Practical Dilemmas and Theoretical Reflections on Innovation Corridor Development in China

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Abstract

Innovation corridors are an important spatial vehicle for advancing coordinated regional innovation. Their development in China is now moving from initial experimentation to accelerated implementation, and the practical difficulties that have emerged call for systematic theorization and reflection. This paper summarizes two overall features of innovation corridor development in China: the coexistence of top-down and bottom-up driving paths, and spatial forms that vary by scale and type. It then analyzes four major practical dilemmas: conceptual bias, insufficient endogenous momentum, weak overall coordination, and an inadequate evaluation system. On this basis, the paper discusses the theoretical foundations of innovation corridor development from three perspectives: conceptual connotation, spatial organization, and spatial performance. It argues that an innovation corridor should be understood primarily as a cross-boundary innovation ecosystem; that multi-chain synergy and network formation constitute the basic logic of its spatial organization; and that network externalities should be a key dimension in evaluating its spatial performance.

Keywords

innovation corridor; innovation ecosystem; cross-boundary collaboration; multidimensional proximity; spatial performance

1 Introduction

As a spatial organization form that relies on linear or belt-shaped infrastructure to allocate factors at high intensity, the development corridor has long attracted attention in urban and rural planning, human geography, regional economics, and related fields [1-2]. Since the success of large-scale corridor planning in Europe in the 1990s, the concept has evolved alongside globalization and urbanization. In its early use, a development corridor described transport routes connecting multiple cities [3]. It later became a spatial planning tool for promoting multi-level and multidimensional intercity linkages [4], and generated economic, industrial, technological, and other functional variants [5]. Its spatial expression has therefore become increasingly diverse in scale and type.

Against the background of economic globalization and sustained regional integration, innovation corridors have emerged worldwide. Supported by transport, information, internet, and other infrastructure, they take the distribution of innovation activities along major transport channels as a basic form, and use the high agglomeration and frequent interaction of innovation actors along innovation chains, industrial chains, and supply chains to create networked spatial organization. They have become an important spatial form for regional collaborative innovation and represent the transformation of the traditional development corridor toward higher value added and stronger agglomeration. Well-known examples include high-tech corridors along Route 128 in Boston and Route 101 in California, the M4 corridor in the United Kingdom, and the Tsukuba-Tokyo-Yokohama innovation belt in Japan. These corridors show strong capacity to integrate innovation resources and produce regional collaborative innovation effects, thereby supporting the agglomeration and circulation of innovation factors and the optimization of regional science and technology ecosystems.

In recent years, innovation corridor development has grown rapidly in China and has received broad attention from academia, industry, and government. Since Shanghai, Hangzhou, and other places first proposed science and technology innovation corridors around 2016, many regions have treated innovation corridors as important spatial carriers for regional collaborative innovation and intercity cross-boundary cooperation. They have also become a frontier in the planning and design of innovation space. With active promotion by local governments at different levels, the scale and intensity of innovation corridor development have continued to increase. According to an incomplete count by the authors, by the end of 2024, more than 100 "innovation corridors" had been proposed across China, covering urban, intercity, and urban-agglomeration scales and regions at different stages of development. Yet under the influence of policy enthusiasm and practical momentum, some regions have followed the trend blindly, leading to inefficient or even ineffective allocation of innovation resources. In some cases, the planned innovation corridors suffer from unclear concepts, ambiguous spatial scope, and weak innovation capacity. In addition, different corridors often operate in isolation, lacking overall coordination and differentiated guidance, which makes effective linkage and collaborative development difficult.

Existing research on innovation corridors has increased steadily. It has mainly addressed conceptual connotations [6-8], evolutionary features [9-10], development evaluation [5,11], policy effects [12-13], and planning strategies [14-16], covering spatial scales from intra-urban areas [17-19] and intercity corridors [20] to urban agglomerations [21-22] and international regions [23]. Most studies, however, focus on specific corridors, with relatively limited overall analysis and theoretical reflection on China's innovation corridor development as a whole. The problems facing current practice have also received insufficient attention. This paper therefore first reviews the overall features of innovation corridor development in China, then analyzes the main practical dilemmas, and finally reflects theoretically on key issues that must be addressed in innovation corridor research. It proposes planning strategies with the aim of providing theoretical and practical references for the high-quality development of innovation corridors in China.

