The Fostering Policies of the World-Class Advanced Manufacturing Industrial Innovation Ecosystem Based on Knowledge Advantage Perspective

Yifan Zhang and Changyi Zhao*

***Abstract*—"Made in China 2025" clearly put forward the strategic goal of becoming a powerful manufacturing country, including the prospect of advanced manufacturing industry. Government policy support has played an increasingly important role in the fostering of advanced manufacturing clusters. Based on the two-dimensional analysis framework construction combined with the X-axis of policy tools and the Y-axis of knowledge advantage, we studied the fostering policies of the world-class advanced manufacturing industrial innovation ecosystem, especially focusing on the dynamic development process of knowledge production, and knowledge transformation, and knowledge application. Additionally, we also analyzed the trends in risk and knowledge advantage during the life cycle of the world-class advanced manufacturing industrial innovation ecosystems. We provide a fostering policy framework and believe that this study could provide references for the cultivation of a world-class advanced manufacturing industrial innovation ecosystem in China.**

***Index Terms*—Fostering policies, innovative ecosystem, world-class advanced manufacturing industry, knowledge advantage**

I. Introduction

In May 2015, the Chinese government released "Made in China 2025", proposing that China would highlight innovation-driven, rely on and develop high-end equipment manufacturing through special policies and institutional advantage, to achieve a great leap from a large manufacturing country to a world manufacturing power. An important symbol of this great leap is to create several world-class advanced manufacturing clusters [1].

Fostering a world-class advanced manufacturing industrial innovation ecosystem is a must for China to become a manufacturing power. Therefore, what policy tools are adopted by the government to successfully foster a world-class advanced manufacturing industrial innovation ecosystem becomes an important research issue. As knowledge advantage can provide a sustainable impetus for the development of the industrial innovation ecosystem, making it difficult for competitors to crack, imitate, and catch up [2], we chose it as a new perspective to explore and study the policies of fostering world-class advanced manufacturing industrial innovation ecosystem. In this way, we can help the achievement of fostering a world-class advanced manufacturing industrial innovation ecosystem in China.

Manuscript received April 11, 2022; revised May 15, 2022; accepted June 27, 2022.

Yifan Zhang and Changyi Zhao are with the Business School, Sichuan University, Chengdu, China.

*Correspondence: zhaochangyi@scu.edu.cn

II. Literature Review

There are few studies on the fostering policies of the world-class advanced manufacturing innovation ecosystem, and the analogy is drawn here from the relevant fostering policy studies of industrial clusters and innovation ecosystems. The policy tools approach has emerged since the late 1980s, focusing on examining the public policy provision in specific government actions [3]. Innovation ecosystems benefited from regional public policies which promoted innovation collaboration [4].

Zhang (2006) [5] concluded that the formation of industrial clusters was divided into three categories: spontaneous formation, "bottom-up" and "top-down". "Top-down" meant that the government made a clear strategic plan for the development of industrial clusters. In this formation mode, the government was undoubtedly the cultivator, organizer, and implementer of the industry clusters. Feng (2019) [6] argued that the role of government in the growth of advanced manufacturing clusters was mainly in three aspects: firstly, it was the facilitator of cluster network, promoting the network of cluster enterprises, and creating a mutually beneficial and symbiotic cluster network structure; Secondly, it was the catalyst of dynamic comparative advantage, supporting potential comparative advantage industries, core enterprises, and so on; Thirdly, it was the builder of public institutions, providing public products, supporting generic technology R&D, and promoting industrial alliances. Although most of the formation and development of traditional manufacturing clusters in developed were based on the spontaneous evolution of the market, the formation and development of new-emerging advanced manufacturing clusters are increasingly labeled with government policy support [7].

According to the life cycle of clusters, the government plays a major role in the early stages of cluster formation by creating a legal and policy environment conducive to the growth of clusters, acting as a "facilitator" [8]; it also plays a leading role by formulating cluster plans or strategies, facilitating the formation, building cluster organizations, and providing financial support channels for the networking of economies [9]. Watanabe C and Fukuda K (2006) [10] also mentioned the importance of the cycle, thinking technology policy should strive to promote innovation to build a synergistic evolution between the innovation development cycle and the progress of institutional systems.

