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Measurement and statistical evaluation of industrial synergy and new productive forces in the Beijing-Tianjin-Hebei Region: from the perspective of modern capital metropolitan area construction

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Abstract. After the implementation of the Beijing-Tianjin-Hebei coordinated development strategy, industrial synergy has become the focus of the earliest breakthrough. In 2023, the modernization plan of the metropolitan area with the capital as the core was introduced, which made the industrial synergy of Beijing, Tianjin and Hebei have the dual significance of collaborative innovation and double chain integration. Most of the research on industrial transfer or regional division of labor is qualitative thinking, lacking statistical measurement standards or methods designed according to metropolitan areas. In this paper, industrial synergy and new productivity are combined to investigate, and statistical indicators are given for the subsystems involved in the two. The entropy weight-CRITIC model and the coupling coordination method are used as analytical tools. Due to the limitations of public data, this paper does not make specific numerical calculations. The relevant conclusions are a methodological inspiration for the subsequent quantitative analysis. Qualitative analysis under this framework reveals that the Beijing-Tianjin-Hebei region has achieved phased progress in non-capital function relocation, industrial structure optimization, and the integration of innovation and industrial chains. A preliminary pattern featuring "R&D in Beijing, achievement transformation in Tianjin, and manufacturing in Hebei" has taken shape. Nevertheless, the synergistic performance of the two systems is still constrained by several challenges, including the gradient gap in regional development, uneven distribution of innovation resources, inadequate benefit-sharing and cost-sharing mechanisms, and restricted mobility of production factors.

Keywords: Beijing-Tianjin-Hebei industrial synergy, new quality productivity innovation chain industry chain integration, profit appreciation and cost sharing, modern capital metropolitan area

1. Introduction

The coordinated development strategy of Beijing-Tianjin-Hebei has been implemented for more than ten years. Industrial synergy is one of the three first breakthroughs [1].

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According to the published research, the industrial synergy of Beijing, Tianjin and Hebei discussed by the academic community is basically an analysis of industrial transfer or regional division of labor. In the existing literature, scholarly discussion of industrial synergy in the Beijing-Tianjin-Hebei region has largely remained at the level of industrial transfer and regional division of labor. Even studies centered on innovation factors fall within this frame: Chen and Zhang [2], applying a compound-system synergy model, measured the collaborative innovation level of 12 subsystems linking Zhongguancun with prefecture-level cities in Tianjin and Hebei during 2008–2014; Li et al. [3] later examined sci-tech talent agglomeration and spatial spillover effects across the region's "innovation triangle". Both nonetheless operate within the logic of regional division and innovation-resource allocation, leaving underexamined how Beijing-Tianjin-Hebei can foster new quality productive forces and how the industrial chain and innovation chain couple across administrative boundaries.

There are not many complete discussions on the double-chain combination, interest growth and cost distribution in the context of the metropolitan area [4]. The theoretical summary of the Zhongguancun spillover area and the Beijing-Tianjin Zhongguancun Science and Technology City is also relatively brief. More importantly, there is no industrial synergy or new quality productivity statistical index system for the modern capital metropolitan area, and there is no statistical method or calculation tool that can be used for quantitative analysis.

As far as the gap is concerned, the methods used are basically literature review, comparative analysis and case study. The spillover park derived from the Zhongguancun National Independent Innovation Demonstration Zone is used as an example to illustrate. As the primary source of innovation resources in the Beijing-Tianjin-Hebei region, the Zhongguancun National Independent Innovation Demonstration Zone anchors a network of spillover parks across Tianjin and Hebei that host the cross-regional outflow of technology and talent and mediate the coupling of the innovation and industrial chains across administrative boundaries, thereby underpinning the cross-regional rollout of new quality productive forces. Considering the limitations of current data acquisition, this paper focuses on the content of the framework and does not calculate the complete value of the panel data for the time being. From a theoretical point of view, it has the potential to make a more complete discussion on the " double-chain integration " and new productivity in the context of metropolitan areas.

