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Spatial-Topological Analysis of China's Cooperative Innovation Networks in Agri-Biotech Development

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Abstract

This paper evaluates how the network of collaboration innovation in the field of agricultural biotechnology in China evolves and how it is organized by examining it in spatial-topological terms. Combing both social network theory and spatial analysis, the study reveals the nature of the relationship between geographic distribution and institutional relations and their influence on determining the patterns of innovation in various regions. Important observations show that there is a clustering of core locations of innovation in economically developed provinces with peripheral regions assuming subordinate roles in knowledge diffusion. Such network has a hierarchical and clustered feature, which means uneven regional participation and level of collaboration. This geographically situated clustering of innovation network presents vital information on how the policy versus the institutional connection of the regional developments affect the technological progress in agri-biotech technology in China.

Keywords: ***Collaborative Innovation, Agricultural Biotechnology, Spatial-Topological Analysis, Innovation Network, China, Knowledge Diffusion, Regional Development, Social Network Analysis, Technological Advancement, Institutional Collaboration.***

1.Introduction

Innovation has increasingly moved away, in the context of globalization and growing centrality of knowledge economy, in its forms that are linear and hierarchical to a more network-based paradigm. Such changing frameworks through collusive frameworks have surfaced as effective drivers of technological innovation and socio-economic change. This has become the most apparent in the Chinese agricultural industry of biotechnology where there has been an increasing cooperation between institutions as there is a growing cross-institutional cooperation between universities, research centers and privately owned companies as a core catalyst of technological advancements. In the last three decades, China has been strategic in creating an unfriendly environment that facilitates such type of cooperative innovation. Government programs, public-private ventures and control systems have increasingly been supporting this conflux of spatial and organizational powers as a way forward towards driving agricultural biotech(1).

This article offers a new angle through which this transformation in China can be analysed through a two-dimensional approach; a spatial and a topological analysis of collaborative innovation networks of China in agricultural biotechnology. This study differs with previous research in its analysis, where economic geography literature and node-based measures were quite segregated in analysis; whereas, this research integrates the views on both perspectives to provide a complex interpretation of the positioning and interconnectivity of innovation actors across space and institutional forms. Given a rich dataset of co-applied patents within 1985-2017, the study uses rich social network analysis (SNA) methodology and geographic information systems (GIS) to plot knowledge and collaboration topology and spatial flow. In that way, it locates the main trends, structural changes, and the appearance of powers in the ecosystem, and also manifests how the proximity impact, whether geographical, cognitive, or organizational, has changed regarding the patterns of innovation cooperation.

The groundbreaking aspect of the study is the division of evolution of collaborative networks into three important points in time, the introduction stage (19852007), the growth stage (20082015), and the maturity stage (20162017). The kind, extent and amplitude of innovation relationships changed considerably in every of these stages. To begin with, universities were the most important nodes in patent creation and cooperation. With the growing capacity to innovate in China, firms slowly became more dominant, a trend pointing to the transition between basic research to application-oriented industrialized innovation. Spatially, the network, which had a very fragmented structure that focused in some coastal and metropolitan areas to start with, increasingly absorbed larger regional networks to become an innovation belt around important economic regions such as the Beijing-Tianjin-Hebei axis, the Yangtze River Delta and the Pearl River Delta.

Importantly, the research discovery determines the evolving character of closeness in the context of collaborative networks. In the initial stage, geographic proximity or in other words ease of accessing has been the key determinant of partnerships. In the course of time, this changed to cognitive and organizational proximity, which implies that the knowledge bases, institutional affiliation, and strategic compatibility became more important in brokering fruitful relationships. The transition demonstrates the growing up of the Chinese agri-biotech sector into a distinct, territory-based innovation and into a more composed, network-based and intellectually integrated ecosystem.

The fundamental technique added to the research is its analytical granularity. Contained in the dataset is more than 13,000 co-filed patents where multiple applicants are identified and the dataset is carefully screened when it comes to identifying patents initiated in mainland China. Collaborations are studied on the topological level of individuals or institutions involved (topological network) as well as on the spatial one of their geographic location (spatial network). Measurements of the strength and pattern of these collaborations are measured by social network measures (degree centrality, weighted edge strength, clustering coefficients, and network density). The spatial studies are augmented by an inter-city and inter-provincial collaboration distance that show us how far actors are prepared to extend their partnerships with time.

