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Study on Tianjin's Role in Promoting Higher Education Coordination in Beijing-Tianjin-Hebei Region

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Abstract **Original Research Article**

The collaborative development of higher education in the Beijing-Tianjin-Hebei (BTH) region has emerged as a pivotal driver for advancing regional cooperation. Leveraging a comprehensive dataset on higher education institutions and policy frameworks within the BTH region, this study evaluates the current level of collaborative development using a multidimensional assessment index system. Focusing on Tianjin's role in this tripartite synergy, the analysis identifies systemic challenges in institutional mechanisms, resource allocation efficiency, talent retention, and service orientation. To enhance Tianjin's contribution to regional integration, strategic recommendations are proposed, including establishing an independent regulatory and evaluation body, optimizing resource supply-demand dynamics, innovating talent recruitment mechanisms, and cultivating discipline-specific strengths aligned with regional priorities. These insights aim to inform policy design and foster a more cohesive, sustainable higher education ecosystem within the BTH framework.

Keywords: *Collaborative Development, Higher Education, Synergy Evaluation, Regional Integration.*

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1. CONTEXT OF HIGHER EDUCATION COLLABORATION IN THE BEIJING-TIANJIN-HEBEI REGION

The Beijing-Tianjin-Hebei (BTH) collaborative development strategy, a national priority, aims to establish a modern capital economic circle, foster balanced regional growth across China, and consolidate regional resources to cultivate new economic growth poles for global competitiveness. Within this framework, higher education collaboration has emerged as both a defining feature and a critical enabler of the BTH integration agenda. The region's higher education institutions (HEIs), leveraging their unique collaborative advantages, now serve as a catalytic force in advancing regional partnerships. However, significant disparities in resource allocation—particularly the concentration of elite institutions in Beijing—pose structural challenges to equitable collaboration. Addressing these imbalances is central to the ongoing decentralization initiatives aimed at relocating non-capital functions from Beijing, thereby reconciling resource asymmetry with deeper synergy. Grounded in empirical data and policy analyses from the BTH region, this study employs a multidimensional evaluation index system to quantify higher education collaboration levels. It further examines Tianjin's systemic bottlenecks in institutional coordination, resource integration, talent mobility, and functional positioning, proposing actionable strategies to amplify its role in the regional collaboration ecosystem.

2. LITERATURE REVIEW

Synergy degree serves as a pivotal metric to quantify the developmental alignment among subsystems or constituent elements within a system. It evaluates both the progression from disordered to ordered states and the attainment of synergistic equilibrium during systemic evolution. Current methodologies for synergy analysis include: Distance Synergy Model, Coupling Coordination Model, Grey Relational Analysis, Composite System Synergy Model. These models have been widely applied across disciplines. The selection of an appropriate model hinges on its capacity to address specific research questions with precision. Notably, the composite system synergy model has gained prominence in cross-regional studies due to its theoretical robustness. A composite system constitutes an open, heterogeneous network of subsystems with distinct attributes. Internally, subsystems interact synergistically, generating emergent structures and functionalities that transcend individual contributions. Externally, the system engages in continuous exchanges of

information, energy, and resources with its environment. These dual interactions—internal synergy and external adaptation—drive the system toward dynamic equilibrium, where the composite system's aggregate functionality exceeds the mere sum of its parts. This process fosters structural optimization, functional amplification, and progressive ordering, ultimately achieving a metastable equilibrium that sustains systemic resilience and innovation capacity.

3. ASSESSING SYNERGY LEVELS IN BTH HIGHER EDUCATION COLLABORATION

3.1 Indicator Selection for the Collaboration Evaluation Model

Higher education collaboration entails cross-regional partnerships that facilitate resource sharing, knowledge exchange, and institutional alignment. Its efficacy hinges on three interdependent dimensions: educational inputs, processes, and outputs. These dimensions respectively reflect the core elements of higher education systems: structural rationality, resource optimization, and functional effectiveness. To operationalize this framework, a quantifiable evaluation index system was developed through literature synthesis and stakeholder input. Guided by principles of scientific rigor, objectivity, and measurability, the system hierarchically organizes: Tier 1 Indicators: Scale of Collaboration, Input Intensity, and Output Performance. Tier 2-3 Indicators: Context-specific metrics such as cross-institutional program density, funding parity ratios, and industry-academia co-publication rates (see Table 1).

