, with multi-port balanced development across northern and southern Xinjiang. However, the relatively lagging socioeconomic development of certain carrier towns constrains further enhancement of the coordinated development level with ports.

Full Text

Preamble

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Spatiotemporal Differentiation Characteristics of Coupled Coordinated Development Between Xinjiang Land Ports and Carrier Towns

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Abstract: Promoting coordinated development between border ports and their carrier towns constitutes a crucial component of high-quality development for "port economic belts." This study employs the entropy weight method and coupling coordination model to measure the spatiotemporal evolution characteristics of coupling coordination levels between Xinjiang' s land ports and their carrier towns from 2009 to 2019. The results indicate: (1) The comprehensive development level of Xinjiang' s major land ports and their carrier towns has generally risen steadily, with the development dynamic shifting from port-led to carrier town-led. Over-reliance on import-export volume represents the primary reason for the slowdown in port economic growth. (2) The coupling coordination level between Xinjiang' s major land ports and their carrier towns has generally improved and can be classified into three types: sound coordination represented by Alashankou Port, primary coordination represented by Baketu Port, and barely coordinated represented by Takeshiken Port. (3) Spatially, Xinjiang' s land port economic development pattern is evolving toward a new configuration featuring both Alashankou and Khorgas ports as dual cores, with multiple ports achieving balanced development across northern and southern Xinjiang. However, the relatively backward socioeconomic development of some carrier towns constrains further enhancement of port-town coordination levels.

Keywords: port economic belt; Xinjiang land ports; carrier towns; coupling coordination degree; spatiotemporal characteristics

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1. Introduction

Border ports and their carrier towns form a symbiotic economic community characterized by dynamic collaborative development patterns. As essential channels for national foreign trade, border ports leverage their geo-economic advantages and openness to perform economic agglomeration functions, facilitate spatial reallocation of production factors, and drive leapfrog development in border regions. Port economic development stimulates regional production activities

by expanding demand, increasing employment, and optimizing industrial structures. Conversely, regional economies supply ports with labor, capital, and other production factors essential for their normal operation, while simultaneously expanding foreign trade demand, thereby creating a virtuous cycle of mutual promotion between ports and carrier towns.

Recent domestic scholarship has extensively examined coordinated development between border ports and carrier towns, focusing primarily on coordination mechanisms and micro-scale assessments of coupling coordination levels. Research demonstrates that port economies accelerate resource concentration in border areas, directly influence urban spatial layouts, optimize industrial structures, and cultivate export-oriented economies in carrier towns, thereby achieving the goal of "enriching borders and benefiting residents." Quantitative studies further reveal that port import-export volumes, cargo throughput, and cross-border passenger flows significantly promote carrier town economic development. Carrier towns, in turn, serve as consumer markets, raw material suppliers, labor sources, and processing bases for foreign trade commodities. The practical value of ports depends largely on their relationship with carrier towns, with the intensity of this relationship determined by spatial distance and transportation capacity.

Building on these theoretical foundations, scholars have constructed port economic development evaluation systems using indicators such as import-export cargo volume, trade volume, and cross-border passenger flows. Applying methods including the improved dynamic concentration index, coupling coordination models, and grey correlation analysis, researchers have investigated coordination levels between ports and their carrier towns in Manzhouli, Yunnan' s Houqiao Port, Hunchun City in Jilin Province, and Xinjiang' s land ports. However, most studies concentrate on provinces such as Yunnan, Inner Mongolia, Guangxi, and the three northeastern provinces, with limited quantitative research on Xinjiang' s land ports despite its status as a crucial gateway for China' s westward opening-up. Existing Xinjiang studies suffer from unreasonable indicator selection and insufficient analysis of spatial characteristics.

Under strong national support, Xinjiang' s port economy has achieved considerable progress, yet most ports still exhibit prominent "cargo transit" tendencies with underdeveloped capacity to radiate and drive regional socioeconomic development. Simultaneously, Xinjiang' s port carrier towns generally lag in socioeconomic development, struggling to provide adequate support for port economies. As of 2018, Xinjiang' s border small-scale trade reached 142.271 billion RMB, accounting for 39.58% of the region' s total foreign trade and 60.01% of national border small-scale trade, ranking second nationally after Guangxi. Despite this progress, significant imbalances persist among ports, indicating substantial untapped development potential. More than half of carrier towns have GDP below 8 billion RMB and populations under 50,000, with most located far from Xinjiang' s economic centers, exhibiting characteristics of oasis economies.