2 Overall Features of Innovation Corridor Development in China

Since the National Innovation-Driven Development Strategy Outline was issued in 2016, regions across China have launched many innovation corridor initiatives, forming a multi-regional and multi-level pattern of exploration. Shanghai and Hangzhou were among the earliest movers. In 2016, Shanghai first proposed the idea of building the Songjiang Science and Technology Innovation Corridor; in the same year, Hangzhou began planning the Hangzhou West Science and Technology Innovation Corridor, relying on the provincial industrial agglomeration area in the western part of the city. In 2017, Guangdong Province issued the Guangzhou-Shenzhen Science and Technology Innovation Corridor Plan, proposing an innovation corridor that links multiple cities and coordinates functions along major transport axes such as the Guangzhou-Shenzhen Expressway and the eastern section of the Pearl River Delta Ring Expressway. In recent years, the Ningbo Yongjiang Science and Technology Innovation Corridor, the Nanjing G312 Industrial Innovation Corridor, and the Zhengzhou-Kaifeng Science and Technology Innovation Corridor have also been placed on local government agendas. A nationwide wave of innovation corridor development has gradually taken shape (Table 1). Based on typical cases, this section summarizes China's innovation corridor development from two dimensions: driving paths and spatial forms.

Table 1 Overview of Selected Representative Innovation Corridors

Scale	Name	Year	Cities / districts involved	Selected related documents
Municipal	Hangzhou West Science and Technology Innovation Corridor	2016	Hangzhou: Xihu District, Yuhang District, Lin'an District	Strategic plan for Hangzhou West Science and Technology Innovation Corridor; Fourteenth Five-Year Plan for Hangzhou West Science and Technology Innovation Corridor
Municipal	Ningbo Yongjiang Science and Technology Innovation Corridor	2017	Ningbo: Jiangbei District, Zhenhai District, Beilun District, Yinzhou District	Spatial plan for Ningbo Yongjiang Science and Technology Innovation Corridor (2019-2035)
Municipal	Qilu Science and Technology Innovation Corridor	2019	Jinan: Licheng District, High-Tech Zone, Zhangqiu District	2019 Jinan Municipal Government Work Report; 2019 Jinan National Economic and Social Development Plan
Municipal	Wenzhou Around-Daluo Mountain Science and Technology Innovation Corridor	2019	Wenzhou: Ouhai District, Longwan District, Rui'an City	2019 Zhejiang Provincial Government Work Report; three-year action plan for Wenzhou Around-Daluo Mountain Science and Technology Innovation Corridor
Provincial	Zhengzhou-Kaifeng-Luoyang Science and Technology Innovation Corridor	2018	Zhengzhou, Kaifeng, Luoyang	Thirteenth Five-Year Plan for National Economic and Social Development of Henan Province; conceptual plan for the Kaifeng section; Henan territorial spatial plan (2021-2035)
Provincial	Optics Valley Science and	2019	Wuhan, Ezhou, Huangshi, Huanggang,	Strategic cooperation agreement; development

	Technology Innovation Corridor		Xianning	strategic plan for Optics Valley Science and Technology Innovation Corridor (2021-2035)
Provincial	G312 Industrial Innovation Corridor	2017	Nanjing, Zhenjiang	Ningbo-Zhenjiang integration planning research; framework agreement on jointly building the G312 Industrial Innovation Corridor
Provincial	Guanzhong Science and Technology Innovation Corridor	2022	Xi'an, Baoji, Xianyang, Tongchuan, Weinan	2022 Shaanxi Provincial Government Work Report
Urban agglomeration	Yangtze River Delta G60 Science and Technology Innovation Corridor	2016, 2017, 2018	Shanghai, Jiaxing, Hangzhou, Jinhua, Suzhou, Huzhou, Xuancheng, Wuhu, Hefei	Shanghai-Jiaxing-Hangzhou G60 cooperation agreement; construction plan for the Yangtze River Delta G60 corridor; plan for the Zhejiang section
Urban agglomeration	Guangzhou-Shenzhen-Hong Kong-Macao Science and Technology Innovation Corridor	2017, 2018	Guangzhou, Shenzhen, Hong Kong, Macao, Dongguan, Zhongshan, Zhuhai	Guangzhou-Shenzhen corridor plan; outline development plan for the Guangdong-Hong Kong-Macao Greater Bay Area; Guangdong Fourteenth Five-Year Plan for science and technology innovation

2.1 Driving Paths: Coexistence of Bottom-Up and Top-Down Approaches

China's innovation corridors display both bottom-up and top-down driving paths, with marked regional variation.

On the one hand, bottom-up driving paths are concentrated mainly in eastern urban agglomerations, where innovation resources are relatively dense and market vitality is strong. In these regions, innovation corridors often originate from practical needs for local industrial development, have strong endogenous momentum, and usually develop spatially before being fully institutionalized by policy. They tend to form spontaneous agglomeration and then expand and upgrade gradually after government intervention [22]. For example, the G60 Science and Technology Innovation Corridor began as a grassroots exploration in Shanghai's Songjiang District in 2016. To promote frontier science and technology innovation and industrial development, the local government first proposed the Songjiang Science and Technology Innovation Corridor along the G60 Expressway, seeking to connect industrial space and concentrate innovation factors. In the following year, Songjiang cooperated with neighboring Hangzhou and Jiaxing along the G60 route, forming the cross-city Shanghai-Jiaxing-Hangzhou G60 corridor. Jinhua, Suzhou, Huzhou, Xuancheng, Wuhu, and Hefei later joined, upgrading it into a cross-regional innovation corridor covering nine cities in three provinces of the Yangtze River Delta. In 2021, the Ministry of Science and Technology, the National Development and Reform Commission, and other ministries issued the Construction Plan for the Yangtze River Delta G60 Science and Technology Innovation Corridor. The corridor thus entered a new phase, moving from concept to implementation and from local practice to national-level deployment [24].