The study provides the interesting evidence on the issues of concentration and dispersion of innovation capacity. Although the distribution of super connectors or innovation hubs around major cities: Beijing, Shanghai, Shenzhen, and Guangzhou has been on the increase, the general trend is in the spread of collaborations through provinces into the emerging economic regions. Besides, the intensity of interaction has more of a core-periphery nature, with a small number of very connected nodes (the core), and a larger number of actors that are comparatively weakly affiliated (periphery)(2). This structure common in resilient innovation systems is one that shows an increasing degree of functional specialization and stratification within the network.

The institutional level also experiences a flip-flop between the academia and the industry. The former bastions of innovation of universities have been losing their relative strategic centrality to enterprises which may have greater resources in the downstream application and commercialization. The universities nonetheless continue to be important in developing the broad, low-fidelity alliances, implying that they continue to take a crucial role in basic research and exploratory innovation. Conversely, high-frequency, high-value partnerships prevail among enterprises, especially in the weighted networks where the existence of links are not only measured but also the strength of the partnering.

The second trend is that organizational proximity is gaining importance especially between parent-subsidiary firms or institutions that belong in the same group of industries. Such partnerships are more intense, more regular, and more effective, indicating that both institutional fit and coherence in strategic thinking have since surpassed geographic proxinity as a propeller of the partnerships. Such shift is consistent with the world trends to the adaptation of innovation capabilities in which digital infrastructure, strategic planning rather than physical co-location, is the primary driver in the flow of innovations.

Summing up, the integrated spatial-topological method applied in this paper provides a more comprehensive picture of the changing innovation system in Chinese agricultural biotechnology industry. It allows seeing the interaction of policy incentives and institutional maturity and technological advancement and their correlation with the creation of collaboration networks. The results also have tremendous implication on national innovation strategies and significantly in the allocation of resources, regional development planning and enterprise-led innovation supported by institutions. The research draws a roadmap that will be beneficial to stakeholders to make improvements of the effectiveness and the inclusiveness of agri-biotech innovation landscape in China by plotting the topology and geography changes in collaborative innovation.

2.Spatial Dynamics of Collaborative Innovation in Agri-Biotech

2.1 Urban Spread of Inventors

During the last 30 years, the agricultural biotechnology innovation network in China has seen a tremendous spatial evolution, which was characterized by the intense growth in the geographic spread of the members of this innovation system. The state of the first era (19852007) corresponded to the fact that innovators engaged in co-patenting practice were consolidated in 153 cities, which were embodied by 1,308 actors. Since the innovation system had reached the growth stage (20082015), this network continued growing not only in numbers but also in terms of range by embracing 4,154 innovators who were located in 256 cities. The trend has persisted even in the brief period of maturation (20162017), as 3,005 collaborative actors have offered their services in 238 cities. This is a consistent and deliberate geographical spread of the centres of innovation across the nation that is created with the help of favourable national innovation policy, growing investment in R&D, rise in infrastructure and connection.

Although there is this spatial dispersal, cities have uneven relative importance. A number of the urban centers have become well interconnected nodes of innovation sometimes referred to as the star cities. There was unanimous emergence of various cities like Beijing, Shanghai, Shenzhen, and Guangzhou as the main players with much higher scores in centrality. Not only these urban areas were associated with increased collaboration, but they also acted as virtual centers of gravity, attracting peripheral actors to their orbit. An example is the city of Beijing whose absolute degree centrality increased during the introduction stage by 0.04 as compared to 0.045 during the early maturity stage. It means the growing size of partnerships as well as their greater attractiveness and concentration of innovation activities in the capital. This has led to the formation of three innovation clusters that dominate the biotech activities in China namely the Beijing-Tianjin-Hebei cluster in the northern region, the Yangtse River delta cluster in the eastern part and the Pearl River delta cluster in the south(3).

2.2 Urban Collaborations and Scale Distance

One different notable change that has occurred in the agri-biotech collaboration in China has been the dimension of urban partnership relationship, both on level and real proximity. At first, there was very strong localization in terms of co-patenting activity, which mainly occurs across the same city or province. But this situation changed significantly as the time went by, displaying quite substantial shift toward the replacement of the regional level (collaborations between the cities of the same province) with the inter-provincial collaborations, which extended the provincial borders. In particular, in the early period (19852007), the proportion of cross-city partnerships between the same province was more than 50 percent. By the maturity stage (20162017), this proportion went down to under 40 per cent, and the proportion of inter- provincial partnerships had risen to almost 50 per cent, as a change towards long-range strategic alliances became apparent.