At the end of 2018, the Sixth Plenary Session of the Ninth Xinjiang Regional

Party Committee and the Regional Party Committee' s Economic Work Conference explicitly emphasized the need to accelerate core area construction of the Silk Road Economic Belt by focusing on "one port, two zones, five centers, and port economic belts," making coordinated port-carrier town development an urgent priority. This study employs the coupling coordination model with a reasonably constructed evaluation indicator system to conduct spatiotemporal analysis of coordination levels between Xinjiang' s major land ports and their carrier towns. The research identifies key factors hindering coordinated development and proposes corresponding countermeasures, providing valuable references for promoting coordinated development and accelerating "port economic belt" construction in Xinjiang.

2. Study Area and Methods

2.1 Study Area Overview

Xinjiang is situated in the heart of the Eurasian continent, bordering eight countries with 17 state-level Class I land ports approved by the State Council, including 4 China-Mongolia ports, 7 China-Kazakhstan ports, 2 China-Kyrgyzstan ports, 1 China-Pakistan port, and 1 China-Tajikistan port. Among these, the Ashitubieke and Muzhaerte ports remain unopened, while Hongshanzui and Wulasitai ports have minimal and unstable trade volumes of only several hundred thousand dollars, making them unsuitable for analysis. The final selection includes 12 land ports as study objects (Table 1).

2.2 Indicator System and Data Processing

2.2.1 Indicator System Establishment To accurately measure the coordinated development level between Xinjiang' s land ports and carrier towns, this study constructs an objective and reasonable evaluation indicator system based on principles of comprehensiveness, systematicity, and data availability. Drawing on relevant research and making adjustments according to actual conditions, the system incorporates geographic location, cargo value, and logistics development level indicators to compensate for previous shortcomings in port development evaluation. Geographic location significantly influences land port development, as ports closer to carrier towns benefit from lower transportation costs and tighter economic integration. Accurate measurement of port economic development must also consider import-export cargo value, as high-value goods exert greater impact on port logistics activity. Since direct logistics industry indicators for Xinjiang ports are unavailable, this study substitutes them with carrier towns' transportation, warehousing, postal service values, and cross-border vehicle counts (Table 2).

2.2.2 Data Sources and Preprocessing Port and carrier town data were collected from the *Xinjiang Statistical Yearbook* and *China Port Yearbook* (2009-

2019), with missing values replaced by mean values. Alashankou City was established on July 29, 2012, and Khorgas City on June 26, 2014, both originally under the jurisdiction of Bole City and Huocheng County respectively. For statistical consistency, data for these new cities were aggregated back to their original jurisdictions.

2.2.3 Data Standardization and Weight Determination Due to significant fluctuations in some indicators that could affect entropy method accuracy and produce excessively small dimensionless values for ports other than Alashankou and Khorgas, logarithmic transformation was applied before dimensionless processing to compress absolute differences and enhance comparability:

$$Y_{ij} = \ln(X_{ij})$$

To eliminate dimensional effects and ensure comparability, normalization was employed using linear transformation:

$$Y_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \text{ for positive indicators}$$
$$Y_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)} \text{ for negative indicators}$$

where X_j represents the minimum and maximum values of indicator j in the same year, X_{ij} is the original data, and Y_{ij} is the dimensionless value ($0 \leq Y_{ij} \leq 1$). For subsequent logarithmic operations, non-negative processing was applied: $Y'_{ij} = Y_{ij} + a$, where a is the minimum value after dimensionless processing to preserve data properties.

The entropy method reveals information content across all data streams through entropy' s additivity, providing objective weight determination:

$$p_{ij} = \frac{Y'_{ij}}{\sum_i Y'_{ij}}$$
$$e_j = -\frac{1}{\ln(n)} \sum_i p_{ij} \ln(p_{ij})$$

where e_j is the entropy value (higher values indicate greater indicator importance), p_{ij} is the proportion of indicator j in year i, and n is the number of indicators. Comprehensive development levels for ports and carrier towns were calculated by summing weighted indicators (Table 2).

