

Dual-Dimensional Analysis of China's Post-Olympic Ice and Snow Economy: Industrial Ecology, Regional Coordination and Sustainable Development

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Abstract. Under the impetus of the 2022 Beijing Winter Olympics, China's ice and snow economy has expanded rapidly in the post-Olympic era. However, the industry is still constrained by seasonal limits, industrial chain fragmentation, unbalanced regional development, talent shortages and climate change risks. Based on industrial ecology theory and regional coordination theory, this paper constructs a vertical-horizontal dual-dimensional framework to analyze the development status, characteristics and dilemmas of China's ice and snow economy. Taking Beijing-Zhangjiakou, Shenzhen and Xinjiang as cases, this paper explores differentiated sustainable development models suitable for different regional endowments. The results show that vertical industrial integration and horizontal regional coordination are critical to improving industrial resilience. To boost the winter sports industry's sustainable and high-quality development, we need to focus on four key aspects: enhancing collaboration among related industries, eliminating administrative obstacles to development, advancing technological innovation, and prioritizing the training of professional talents. These practical steps can effectively underpin the industry's long-term growth.

Keywords: Post-Olympic Ice-Snow Industry, Industrial Ecosystem, Regional Synergy, Sustainable Growth

1. Introduction

1.1. Research background

The ice and snow economy has become a new growth driver for global tourism and regional development [1]. Driven by the 2022 Beijing Winter Olympics and the "300-million people participating in ice and snow sports" strategy, China's ice and snow industry has grown rapidly [2]. Yet it grapples with challenges: seasonal restrictions, uneven regional development, and homogeneous products [3]. Climate change also poses long-term risks [4]. Existing studies lack in-depth research on industrial integration and sustainability, making this study necessary [5].

1.2. Research purpose and significance

This study analyzes the status, characteristics and challenges of China's post-Olympic ice and snow economy. By examining typical industry cases, it explores the interaction between industrial ecology and regional coordination. Theoretically, it enriches relevant research with a dual-dimensional framework. Practically, it provides workable approaches and policies to resolve industry dilemmas and advance its high-quality sustainable development.

1.3. Research objectives and questions

Guided by the above purpose, this study focuses on one core question: How can the dual-dimensional framework (vertical industrial ecology and horizontal regional coordination) explain the differentiated development patterns and sustainable pathways of China's post-Olympic ice and snow economy?

Three sub-questions address this core issue:

- 1). What are the status and key challenges of China's post-Olympic ice and snow economy?
- 2). How to build a dual-dimensional analytical framework for the sector?
- 3) What differentiated development pathways exist across different regions?

2. Theoretical foundation

2.1. Core concepts

This study translates two theoretical perspectives into analytical concepts. Industrial Ecology Theory (Section 2.2) is defined as industrial ecology—a dynamic system including the "core-related-support" industrial chain and its external environment [5]. Regional Coordination Theory (Section 2.2) underpins regional coordination: removing administrative barriers for cross-regional resource integration and benefit sharing [6]. The post-Olympic ice and snow economy is their empirical intersection: a comprehensive economic form driven by Olympic heritage and policies, centered on ice and snow sports and tourism [2, 3].

2.2. Theoretical basis

Industrial Ecology Theory, originating from industrial ecosystem research, views industrial development as an organic system emphasizing symbiosis between industrial links and the external environment [5]. It provides a systematic perspective for building the ice and snow industrial chain, relevant given the sector's multi-industry interdependence. Regional Coordination Theory focuses on inter-regional synergy, aiming for complementary advantages and resource sharing through improved governance [4]. It supports addressing uneven regional development, especially where resources, capital and markets are spatially mismatched.

These two theories form the study's dual-dimensional framework: industrial ecology (vertical, industrial chain structure) and regional coordination (horizontal, spatial governance). Together, they lay the theoretical groundwork for analyzing the ice and snow economy's structural dynamics and sustainable paths [6].

Using this integrated framework, the next section examines the current status and challenges of China's post-Olympic ice and snow economy.