At present, foreign cluster fostering policies are more mature, therefore, many scholars have studied and analyzed the fostering policies of developed countries such as the

doi: 10.18178/ijimt.2023.14.1.934

United States and Japan. Liu and Yao (2011) [11] found that the U.S. adopted a market-oriented co-cultivation model, focusing on the development and application of strategic technologies and multiparty cooperation in high-tech industries. Japanese government intervened in cluster formation through industrial policies and played a great role in macroeconomic policies, forming a government-led model of strategic emerging industries. Li and Cao *et al*. (2008) [12] analyzed the EU's industrial cluster policies and concluded that they mainly focused on policies to create the environment for cluster establishment, including the provision of the institutional framework, scientific planning, and infrastructure; policies that provided "conditions for cluster development", included support for cooperation and promotion of communications; policies which were used to develop and improve clusters and overcome system failures, included regulating change, establishing venture capital funds, government procurement, and other initiatives. Government funding policies are essential to support cluster incubation policies in each country. Funding is the "blood" of world-class clusters to implement cluster policies and run the clusters themselves, and it is the guarantee for the vitality of cluster organizations [13]. Engel and Eckl *et al*. (2017) [14] found that public R&D funding induced more knowledge flows.

Additionally, the implementation of the government's incubation policy should be characterized by medium- to long-term and phased implementation [15]. For example, the Japanese government attached great importance to the continuity and evolution of cluster policies and had implemented three cluster development strategies, such as the Industrial Cluster Plan, the Knowledge Cluster Plan, and the City District Plan, to continuously improve cluster policies and solve the problems faced in cluster development [16].

III. Fostering Policy Framework

A. Based on Policy Portfolio Concept

Rogge and Reichardt (2016) [17] extended the policy portfolio concept, arguing that it emphasized that a policy portfolio was not just a combination of interacted instruments-instrument combinations, but also included policy strategies, policy processes, and characteristics. They found that a certain degree of policy mix consistency was central to firms' innovation activities [18]. We drew on Rothwell and Zegveld's research methodology [19] to consider the three types of policy instruments involved in the basic policy instruments: supply-side, demand-side, and environment-side, using them as the X dimensions of the policy framework for fostering world-class advanced manufacturing industrial innovation ecosystems.

1) Supply side

The supply-side fostering policy mainly refers to the government expanding innovation investment, increasing technology supply, and improving the efficiency of results transformation so that enterprises have sufficient innovation resources to invest in innovation activities [20] and promote the formation of knowledge advantage in advanced manufacturing industries as soon as possible.

2) Demand side

The demand-side fostering policy mainly refers to the government's efforts to reduce market uncertainty for actively developing and stabilizing the market of new technology applications through government procurement, outsourcing trade controls, and overseas institutional support, driving technological innovation and new product development [21]. Among these policies, government procurement is seen by some scholars as one of the key tools of demand-side innovation policy [22].

3) Environment side

The environmental-side fostering policy mainly refers to environmental factors influenced by government in science and technology development through finance, taxation system, and regulation policies, to provide a favorable policy environment for scientific and technological activities, indirectly influencing and promoting scientific and technological innovation and new product development [23].

B. Based on Knowledge-Based Advantage

Knowledge chain refers to a chain network based on the knowledge flows, where enterprise innovation is the core factor, while knowledge advantage is a kind of advantage shown as one knowledge chain compared with another during the process of knowledge flowing [24]. Mavrot and Sager (2018) [25] proposed that scientific knowledge and consensus not only supported horizontal coordination among different groups but were actively included in a vertical network so that specific policy goals were pursued in a top-down manner. Therefore, government policies for fostering world-class advanced manufacturing industrial innovation ecosystems could facilitate knowledge flows in a top-down manner, promoting knowledge advantage among organizations within the innovation ecosystem in competition and cooperation. knowledge advantage is dynamically divided into three dimensions: knowledge production, knowledge transformation, and knowledge application, which are used as the Y dimension of the policy framework for fostering world-class advanced manufacturing industrial innovation ecosystems.

1) Knowledge production

Knowledge production is the creation of new knowledge, the acquisition of existing knowledge, and the storage of knowledge [26]. Knowledge production is mainly the advanced basic knowledge and patent outputs constructed by universities and research institutes. These papers, monographs, and patents are exactly the innovation and value creation in the process of knowledge formation.

2) Knowledge transformation

Knowledge transformation is the transformation of basic knowledge and patents formed by universities or research institutes into applied knowledge through intermediaries and incubators. The process of knowledge transformation is the process of value creation.