On the other hand, top-down driving paths have also become an important way of building innovation corridors. In most regions, local governments treat innovation corridors as an important instrument for regional collaborative innovation, actively plan and deploy them, and implement them through planning documents. In this approach, the innovation corridor is seen as an institutional space designed to realize cross-regional division of labor and complementarity of comparative advantages [22]. Policy instruments are used to drive the sharing and circulation of innovation resources and factors between cities with development differentials, thereby improving regional innovation capacity. The G312 Industrial Innovation Corridor, for instance, was proposed and promoted under the dual background of building the Yangtze River Delta science and technology innovation community and advancing Nanjing-Zhenjiang integration. By strengthening infrastructure connectivity between the two places and improving the agglomeration of innovation factors, it has gradually created a functional platform for collaborative innovation in the Nanjing-Zhenjiang region. Similarly, the Guangzhou-Shenzhen Science and Technology Innovation Corridor was planned by the Guangdong provincial government under the innovation-driven transformation strategy of the Guangdong-Hong Kong-Macao Greater Bay Area. It integrates innovation resources in Guangzhou, Shenzhen, and Dongguan, relies on a spatial pattern of "one corridor, ten cores, and multiple nodes", and forms an innovation economic belt that combines industrial linkage, spatial coupling, and functional continuity.

Overall, most innovation corridors in China do not depend on a single driving mode. Instead, they show a compound pattern in which bottom-up and top-down forces are intertwined. The agglomeration of innovation actors and exploratory grassroots practice provide the development basis and spatial prototype of corridors, while higher-level policies and plans guide and regulate development by coordinating resource allocation, optimizing spatial layout, and improving institutional arrangements. The Yangtze River Delta G60 corridor is a typical case. It began with spontaneous local exploration and gradually achieved standardized and institutionalized development under national policy guidance, forming a mutually reinforcing relationship between local innovation vitality and regional strategy.

2.2 Spatial Forms: Multiple Scales and Diverse Types

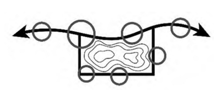
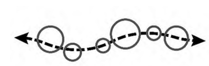
In terms of spatial form, many innovation corridors in China show clear multi-scale and multi-type characteristics.

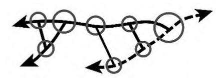
First, existing innovation corridors operate at municipal, provincial, and urban-agglomeration scales, and therefore involve cross-district, cross-city, and cross-provincial spatial scopes (Table 1). The Hangzhou West Science and Technology Innovation Corridor covers Xihu, Yuhang, and Lin'an districts within

Hangzhou. The Zhengzhou-Kaifeng-Luoyang corridor involves three cities in Henan Province. The Yangtze River Delta G60 corridor involves Shanghai and eight cities in Jiangsu, Zhejiang, and Anhui.

Second, while continuing the traditional belt-shaped form of development corridors, innovation corridors have gradually produced multiple spatial forms, including cluster-belt, linear-belt, ring-belt, and networked patterns. These forms partly reflect the developmental stages and evolutionary paths of innovation corridors (Table 2). Cluster-belt and linear-belt corridors are the most common. Both connect innovation-resource agglomeration areas along development axes to realize spatial linkage and functional coupling, and both appear across multiple scales. Their difference lies in emphasis. Cluster-belt corridors tend to provide conceptual guidance for organizing specialized industrial clusters, whereas linear-belt corridors usually rely on physical transport corridors to guide the spatial distribution of innovation activities. Ring-belt corridors are mostly located within cities, using landscape and ecological bases to build transport and green infrastructure and to guide the agglomeration and diffusion of innovation factors around mountains or water systems. Networked corridors mainly appear at the scale of urban agglomerations, where multiple cities rely on two or more development axes to share resources, complement functions, and coordinate mechanisms. They can be regarded as the spatial expression of innovation corridors at a more advanced stage. The Yangtze River Delta G60 corridor and the Guangzhou-Shenzhen-Hong Kong-Macao corridor are typical cases; both have undergone several rounds of expansion and now show networked patterns of collaborative innovation [6].