2.3 Coupling Coordination Models

2.3.1 Coupling Degree Model Derived from physics' capacity coupling concept, the coupling degree model has become a mature quantitative tool for measuring interaction levels among multiple systems in economic, social, ecological, and geographic research. It reveals the internal coordination mechanism of mutual influence between ports and carrier towns:

$$C = 2 \times \sqrt{\frac{U_1 \times U_2}{(U_1 + U_2)^2}}$$

where U_1 is port development level, U_2 is carrier town development level, and C is the coupling degree (higher values indicate stronger mutual association).

2.3.2 Coupling Coordination Degree Model The coupling degree model only measures correlation without reflecting development levels, potentially creating "pseudo-coordination" with high coupling at low development levels. To address this, the coupling coordination degree model is introduced:

$$D = \sqrt{C \times T}$$
$$T = \alpha U_1 + \beta U_2$$

where D is the coupling coordination degree, T is the comprehensive development level, and α and β are coefficients (both set to 0.5 as port and carrier town systems are considered equally important). Higher D values indicate better coordinated development. Based on existing research and this study' s context, coupling coordination degrees are classified into eight types (Table 3).

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3. Results and Analysis

3.1 Temporal Evolution of Coordinated Development

Overall, the comprehensive development level of Xinjiang' s land ports and carrier towns exhibited fluctuating upward trends from 2009-2019 (Figure 1). Two distinct phases emerged: Phase 1 (2009-2014) showed stable growth, while Phase 2 (2015-2019) experienced initial decline followed by gradual recovery. In Phase 1, both port and carrier town systems developed synchronously upward, with port system development significantly exceeding carrier towns and serving as the primary development driver. In Phase 2, port economic development declined after peaking in 2014, then gradually recovered, while carrier town development continued rapid growth with only minor fluctuations in 2015, narrowing the gap between systems. During 2015-2019, carrier towns contributed 76.94% to comprehensive development growth versus only 23.06% from ports, marking a shift from port-led to carrier town-led development. The slowdown in port system development became the main constraint on further progress, primarily attributable to declining import-export volumes (Figure 2).

Specifically (Figures 3 and 4), Xinjiang' s land ports and carrier towns show strong similarities in development patterns. The top three performers in both systems were Alashankou Port, Khorgas Port, Baketu Port, and their respective carrier towns, demonstrating strong correlation. Alashankou Port, Xinjiang' s earliest modern border port town, maintained large advantages in cargo volume and trade value but experienced slowed growth in Phase 2 due to transport capacity saturation and cargo diversion to other ports. Khorgas Port, leveraging the Khorgas Economic Development Zone and China-Kazakhstan Khorgas International Border Cooperation Center, achieved sustained rapid development, reaching Xinjiang' s highest port economic level. Baketu Port performed well

in Phase 1 but gradually declined in Phase 2, showing insufficient momentum. Other ports exhibited considerable volatility, reflecting generally weak and externally vulnerable port economic development without stable growth models.

While carrier town development maintained overall upward momentum, inter-town disparities widened significantly. Bole City and Huocheng County ranked in the first tier, Tacheng City and Balikun County in the second tier, and others in the third tier, displaying a "strong remain strong" pattern. This likely stems from superior initial economic conditions in top-ranked towns and port economies reaching stages where they can radiate and drive carrier town development.

Comparing port development levels with cargo volumes across the two phases reveals that Phase 1' s port-led model achieved 21.94% average annual growth in port development, supported by stable import-export volume growth (4.44% annually). However, the 2015 cargo volume decline severely impacted port economies, exposing over-dependence on throughput in the "channel economy" model. Phase 2' s slower import-export growth could no longer sustain previous rapid port economic expansion, making transformation imperative. Yet Xinjiang' s land ports remain in an adaptation period for this economic transition.

