Innovation Synergy Mechanisms and Guidance Strategies for Cross-Boundary Regions from a Potential Difference Perspective: An Empirical Study of the Shanghai-Suzhou-Jiaxing Cross-Boundary Region

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Abstract

Innovation synergy in cross-boundary regions is a necessary step toward deep regional integration and an indispensable component of regional innovation networks. Compared with the one-way pull of the "core-periphery" model, the multidirectional "periphery-periphery" linkages in cross-boundary regions offer a key way to understand how their innovation-synergy patterns take shape. From a potential difference perspective, this paper explains the mechanism of innovation synergy in cross-boundary regions. It first clarifies the meaning of potential-difference coupling and the matching mechanism among three structural phases - endowment, efficiency and environment - and then develops a four-quadrant framework of innovation synergy under the logic of potential difference. Two typical spatial organization models are identified: multidirectional linkage and balanced interaction. Using the Shanghai-Suzhou-Jiaxing cross-boundary region as an empirical case, the paper identifies a development pattern of "salient potential differences and differentiated phases" and a synergy condition of "broad connectivity but weak stability". It verifies the proposed mechanism and then proposes a guidance framework of "proximity-based complementarity plus network linkage" and a leapfrogging path from "absence" to "emergence", "optimization" and "refinement". The study provides theoretical and empirical references for addressing innovation-synergy dilemmas in cross-boundary regions.

Keywords

cross-boundary region; innovation synergy; innovation potential difference; Shanghai-Suzhou-Jiaxing

Introduction

Regional innovation synergy has become a key clue and a broad consensus for advancing deep regional integration and high-quality regional economic development. The classical "core-periphery" theory holds that innovation activities are highly concentrated in core areas, while peripheral areas, constrained by limited resources, become dependent on core areas for development [1]. Yet with the cross-jurisdictional, high-frequency and networked flow of innovation factors, cross-boundary areas located at the edges of different cities are breaking through administrative barriers and weakening their traditional dependence on core areas. They are becoming potential zones for regional innovation synergy.

As spatial nodes in regional innovation networks, cross-boundary regions refer to geographic areas at the junction of different administrative units. They are especially prominent where municipal boundaries meet, commonly described as intercity boundaries, and where provincial boundaries meet, commonly described as interprovincial boundaries. The innovation development of such regions is related to the innovation levels and interactions on both sides of the boundary [2]. They may remain peripheral for a long time because of administrative barriers, but they may also release considerable potential through complementary conditions and functional coordination [3]. The cross-boundary area at the junction of Shanghai, Suzhou and Jiaxing, hereafter the Shanghai-Suzhou-Jiaxing cross-boundary region, is gradually becoming an emerging growth pole in the Yangtze River Delta innovation network. Covering 11 districts and county-level cities, it reflects both the agglomeration of innovation in cross-boundary areas and a new trend in regional innovation synergy.

Existing studies usually treat "cross-boundary" as a precondition rather than as the central analytical object. They mainly address the evaluation of influencing factors [4-5], the intensity of intercity cooperation [6] and the design of collaborative policies [7], while commonly introducing spatio-temporal behavioral big-data analysis and social network analysis [8-10]. However, they often understate the cross-boundary attribute of the research object and the collaborative value generated by that attribute. This points to the need for a more explicit explanation of the mechanism of innovation synergy in cross-boundary regions.

This paper therefore starts from the cross-boundary attribute and introduces the concept of potential difference [11]. Originally, potential difference refers to energy transfer caused by differences in position and state. In cross-boundary regions, different internal areas have different levels of innovation development because of administrative segmentation, resources, policy conditions and other differences [12]. These differences constitute innovation potential differences. Scholars have applied this concept to intercity innovation-synergy studies to explain the internal drivers of innovation linkages [13] and the formation of innovation networks [14]. Related concepts such as technological potential difference and economic potential difference have also emerged. Building on this literature, the paper extends potential-difference analysis from a single driving factor to the internal structural relationships among factors, thereby providing a systematic analytical perspective for examining multidimensional structural drivers and constraints of collaborative development.

In sum, the paper focuses on "periphery-periphery" innovation synergy in cross-boundary regions. It seeks to reveal the basic meaning of innovation synergy in such regions from a potential difference perspective, clarify the internal mechanism through which innovation synergy forms, analyze its operating logic and infer its spatial organization models. It then uses the Shanghai-Suzhou-Jiaxing cross-boundary region as an empirical case, drawing on statistical yearbooks and Incopat patent data to examine its existing innovation-development pattern and synergy condition, to verify the theoretical analysis, and finally to propose targeted guidance strategies for the development of innovation synergy in cross-boundary regions.

1 Connotations and Mechanisms of Innovation Synergy in Cross-Boundary Regions from a Potential Difference Perspective

From a potential difference perspective, cross-boundary regions are convergence zones for the flow of innovation factors. Innovation potential differences among their internal areas are both an existing reality and the basic logical clue for understanding the meaning and mechanism of innovation synergy.

1.1 The meaning of innovation synergy in cross-boundary regions: potential-difference coupling

In the process of deep regional integration, cross-boundary regions become intersections for various innovation factors. Yet when factors cross boundaries, administrative barriers, geographic marginality and other constraints become obstacles to the coupling of innovation potential differences between the two sides of the boundary (Fig. 1). Innovation activities therefore often form only low-level, small-scale initial agglomerations, producing fragmented innovation-island phenomena.