3. Status and challenges of ice and snow economy development of China in the post Olympic period

3.1. Status of development: Scale of industry, regionalization, and structure of industrial chains

The 2022 Beijing Winter Olympics represented a turning point. The idea of ice and snow resources being as valuable as gold and silver was first coined in the mid-2010s and became strategic in the strategy after the successful bid of 2022 Winter Olympics in 2015, leading to a transformative development phase after 2022 [7]. It has today become a national sector, where it involves more than 300 million people; a figure that is not only ambitious in policy terms, but also indicative of the real market demand. The ice and snow economy of China is analyzed in the context of dual-dimensional framework developed in Section 2, which has peculiar structural and spatial features. At the vertical level, the industrial chain has already assumed an initial form but is not integrated, at the horizontal level, the distribution of resources in different regions is disproportional. Even though upstream manufacturing, midstream operations, and downstream service formats have emerged, China has not yet established a mature vertical integration along the entire industrial chain with design, production, operation and consumer experience being closely interrelated. An example is snow-making equipment. Despite the rapid development of domestic technology, the market of high-end is still dominated by foreign capital. This imbalance of structure causes the poor connection between the upstream manufacturing and midstream operations, which makes it hard to create a closed-loop value chain, and limits the maturity of the industrial ecosystem [8].

From the industrial ecology perspective, the current "upstream-midstream-downstream" structure represents a linear value chain rather than an integrated ecosystem. Meanwhile, the absence of feedback mechanisms between manufacturing and service sectors and the lack of risk-sharing arrangements among core-related-supporting industries is evident in practice.

The ski resorts, hotels, catering and other business forms are each under pressure, and there is a lack of joint marketing and risk-sharing mechanisms. In contrast, some integrated operation resorts (such as Chongli Taiwu Ski Town) have smoothed the impact of weather fluctuations through models like season pass users and accommodation and catering linkage. The proportion of ticket consumption in their core customer group (season pass users) is very small, and most of their consumption is concentrated on supporting services such as accommodation, catering and entertainment [9].

The absence of feedback mechanisms and the lack of risk-sharing arrangements together indicate that ecosystem functions remain underdeveloped.

Overall, the ice and snow industrial chain is structurally fragmented, and the symbiotic and risk-sharing mechanisms among upstream, midstream and downstream sectors are far from mature, which lays a realistic foundation for the subsequent dual-dimensional analysis.

3.2. Key characteristics: Infrastructure transformation, market expansion, and industrial integration

The development of China's ice and snow economy presents three distinct characteristics.

Firstly, the Olympic venues must be used sustainably. The Winter Olympics venues in Beijing and Zhangjiakou have not been idle and wasted. Instead, they have been transformed and upgraded and opened for public leisure, commercial events, and professional training.

Secondly, the consumer customer base continues to expand. Ice and snow sports are no longer limited to niche enthusiasts, but are gradually attracting participation from family groups, working youth and research students.

Thirdly, spatial restructuring through regional coordination emerges. The boundaries between ice and snow sports and the tourism, culture, and education industries are gradually blurring, reflecting cross-regional resource flows and horizontal governance responses to spatial mismatches. A large number of integrated businesses such as "ice and snow + tourism", "ice and snow + cultural tourism and performing arts" and "ice and snow + study tours" have emerged, Winter sports are driving the transformation of traditional sightseeing tourism into experiential and interactive tourism. Research shows that through the synergy of the industrial chain such as ski facility construction, event operation and resort development, ice and snow tourism has promoted the diversified development of the market and the deep integration of local culture. Taking Jilin City as an example, the path of tourism scene reconstruction driven by ice and snow sports includes: event leadership, facility upgrading, research and study product development, and cultural IP creation, effectively achieving the industrial integration of "ice and snow + cultural tourism" [10]. These changes are reshaping the consumer market structure and industry competition across provincial and municipal boundaries. The coordinated development of cross-provincial ice and snow tourism has achieved initial results. In October 2025, Heilongjiang, Xinjiang, Hebei, Liaoning, Inner Mongolia and Jilin provinces and autonomous regions jointly established the "Collaborative Innovation Center for Safety Assurance of Winter Sports in the Six Northern Provinces and Autonomous Regions", integrating nearly 100 universities, ski resorts, medical institutions and technology enterprises, covering nearly 60% of ski resorts across the country, and released the first "Index System for Safety Assurance of Winter Sports". This mechanism innovation provides institutional guarantees for cross-provincial ice and snow tourism cooperation [11]. By early 2021, on the eve of the Winter Olympics, China had 803 indoor and outdoor ski resorts of various types, covering 29 provinces, autonomous regions and municipalities, an increase of 41% over 2015 [12].