3) Knowledge application

Knowledge application is the extent to which knowledge acquired from other employees or units has been applied in a

beneficial manner in a given organizational unit [27]. Enterprises apply the knowledge in actual production or product to realize the value created by the previous process. At the same time, users are also important participants in knowledge application.

C. Two-Dimensional Analysis Framework Construction

Combining the X-axis of policy tools and the Y-axis of knowledge advantage, we constructed the policy framework diagram for fostering a world-class manufacturing industrial innovation ecosystem (shown in Fig. 1).

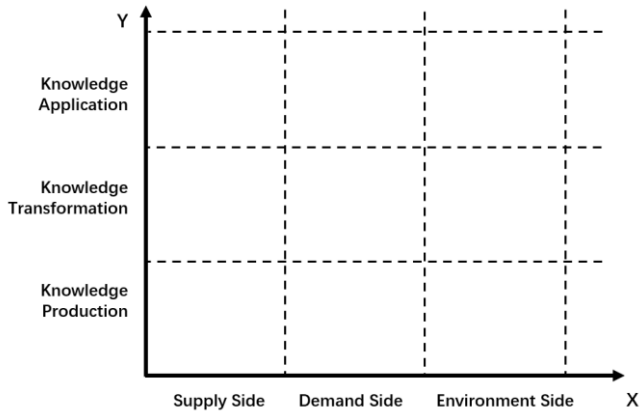

Fig. 1. Policy framework map for fostering a world-class manufacturing industrial innovation ecosystem.

IV. Fostering Mechanism of Policy System

According to Figure 1, we analyzed the fostering mechanism of the world-class advanced manufacturing industrial innovation ecosystem. Government support is the external driving force that has the widest impact on independent innovation [28]. From the X-axis, the fostering policy provides the driving mechanism, realization mechanism and guarantee mechanism to form knowledge advantages.

The supply-side fostering policy provides the dynamic mechanism, mainly addressing the problem of value creation. The government provides resources such as capital, technology, and talents to deal with the lack of resources for each innovation subject in each stage of knowledge advantage formation. policies can be introduced to facilitate innovation incubation to promote the transformation of scientific and technological achievements.

Demand-side fostering policies provide a realization mechanism, mainly addressing the problem of value realization. Through a series of policies such as government procurement, outsourcing, and provision of incentives to consumers or firms to buy newly developed products [29], even when the market demand for them is small, to motivate enterprises to sustain innovation.

Environmental-side fostering policies provide a guarantee mechanism, mainly addressing the problem of guaranteeing the value creation and the value realization. Government can guarantee the formation by policies such as improving laws and regulations on intellectual property protection and cultivating an innovation and entrepreneurship environment. It can promote a cultural atmosphere to encourage innovation and improve the quality of government services.

From the Y-axis, the formation of knowledge advantage is a dynamic development process where knowledge production, knowledge transformation, and knowledge application interact are in a cycle. The innovation ecosystem is essentially a dynamic system formed by the organic fusion made of collaborative and linked innovation subjects, abundant and free-flowing innovation elements, and a good innovation environment [30].

In the process of knowledge production, the government introduces relevant policies to encourage all innovation subjects to invest in the innovation, guiding universities, research institutes, and other R&D institutions to collaborate in research and production of advanced knowledge.

In the process of knowledge transformation, intermediaries, incubators, and enterprises develop and transform the knowledge produced by the system. Government policy promotes the coupling and interaction among them by encouraging and guaranteeing the smooth implementation of industry-university-research cooperation, forming a triple-helix transformation chain of R&D and industry development, to realize the transformation of innovation into value [31].

In the process of knowledge application, the government use policies to encourage and guide enterprises to actively apply the transformed knowledge, develop innovative products or services and enhance innovation performance. Knowledge production, knowledge transformation, and knowledge application are in an interactive dynamic development process (shown in Fig. 2). To solve the problems encountered and driven by market demand, enterprises will actively guide other innovation subjects of the system to carry out the formation of knowledge advantage. Gradually, the system's knowledge advantage will achieve the leap in the form of a "point-chain-network" and will form the knowledge advantage of a world-class manufacturing industrial innovation ecosystem (shown in Fig. 3).

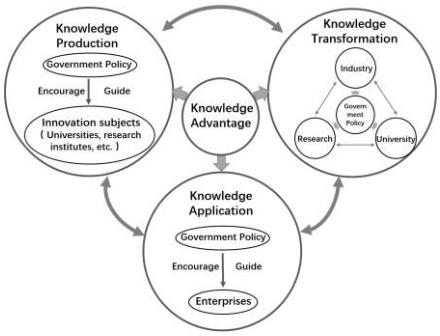

Fig. 2. The dynamic formation process of knowledge advantage.