The trend is also supported by the positive increased mean of spatial distances between collaborators. With the application of GIS-related spatial analytical methodologies, the research establishes that the collaboration distance average has steadily grown over the years, and the abovementioned phenomena can be explained by the development of better transportation infrastructure, high-speed rail networks, as well as digital communication media. It is the ease of movement and telepresence that has greatly reduced the cost of collaboration over long distances to the point that innovation players now operate above provincial boundaries and can collaborate on strategic basis instead of geographically close areas.

2.3 Area biases and cluster effects

Although the national policy was to support the creation of a balanced development of innovation, the reality of the placement of the agri-biotech collaboration indicates an increase in unequitable distribution along regional lines. The country of China has the east coast provinces that take the ascendancy in terms of space provisions of innovation in regard to number and quality of ties. The core cities described above, which include Beijing, Shanghai, Guangzhou and Shenzhen and the adjacent cities: Suzhou, Hangzhou and nanjing, serve to be the backbone of regional innovation systems. Such regions have sophisticated research facilities, connections to high-quality universities and research establishments, and good industry-academy collaborations.

Due to this, there has developed three regional innovation clusters:

- Beijing-Tianjin-Hebei Cluster: It is an academically and government-based R&D resource cluster anchored by Beijing.
- Yangtze River Delta Cluster: Comprising of Shanghai, Hangzhou, Nanjing and Suzhou, it is a strong combination of industrial capacity and academic superiority.
- Pearl River Delta Cluster: The Chinese lead this cluster with Shenzhen and Guangzhou fronting it and it is enterprise-based and very active in commercialization of biotech.

The cohesiveness of the network of biotech innovation based on collaboration between the clusters has improved with the passage of time, and additionally, the inter-clusters interactions have been experiencing reinforcing, which implies growing cohesiveness at the national level. Nevertheless, western and central provinces are still performing poorly in both participation density and network centrality indicating that there is possibly a continuous gap in innovation(4).

2.4 The Most effective Cities-to-Cities Collaborative Relationships

A breakdown of the strongest inter-city innovation cooperation has demonstrated significant dynamics of the innovation cooperation structure. Due to the local aspects of the speed, strong ties could be established in the early phase between actors who are geographically close to each other, including Beijing Qinzhou and Shanghai Suzhou, signifying that the local synergies and convenience of transportation are important. With the maturation of the network, spurling new strong connections were forged between far-flung centers of innovation power. There is a good one such as Beijing-Hangzhou, Beijing-Shenzhen, and Guangzhou-Shenzhen, indicating that it is moving towards strategic and high-value partnership regardless of the geographical distance.

The definition of these relations is no more based on physical proximity, but on the strength of institutions, the intensity of innovations, and the complementary capabilities. It is important to note that most of the greatest linkages are made through one of the key hubs of innovations and thereby, highlights them as key integrators in the national network. Strong and dense relationships among these cities indicate that the hierarchical structure of innovation architecture has become very linear with the smaller number of central cities determining a substantial part of national interactions in innovation.

2.5 Pictorialization and Macro Trends of Spatial Dynamics

Spatial pattern of the network can be further brought out through visual illustrations of the network which bring out a number of important patterns. To begin, the collaboration emanates inwardly within the eastern cities and spreads westwards and to the centre of the nation which implies a progressive spread of innovational activity throughout the country. Second, network snapshots demonstrate the strengthening of collaborations both inside and outside of clusters and create a dense network of innovation flows within and between the Chinese clusters, mostly located in the eastern belt. Third, the visual power of some cities, which is characterized by the high thickness and size of collaborative edges, highlights the core-periphery system that lies in the basis of the Chinese innovation ecosystem(5).

These macro trends point to a paradox, namely, the fact that as the collaborative network gets broader lock geographically, collaboration power and influence is highly concentrated in just a number of strong influence regions. This ambivalence highlights the effectiveness of the policies of innovation cluster in China as well as the problems of having balanced innovation development among regions.