Table 1. Evaluation Index System for Higher Education Synergy Development

System	Tier 1 Indicators	Tier 2 Indicators	Tier 3 Indicators
Regional Higher Education System	Scale of Collaboration	Institutional Scale	Number of HEIs (units)
			Number of Project 211 HEIs (units)
		Student Enrollment	Undergraduate/College Students (persons)
			Master's Students (persons)
			Doctoral Students (persons)
			Students per 100,000 Population (persons)
	Input Intensity	Human Resources	Full-time Faculty Members (persons)
			Percentage of Senior Faculty (Associate Professor+) (%)
			Student-to-Faculty Ratio (%)
		Physical Resources	Campus Area (m²)
			Library Holdings (10,000 volumes)
			Total Fixed Assets (CNY 10,000)
		Financial Investment	Total Higher Education Expenditure (CNY 10,000)
			Higher Education Expenditure as % of Regional Education Budget (%)
			Per-Student Expenditure (CNY)
	Output Performance	Research Output	Published Papers (articles)
			Academic Monographs (titles)
			Patent Applications (units)
		Talent Cultivation	Undergraduate Graduates (persons)
			Master's Graduates (persons)
			Doctoral Graduates (persons)

3.2 Determination of the Higher Education Synergy Measurement Model

The research subject constitutes a composite system comprising multiple subsystems $S=(S_1,S_2,S_3,\ldots,S_n)$, (where S_j denotes the j-th subsystem). These subsystems interact synergistically, generating emergent properties that exceed the sum of their individual functionalities. Each subsystem S_j is further composed of heterogeneous elements governed by order parameters, which dictate the system's evolutionary trajectory. $e_j=(e_{j1},e_{j2},e_{j3},\ldots e_{jn})$, $n_j\geq 1$, $\beta_{ji}\leq e_{ji}\leq\alpha_{ji}$, $i\in[1,\ n_j]$ represent the S_j, with α and β denoting its upper and lower bounds, respectively. The contribution of u_j to the subsystem's orderliness depends on its polarity:

$$u_j(e_{ji})=\begin{cases}\dfrac{e_{ji}-\beta_{ji}}{\alpha_{ji}-\beta_{ji}}, & i\in[1,\ k_1]\\ \dfrac{\alpha_{ji}-e_{ji}}{\alpha_{ji}-\beta_{ji}}, & i\in[k_1+1,\ n_j]\end{cases} \quad (1)$$

From the composite system perspective, the collective influence of order parameters on the ordered state of subsystem e_j can be quantified by aggregating the order degrees of all its order parameter components via a linear weighting method:

$$u_j(e_j)=\sum_{j=1}^{n}\xi_j u_j(e_{ji}),\quad \xi_j\geq 0,\sum_{j=1}^{n}\xi_j=1 \qquad (2)$$

The synergy degree of a composite system can be expressed as:

$$C=\theta^n\sqrt{\prod_{i=1}^{n}\left[u_j^i(e_j)-u_j^0(e_j)\right]} \qquad (3)$$

Establishing synergy levels and evaluation criteria for composite systems is pivotal for assessing their collaborative development status. This study classifies synergy degree into four tiers based on its magnitude, as detailed in Table 2:

Table 2. Synergy Levels and Criteria for the Regional Higher Education Composite System

Synergy Degree	$-1 \leq C \leq 0$	$0 < C \leq 0.3$	$0.3 < C \leq 0.7$	$0.7 < C \leq 1$
Synergy State	Non-synergistic	Low Synergy	Moderate Synergy	High Synergy