2. Theoretical basis and analytical framework

2.1. The theoretical connotation and collaborative form of industrial synergy

The concept of industrial synergy draws on synergy theory and the regional division of labor framework: different regions or industrial entities achieve outcomes better than their independent development through factor flows, division of labor, and coordination of interests. In the Beijing-Tianjin-Hebei context, this process cannot be reduced to "Beijing relocating, Tianjin and Hebei absorbing". It requires aligning the innovation chain, industrial chain, capital chain, and talent chain across administrative boundaries. Ye et al. [5] approach the Zhongguancun–Xiongan New Area dynamic as a dual engine, decomposing industrial synergy into micro-level factor mobility, meso-level industrial collaboration, and macro-level policy alignment. The actual forms of collaboration now under way fall roughly into four types.

For co-built park platforms, Zhongguancun and Xiongan form a dual engine: Zhongguancun, as a primary source of original innovation, exports technology, talent, and management expertise, while Xiongan offers large-scale application scenarios and absorptive space. Their collaboration covers S&T innovation platforms, enclave parks, and achievement-commercialization bases.

On the spillover of S&T achievements, Zhongguancun's innovation resources diffuse into Xiongan through the dual-engine mechanism. Frontier technologies such as AI, quantum information, and blockchain are being piloted in Xiongan's smart city and urban-governance settings, while in intelligent connected vehicles, Beijing supplies the technology and Xiongan provides road-testing and deployment scenarios.

As for upstream and downstream industrial-chain support, the two places have developed a cross-regional division of labor in high-end sectors such as biomedicine and intelligent connected vehicles. These practices overlap and resist any single-model summary.

2.2. Analysis framework of benefit increment and cost sharing

Cross-regional industrial synergy tends to stall at administrative boundaries largely because costs and benefits are distributed asymmetrically across regions. The framework of value-appreciation gains and cost sharing proposed by Tian et al. [1] offers a useful entry point: industrial synergy generates cross-regional value-added gains, yet the costs of functional easing, environmental protection, and infrastructure investment tend to concentrate in the recipient region. Without a reasonable benefit-sharing and cost-sharing mechanism, cooperation cannot be sustained.

This framework cuts to the core of the Beijing-Tianjin-Hebei predicament because the region spans three administrative tiers—Beijing and Tianjin as municipalities directly under the central government, plus Hebei Province—with pronounced industrial-gradient gaps. As the relocating party, Beijing captures the upgrading and innovation gains after functional easing; as recipients, Tianjin and Hebei absorb sunk costs in environmental governance, land development, and transport infrastructure, while tax revenues and output values remain largely in Beijing. This spatial mismatch between costs and benefits is precisely why subregional coordination has long remained at the project level and struggled to deepen, making cost-benefit sharing an unavoidable institutional arrangement.

That said, Tian et al.'s, first, it says little about institution-specific arrangements such as ecological compensation and enclave-economy schemes distinctive to the region. Second, the model presumes symmetric standing among participants, whereas the municipalities and the province sit at unequal administrative tiers, with unequal bargaining power and policy voice—a gap that directly affects how any sharing formula is implemented on the ground.

2.3. The internal relationship between the modern capital metropolitan area and the new productivity

The modern capital metropolitan area is different from the urban agglomeration in the general sense. It emphasizes Beijing as the core innovation source and drives the surrounding areas to form a spatial division of "R&D-transformation-manufacturing". The core symbol of new quality productivity is innovation-driven, industrial upgrading and total factor productivity improvement. It just needs a space carrier that allows the free flow of innovation factors and the rapid landing of technological achievements. There is an internal echo between the construction of metropolitan area and the cultivation of new quality productivity: metropolitan area provides the spatial scale of factor integration for new quality productivity, and new quality productivity provides new kinetic energy for the high-quality development of metropolitan area.

2.4. Statistical evaluation index system and analysis framework for modern capital metropolitan areas

This paper takes the coordinated development of Beijing-Tianjin-Hebei industry as the overall framework, takes Zhongguancun National Independent Innovation Demonstration Zone as the core innovation source, and

constructs an evaluation system suitable for the regional division mode of "Beijing R&D, Tianjin-Hebei transformation".

The indicators used are determined according to three principles. First, consider the matching degree of the metropolitan area; that is, not only a single city as the analysis object, but also the innovation spillover, cross-regional resource flow, industrial change and park cooperation of Zhongguancun are included in the scope of collaborative investigation. Secondly, the availability of data is required, and the indicators are mostly from statistical yearbooks, science and technology statistics or public and authoritative statistical documents of technology transactions.