3.Topological Evolution of China’s Agricultural Biotechnology Collaboration Network

Along with its space fashion, the process of collaborative innovation of China in agricultural biotechnology can be professional analyzed topologically. In contrast to spatial tasks where activities are ordered by geographical proximity and distribution, topological network analysis stresses the structural connections between actors- based on their positions, not necessarily their geographical position. Within such a network, individual nodes are innovators (e.g. universities, research institute, or enterprises), and individual edges represent collaborative links (e.g. a co-applied patent). In the last 30 years, the internal structure of China agri-biotech networks has continuously altered. These are actor dominance changes, intensity of connectivity, and basic topology of innovation web. These transformations are very important to understand when it comes to understanding how the innovation necessary resources are distributed among them as well as how experimentation of influence shifts, and how the system becomes resilient or vulnerable.

3.1 Transforming Leadership: Higher Education to Business

During the initial phase in the development of agricultural biotechnology in China, the most important role was provided by universities and research centers as the driving engines of collaborative innovation. They were knowledge creation institutions and the major nodes of connection, usually financed publicly. During 1985 to 2007, they have always been the dominant node (by degree centrality) on the network, such that degree centrality measures how many direct relationships a node has. As an example, Tsinghua University, Fudan University, and Jiangnan University took leading places and had extensive networks of partners. The network simplified into a binary (yes/no) version of number of collaborations clearly showed the involvement of academic institutions as the highest ones and the birds-of-the-system approach to collaborations, but low in frequency(6).

Nevertheless, as the innovation ecosystem matured especially at the growth stage (20082015) and the early maturity stage (20162017), the power transition has significantly taken place. The development of enterprises started to appear not only as fellow actors but also as key nodes of the network. Greater visibility to this transition in the weighted form of topological network, where the focus is no longer on the counts of collaborators but on intensity of such collaborations (i.e. number of times two particular innovators collaborate). The firms like the COFCO or Beijing Dabeinong Group or BGI became prominent, and they have developed numerous, repeated, strong connections especially between intra-associated or strategic partners.

This is the transition of a wider perspective in the system. As universities remain central in the basic research and initial brokering of various collaborations, enterprises are on the forefront of the innovation in applications, commercialisation, and industrial scaling. Their greater resource endowment and greater fitness to the market demand enables them to maintain more and intense levels of collaboration. Academia-to-enterprise shift in innovation networks is a significant step towards the industrialization of biotechnology in China.

3.2 Edge Dynamics: Conspiracies and Their Powers

Other than the actors per se, the boundaries/interfaces in the network have also become more differentiated and complex. First, the collaborative relations were relatively homogeneous with regard to structure and strength. They were mostly established between universities and local partners and were mostly in one-time or infrequent relations. The nature of all such connections however over time have diversified greatly.

Between 1985 and 2007 universities or research institutes were linked to more than half of all collaborations. Yet, by 2016 2017, the figure had fallen to 35 per cent(7). The enterprise-driven collaborations, in contrast, increased by a hefty margin to 76%, which demonstrates a significant talent flip-flop of innovation leadership and resource channels. More dramatic still is the upsurgence of intra-enterprise alliances i.e. partnerships that happen to be between subsidiaries or sister firms under the same umbrella of corporation. As an illustration, repeated, high-linked relations were characterized by COFCO and COFCO NHRI, or Beijing Dabeinong group and its biotech subsidiaries. The relationships were not project and opportunistic anymore but have became strategically entrenched in corporate innovation approaches.

In addition, it is revealed through analysis that proximal drivers of collaboration also shifted. In the initial stages, physical location played a big role in determining relationships. Universities also routinely partnered with local companies and this was either within the city or within the province. However, in the later stages, organizational closeness (common ownership, institutional affiliation or strategic fit) came out as the overriding power. Cognitive proximity in terms of shared areas of expertise and knowledge also helped build long-lasting relationships between actors including Sinochem and SYRICI because of similar interests in bio pesticides. Such a development represents a coming-of-age of the logic of collaborating: proximity-led and adventurous to premeditated, strategic, and capability-centered.

3.3 Changes in the Entire Network Structure

The structure of the topological network in general was also subjected to major changes. To begin with, scale was significantly expanded on the networks. During the maturity stage, the quantity of innovators and the aggregation of the collaborations had increased more than twice between the introduction stage. There was an increase in the average degree (average number of connections per node) in both binarized and weighted networks but also a stronger sense of integration between innovators since it is not a very narrow participation.