Table 2 Spatial Characteristics of Representative Innovation Corridor Forms

Form	Basic characteristics	Main transport framework		Examples
Ring-belt	Innovation factors agglomerate around mountains or water systems	Urban water systems and urban arterial roads		Ningbo Yongjiang Science and Technology Innovation Corridor; Wenzhou Around-Daluo Mountain Science and Technology Innovation Corridor
Cluster-belt	Agglomeration areas connect into clusters and form development axes	Urban rivers and urban arterial roads		Hangzhou West Science and Technology Innovation Corridor; Optics Valley Science and Technology Innovation Corridor
Linear-belt	Linear extension along transport corridors	Expressways and national highways		G312 Industrial Innovation Corridor; Qilu Science and Technology

				Innovation Corridor
Networked	Multiple belts interact and develop as a network	Integrated transport systems including high-speed rail and expressways		Yangtze River Delta G60 Science and Technology Innovation Corridor; Guangzhou-Shenzhen-Hong Kong-Macao Science and Technology Innovation Corridor

3 Practical Dilemmas in Innovation Corridor Development in China

3.1 Conceptual Bias

The development of an innovation corridor is a gradual process that moves from conceptual cognition to spatial shaping and then to mechanism cultivation. In current practice, however, many innovation corridors face the dilemma of conceptual generalization. At the level of cognition, some regions simply combine the term "innovation" with existing terms such as "development corridor" or "development axis". As a result, the basic connotation is unclear, the spatial scope is ambiguous, and innovation capacity is weak. These corridors differ little from traditional development corridors in functional division, spatial organization, and innovation capability.

Based on field investigations and analysis of relevant policy texts, some innovation corridors have overly broad spatial scopes and lack clear linear spatial features. The Optics Valley Science and Technology Innovation Corridor (Fig. 1), for example, has a clear strategic intention: to use Wuhan as the innovation core and radiate development to Ezhou, Huangshi, Huanggang, and Xianning. Yet its spatial scope is relatively vague. Its three innovation industrial belts and several industrial clusters deviate to some extent from the core development axis. Some corridor locations also ignore the internal foundations of innovation development and merely recombine existing industrial spaces through linear stitching. They are difficult to distinguish from other development corridors in functional division and construction priorities. For example, in the Zhengzhou-Jiaozuo Integration Development Plan, the spatial nodes of the Zhengzhou-Jiaozuo Science and Technology Innovation Corridor are broadly similar to those of the Zhengzhou-Jiaozuo Intelligent Manufacturing Corridor and the Zhengzhou-Jiaozuo-Jincheng Smart Logistics Corridor.2

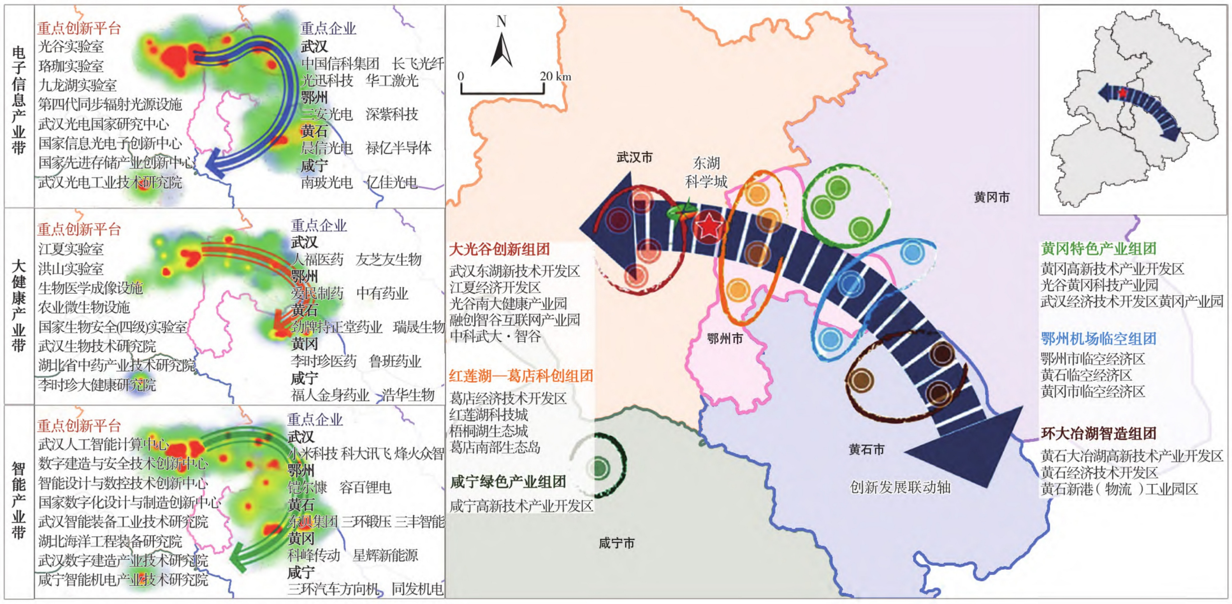


Fig. 1 Spatial layout of the Optics Valley Science and Technology Innovation Corridor and its three innovation industrial belts