Considering the problem from the proposed principles, this paper evaluates industrial synergy and new quality productivity as two layers. The industrial synergy system mainly takes the innovative resources owned by Zhongguancun as the starting point, and analyzes the differences in the industrial division of labor in the three places, whether the technological achievements are outflowed, whether the funds and talents can be used across the region, and the supporting effect of the co-construction park on the industry; the new productivity system focuses on the overall innovation status of the metropolitan area, the ability to transform technology into reality, the development level of emerging industries, and the characteristics of green and high efficiency. The two systems are not isolated from each other, but have interactive effects: the resource output, innovation activities or enterprise development of Zhongguancun contributes to the improvement of synergy, and the progress and results of synergy will promote the improvement or optimization of new productivity.

Table 1. Evaluation index system of industrial synergy system

The first level subsystem	Secondary dimension	Three-level alternative indicators	Index attribute
Industrial Synergy System	Industrial division and transfer	Regional industrial structure similarity index	Negative
		The proportion of Beijing to Tianjin-Hebei technology contract turnover	Positive
		Number of branches set up by Zhongguancun enterprises in Tianjin and Hebei	Positive
	Cross-regional flow of factors	Beijing 's actual investment in Tianjin and Hebei accounts for the proportion of the metropolitan area	Positive
		The scale of cross-market flow of employees in high-tech industries	Positive
	Build platform carrier together	Number of registered enterprises in Zhongguancun Cooperation Park	Positive
		The proportion of Beijing source projects in the co-construction park	Positive
	Collaborative obstacle constraints	Regional market segmentation index	Negative

According to the weighting method, this paper will use the combination weighting method of entropy weight-CRITIC. Entropy weight is an objective weighting based on the discrete state of the information contained in each index, which is conducive to explaining the different development levels of cities in the metropolitan area; the criteria used in CRITIC take into account both variation and variable correlation, and can deal with the phenomenon of information overlap more completely. The combined weight (i.e., weighted average) is a supplement to a single method and can reduce its limitations [6]. As far as the coupling

coordination analysis is concerned, the total index U_1 of the industrial synergy system and the total index U_2 of the new productivity system should be calculated, and then the overall development index of the system $T = \alpha U_1 + \beta U_2$ should be constructed. If the value is determined according to the idea that the two systems are equally important, α and β are both 0.5. The coupling coordination degree is $D = \sqrt{(C \times T)}$, which belongs to [0, 1]. If the coupling coordination degree is very large, the industrial synergy driven by Zhongguancun is a more powerful promotion to the new productivity. In turn, it means that the innovation resources are not well utilized or the cooperation of each link is lacking.

Table 2. Evaluation index system of new quality productivity system

The first level subsystem	Secondary dimension	Three-level alternative indicators	Index attribute
New Productivity System	Innovation investment ability	The proportion of internal expenditure of R&D expenditure in GDP	Positive
		Number of R&D personnel per 10,000 people	Positive
	Innovation output level	Invention patent authorization per 10,000 people	Positive
		The proportion of sales revenue of new products in high-tech industry to industrial revenue	Positive
	New Industry Development	The proportion of output value of strategic emerging industries in GDP	Positive
		The proportion of added value of core industries in digital economy to GDP	Positive
	Development benefit quality	Total labor productivity	Positive
		Energy consumption per unit of GDP	Negative

3. Qualitative research and judgment of Beijing-Tianjin-Hebei based on a statistical evaluation framework

3.1. Realistic judgment of industrial synergy dimension

The homogeneity of regional industries has been slightly alleviated, and the statistics of the "industrial division and transfer" indicators described in Table 1 are also more favorable[1]. In terms of technology contract transactions, the turnover of technology contracts issued by Beijing to Tianjin and Hebei is increasing year by year, and the phenomenon of relevant enterprises in Zhongguancun setting up branches in Tianjin and Hebei is also increasing. For the co-construction park, there are many registered enterprises in the platforms such as Zhongguancun Cooperation Park and Beijing-Tianjin Zhongguancun Science and Technology City, but the projects involved in the source of Beijing's industrial chain can still be further expanded [2].