On the one hand, administrative and geographic constraints raise innovation costs, intensify homogeneous competition among localities, restrict the free flow of factors and the efficient allocation of resources, and make it difficult for cross-boundary regions to overcome their peripheral status. On the other hand, these very constraints generate a strong demand for innovation synergy. Such regions urgently need to overcome uneven resource allocation, high cooperation costs and frequent institutional frictions, narrow innovation-development gaps, and form cross-boundary innovation communities. This process is precisely the process of innovation synergy in cross-boundary regions; in essence, it is the gradual breaking of multiple constraints and the coupling of innovation potential differences.

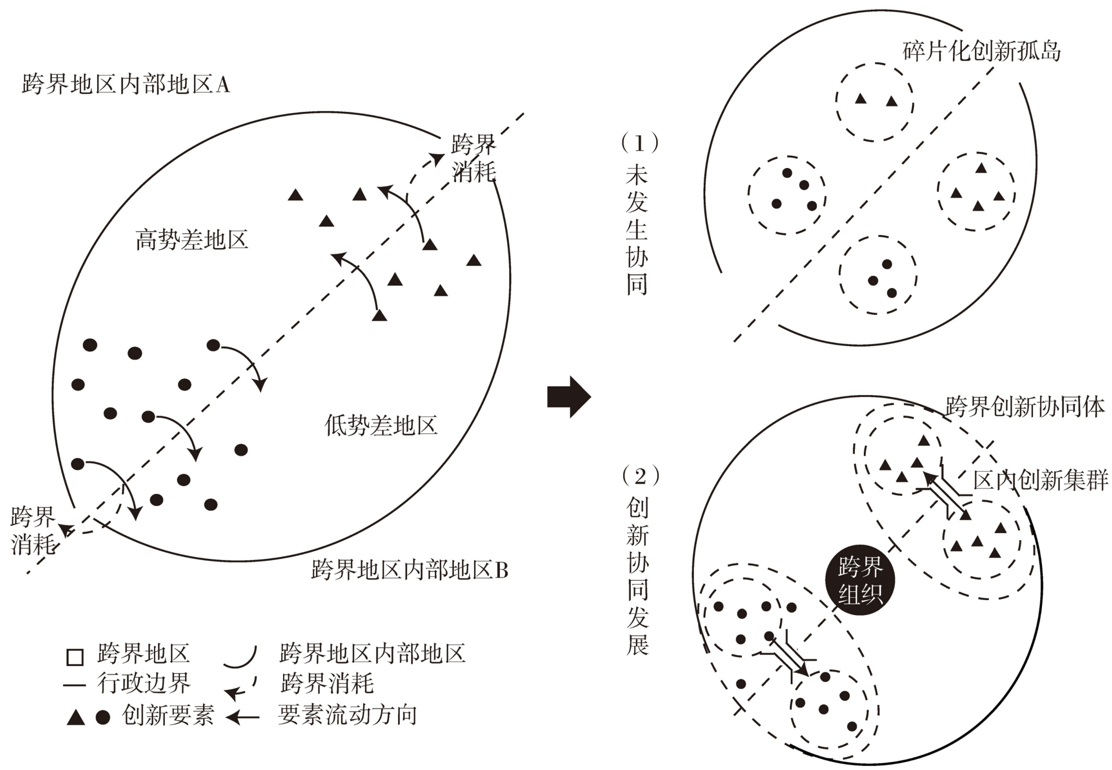

Fig. 1 Diagram of innovation synergy in cross-boundary regions

The classical "core-periphery" theory usually emphasizes the innovation advantages of core areas and relatively neglects the decomposition of innovation potential in peripheral areas [15]. As a result, synergy strategies based on radiation from the core often fail to fit the real development of cross-boundary regions [16]. Under conditions of significant differences in initial endowment, policy attention and spatial location, "core-periphery" innovation synergy relies heavily on one-way resource spillovers and policy transmission from core areas to construct potential differences and promote peripheral development [17]. By contrast, "periphery-periphery" synergy is a multidirectional integration and restructuring of innovation resources, institutions and efficiency among peripheral areas. Its purpose is to couple innovation potential differences through the effective complementarity of each area's innovation advantages [18].

Table 1 Differences in the connotations of innovation synergy between "periphery-periphery" and "core-periphery" models

Item	"Periphery-periphery" synergy	"Core-periphery" synergy
Relational pattern	Builds an innovation network by breaking administrative barriers	Relies on the core area to drive peripheral development
Synergy features	Multidirectional interaction among multiple actors, with internal resource optimization and capacity complementarity	One-way resource transfer radiating from the core, with lower trial-and-error costs but stronger dependence
Typical practice	Joint construction of cross-boundary institutions	Industrial transfer

The comparison shows that innovation synergy in cross-boundary regions is not a simple gradient division of labor. It requires shared understanding among different administrative units of the stage of deep regional integration, systematic recognition and matching of their respective innovation-potential structures, and corresponding cooperation institutions and platforms to break through traditional peripheral dilemmas.