3.2 Insufficient Endogenous Momentum

At present, most innovation corridors are built and developed through government-led top-down paths. There is insufficient systematic identification of, and institutional response to, the internal logic, linkage mechanisms, and influencing factors that shape the agglomeration of innovation actors. This makes sustainable endogenous growth difficult. Many corridors still follow a traditional spatial logic centered on physical "points" and infrastructure "axes", without fully considering how relational factors such as technological proximity, institutional proximity, and organizational proximity affect corridor organization.3

Experience shows that government-led construction of physical nodes and infrastructure axes can concentrate innovation actors and factors to some extent, but it does not necessarily stimulate endogenous linkages among innovation actors or form true corridor agglomeration [5]. Neglecting the internal rules and mechanisms of actor linkages can leave an innovation corridor at a weakly integrated stage [24]. The transformation of the G60 corridor from concept to implementation, for instance, depended not only on national-level coordinated planning and institutional innovation, but also on pre-existing spatial proximity and industrial linkages among the nine cities, as well as institutional proximity in planning coordination and policy connection among the three provinces and one municipality of the Yangtze River Delta. These forms of multidimensional proximity interact to improve the collaborative efficiency of the corridor as a regional innovation ecosystem.

3.3 Weak Overall Coordination

As a spatial organization form that crosses administrative boundaries and contains multi-scale nested attributes, the innovation corridor naturally carries the strategic intention of promoting regional integration and collaborative development. Yet because of insufficient overall coordination and lack of classification-based guidance, many corridors have produced overlapping spatial scales and duplicated strategic goals. This increases implementation difficulty and governance costs, and highlights the need for a collaborative pattern of differentiated layout, complementary functions, and shared factors.

Zhejiang Province provides an example (Fig. 2). Its Guidelines for Science and Technology Innovation Corridor Development in Zhejiang Province (Trial) clarify the development positioning and leading industries of the Hangzhou West, Ningbo Yongjiang, Wenzhou Around-Daluo Mountain, Central Zhejiang, and Jiaxing G60 corridors. Yet the Ningbo Yongjiang corridor remains at risk of homogeneous competition with the Shaoxing corridor, which is spatially close, less than 80 km away, and focused on similar industries such as new materials and the internet.4 At the same time, the pattern of "corridors nested within corridors" creates overlapping strategic goals across multiple levels and makes coordination of innovation-resource allocation and spatial layout more complex. Hangzhou, Jinhua, and Quzhou, for example, all undertake multiple innovation corridor tasks, involving many dispersed actors and generating risks of multi-headed management and difficult policy coordination. Similarly, the G312 Industrial Innovation Corridor proposed by Nanjing overlaps spatially with the Purple Mountain Science and Technology Innovation Belt (Fig. 3), and G312 is also an important component of the Shanghai-Nanjing Industrial Innovation Belt [20].

Fig. 2 Representative innovation corridors in Zhejiang

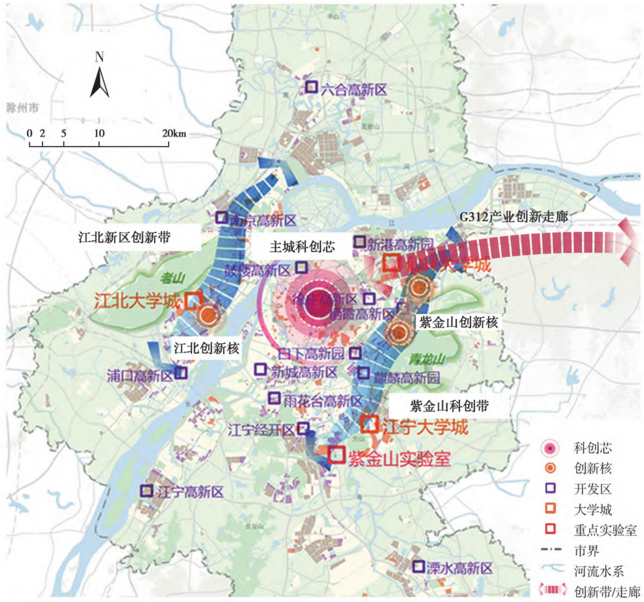


Fig. 3 Representative innovation corridors in Nanjing

3.4 Weak Evaluation System

As spatial carriers that agglomerate innovation factors and promote regional collaboration, innovation corridors have received substantial policy support and resource allocation in recent years. How to evaluate and improve their overall development quality has therefore become increasingly important. In October 2022, Zhejiang Province issued the Evaluation Indicator System for High-Quality Development of Science and Technology Innovation Corridors in Zhejiang Province (Trial), aiming to establish a monitoring and evaluation mechanism for corridor quality. In November of the same year, the stage evaluation report of the Yangtze River Delta G60 corridor was released. It built an evaluation system around five dimensions - innovation, coordination, green development, openness, and sharing - and included 85 specific indicators, such as regional R&D input, number of enterprises with key core technologies, and construction of innovation carriers.5