Secondly, the network was indicated by an increased level of decentralization. Though not completely disappeared, it showed a decrease in the overall index of centralization with time. This implies that power and the opportunities of influence are not confined to a few elite institutions any more. Rather, activity has fragmented into several centers, and the structure of innovation is more decentralized and robust. This decentralization improves the ability to change and to absorb new knowledge and remain innovative in the long run(8).

Third, small-world and scale-free properties became evident in the network and showed classic characteristics of complex systems. Short path lengths and high clustering coefficients are those characteristics of the small-world networks, which allow efficient knowledge transfer within a large network. Mean path lengths in this study do not exceed 10 and clustering coefficients are highly adjusted above 0.01 indicating a stable small-world architecture. This setup is particularly useful in the biotechnology world where transmission of the ideas and feedback are paramount to a success.

Similarly, the network was scale free distribution so that a small number of connections are highly connected and many less connected. This disproportionate design increases resilience and enables an efficient differentiation and diffusion of resources, however, it also generates instability as long as hubs are eliminated or derailed. Therefore, as the network has grown and become complex, it has become stronger, but a dependency on few major players might demand some policy protection measures to maintain stability in the entire system(9).

3.4 Topological Visualization and Core-Periphery Set up

The visualization of the network shows additional information into its development. Historically the innovation land space transformed into core-periphery form. At the centre, there are huge universities and powerful businesses that have a wide range of peripheral innovators with indirect connections. The center is more dense and complicated, whereas in the periphery, there are actors with minor reach-out or influence. Notably, both binary and weighted graphs all verify that albeit universities continue to exert control at the broader level, enterprises have taken over the depth and richness of ties.

This organization indicates that the capacity to innovate is not equally spread but it is stratified according to the hierarchical access to resources, absorptive capabilities and institutional development.

Maturation summary: Maturation of innovation Network Topology

The history of the development of agricultural biotechnology innovation network in China brings to light a radical change in its inner structure. The innovation system that started its implementation out of the paradigm of a university-based, spatially constrained system has evolved into a structurally diverse, enterprise-driven, and globally dispersed innovation web. All these trends, such as the growing numbers of enterprises, the diversification of forms of collaboration, the appearance of the small-world and scale-free properties, etc., speak of the maturing community of innovation(10). Notably, these transformations are indicative not only of organic growth, but also of the conscious actions of policymakers and their reforms of the larger institutional environment, along with technology convergence. Since China has declared agri-biotech a strategic industry, then a better comprehension and improvement of its network topologies in innovation will play crucial roles in ensuring the continuity of levels of growth, strength, and competitiveness amid others.

4.Conclusion

The development of Chinese agricultural biotechnology industry poses an interesting question of the national innovation system that is changing due to the concerted effects of policy, institutional realignments, and changes in technology. This research has enabled us to describe the trend of network of collaborative innovation with a time perspective of more than 30 years (1985-2017) regarding the spatial topological behavior by means of its spatial factors and structural configurations.

Fundamentally, the analysis shows that collaborative innovation network in agricultural biotechnology has experienced a definite three-state evolutionary process, move on to the introduction phase (19852007) where an initial stage of capacity-building is the key characteristic, growth (20082015) where speed of expansion and heightened linkages were observed, and maturity (20162017) where greater institutionalized partnerships and management leadership came to be a common feature. The change is not only chronological, but also structural, and announces a jump in the quality of interaction between innovation actors and their organization in the national system.

In spatial terms, the research reflects the clearly discernible trend of widening of the geographic footprint of innovation activities. Initial endeavors were focussed on few metropolitan centres, viz.: Beijing, Shanghai, Shenzhen and Guangzhou, and they were innovative epicenters. Gradually however, the network did spread out into secondary cities and inland provinces. This expansion is in deliberate policy planning (e.g. regional innovation cluster policies, tax break and biotech-specific R&D investment) but there is the natural spreading of talent and capital as well. Although broader in nature, the study reveals a regional imbalance that remains consistent where regions in the east coast still lead in terms of frequency of collaboration, network centrality, and innovation production. This begs critical questions to the policymakers who wish to enhance a better distributed innovation across the country.