1.2 Mechanism of innovation synergy in cross-boundary regions: three-phase matching

Current scholarship generally evaluates the state of regional innovation synergy and explains its evolution from three dimensions: innovation endowment, innovation efficiency and innovation environment [19-20]. Innovation endowment constitutes the basic condition for synergy; innovation efficiency reflects the capacity to transform synergy into outcomes; and innovation environment reflects the level of collaborative regulation. The same applies to cross-boundary regions. Their innovation-synergy condition forms and evolves through the interaction of carriers on both sides of the boundary, the transformation of efficiency, and the adaptation of the environment. These dimensions also constitute the three structural phases of innovation potential difference in cross-boundary regions.

If the existence of innovation potential difference is the premise for synergy demand, then the spatial diffusion of synergy effects and the continuous improvement of local innovation levels require the matching of the endowment, efficiency and environment phases, that is, the coupling of innovation potential difference. Specifically, the endowment phase is represented by the growth of innovation carriers, including the number of carriers and the degree of group-chain linkage. It is a key means for cross-boundary regions to break constraints imposed by single administrative units and optimize resource allocation. The efficiency phase is represented by production-organization efficiency, especially the diffusion, reorganization and transformation of factors under market regulation and policy guidance. When transaction costs and cross-boundary losses increase significantly under administrative barriers, they force the emergence of innovation synergy; in this process, knowledge and technology sharing and dynamic factor matching accelerate the narrowing of efficiency-phase gaps. The environment phase is represented by the policy-support environment, reflecting the comprehensive level of governmental action in removing administrative barriers and improving the matching between factor supply and demand. Through institutional design, policy tilt and mutual recognition of standards, governments can accelerate synergy between high- and low-potential areas and provide a secure and open collaborative-support system.

The matching of innovation-carrier growth, production-organization efficiency and policy-support environment turns innovation synergy in cross-boundary regions from a potential possibility into a practical phenomenon. The three phases form a circular feedback relationship in the coupling process (Fig. 2): policy empowerment accelerates the growth of innovation carriers and improves production-organization efficiency; innovation carriers are the action focus of policy design, and their growth and linkage feed back into improved production-organization efficiency; production-organization efficiency embodies the concentration and flow effects of innovation factors and, in turn, optimizes market regulation and policy control.

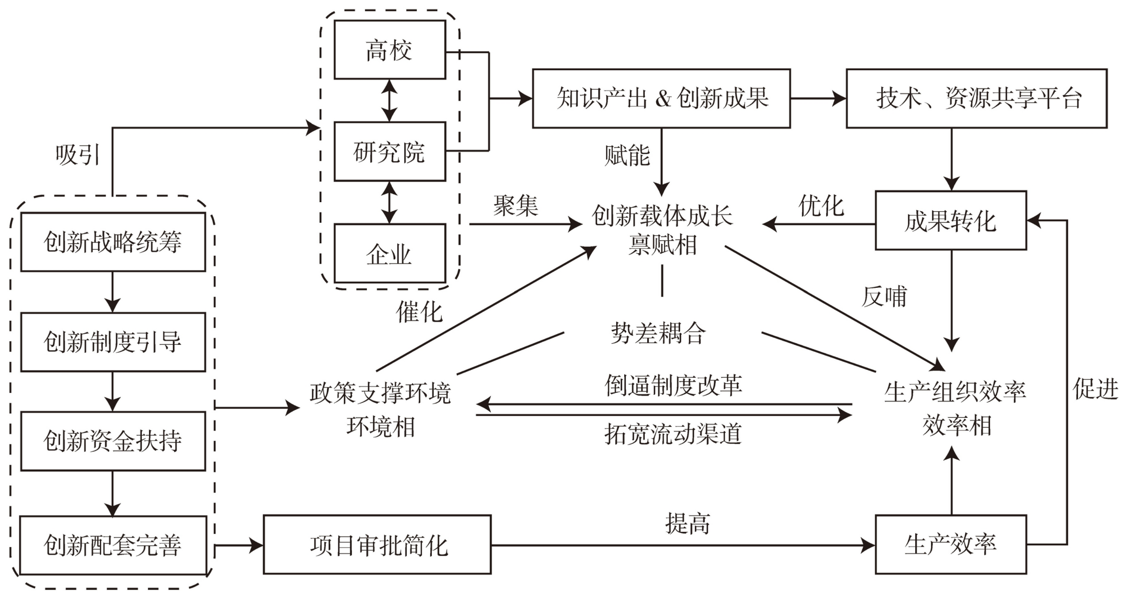

Fig. 2 Diagram of the three-phase structural matching mechanism for innovation synergy

2 Logic and Models of Innovation Synergy in Cross-Boundary Regions from a Potential Difference Perspective

The spatio-temporal differentiation and interaction of innovation potential differences in cross-boundary regions not only create the dynamics of collaborative development, but also produce diverse synergy states. Under the logic of potential difference, they form typical spatial organization models along different collaborative trajectories.