Nevertheless, a comprehensive, diverse, and systematic evaluation framework for corridor development has not yet been formed. This weakens policy feedback mechanisms and makes it difficult to guide optimization and adjustment of development paths. On the one hand, current performance evaluation often emphasizes the quantity of science and technology outputs within a region, such as patent applications, technology contract turnover, and the number of technology-based firms, or focuses mainly on typical project progress. It has not yet formed a multidimensional system for assessing deeper variables that affect corridor development, such as the structural efficiency of knowledge-flow networks and the degree of synergy between innovation chains and industrial chains. On the other hand, as cross-regional, cross-level, and multi-actor spatial systems, innovation corridors differ by development type and stage. Current evaluation systems rarely classify and assess different types and stages of corridors accordingly.

4 Theoretical Foundations and Optimization Strategies for Innovation Corridor Development

Innovation corridor development in China is at a key turning point, moving from initial exploration to accelerated advancement. It is therefore necessary to deepen scientific understanding of the concept, organizational logic, and spatial performance of innovation corridors, and to provide theoretical support for addressing current practical dilemmas. Research should accordingly shift from discussion of practical experience toward the discovery of scientific rules and the construction of foundational theory.

4.1 Cross-Boundary Innovation Ecosystems as the Core Connotation of Innovation Corridors

An innovation corridor is essentially a cross-boundary innovation ecosystem formed on the basis of rapid transport infrastructure [7,25]. It provides a specific territorial space for cross-regional and multi-level exchange among governments, firms, universities, research institutions, and other actors. The formation and development of this cross-boundary innovation ecosystem depends mainly on three dimensions.

First is spatial cross-boundary connectivity. Interconnected transport facilities improve geographic proximity, reduce spatial barriers to face-to-face knowledge exchange and diffusion, and open channels for the high-frequency cross-boundary flow of talent, technology, information, and other innovation factors. They provide basic support for the formation of an innovation ecosystem. Second is functional cross-boundary linkage. Under the premise of physical proximity, corridor development cannot be separated from the self-organizing behavior of innovation actors. Firms, universities, and research institutions usually need to cooperate externally in order to maximize benefits. Through cognitive, technological, and social proximity, they generate cross-boundary innovation linkages within the corridor and jointly form an adaptive system with complementary functions and co-evolution. Third is governance-based cross-boundary coordination. Innovation corridor development also depends on the other-organization and re-organization provided by policy systems. Systematic institutional arrangements and coordination mechanisms across regions and departments strengthen institutional proximity, reduce transaction costs, and provide a shared and interconnected policy environment for the sound operation of the innovation ecosystem.

The Cascadia Innovation Corridor, extending from the northwestern United States to southwestern Canada, illustrates the organic combination of these three dimensions [23]. Spatially, it builds physical channels through expressways, high-speed rail, airports, and other integrated transport systems, while also reducing border closure through shared border-infrastructure data. Functionally, with technology leaders such as Microsoft and Amazon, the corridor has spontaneously established broad research collaboration, enabling Seattle and Vancouver to use their respective strengths for functional complementarity and strong collaborative development. In governance, it has established a Cascadia steering committee composed of government officials, business leaders, university representatives, and research institutions to jointly address infrastructure, cross-border flows, technological innovation, labor, and other key issues and to formulate action plans.

This shows that the connotation of an innovation corridor is not limited to crossing geographic space; it also includes the cross-regional integration of "invisible" boundaries such as policies and institutions. In practice, cross-boundary coordination should therefore be the core task. First, cross-boundary spatial databases should be built by integrating remote sensing, geographic information, socioeconomic, and other multi-source data. These databases should clarify the scope and scale of innovation activity agglomeration along transport corridors, identify innovation-potential areas on urban edges and infrastructure breakpoints, and provide scientific support for spatial stitching across administrative boundaries through integrated transport systems such as high-speed rail, expressways, and intercity rail. Second, metropolitan integration in cross-boundary areas should be strengthened. Spatial integration in adjacent provincial and municipal boundary areas should be used as an anchor to promote industrial division of labor and innovation cooperation, while avoiding one-sided development caused by disparities in development level. This can move innovation corridors from geographic proximity toward deeper functional integration. Third, cross-boundary benefit-sharing systems should be explored, including tax-sharing arrangements, adjustment of land-use quotas, unified technical standards, mutual recognition, intellectual property protection, and other policy systems, in order to build a favorable innovation ecosystem.

4.2 Multi-Chain Integration and Network Formation as the Basic Logic of Spatial Organization

The spatial organization logic of an innovation corridor is not the linear expansion of a single chain. Rather, it is supported by the spatial coupling of multiple chains, including innovation chains, industrial chains, and supply chains. Different innovation actors form connections by participating in different chain links, thereby creating a regional innovation community with multi-chain integrated development [26-27] (Fig. 4).