3.3. Structural challenges: Seasonal constraints, industrial chain fragmentation, and talent shortages

At this stage, China's ice and snow economy faces structural constraints corresponding to both analytical dimensions. Vertically, seasonal operational constraints impede ecosystem maturation. Most northern ski resorts operate only 4-5 months annually, leaving infrastructure idle during off-seasons and complicating resource deployment. Climate change poses a parallel vertical threat to resource reliability. The 2025-2026 snow season is a clearly warm winter year. According to a survey by The China Times, the ticket revenue of a ski resort in Northeast China has dropped by about 30% year-on-year due to the repeated melting and freezing of artificial snow. From domestic data, the spatial distribution of 899 ski resorts in China shows the characteristics of "denser in the north and sparser in the south, more in the east and less in the west". Natural environment and climatic conditions are the dominant factors driving the spatial differentiation of ski resorts [13, 14]. Instrumental records from the State of Global Climate 2024 reveal global mean temperatures have reached 1.55°C above pre-industrial levels, breaching the Paris Agreement's 1.5°C threshold and endangering long-term natural snow stability. Rising temperatures shorten the snow season and reduce snow reliability, which directly impacts the operation of core industries and further triggers the ripple effect on related industries such as accommodation and catering, exposing the fragility of the industrial ecosystem.

Uneven regional development and governance fragmentation persist. Analysis based on the spatial data of 899 ski resorts in China shows that the distribution of ski resorts presents a spatial agglomeration feature of "one core, three areas and multiple faces". The high-density areas are mainly concentrated in the Northeast region (Heilongjiang Province, Jilin Province), the North China region (Beijing City, Hebei Province) and the northwest region (Xinjiang Uygur Autonomous Region), while the distribution in the Central China, South China and Southwest regions is relatively sparse. The ranking of factors driving the spatial differentiation of ski resorts is as follows: natural environment > transportation capacity > social and economic development > tourism development level [14]. Additionally, talent shortages seriously restrict the industry's transformation and upgrading to high-end. The industry urgently needs high-quality certified coaches, venue operations managers, event planners and equipment maintenance specialists. The shortage of professional talents has become a key bottleneck restricting the high-quality development in the ice and snow sector. Taking Heilongjiang Province as an example, research shows that the current ski tourism industry is confronted with problems such as the incomplete certification system for professional coaches, differences in teaching service standards, and the superficial integration of ski resort cultures. In the field of coaching, during the peak season, some ski resorts in Northeast China hire a large number of part-time staff who have only received short-term training, and their teaching levels vary greatly. In the field of equipment manufacturing, although domestic snow-making machines, snow groomers and other large-scale equipment have made considerable progress, in the high-tech content and high brand added value personal skiing equipment sector (such as high-end snowboards, snowshoes and functional clothing), foreign brands still dominate, and a large number of the most profitable links in the industrial chain have flowed out. In terms of professional coach supply, under the background of supply-side reform, there are prominent problems in the group of social sports instructors for skiing in China, such as insufficient supply quantity and low supply quality. In addition, the functional supporting facilities of ski resorts have not yet formed a system, the supply of ski equipment is homogeneous, and the equipment renewal and maintenance system urgently needs to be improved. The ineffective implementation of the ice and snow campus policy and the insufficient cross-departmental collaboration have further exacerbated the systemic predicament in talent cultivation [15].