2.1 The operating logic of potential difference in innovation synergy

Different internal areas of a cross-boundary region display differentiated innovation-potential patterns at different development stages. According to the progress of innovation synergy, the coupling process can be roughly divided into three basic stages: a start-up stage driven by a single phase, a growth stage driven by the superposition of two phases, and a peak stage characterized by three-phase resonance. In the start-up stage, the endowment phase acts as the main pull, and potential-difference coupling is explored through gradual accumulation. In the growth stage, either "endowment plus environment" or "endowment plus efficiency" jointly promotes the process, and a benign mutually reinforcing innovation ecosystem begins to form. In the peak stage, three-phase resonance occurs: the cross-boundary region enters a state in which the three phases are highly matched and mutually reinforcing, and the innovation-synergy pattern is fully formed.

When the overall level of innovation development in a cross-boundary region is low and no salient innovation potential difference exists, linkage effects are difficult to form. The region displays a state of "separate governance and disconnected action". When innovation potential differences are large but the overall innovation level remains low, linkage between high- and low-potential areas may emerge, but its visibility is limited. This is a state of "sequential matching and shallow linkage". When the innovation level is high but potential differences are small, the relatively good innovation base among internal areas makes linkage easier to form and produces innovation-linkage effects. This is a state of "partnered growth and mutually reinforcing superposition". When the innovation level is high and internal potential differences are salient, linkage between high- and low-potential areas becomes more frequent, and innovation-linkage effects are more visible. This is a state of "top-end traction and gradient matching" (Fig. 3).

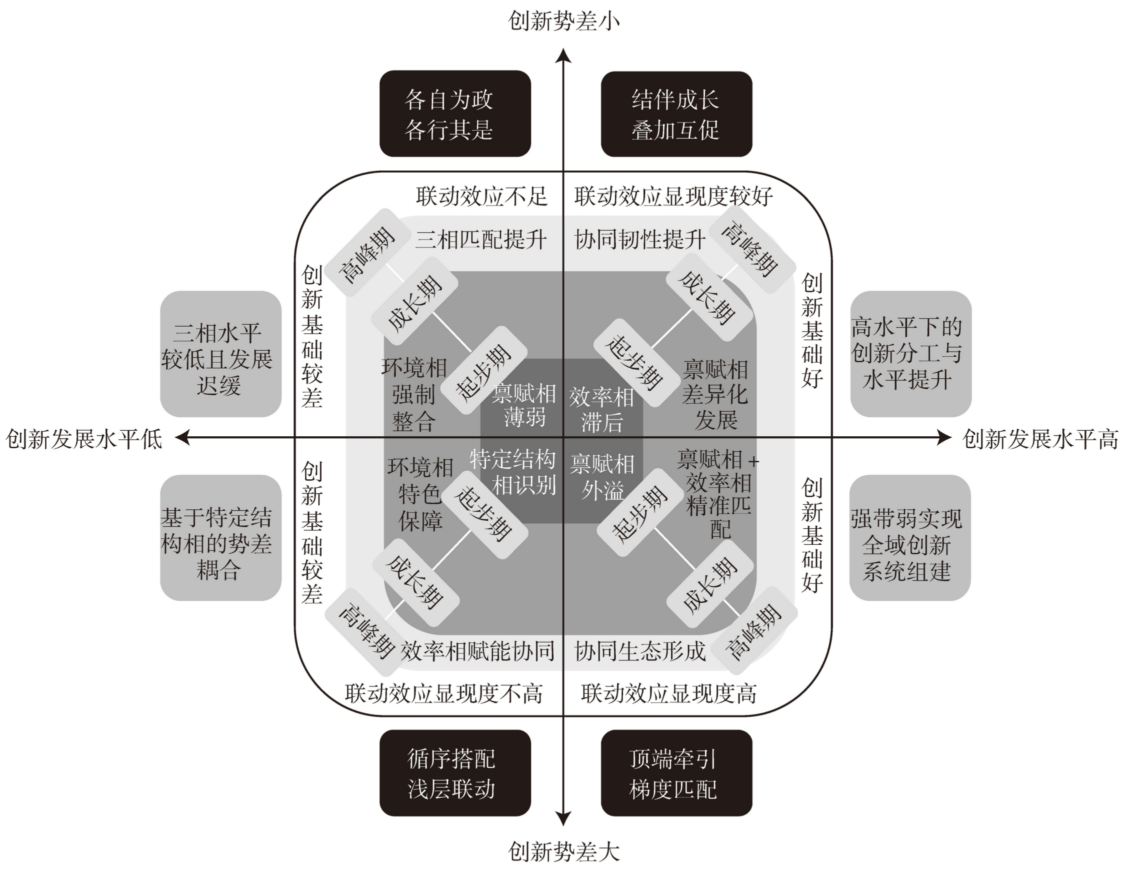

Fig. 3 Four-quadrant diagram of innovation synergy shaped by innovation potential difference

2.2 Spatial organization models of innovation synergy in cross-boundary regions

The operating logic of innovation potential difference reveals two basic trajectories through which cross-boundary regions realize innovation synergy. One trajectory is led by high-potential areas, which dominate the innovation division of labor in the cross-boundary region and form structural-phase matching with multiple low-potential areas. Through factor flows and technological spillovers among high- and low-potential areas, the region enters a state of innovation synergy. The other trajectory depends on each internal area gradually forming its own innovation advantages based on differences among the three structural phases, and then implementing structural-phase matching through jointly built and shared platforms, thereby generating a balanced collaborative state among internal areas.