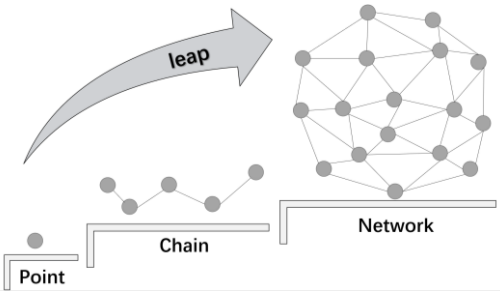

Fig. 3. Leap of knowledge advantage in "point-chain-network".

The life cycle of a world-class manufacturing industrial

innovation ecosystem includes a sprouting period, growth period, mature period, and declining period. So does the life cycle of knowledge advantage. As shown in Figure 4, the dynamic formation process of a world-class manufacturing industrial innovation ecosystem and its knowledge advantage is cyclical and risky. Habib and Hasan (2017) [32] examined the risks borne by firms at different stages of their life cycle and found that the degree of risk-taking was higher in the sprouting and declining periods of the life cycle, and lower in the growth and mature periods. Innovation is high-risk behavior, and breakthrough innovative behavior even [33]. Firms themselves face the risk of failure at all periods of innovation, especially in the sprouting period, because of the uncertainty of innovation. Additionally, enterprises and other innovative subjects often inhibit innovation because of core rigidity or other concerns, which makes it difficult to form knowledge advantages. During the sprouting and growth periods of knowledge advantage, enterprises need a lot of financial support and face the risk of capital shortage. Even after entering the maturity period, enterprises still have the risk of knowledge degradation because of technology paradigm evolution [34], meaning that they are clinging to the old technology paradigm rather than continuing innovation research on the new technology paradigm. Yan and Wu (2020) [35] found that government subsidies played a significant positive impact on substantive and strategic innovation. Therefore, during the sprouting period, policies such as reasonable subsidies for innovation failure and risk-sharing play a pivotal role.

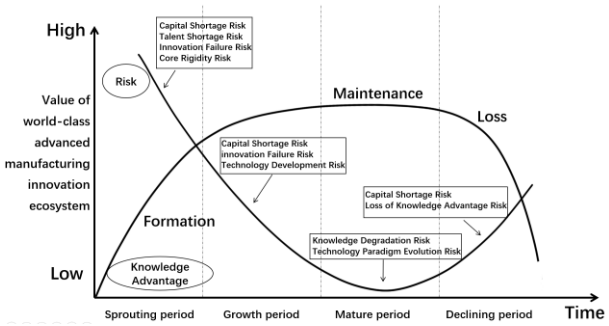

Fig. 4. Trends in risk and knowledge advantage in world-class advanced manufacturing industrial innovation ecosystems.

TABLE I: FOSTERING POLICY FRAMEWORK TABLE

Knowledge Advantage	Supply Side	Demand Side	Environment Side
Knowledge Production	1. Human resource support 2. Technology information support 3. Innovative R&D financial support 4. Basic research and advanced technology development 5. Venture capital support	1. Implementation of National Major Science and Technology Projects 2. National development vision 3. Stimulating universities, research institutes, and enterprises' own needs 4. Consumer demand information provision 5. Market demand information provision	1. Protection of intellectual property rights 2. Innovation and entrepreneurship environment cultivation 3. Legal and regulatory control 4. Establishment of technical standards 5. The establishment of a reasonable salary system 6. Venture capital protection system
Knowledge Transformation	1. Science and technology infrastructure construction 2. Technology R&D center construction 3. Tripartite cooperation among industry, research, and university 4. Entrepreneurial fostering 5.R&D subsidies 6. Technology licensing and transfer policy	1. Tracking implementation of National Major Science and Technology Projects 2. Government procurement 3. Provide special funds 4. Transfer of scientific and technological achievements to enterprises	1. Intellectual property protection 2. System support 3. Financial policy support 4. Creating an innovation policy environment 5. Constructing knowledge development supervision and evaluation system
Knowledge Application	1. Public services 2. Increase financial investment 3. Cultivate talents 4. Government coordination policy 5. Venture capital policy	1. Government procurement 2. Outsourcing 3. Trade control 4. Overseas agency management 5. User policy (consumer subsidies) 6. Use of the market mechanism	1. Market environment 2. Government services 3. Tax incentives 4. Active financial policy 5. Industrial policy