In summary, the post-Olympics ice and snow economy exhibits a dualistic pattern: rapid quantitative expansion coexists with qualitative structural immaturity. Vertically, the industrial ecosystem lacks integration and resilience; horizontally, spatial governance mechanisms remain underdeveloped to address resource misallocation and climate risks. These empirical conditions form the foundation for the framework application in the following section.

4. Dual-dimensional analysis: Structural dynamics and spatial governance

4.1. Vertical dimension: Industrial ecology and chain structure

Building on the vertical diagnosis, this section applies Industrial Ecology Theory to analyze the "core-related-supporting" industrial structure.

Industrial ecology provides a vertical perspective to examine the internal integration of the ice and snow industrial chain. The core industries are mainly skiing resort operations, skills training, and event hosting. Their market demand can drive the development of related industries, covering equipment manufacturing, cultural tourism, health care, hotel services and other fields. The three major industrial circles are interdependent and interconnected, and shortcomings in a single link will be transmitted to the entire system. For example, upgrading snow making technology can extend the

operation cycle of ski resorts across the region; insufficient supply of professional talents will simultaneously lower the quality of core businesses and related service industries [16]. This system is not a simple linear value chain, but an ecological community with feedback regulation, substitution and complementarity, and risk transmission functions. External shocks such as climate change and internal linkage effects such as talent shortages profoundly affect the overall operation and resilience of the industrial ecosystem.

4.2. Horizontal dimension: Regional coordination and governance mechanisms

If the ecosystem lens captures internal structure, the regional coordination lens captures spatial arrangement. China's ice-snow resources are distributed unevenly: natural snow in the north, capital and consumers in the south, distinctive cultural and landscape assets in the west [17]. This spatial mismatch requires governance innovations including shared standards, cross-regional information platforms, and coordinated to prevent the redundant construction [18]. Regional coordination helps break administrative barriers, promote cross-regional resource integration and benefit sharing, and improve the overall spatial allocation efficiency of the ice and snow economy. It provides a theoretical basis for explaining the spatial differences and collaborative paths of regional development.

5. Case studies: Validating the dual-dimensional framework

5.1. Beijing-Zhangjiakou corridor: A model of horizontal governance

The Beijing-Zhangjiakou Corridor is a typical example of the implementation of horizontal governance enabling the ice and snow economy. Before the 2022 Winter Olympics, the two places were restricted by administrative divisions and economic distance, and their industrial development was independent. The hosting of the Winter Olympics has reshaped the development pattern: investments in infrastructure such as Beijing-Zhangjiakou high-speed rail, upgraded road networks, and integrated venue systems have significantly shortened time and space distances and achieved physical connectivity. Institutional innovations followed, including venue management structures that combine government oversight with commercial operations, joint marketing under the "Beijing-Zhangjiakou Cultural Tourism Brand", and coordinated tourism development. The result is an industrial system that spans professional events, mass participation, cultural tourism, and vacation experiences—not as separate activities but as an integrated whole. What makes this model sustainable is not just the infrastructure but the governance mechanisms that maintain coordination beyond the initial Olympic moment [16].

5.2. Shenzhen's indoor ice and snow economy: Technology-vertical ecosystem

The total construction area is about 100,000 square meters, equipped with 5 professional ski trails, with a maximum vertical drop of 83 meters. Qianhai Ice and Snow World is not only a ski resort, but also a platform for Shenzhen to promote the integration of culture and tourism and sports competition exchanges. It is also a new engine for the upgrading of Shenzhen's cultural tourism industry and consumption upgrading, boosting the ice and snow economy to continue to heat up in the hot land of southern China [19]. Shenzhen accurately deploys high-quality resources to build large-scale comprehensive indoor ice and snow venues, taking into account the hosting of international events and public leisure experience; it deeply develops core technologies of

snowmaking, temperature control, and venue operation and maintenance to ensure stable operations throughout the year. This represents a technology-driven model that overcomes natural resource constraints through artificial ecosystem construction.