Corresponding to these two trajectories, cross-boundary regions display two typical spatial organization models in the process of innovation synergy: the multidirectional linkage model and the balanced interaction model. The former has a web-like spatial structure. Low-potential areas surround a high-potential area and construct a multilevel and multidirectional complementary innovation network around specific structural phases. This model is suitable for cross-boundary regions with salient innovation potential differences but high matching in particular structural phases. The latter has a clustered symbiotic structure. It uses geographic proximity to strengthen the cohesion of innovation synergy through material-space reconstruction, social-space integration and institutional-space fusion. This model is suitable for cross-boundary regions where innovation potential differences exist but are not yet prominent and where three-phase differences are clear.

In concrete practice, the multidirectional linkage model and the balanced interaction model within a cross-boundary region are not mutually independent. Because internal areas often have multilateral cross-boundary roles, innovation potential differences among them and the matching of internal structural phases change dynamically. The two models are therefore often nested or appear alternately in the coupling process of innovation potential differences.

3 Empirical Analysis of Innovation Synergy in the Shanghai-Suzhou-Jiaxing Cross-Boundary Region

The Shanghai-Suzhou-Jiaxing cross-boundary region is a frontier case for studying innovation synergy in cross-boundary regions. Its internal areas show evident differences and dynamic characteristics in innovation-development level and in the matching of the three structural phases. This section uses its innovation-synergy practice to verify the logic and models proposed above.

3.1 A development pattern of "salient potential differences and differentiated phases"

This paper selects the number of high-tech enterprises, labor productivity and total investment in the secondary and tertiary industries from 2011 to 2023 as representative indicators of innovation-carrier growth (endowment phase), production-organization efficiency (efficiency phase) and policy-support environment (environment phase), respectively. Incopat patent-grant data are used to represent local innovation-development level, and standardized entropy weighting is used to obtain the relative level of each indicator.

Comparative analysis shows that innovation-development levels vary greatly among the districts and county-level cities in the Shanghai-Suzhou-Jiaxing cross-boundary region, and that the relative levels of the three structural phases differ significantly in most of them (Fig. 4). Overall, the region presents a development pattern of "salient potential differences and differentiated phases". It has a clear need for innovation-potential coupling and the feasibility of three-phase matching, making innovation synergy among districts and county-level cities imperative.