Applying the coupling coordination model (Figure 5) shows that Xinjiang' s major land ports and carrier towns experienced steadily rising coupling coordination degrees from 2009-2019, with most crossing one coordination level despite increased fluctuation after 2015. Three coordination types emerge: (1) Sound coordination (Alashankou and Khorgas ports) characterized by leading national cargo volumes, established county-level cities, and strong economic platforms; (2) Primary coordination (Baketu, Turugart, Irkeshtam, Jeminay, Dulata, and Laoyemiao ports) featuring high-value import-export goods but insufficient processing capacity, weak carrier town economies, and extensive trade methods; (3) Barely coordinated (Takeshiken, Karasu, and Khunjerab ports) with resource-energy import orientation, weak primary processing capacity, and carrier towns unable to provide adequate support.

3.2 Spatial Characteristics of Coordinated Development

Spatially (Figure 6), Xinjiang' s vast territory and complex geography result in scattered, point-distributed ports, with only the Tacheng-Yili corridor showing relative concentration. This distance from economic centers constitutes a major disadvantage. In 2009, the development pattern was dominated by Alashankou Port, with Khorgas and Baketu ports in primary coordination and others in imminent imbalance, displaying a "strong north, weak south" pattern. By 2019, this landscape transformed significantly: Khorgas Port' s establishment as a county-level city elevated its development potential and driving capacity, allowing it to surpass Alashankou Port in coupling coordination. Ports along the Tacheng-Yili corridor saw their development 重心 gradually shift southward, while Mongolia-oriented ports (Laoyemiao, Takeshiken) benefited from rising

energy resource imports and infrastructure development. Southern Xinjiang ports (Turugart, Irkeshtam, Karasu) also progressed, reflecting effective policy support for the Silk Road Economic Belt core area.

However, most carrier towns remain economically backward with incomplete industrial systems and weak transportation infrastructure, limiting their support for port economies. Notably, development gaps among carrier towns continue widening, with southern Xinjiang towns lagging further behind, severely restricting coupling coordination improvement for southern ports. The "strong north, weak south" pattern is likely to persist long-term.

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4. Conclusions and Recommendations

4.1 Conclusions

This study constructed an evaluation indicator system and employed entropy weight and coupling coordination models to analyze spatiotemporal characteristics of coordinated development between Xinjiang's major land ports and carrier towns. Key findings include:

1) From 2009-2019, the comprehensive development level of Xinjiang's major land ports and carrier towns rose steadily overall. Specifically, during 2009-2014, both systems developed synchronously upward; after 2015, the development dynamic shifted from port-led to carrier town-led as port system growth slowed. The "channel economy" model' s over-reliance on import-export volume represents the primary cause of port economic deceleration.

2) The coupling coordination degree between Xinjiang' s major land ports and carrier towns showed stable improvement, with most crossing one coordination level and the "strong north, weak south" pattern moderating. Current coordination levels divide into three categories: sound coordination (Khorgas and Alashankou ports), primary coordination (Baketu, Turugart, Irkeshtam, Jeminay, Dulata, and Laoyemiao ports), and barely coordinated (Takeshiken, Karasu, and Khunjerab ports).

3) Spatially, Alashankou Port' s dominance has gradually diminished, with Xinjiang' s land port development pattern evolving toward dual-core leadership by Alashankou and Khorgas ports alongside balanced multi-port development across northern and southern Xinjiang. However, southern Xinjiang' s carrier towns lag significantly behind their northern counterparts, constraining coordinated development enhancement.

4.2 Recommendations

1) **Accelerate Port Economic Model Transformation**
The port economic slowdown reflects bottlenecks in the "channel econ-

omy" model. To break through: (a) improve port infrastructure capacity based on local conditions; (b) implement preferential policies encouraging local processing of imported resources to transform ports from "channel economy" to "industrial economy."

2) **Enhance Hinterland Support for Port Economies**
Given carrier towns' generally backward socioeconomic development, consider coordinating port resources at the prefecture level to accelerate port-hinterland integration. Provide special funds for infrastructure construction based on port positioning, while strengthening various forms of economic and technical cooperation between regional economic centers and ports to provide industrial support for port transformation.

3) **Build Functionally Complementary, Distinctive Port Clusters**
The southward shift in the Tacheng-Yili corridor' s development 重心 reflects both improved backward ports and 同质化 competition. Therefore, clarify each port' s functional positioning, strengthen inter-port division of labor and cooperation, and develop functionally complementary, distinctive port clusters with strong driving force for border regions to optimize resource allocation and maximize overall benefits.

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