The higher education system can be regarded as a composite system consisting of several subsystems, with the higher education in each province and city acting as a subsystem. Overall, the higher education system is made up of the order parameter of regional internal higher education scale, the order parameter of higher education input, and the order parameter of higher education output. On a microscopic level, each order parameter encompasses various elements, such as school scale, student scale, human resource input, material resource input, financial input, talent cultivation, and research output. The order parameters are composed of components such as the number of regular higher education institutions, the number of 211 Project universities, the number of undergraduate and college students, the number of master's and doctoral students, the number of students per 100,000 people, the number of full-time teachers, the proportion of teachers with associate senior titles or above, student - teacher ratio, school land area, the number of books, total value of fixed assets, regular higher education funding, the proportion of higher education funding in regional education funding, per - student educational expenditure, published papers, books, patent applications, the number of undergraduate and college graduates, and the number of master's and doctoral graduates.

This study looks at higher education data from the Beijing - Tianjin - Hebei region for 2010 - 2020. It uses a built index system and model to measure the coordinated development level of higher education there. The data mainly comes from China's Education Finance Statistical Yearbook, China Statistical Yearbook, and provincial - municipal statistics bureau websites. Some data is directly accessible, while other data needs calculation and organization. Due to different indicator - data measurement units, data standardization is necessary.

Weight calculation is crucial for analyzing higher education coordinated - development levels across regions. Before measuring the orderliness of provincial - municipal higher education subsystems and the regional higher - education composite - system's coordination, weighting indicators with relevant data and methods is essential. There are two main weighting approaches: subjective and objective. Subjective methods rely on decision - makers' knowledge and experience, like expert review and fuzzy - comprehensive evaluation. Objective methods determine weights via sample - data analysis and inter - data associations, such as entropy and principal - component analysis methods. PCA, a spatial - mapping method reducing variable linear correlation, avoids subjectivity, resolves time - series and cross - sectional data measurement inconsistencies, and reflects dimensional changes for scientific and practical results. The entropy method, based on information - entropy definition, determines indicator weights by entropy values. It shows the indicator's effectiveness in evaluation systems. Compared to subjective methods, objective ones reduce subjectivity, offering more scientific and accurate weights that better reveal original environmental information. Thus, objective weighting improves evaluation - model accuracy. The entropy method provides more objective and scientific weights, is easy - to - use, and minimizes subjective influences. Larger entropy - based indicator weights indicate more effective information. As an objective weighting approach it, reflects information - entropy utility value. To ensure accurate and objective analysis results, this study uses the entropy method to determine indicator weight coefficients. This provides precise weights, making the index system more scientific and objective and laying a solid foundation for follow - up research.

The entropy method determines weights based on indicator sample data. It is easy to understand, simple to calculate, easy to operate, and highly practical. It has a wide range of applications, can be used alone, improved on its own, or combined with other methods for comprehensive evaluation.

This study uses the entropy method to determine indicator weight coefficients. This makes the index system verification more objective and scientific. The weights of various indicators, calculated via the entropy method from higher education data of provinces and cities from 2010 to 2020, are shown in Table 3.

Table 3: Weights of Higher Education Coordinated Development Evaluation Indicators

Level 1	Weight	Level 2	Weight	Level 3	Weight
Educational Scale	0.3478	School Scale	0.1451	Regular Higher Education Institutions	0.0412
				211 Project Universities	0.1039
		Student Scale	0.2026	Undergraduate and Junior College Students Enrolled	0.0419
				Master's Degree Students Enrolled	0.0507
				Doctoral Degree Students Enrolled	0.0744
				Enrolled Students per 100,000 People	0.0355
Educational Investment	0.31548	Human Resource Investment	0.0764	Full-time Teachers	0.0347
				Teachers with Associate Senior Titles or Above	0.0273
				Student-Teacher Ratio	0.0144
		Physical Resource Investment	0.1132	Campus Area	0.0445
				Number of Books	0.0313
				Total Value of Fixed Assets	0.0374
		Financial Investment	0.1257	Funding for Regular Higher Education	0.0518
				Higher Education Funding in Regional Education Funding	0.0379
				Per-student Educational Expenditure	0.0358
Educational Output	0.33670	Research Achievements	0.1702	Published Papers	0.0527
				Published Books	0.0513
				Patent Applications	0.0661
		Talent Development	0.1664	Undergraduate and Junior College Graduates	0.0416
				Master's Degree Graduates	0.0410
				Doctoral Degree Graduates	0.0838