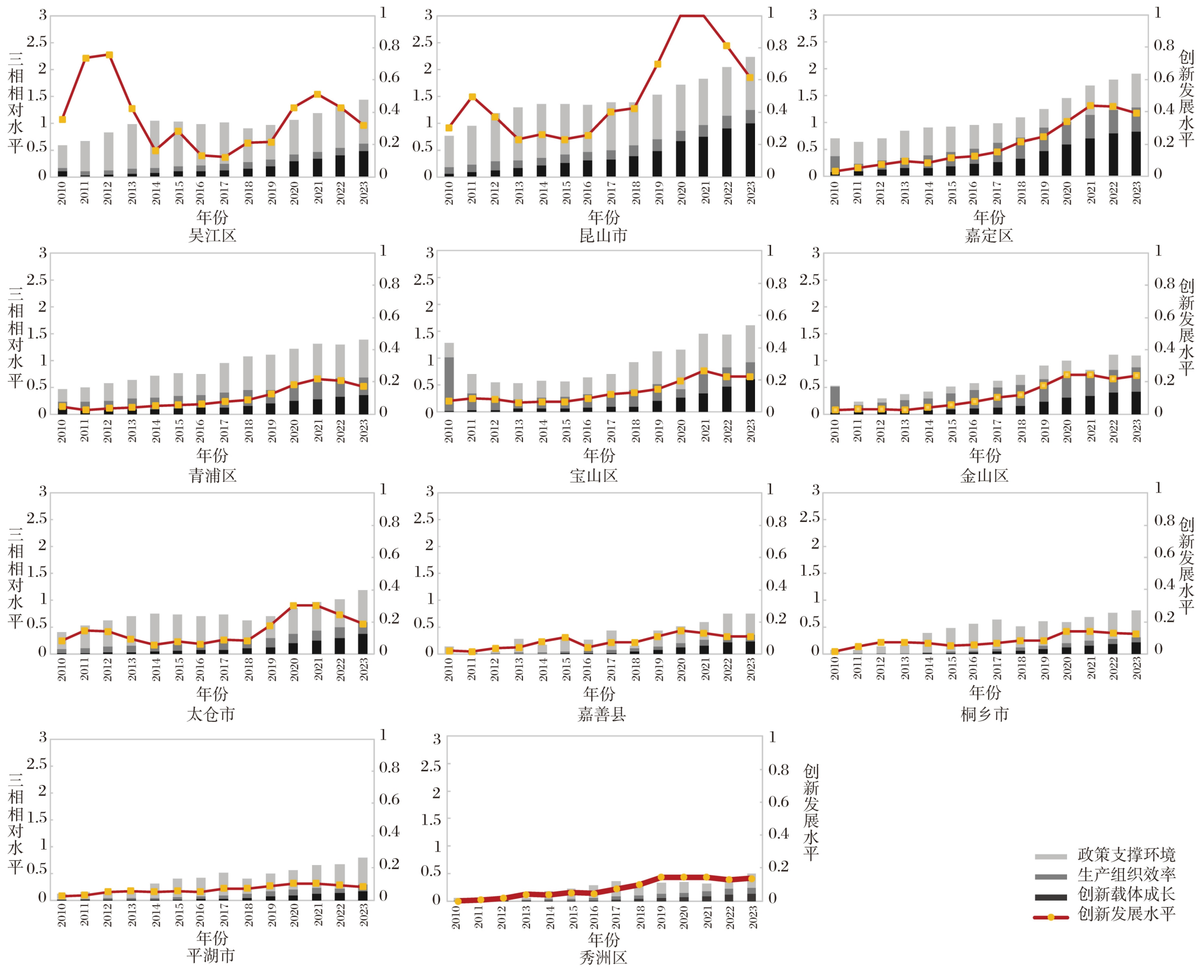

Fig. 4 Innovation development levels and three-phase evolution of counties and county-level cities in the Shanghai-Suzhou-Jiaxing cross-boundary region, 2011-2023

The dynamic changes of the three-phase indicators show that the level of innovation-carrier growth has a significant influence on innovation-development levels within the cross-boundary region. When the three phases differ greatly or are generally low, the innovation-development level is unlikely to be high. In the start-up stage driven by a single phase (`D <= 0.2`), the internal areas of the cross-boundary region are generally led by relatively strong policy-support environments, as seen in Jiashan County, Xiuzhou District, Pinghu City and Tongxiang City. Their production-organization efficiency is relatively low, and their innovation carriers grow slowly. In the growth stage driven by two-phase superposition (`0.2 < D <= 0.4`), innovation-carrier growth becomes the key driver. Through linkage with the policy-support environment or production-organization efficiency, these areas narrow the innovation-development gap with high-potential areas, but they also show instability, as in Taicang City, Qingpu District, Jinshan District and Baoshan District. In the peak stage of three-phase resonance, all indicators are at relatively high levels. When innovation-carrier growth is faster than government innovation input, the innovation-development level rises significantly faster, as in Wujiang District, Kunshan City and Jiading District.

This indicates that higher production-organization efficiency and a good policy-support environment have positive effects on local innovation development inside a cross-boundary region. A good policy-support environment guarantees sustained local innovation development; unstable policies or policies that do not match local innovation needs may create obstacles. High production-organization efficiency alone has a longer effect cycle, and its effectiveness depends on matching with the speed of innovation-carrier growth or with a strong policy-support environment. Moreover, both the efficiency and environment phases are weaker than the endowment phase in independently activating local innovation vitality and improving innovation-development levels. In some cases, they must link with innovation-carrier growth to exert a more significant effect on local innovation development and narrow innovation potential differences among internal areas.

3.2 A synergy condition of "broad connectivity but weak stability"

Incopat patent-cooperation data show that, in the innovation-synergy practice of the Shanghai-Suzhou-Jiaxing cross-boundary region, the multidirectional linkage model and the balanced interaction model coexist. A multidirectional innovation-linkage network led by high-potential areas and proximity-based mutually reinforcing clusters guided by policy have begun to form. Yet in terms of synergy condition, the growth of both networks and clusters is generally characterized by "broad connectivity but weak stability", leaving considerable room for improvement.

During the coupling of potential differences, the Shanghai-Suzhou-Jiaxing cross-boundary region has formed a multicenter radial patent-linkage network with both high density and low intensity (Fig. 5). However, stable linkage loops have not formed, and declines in patent cooperation or shifts from bidirectional to unidirectional linkages occur frequently. Specifically, innovation-development level and innovation-linkage intensity do not show a clear positive correlation. Some areas with high innovation-development levels do not play core roles in the cross-boundary innovation network. The establishment of multidirectional linkages among internal areas depends more on potential-difference coupling based on specific structural phases, such as the post-2020 bidirectional linkages based on the endowment phase represented by Wujiang-Tongxiang, Wujiang-Kunshan and Tongxiang-Pinghu.