[1] Statistical Monitoring Office for the Coordinated Development of the Beijing-Tianjin-Hebei Region. Accelerating the Establishment of a Coordinated Development Framework: The 2024 Regional Coordinated Development Index for the Beijing-Tianjin-Hebei Area continues to rise [EB/OL]. (December 25,2025)

3.2. The realistic judgment of the development dimension of new quality productivity

The R&D funds used in the Beijing-Tianjin-Hebei region reach an intensity of 4.27% in 2023, 1.62 percentage points higher than the national average level, and the R&D team is relatively concentrated, with 63.1 person-years of R&D researchers per 10,000 residents[2,3]. The granting of invention patents and the sales data of high-tech products are on the rise, which is a manifestation of the gradual maturity of innovation achievements and industrialization capabilities. However, in terms of strategic emerging industries or digital core industries, regional allocation is still extremely unbalanced. Beijing incorporates most of the high value-added parts into its own scope, and Tianjin and Hebei are only in the secondary and final positions of the industrial chain.

3.3. Comprehensive qualitative judgment of the synergistic relationship between the two systems

Combined with the two subsystems, a basic judgment can be drawn: Beijing-Tianjin-Hebei has made progress in some dimensions, yet shortcomings exist in the collaborative matching degree between the systems. The "hardware" of industrial synergy parks, projects, and technical contracts-has been put on the shelf, but the "software" in the sense of new productivity-the industrialization of innovation achievements in the local area, the cross-regional flow of high-end talents, and the rational distribution of value-added benefits-have not yet fully kept up. If measured by the idea of coupling coordination degree, the two systems may be in the stage of "preliminary coordination but have not yet formed a benign interaction".

4. The realistic dilemma that restricts the development of industrial synergy and new productivity

4.1. Regional development gradient gap and industrial structure imbalance

According to the industrial division of labor described in Table 1 and the relevant new industrial indicators in Table 2, there is still a large development gradient gap within the Beijing-Tianjin-Hebei region. Beijing has obvious advantages over Tianjin and Hebei in terms of per capita GDP, fiscal revenue and innovation investment. However, most of the cities under the jurisdiction of Tianjin and Hebei are in the middle stage of industrialization, and the industry itself is more traditional, so it is difficult to absorb high-end manufacturing or innovation achievements. As far as the spillover park of Zhongguancun is concerned, although the term "Zhongguancun" has appeared, it may not be possible to establish a direct and complete upstream and downstream industrial connection between the calibrated park and Beijing headquarters.

4.2. Unbalanced distribution of innovation resources and insufficient transformation of achievements

If measured by the standards of innovation investment and achievement transformation, Beijing has concentrated the best universities, research units and senior R&D personnel in China, while Tianjin and Hebei

[2] Office of Beijing-Tianjin-Hebei Coordinated Development Statistical Monitoring. Further Promoting Coordinated Development: The 2023 Beijing-Tianjin-Hebei Regional Coordinated Development Index Continues to Rise[EB/OL]. (2025-01-03)

[3] National Bureau of Statistics of China, Ministry of Science and Technology of China, Ministry of Finance of China. 2024 Statistical Bulletin on National Science and Technology Funding [EB/OL]. (September 29, 2025)

have relatively few resources. This gap has taken shape over decades of national strategic resource allocation: as the national political and cultural center, Beijing hosts the vast majority of China's top-tier universities, national key laboratories, and central-level research institutes, while Tianjin and Hebei have long been positioned as manufacturing and service supporting hubs in the regional industrial division, resulting in a persistent path-dependent accumulation of innovation resources that overwhelmingly favors Beijing. At the same time, the scientific and technological achievements produced in Beijing can be basically applied in the region, and the proportion of the actual application in Tianjin and Hebei is still not large [3, 7]. Zhongguancun Spillover Park has taken a number of projects into consideration, but some of them have the suspicion of "research and development links remain in Beijing and manufacturing links are transferred out", and the relevant areas may not be able to share high-profit industrial link income.

4.3. Value-added distribution of benefits and cost-sharing mechanism is not perfect

This is the core issue of the interest synergy dimension in the corresponding industrial synergy system. This gap comes from long-term regional development patterns: Beijing is home to most of the country's top universities and national research institutes, while Tianjin and Hebei have mainly focused on manufacturing and supporting industries over the years. As a result, high-value R&D activities tend to stay in Beijing, and only production links are moved to neighboring areas. The practice of Zhongguancun Science and Technology City and Zhongguancun Spillover Park in Beijing and Tianjin shows that in the process of cross-regional co-construction, problems such as tax sharing, GDP statistical attribution, and land and infrastructure investment sharing have not been fully straightened out and solved. The undertaking place often has to bear the initial costs of park construction, environmental protection management and infrastructure support.