First, the innovation chain must achieve a high level of coordination. Different innovation actors and regions form nonlinear cooperative networks through basic research, applied development, and commercialization, creating closed-loop connections among research, pilot testing, incubation, and application. Second, the industrial chain must remain highly connected. Firms within the corridor realize complementarity and cooperation through technological connection, production collaboration, and resource sharing according to upstream and downstream industrial relations, forming a specialized production network. Finally, the supply chain must ensure smooth circulation, covering raw material supply, production, product distribution, and the efficient flow of materials, products, and information within the corridor, so that it can respond quickly to market and technological change. Through multi-chain integration in spatial allocation, an innovation corridor forms a spatial organization structure composed of point-like innovation actors such as firms, governments, and universities; area-based innovation-activity agglomeration zones with functions such as education, research, production, and services; and multi-chain integrated networks such as knowledge flows, technology flows, and logistics.

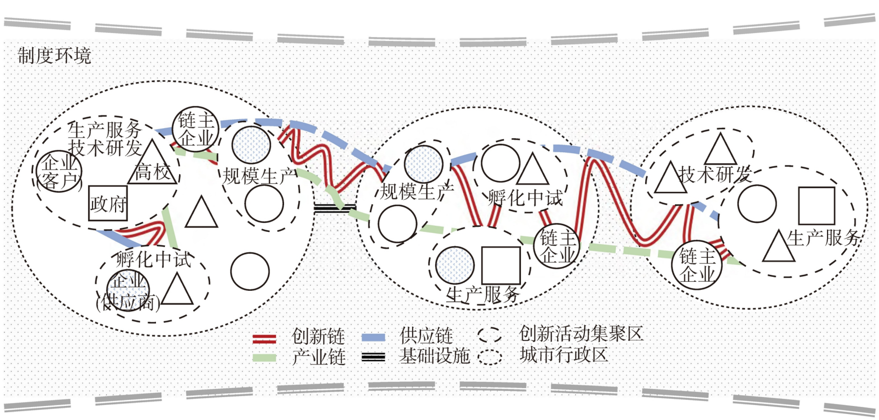


Fig. 4 Schematic diagram of multi-chain integration in the innovation corridor

The development of Boston Route 128 illustrates the spatial organization logic of multi-chain integration [28]. With MIT, Harvard University, and other universities and research institutions as upstream knowledge sources in the innovation chain, the corridor connects to market demand and incubates spin-off firms, allowing these actors to participate directly in industrial-chain and innovation-chain links. At the same time, incubation platforms such as Kendall Square, built within and around universities, continue to nurture start-ups and generate emerging industrial clusters such as biotechnology. Technology firms represented by Novartis and Merck have located R&D centers around universities, accelerating the transformation of research results into industry and realizing deep integration between innovation chains and industrial chains. Government policy tools such as venture capital and tax incentives provide institutional support for the efficient flow of knowledge, technology, and capital across chains.

Based on this analysis, the integration of innovation chains, industrial chains, and supply chains depends not only on cooperation among micro-level innovation actors, but also on spatial carriers that support innovation and production activities, as well as institutional support systems. In practice, spatial layout should therefore be optimized to support multi-chain integration. First, resource integration should be promoted around "chain-owner" firms. Leading enterprises should be encouraged and supported to build joint laboratories, industry-university-research cooperation platforms, and regional innovation consortia. As links among upstream and downstream firms, R&D and market ends of innovation chains, and key supply-chain nodes, such chain-owner firms can form multi-level innovation networks in which large, medium, and small firms interact, compete, cooperate, and coexist. Second, a chain-oriented spatial carrier system should be built around key industrial-chain links, major innovation-chain activities, and supply-chain support systems. By combining the technological conditions, industrial foundations, and market demand of different areas, a multi-level spatial layout should be explored that links headquarters R&D, specialized industrial parks, and supporting production bases. Third, support mechanisms for multi-chain collaboration should be improved. Chain-owner firms, local governments, industrial alliances, and other actors should jointly build normalized cooperation platforms to share data, market information, and supporting resources.

4.3 Network Externalities as an Important Dimension of Spatial Performance

The spatial performance of an innovation corridor is reflected not only in visible innovation outputs, but also in knowledge spillover effects generated when innovation actors use network connections to transcend geographic constraints. Network externalities emphasize that innovation actors can acquire external knowledge and resources by embedding themselves in innovation networks. Their role in innovation corridors is mainly reflected in two aspects.

On the one hand, high-capacity cities can use their core position in innovation networks to attract more innovation factors, form more frequent external innovation linkages, and promote the multidimensional integration of knowledge, technology, and capital, thereby generating clear "Matthew effects" [29]. On the other hand, in the allocation of network nodes, collaborative innovation generated by knowledge flows can break through the limitations and imbalance associated with traditional agglomeration externalities [30]. Therefore, cities with lower innovation capacity within a corridor can also participate in innovation cooperation through geographic, technological, and cognitive proximity, use innovation resources, and transform their comparative advantages into development momentum, thus promoting balanced corridor development.