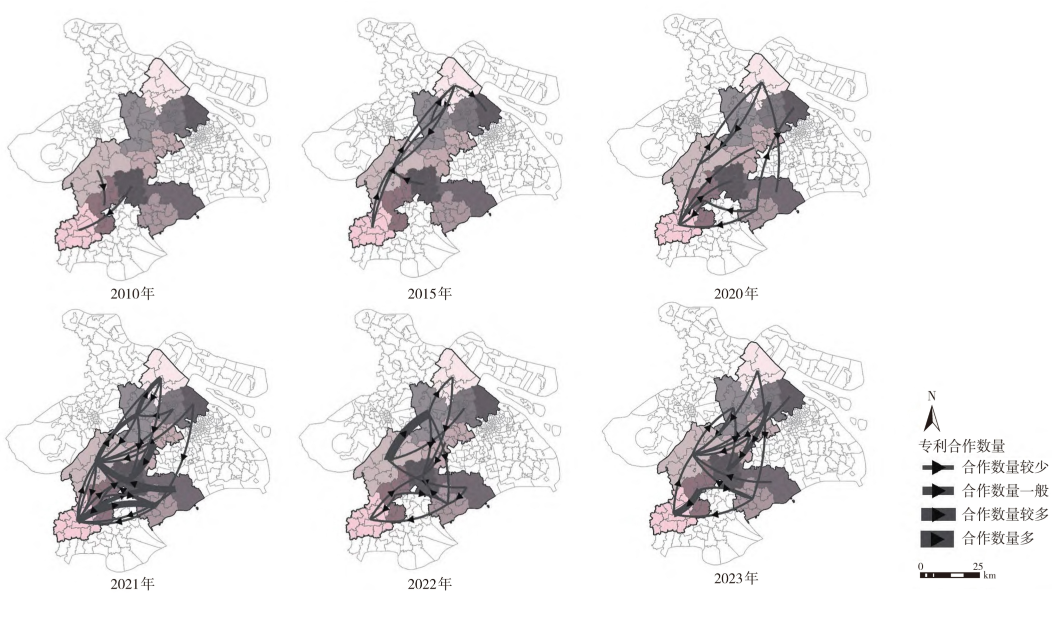

Fig. 5 Evolution of patent cooperation in the Shanghai-Suzhou-Jiaxing cross-boundary region, 2010-2023

Compared with the multidirectional linkage model, the balanced interaction model based on geographic proximity is more common in the Shanghai-Suzhou-Jiaxing cross-boundary region. Examples include the Jiading-Kunshan-Taicang collaborative-innovation core circle and the Yangtze River Delta Ecological and Green Integrated Development Demonstration Zone. The Jiading-Kunshan-Taicang core circle integrates innovation resources through upstream and downstream linkages in the automobile industry chain, forming a basic division of labor in which research and development are located in Jiading while production is concentrated in Kunshan and Taicang. This reflects a leap from high matching between the endowment and efficiency phases to three-phase resonance, and it is a typical multidirectional linkage model. The Yangtze River Delta Ecological and Green Integrated Development Demonstration Zone uses institutional innovation synergy as a breakthrough point, emphasizing ecological integration among collaborative areas rather than cooperation in a single industry. It highlights the role of environment-phase matching and displays the features of the balanced interaction model.

Overall, although the Shanghai-Suzhou-Jiaxing cross-boundary region has initially formed innovation clusters, the depth of innovation synergy remains insufficient and is generally based on endowment-phase potential-difference coupling. The balanced interaction model has been widely practiced, but innovation linkages among relevant districts and county-level cities remain weak. The multidirectional innovation network is not yet mature and is vulnerable to development fluctuations in high-potential areas. This suggests that current innovation synergy is still somewhat superficial.

4 Guidance Strategies for Innovation Synergy in the Shanghai-Suzhou-Jiaxing Cross-Boundary Region

The empirical analysis shows that the resilience of the innovation-cooperation network and the depth of synergy among internal areas in the Shanghai-Suzhou-Jiaxing cross-boundary region remain insufficient, and channels for cross-boundary cooperation still need improvement. Differentiated guidance strategies should therefore be adopted according to the innovation-synergy pattern and stage, and on the basis of the three-phase matching logic from a potential difference perspective.

4.1 An innovation-synergy linkage framework of "proximity-based complementarity plus network linkage"

The innovation-synergy dilemma in the Shanghai-Suzhou-Jiaxing cross-boundary region has two main sources. First, the supporting conditions for the circulation and agglomeration of innovation factors among internal areas are insufficiently linked. This problem extends from innovation carriers to infrastructure networks and is especially prominent in boundary zones, where administrative barriers, geographic marginality and other constraints persist. Second, the internal areas lack sufficient agency in innovation synergy. Areas with low innovation-development levels have not yet achieved breakthroughs in specific structural phases or linkage with multiple structural phases in neighboring areas. Large gaps in innovation-development levels increase the difficulty of potential-difference coupling and intensify innovation polarization. The paper therefore proposes a linkage framework of "proximity-based complementarity plus network linkage".

Implementing a proximity-based complementarity orientation is the key starting point for innovation-synergy practice in cross-boundary regions. First, differentiated innovation-support policies should be established to improve the carrying capacity for innovation factors and the institutional coordination level of low-potential areas. Second, an interactive consensus with neighboring areas should be clarified, and each area's comparative advantages in specific structural phases should be used so that stronger areas lead weaker ones and weaker areas support stronger ones. Third, nearby collaborative clusters should be formed to allocate innovation factors more precisely between high- and low-potential areas and highlight the overall advantages of these clusters.

Building innovation networks is a long-term task for sustainable innovation synergy in cross-boundary regions. First, local characteristics should be taken as the core, and multilevel and multiscale interaction among structural phases should be used to accelerate innovation spillovers from high-potential areas. Second, the constraints of geographic boundaries and institutional barriers should be weakened, while closed loops of connection among actors in material space, cultural-social space and industrial space should be strengthened to form an ecological cross-boundary innovation community. Third, cross-boundary innovation-cooperation mechanisms should be improved, the stability of existing innovation cooperation should be strengthened, and diversified innovation-synergy channels should be established, so as to form a cross-boundary innovation-synergy system with self-regulating capacity.