4.4. Limited flow of production factors and insufficient agglomeration of undertaking platforms

The indicators related to factor flow and platform construction are not ideal. From technology, and talents to capital, there has been a significant improvement in the flow between Beijing, Tianjin and Hebei, but the administrative restrictions involved in household registration, social security and public services are still effective, and the quality and quantity of cross-city mobility of talents still need to be improved. As far as the platform itself is concerned, there are many registered enterprises in individual parks, but the listed industries may not be related. At present, there is still a lack of a well-coordinated and efficient collaborative state promoted by agglomeration [2].

5. The optimization enlightenment based on the perspective of statistical evaluation

5.1. Relying on the market mechanism to improve the benefit-sharing and cost-sharing system

The value-added part created by industrial synergy is fairly classified into the respective income of the output and the receiving areas, and the cost compensation is included in the field of vision, and the infrastructure, environmental protection and services that have been done or are to be done in the receiving areas are appropriately repaid [1]. The idea proposed here is the direct improvement scheme of interest coordination in the industrial coordination system.

5.2. Layout the industrial chain around the innovation chain, and narrow the gap between regional industrial development dimensions

In order to narrow the gap of regional development gradient, it should not simply rely on industrial transfer but should lay out the industrial chain around the innovation chain. Beijing focuses on R&D and source innovation, and Tianjin and Hebei combine their own industrial bases to undertake pilot, transformation, and manufacturing links to form a complete chain of "R&D-pilot-industrialization". This can not only reduce the similarity of regional industrial structure but also make the strategic emerging industries and digital economy-related indicators in the new quality productivity system more balanced between the three places. The income distribution rules of this division of labor chain will be directly implemented and guaranteed based on the cross-regional tax and value-added sharing mechanism proposed in 5.1.

5.3. Optimize the spatial pattern of regional innovation and strengthen the innovation engine of Beijing-Tianjin-Xiong'an

The problem of unbalanced distribution of innovation resources needs to be adjusted from the spatial pattern. The construction direction of the twin engines in Zhongguancun-Xiong'an New Area is worthy of recognition, and the Beijing-Tianjin Zhongguancun Science and Technology City is also gradually playing the role of undertaking transformation. In the future, it should further strengthen the division of labor among Beijing R&D, Tianjin transformation and Hebei manufacturing; promote the rational distribution of innovation platforms, pilot bases and industrial funds in the region; and make the innovation input and output indicators in the new quality productivity system no longer excessively concentrated in Beijing.

5.4. Improve the cross-regional industrial collaboration platform and promote the integration of factors.

In terms of factor mobility and platform agglomeration, administrative obstacles should be continuously reduced, and household registration, social security and qualifications should be included in the unified framework of public services, so that technology, talents and funds can flow freely between regions [4]. When evaluating the co-construction park, it should not only take the number of registered enterprises as the standard, but also take into account the industrial links, the proportion of Beijing-related projects and the actual results, so as to promote the platform from "quantity expansion" to "quality improvement".

6. Conclusion

This paper focuses on the theme of industrial synergy and new quality productivity in Beijing-Tianjin-Hebei under the background of the modern capital metropolitan area. On the basis of theoretical combining, the statistical evaluation index system of two subsystems of industrial synergy and new quality productivity is constructed, and the analysis idea of entropy weight-CRITIC combination weighting and coupling coordination model is adopted. The qualitative analysis based on this framework shows that the Beijing-Tianjin-Hebei region has made phased progress in functional decentralization, industrial structure optimization, and innovation chain industry chain integration and has initially formed a division of labor prototype of "Beijing R&D-Tianjin transformation-Hebei manufacturing". However, problems such as the regional development gradient gap, unbalanced distribution of innovation resources, imperfect benefit sharing and cost sharing mechanisms, and limited factor flow still restrict the synergy level of the two systems. Future research can try to build a panel database, use spatial econometric models to empirically test the coupling and

coordination relationship between industrial synergy and new quality productivity, expand the scope of case comparison, and refine more replicable synergy models.

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