V. CONCLUSION

Tax incentives are a useful resort to push innovation subjects to keep investing in R&D. However, a public policy aimed at promoting innovation cannot only focus on one side. Stimulating innovation requires the implementation of multifaceted, all-encompassing policies. At present, the global advanced manufacturing industries are mainly centered in some developed countries, such as the United States, Germany, and Japan. Chinese advanced manufacturing industries have been increasing and still need strong support from the government's fostering policies. Therefore, we focused on the policies of both the world-class manufacturing industrial innovation ecosystem and knowledge advantages in the sprouting period, constructing a policy table for fostering the world-class manufacturing industrial innovation ecosystem according to the X-axis and Y-axis analyzed above. It is the supplement and improvement of Fig. 1, based on the fostering policies of world-class advanced manufacturing clusters such as Silicon Valley in the

United States, the "Industry 4.0" cluster in Germany, and the Semiconductor industry cluster in Kyushu Japan.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Changyi Zhao designed the conceptual and theoretical framework for the study and the sketches for the figures that was related to her main research field. Yifan Zhang filled in the content of the framework and carried out the work of collecting data, writing the article, and complete the figures. Both authors had approved the final version.

FUNDING

This research was funded by the National Social Science Foundation of China (Grant No. 18BGL032), Soft Science Foundation of Sichuan Province (Grant No. 2021JDR0109), Soft Science Foundation of Chengdu (Grant No. 2019-RK00-00402-ZF), the Fundamental Research Funds for the Central Universities (Grant No. 2021ZY SX20), Sichuan University (Grant No. 2021CXC23), the Fundamental Research Funds for the Central Universities (Grant No. 2021ZZ006).

REFERENCES

[1] Z. B. Liu, "Climbing the global value chain and cultivate world-class advanced manufacturing clusters," *Nanjing Journal of Social Sciences*, pp. 13-20, 2018

[2] Q. W. Li, X. Gu, and C. Y. Zhao, "Factors influencing knowledge advantage in industrial innovation ecosystems: Theoretical framework and empirical study," *Inquiry into Economic Issues*, no. 9, pp. 163-174, 2017.

[3] S. Q. Wang, "Classification and selection of government policy tools to foster social organizations," *Study and Practice*, no. 12, pp. 78-83, 2012.

[4] V. Vlaisavljevic, C. C. Medina and B. V. Looy, "The role of policies and the contribution of cluster agency in the development of biotech open innovation ecosystem," *Technological Forecasting and Social Change*, vol. 155, 119987, June 2020.

[5] H. Zhang, "The path of industry cluster cultivation and the role of government," *Journal of Socialist Theory Guide*, pp. 21-23, 2006.

[6] D. L Feng, "Study on accelerating the cultivation of China's world-class advanced manufacturing clusters," *Academics in China*, pp. 86-95, 2019

[7] X. Y. Zeng *et al*., "Cheng reconstructing the global value chain and fostering the world-class advanced manufacturing clusters," *Huxiang Forum*, vol. 32, no. 04, pp. 72-79, 2019.

[8] H. Wang, "Research on innovation mechanism and competency cultivation of networks in industrial clusters," Ph.D. Thesis Technology Economics and Management Department, Tianjin University, 2008.

[9] P. Zhang and Z. Q. Zhao, "The EU model of cultivating world-class competitiveness clusters," *China Soft Science*, pp. 72-80, 2019

[10] C. Watanabe, K. Fukuda, "National innovation ecosystems: The similarity and disparity of Japan-US technology policy systems toward a service oriented economy," *Journal of Services Research*, pp. 159—186, 2006.

[11] Z. Y. Liu and H. Y. Yao "Cluster characteristic, fostering model and policy orientation of the strategic emerging industry," *Chongqing Social Sciences*, pp. 49-55, 2011.

[12] L. Li, X. G. Cao, and J. Y. Song, "EU industrial cluster policy and the inspiration," *Science and Technology Management Research*, pp. 235-238, 2008.

[13] Z. Q. Zhao and Y. Tian, "Key issues of fostering world-class advanced manufacturing clusters," *Chinese industry and information technology*, pp. 46-51, 2019.