4.2 A leapfrogging path of innovation synergy from "absence" to "emergence", "optimization" and "refinement"

The Shanghai-Suzhou-Jiaxing cross-boundary region has not yet achieved stable and efficient innovation development. Some areas face slow endowment-phase growth, low maturity of the environment phase and evident shortcomings in the efficiency phase, resulting in insufficient innovation-synergy momentum. Some areas have a relatively strong efficiency phase, but because their endowment phase is weak and their environment phase unstable, they cannot effectively transform efficiency into real innovation capacity. Other areas have a relatively good endowment phase, but lack precisely matched innovation-demand support, resulting in resource waste and low innovation efficiency. Using the districts and county-level cities in the region as examples, this paper proposes a leapfrogging path from "absence" to "emergence", "optimization" and "refinement".

Cross-boundary areas with relatively slow innovation-synergy progress should focus on achieving a breakthrough from absence to emergence by addressing the constraints of specific structural phases. Jiashan County, for example, should rely on the environment-phase advantages of the Ecological and Green Integrated Development Demonstration Zone. By constructing technology-receiving carriers such as innovation enclaves, it can accelerate endowment-phase growth, while actively guiding social capital into innovation-infrastructure construction to avoid uneven resource allocation or low efficiency caused by reliance on a single policy instrument. Xiuzhou District and Pinghu City should focus on the pulling role of the efficiency phase, actively receive innovation spillovers from Shanghai and Hangzhou, accelerate endowment-phase accumulation, and build complete upstream and downstream industrial-chain innovation alliances with neighboring clusters. Tongxiang City, which faces a disadvantage in the efficiency phase, urgently needs to improve the precision of policy input, address the current problem of high innovation input and low return, and use its environment-phase advantage to strengthen the targeted supply and efficient cultivation of the endowment phase.

Cross-boundary areas in the growth stage of innovation synergy should focus on upgrading from emergence to optimization. They should emphasize the simultaneous improvement of the three structural phases and the multidirectional integration of regional innovation networks. Taicang City should strengthen the stability of its innovation-synergy process. Improvements in its innovation-development level should be based on its advantages in high-end equipment manufacturing and automobile components, with stable and precise policy design to drive the development of the efficiency phase. Qingpu District should take resource integration and benefit improvement, as well as the construction and improvement of innovation-carrier groups, as its stage-specific development priorities, promoting the efficient transformation of the environment and efficiency phases. Jinshan District should rely on its relative advantage in the efficiency phase, appropriately increase environment-phase input, guide innovation factors toward high-benefit and high-potential development fields, and strengthen the vitality of the endowment phase and the resilience of overall development. Baoshan District should improve both the quality and quantity of its innovation development, increase the share of R&D input, accelerate endowment-phase growth, and actively integrate into cross-boundary collaborative innovation clusters and networks.

Cross-boundary areas where innovation synergy is advancing efficiently should focus on leading the transition from optimization to refinement. They should comprehensively improve the matching and linkage levels among different structural phases and explore the layout of frontier innovation-growth points. Kunshan City, Jiading District and Wujiang District are currently moving relatively fast in building the Shanghai-Suzhou-Jiaxing cross-boundary innovation community. They can be selected as pilot areas to advance institutional experimentation in innovation, improve innovation-risk prevention and control systems, promote the multidirectional agglomeration and diffusion of innovation, and provide experience and demonstration for region-wide innovation synergy from points to the whole area.

5 Conclusion

Innovation synergy in cross-boundary regions is an inevitable requirement for China's leading integrated regions, including the Yangtze River Delta, Pearl River Delta and Beijing-Tianjin-Hebei, to accelerate the construction of innovation communities and deepen regional collaborative development. It also has considerable potential to become a strategic breakthrough for many cross-city regions seeking new pathways of collaborative development. Related phenomena and problems are already emerging in practice. In response, this paper starts from practical needs and argues, from a potential difference perspective, that the core meaning of innovation synergy in "periphery-periphery" cross-boundary regions is the coupling of innovation potential differences. Behind this coupling lies the matching mechanism among the three structural phases of "endowment-efficiency-environment". The paper develops a four-quadrant framework of innovation synergy under the logic of innovation potential difference and identifies two spatial organization models: multidirectional linkage and balanced interaction. These are necessary components for improving regional innovation-system theory and enhancing the precision of regional collaborative governance.

The empirical verification in the Shanghai-Suzhou-Jiaxing cross-boundary region shows a development pattern of "salient potential differences and differentiated phases" and a synergy condition of "broad connectivity but weak stability". The region contains both multidirectional linkage and balanced interaction models and has good potential for innovation synergy. However, its current synergy condition is not sufficiently stable and the resilience of the collaborative system remains inadequate. Its practice also indicates that innovation synergy based on the matching of specific structural phases is highly feasible, but matching a single structural phase is not enough to rapidly improve innovation-development levels. Good synergy effects require greater accumulation in the endowment phase, together with a strong environment phase and a stable efficiency phase.

For the Shanghai-Suzhou-Jiaxing cross-boundary region, the paper designs a linkage framework of "proximity-based complementarity plus network linkage" and clarifies a leapfrogging path from "absence" to "emergence", "optimization" and "refinement". This provides a systematic basis for action in cross-boundary innovation-synergy development, and offers a reference for governments at different administrative levels in policy design, planning guidance and collaborative governance of cross-boundary regions.

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