The collaborative development of cities along the UK's M4 corridor illustrates this network externality well [31]. London remains the core of the corridor by virtue of its research resources and advantages in finance and markets, gradually concentrating and controlling high-end global innovation factors. At the same time, medium and small cities such as Bristol and Cardiff have integrated into the corridor's innovation network through geographic and technological proximity, obtaining knowledge, technology, industrial, and other resources spilled over from London. They have also used local resource endowments to cultivate distinctive innovation nodes in green technology, advanced manufacturing, cultural creativity, and other sectors. Ultimately, the M4 corridor has formed a polycentric structure of differentiated development and collaborative cooperation, improving balanced development and overall regional capacity.

Because of network externalities, the innovation capacity of cities along a corridor depends not only on their own development conditions and node size, but also on their position and division of labor within the innovation network. Practice should therefore be based on the dynamic evolution of the innovation-network structure, and should guide and amplify network externalities. First, dynamic monitoring mechanisms should be established. Big-data and network-analysis methods can be used to track quantitative indicators in real time, including density of innovation actors, intensity of knowledge flows, and frequency of firm cooperation, so as to identify changes in nodes and potential breakpoints. Second, a multidimensional evaluation system should be built to periodically assess the spatial performance of innovation corridors from the perspectives of innovation output, innovation cooperation, network-structure efficiency, and multi-chain synergy, providing a basis for policy adjustment and resource allocation. Third, the innovation-network structure should be optimized. Cooperation methods such as innovation enclaves and jointly built industrial parks should be used to strengthen connections between peripheral and core nodes, while secondary innovation growth poles should also be cultivated to avoid innovation lock-in and improve the overall collaborative efficiency of the corridor.

5 Conclusion

In recent years, China has seen a nationwide wave of innovation corridor development. These corridors show multiple driving paths in which bottom-up and top-down forces coexist, as well as a spatial pattern in which multiple scales - municipal, provincial, and urban-agglomeration - and multiple types - cluster-belt, linear-belt, and ring-belt - coexist. Yet as development accelerates, a series of deeper problems has also emerged. First, the conceptual connotation remains unclear, making spatial implementation and mechanism cultivation insufficiently targeted. Second, excessive reliance on administrative promotion by higher-level governments is not conducive to stimulating endogenous linkages and sustained interaction among innovation actors. Third, the absence of cross-administrative and cross-level coordination mechanisms can lead to fragmented governance and homogeneous competition. Fourth, the evaluation system for development performance remains weak, making it difficult to guide differentiated development of different types of corridors.

For these reasons, innovation corridor research needs to shift from a practice-oriented focus to the systematic construction of foundational theory. Conceptually, a stronger scientific understanding of innovation corridors as cross-boundary innovation ecosystems is needed, with attention to the cross-boundary integration of space, functions, and governance, and to the high-frequency flow of innovation factors and efficient cooperation among actors. In terms of spatial organization, the multidimensional coupling of innovation chains, industrial chains, and supply chains should be promoted, and chain-based thinking should be used to strengthen collaborative linkage and networked integration among innovation actors. From the perspective of spatial performance, understanding and guidance of innovation-network externalities should be deepened, and dynamic monitoring and periodic evaluation mechanisms should be built so that regional collaborative innovation can be realized through structural optimization.

Notes

1. See the Guangzhou-Shenzhen Science and Technology Innovation Corridor Plan.
2. The Zhengzhou-Jiaozuo Integration Development Plan (2020-2035) proposes building the Zhengzhou-Jiaozuo industrial belt, linking Zhengzhou Airport Economy Zone, the Economic Development Zone, the High-Tech Zone, Wuzhi Industrial New City, Jiaozuo High-Tech Zone, and the southern industrial new city, and focusing on three coordinated corridors: the Zhengzhou-Jiaozuo Science and Technology Innovation Corridor, the Zhengzhou-Jiaozuo Intelligent Manufacturing Corridor, and the Zhengzhou-Jiaozuo-Jincheng Smart Logistics Corridor.
3. This point is drawn from Column 2 of the Shaoxing Science and Technology Innovation Corridor Development Plan and Table 2-1 of the Quzhou Four-Province Border Science and Technology Innovation Corridor Development Plan.
4. The Guidelines for Science and Technology Innovation Corridor Development in Zhejiang Province (Trial) propose that the Ningbo Yongjiang Science and Technology Innovation Corridor focus on new materials and the industrial internet, while also guiding the development of the Shaoxing Science and Technology Innovation Corridor. The Shaoxing plan explicitly proposes generating key core technologies in "internet plus", life and health, and new materials.
5. Source: China Development Web, supervised by the National Development and Reform Commission, http://g60.chinadevelopment.com.cn/sjxw/2022/1110/1808179.shtml.

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