In a topological perspective, the internal structure of the network has changed into being a hierarchical constructed network as opposed to the academic-driven almost-flat structure in the past. The first key role was that universities and research institutes served as loci in order to support inter-regional and inter-sectoral knowledge flows. They were pioneering in nature: creating new knowledge, catalyzing a variety of partnerships, and spreading the word about new breakthroughs in biotechnology. But with commercialization and downstream applications emerging in prominence, enterprises evolved to take the role of chief innovation agents. This is confirmed in the weighted network as the business entities develop a stronger relationship not only in the form of partnership but also yielding intra-organizational relationships that enhance the network of strategic innovation channels.

In addition, the very form of cooperation has changed. The initial focus on the geographic proximity of choice-making partners where one collaborates with the most convenient local institutions because of the ease of interaction has also been slowly replaced by more rational points of keeping. Organizational proximity has become more important particularly with vertically integrated relationships of parent firms and its subsidiary companies or industry groups. Cognitive Closeness is also a factor that has been identified to result in long term beneficial relationships and partnerships, founded on knowledge base similarities and technology areas. Such a shift demonstrates one of the important results of the study; it is that proximity in collaborative innovation is becoming more and more relational and strategic, as opposed to being solely spatial.

Of importance is the fact that the network has become a complicated system that is characterized by small-world and scale-free properties. The small-world property including the shortness of the paths and high clustering leads to the effective flow of information and the diffusion of knowledge. In the meantime, scale-free architecture presupposes that there are not a lot of well-connected nodes with disproportionately significant role in ensuring the coherence of the network. There are features which make the innovation capacity and resilience more effective in general, but at the same time indicate some form of systemic fragility is present such that disturbances in central hubs may undermine the strength of the network. Therefore, supporting the existence of redundancy, the actors at the periphery, and the emergence of new hubs are key to the long-term sustainability.

Among the most valuable lessons of this study is the fact that core-periphery architecture cropped in both spatial as well as the topological networks. The accumulation of thick and high quality relations is concentrated in central cities and institutions and not in the periphery. This results naturally because of the effects of preferential attachment and scale driven forces but is a problem to inclusive innovation. Unrestrained, resource levying, technological competencies, and market access across disparity in regions and institutions types may increase disparity between regions and institutions. The new social policy of innovation therefore needs to walk on both extremes, by consolidating excellence at the centre and fostering connectivity at the periphery.

Methodologically, this paper also offers an improvement in the research since they incorporate the spatial level of analysis (due to GIS tools) and social networks analysis (thanks to SNA and Ucinet) as well as disaggregating the network into nodes, edges, and their macro-level measures. In doing so it serves up a more detailed, dimensionalized picture of innovation collaboration beyond the mere patent-counting or local clustering concept. Moreover, the typology of collaboration forms and determination of driving diameters provide a detailed basis of study of analogy in other areas or nations of innovation ecosystems.

These results are very broad. The findings indicate that to policy makers, they should ensure that efforts to invest in R&D as well as institutional connections should be maintained in the interest of the populace, and this should be particularly in the underserved localities. Inter-provincial solidification programs may foster collaboration via R&D and innovative public funds to aid and encourage intermediation activities of enterprises and provision of incentives to enterprises through a business-academia composite award may expand the networks linking and diffusing innovation. To the enterprises, the results remind them of the importance of forging strategic partnerships between institutions, especially the linking up of knowledge producers, such as universities and think tanks. To academia, the diminishing relative centrality implies a demand of reclaiming of leadership in terms of translational research, tech transfer offices, and innovation consortium.

There are however a number of limitations to this study. The method is unique in that it investigates co-patent data which, even when highly effective, is unlikely to cover all informal collaborations, informal dissemination of tacit knowledge or non-patent innovation. Moving further, the existing network description may be seen as the picture of moving processes, and in the future, longitudinal modeling, agent-based simulation, or predictive analysis could be added to predict the way in which the network might develop given different policy or market conditions.

To sum up, the behavior of the collaborative innovation network in agricultural biotechnology in China indicates the approach to transitioning decentralization to organized complexity that may be deemed as strategically motivated. The emergence of a university-led, regionally clustered system has developed into a nationally sized, enterprise-focused and structurally complex system. Through explicating the spatial and topological subtexts of this transformation, this research symploys not just to provide an insight into the genesis and the pre-history of the biotech innovation in China but also provides a strategic plan of creating more inclusive, resilient as well as high performance innovation networks in the future, an issue of relevance to the other parts of the world as well.

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Conflicts of interest

The authors have no conflicts of interest to declare

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