The greater the weight of an indicator, the larger its contribution to the evaluation index system, enabling it to provide more effective information for assessing the coordinated development level of higher education across regions. Conversely, a smaller weight implies a more limited contribution. From Table 3, in terms of third-level indicators, the three with the highest weights are the number of 211 Project universities (0.10397), the number of doctoral graduates

(0.08383), and the number of doctoral students enrolled (0.07442). These offer substantial effective information for evaluation. The student - teacher ratio has the smallest weight (0.01442), indicating it contributes the least effective information.

Regarding second-level indicators, student scale and talent development are the most significant contributors. Among first-level indicators, the three have relatively close weights. Educational scale holds the highest weight (0.34782), while educational investment has the lowest (0.31584), reflecting their respective levels of effective information contribution.

2.3 Measuring Higher Education Coordinated Development Level

Using the constructed index system, determined indicator weights, and selected composite system coordination model, an empirical analysis was conducted on the orderliness of higher education systems and the coordination of regional higher education composite systems across provinces and cities.

System orderliness indicates the degree of system organization. A higher value suggests greater organization. For higher education systems, this reflects the organized development within a region. After standardizing the data and determining the indicator weights via the entropy method, the orderliness of each provincial higher education system from 2010 to 2020 was measured using a subsystem orderliness model. Based on these results and taking 2010 as the starting point, the coordination of regional higher education composite systems was further assessed. The results are shown in Table 4.

Table 4: Orderliness of Higher Education Subsystems in Provinces and Cities

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	0.508	0.521	0.561	0.580	0.631	0.632	0.640	0.662	0.686	0.707	0.745
Tianjin	0.095	0.101	0.113	0.115	0.118	0.119	0.132	0.137	0.154	0.169	0.168
Hebei	0.122	0.131	0.142	0.162	0.164	0.165	0.179	0.199	0.204	0.214	0.235

Using the 2010 baseline and the orderliness data of the Beijing - Tianjin - Hebei region, the coordination of the higher education composite system there was measured. The results are in Table 5.

Table 5: Coordination of Higher Education Composite System in the Beijing - Tianjin - Hebei Region

	Beijing	Tianjin	Hebei	Beijing-Tianjin	Beijing-Hebei	Tianjin-Hebei	All
2011	0.0135	0.0062	0.0095	0.0091	0.0113	0.0077	0.0093
2012	0.0526	0.0182	0.0203	0.0309	0.0327	0.0192	0.0269
2013	0.0724	0.0198	0.0404	0.0378	0.0541	0.0282	0.0387
2014	0.1227	0.0229	0.0424	0.0531	0.0721	0.0312	0.0492
2015	0.1236	0.0234	0.0428	0.0538	0.0727	0.0317	0.0499
2016	0.1318	0.0369	0.0569	0.0697	0.0866	0.0458	0.0652
2017	0.1537	0.0415	0.0768	0.0799	0.1087	0.0565	0.0789
2018	0.1783	0.0584	0.0821	0.1021	0.1210	0.0693	0.0949
2019	0.1989	0.0736	0.0916	0.1210	0.1350	0.0821	0.1103
2020	0.2369	0.0726	0.1132	0.1312	0.1637	0.0907	0.1249

As shown in Table 5, using 2010 as the base year, the coordinated development level of higher education in the Beijing - Tianjin - Hebei region was in a low - level state from 2011 to 2020. But it rose year - by - year, peaking in 2020. Among the regions, Beijing had the highest coordinated development level, while Tianjin had the lowest. The highest inter - regional coordinated development was between Beijing and Hebei.