5.3. Xinjiang's ice and snow economy: Resource-based vertical advantages with horizontal policy support

Xinjiang has world-class ice and snow resources. The snow season lasts for 5 to 8 months, for example, Altay region, the snow season covers from November to April. The "champagne powder snow" known as the "powder snow ceiling" has the natural advantage of developing diversified businesses such as mass skiing, professional training, and wild snow adventures [19]. Policy support, including the Xinjiang Ice and Snow Industry Development Plan and special fund allocation, helps transform natural cultural tourism resources into economic growth momentum, and the ice and snow industry has become an important pillar of the regional economy. The case demonstrates that regions with typical resources do not have to imitate general development patterns and can rise in differentiation on the basis of the fine-tuning of development on the basis of the benefits of the region. This experience is also internationally reference-worthy.

5.4. Cross-case comparison and theoretical implications

This comparative study of three representative examples answers directly the main research question and confirms the dual-dimensional framework: there is no single best development model of the ice and snow economy. Each case navigates the vertical-horizontal dual dimensions differently: Beijing-Zhangjiakou emphasizes horizontal governance (cross-administrative coordination and infrastructure connectivity) to integrate spatially dispersed resources; Shenzhen model constructs an artificial vertical ecosystem (technology-enabled year-round operations) to overcome natural seasonal constraints; Xinjiang leverages natural vertical endowments (superior snow resources) combine with horizontal policy coordination to achieve scale effects.

These differences confirm the dual-dimensional model and produce two important theoretical and practical implications. In practice, sustainable development is about coordinating vertical structural decisions and horizontal governance capabilities based on local circumstances, i.e., by Olympic infrastructure legacy, capital-intensity technology, or natural resource endowments.

6. Policy coordination and governance mechanism

To achieve the sustainable development of the ice and snow economy, a sound policy coordination and governance mechanism is essential. At the institutional level, China should improve its ice-snow industry planning, clearly define ecological red lines, and remove policy barriers that hinder cross-regional collaboration. On the factor supply side, more investment must flow into finance, land, and—crucially—talent.

Technological innovation deserves special attention. High-efficiency snowmaking, intelligent temperature control systems, and low-carbon operation solutions should be prioritized for research funding and pilot applications. At the same time, China can learn from the Alpine experience by building a dynamic, data-driven monitoring system for snow resources. Finally, governance structures need upgrading: a cross-departmental and cross-regional coordination platform would greatly improve supervision capacity and service efficiency. Without such a platform, even the best policies may fail to deliver on the ground.

7. Conclusion

Driven by the 2022 Beijing Winter Olympics, China's ice and snow economy has expanded rapidly with a preliminary industrial chain and a large consumer market. Yet it still faces constraints including seasonal limits, industrial chain fragmentation, unbalanced regional development, talent shortages and climate risks. Based on industrial ecology and regional coordination theories, this paper establishes a vertical-horizontal dual-dimensional framework. Case studies of Beijing-Zhangjiakou, Shenzhen and Xinjiang confirm that regions should follow differentiated development paths according to their resource endowments. The study indicates that vertical industrial integration and horizontal regional coordination are essential to enhancing industrial resilience. Promoting high-quality and sustainable development requires stronger industrial linkage, fewer administrative barriers, more technological innovation and better talent training, so as to support the long-term growth of the post-Olympic ice and snow economy.

This study concentrates on macro and meso-level analysis and lacks micro-level empirical evidence from enterprises and consumers. Only three typical regions are examined, so the universality of conclusions needs further verification. Climate risk is not quantified, and the sustainability evaluation system remains imperfect. International comparative research is also limited. Future studies may use more micro data, cover more regional cases, establish quantitative evaluation models, deepen international comparisons and improve the dual-dimensional framework, thus offering more reliable references for the high-quality development of the ice and snow economy.

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