[14] D. Engel, V. Eckl, and M. Rothgang, "R&D funding and private R&D: Empirical evidence on the impact of the leading-edge cluster competition," *The Journal of Technology Transfer*, vol. 44, no. 6, pp.1720-1743, 2017

[15] P. Zhang and Z. Q. Zhao, "How to cultivate world-class competitiveness clusters? — With Norway as an example," *Studies in Science of Science*, vol. 38, no.02, pp. 218-226, 2020.

[16] 2019 Advanced Manufacturing Cluster White Paper, *China Industry and Information Technology*, pp. 46-65, 2019.

[17] K. S. Rogge and K. Reichardt, "Policy mixes for sustainability transitions: An extended concept and framework for analysis," *Research Policy*, vol. 45, no. 8, pp. 1620-1635, 2016.

[18] K. Reichardt and K. Rogge, "How the policy mix impacts innovation: Findings from company case studies on offshore wind in Germany," *Environmental Innovation and Societal Transitions*, vol. 18, pp.62-81, 2016

[19] R. Rothwell and W. Zegveld, *Reindustrialization and Technology*, London: Longman Group Limited, 1985

[20] Y. Yuan, H. L Zhang and F. Y. Li, "Research on the innovation policy of the Obama administration," *Forum on Science and Technology in China*, pp. 178-185, 2017.

[21] Y. X. Zhang and J. Su, "Policy tools for technology innovation and its application in software industry of China," *Science Research Management*, pp. 65-72, 2001

[22] J. Edler and L. Georghiou, "Public procurement and innovation—Resurrecting the demand side," *Research Policy*, vol. 36, no. 7, pp. 949-963, 2007

[23] X. Y. Zhao and J. Su, "An analysis framework for public S&T policies: the perspective of policy tools," *Studies in Science of Science*, pp. 52-56, 2007.

[24] X. Gu, J. P. Li, and W. C. Wang, "Knowledge chain, knowledge chain management and knowledge advantage," in *Proc. ICSSSM '05. 2005 International Conference on Services Systems and Services Management*, vol. 2, pp. 892-897, 2005.

[25] C. Mavrot and F. Sager, "Vertical epistemic communities in multilevel governance," *Policy & Politics*, vol. 46, no. 3, pp. 391-407. 2018.

[26] R. M. Grant, "Toward a knowledge-based theory of the firm," *Strategic Management Journal*. vol. 17, no. S2, pp. 109-122, 1996.

[27] T. Nesheim, K. M. Olsen and A. E. Tobiassen, "Knowledge communities in matrix-like organizations: managing knowledge towards application" *Journal of Knowledge Management*, vol. 15, no. 5, pp. 836-850, 2011.

[28] B. Sun, "Study on the indigenous innovation motive mechanism in enterprise," *Soft Science*, pp. 104-107, 2007.

[29] A. Arora and W. M. Cohen, "Public support for technical advance: The role of firm size," *Industrial and Corporate Change*, vol. 24, no. 4, pp. 791-802, 2015.

[30] S. Z. Gu, D. M. Cao, and M. Yang, "The strategic thinking of building innovation ecosystem in Guangdong-Hong Kong-Macao Greater Bay Area," *China Soft Science*, pp. 1-9, 2018.

[31] Q. W. Li, X. Gu, and C. Y. Zhao, "The essence, source and forming paths of knowledge advantage of industrial innovation ecosystem," S*cientific Management Research*, vol. 34, no. 05, pp.53-56, 2016.

[32] A. Habib and M. M. Hasan, "Firm life cycle, corporate risk-taking and investor sentiment," *Accounting & Finance*, vol. 57, no. 2, pp. 465-497, 2017.

[33] H. J. Wang, S. T. Jin, C. H. Shu, and R. Zhan, "Why does Silicon Valley continue to pioneer disruptive innovation? Analysis based on the perspective of enterprise innovation ecosystem," *Studies in Science of Science*, vol. 39, no. 12, pp. 2267-2280, 2021.

[34] J. S. Li and D. D. Song, "Dynamic innovation ability model of enterprises based on the evolution of technology paradigm," *Science & Technology Progress and Policy*, vol. 33, no. 11, pp. 73-79, 2016.

[35] Y. Y. Yan and Z. C. Wu, "Regional innovation distribution and its dynamic evolution: Policy impact and spillover effect-Based on the perspective of innovation motivation," *PloS One*, vol. 15, no. 7, e0235828, 2020.