4. CHALLENGES CONFRONTING TIANJIN IN ADVANCING BTH HIGHER EDUCATION COLLABORATION

Promoting coordinated higher education development is integral to establishing the Beijing-Tianjin-Hebei (BTH) region as a world-class urban cluster. As a dual-core city, Tianjin possesses foundational strengths in higher education but faces critical systemic challenges, outlined below.

4.1 Absence of Effective Tripartite Collaboration Mechanisms

Unlike the Yangtze River Delta and Guangdong-Hong Kong-Macao Greater Bay Area initiatives, BTH higher education collaboration has historically relied on top-down administrative mandates rather than institutionalized coordination. Key systemic barriers include: First, no centralized authority oversees cross-regional collaboration, resulting in disjointed management systems. Inter-provincial agreements remain largely symbolic, lacking operational implementation frameworks. Second, no multistakeholder evaluation system exists to enforce accountability or track progress. Lastly, national coordination efforts prioritize planning over actionable incentives, with ambiguous oversight of incentive implementation.

4.2 Insufficient Attraction of Elite Higher Education Resources

Tianjin hosts only 5 Double First-Class universities, lagging behind Beijing's concentration of elite institutions (e.g., C9 League members). Unlike Beijing's proactive support for Xiongan New Area, Tianjin exhibits reactive strategies, forfeiting opportunities to attract global talent and resources amid fierce interregional competition.

4.3 Weak Talent Attraction Capacity

Despite its educational assets, Tianjin struggles to compete with Beijing, Shanghai, and Shenzhen in attracting top-tier international scholars. Systemic issues include: Disparities in R&D funding and faculty compensation exacerbate the "Matthew Effect," diverting talent to elite hubs. Tianjin's talent recruitment strategies lack differentiation in welfare systems, innovation ecosystems, or career development pathways, mirroring generic approaches across Chinese cities.

5. STRATEGIC PATHWAYS FOR TIANJIN IN ADVANCING HIGHER EDUCATION COLLABORATION

5.1 Resolve Systemic Barriers and Strengthen Regulatory Oversight

To address structural contradictions in regional collaboration, a dual approach combining institutional reform and proactive governance is imperative. Key recommendations include: Propose the creation of a BTH Higher Education Coordination Commission under central government leadership to institutionalize cross-regional governance. Introduce a tiered accountability system linking institutional funding to synergy benchmarks. Foster "lead-and-learn" partnerships between universities, prioritizing disciplinary complementarity over homogeneous competition.

5.2 Innovate Talent Recruitment and Retention Strategies

In recent years, the competition for top talents among cities has escalated, particularly for high - end and highly skilled professionals. This is mainly due to the talent shortage caused by an ageing population and the crucial role these top talents play in leading urban development. Today's context of severe population ageing, the ability to attract and utilize human resources effectively will be a key factor determining a city's rapid development over the coming decades. As the economic core of the Beijing-Tianjin-Hebei region, Tianjin should expand talent - introduction channels, increase recruitment avenues, lower employment thresholds, and extend probationary periods to assess the compatibility between talents and positions, thereby enhancing the professional application of talents.

5.3 Optimize Resource Allocation through Benchmarking and Openness

As one of the dual - core cities in the Beijing-Tianjin-Hebei region, Tianjin's primary function in promoting regional coordinated development is to alleviate non - capital functions of Beijing, with the main goal of advancing through competition.

Therefore, it is imperative for Tianjin to break its limitations and enhance the effective allocation of resources. During Tianjin's 14th Five - Year Construction period, Tianjin should benchmark against the development of first - class cities' HEIs in the Yangtze River Delta and Pearl River Delta city clusters. It should actively learn from the development experiences of these cities, broaden its international vision, focus on high - end research platforms, and strive to promote the construction of national first - class and world - class HEIs. Moreover, attracting high - quality higher education resources in the region is also crucial. For instance, Tianjin can enhance the utilization of talents from Beijing and Tianjin, reserve ample land for introducing high - quality HEIs from Beijing, and attract the spill-over resources of Beijing's HEIs.

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