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A Review of Research on Innovation Ecosystem Development

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Abstract: Innovation ecosystem has become a key concern for enterprises and even countries. The innovation model, scope, organization and evolution path of innovation ecosystem have changed with the change of innovation environment. The innovation model is transformed from closed to fully open, the scope extends from technological innovation to other innovation paradigms such as knowledge culture, the subject community gradually rises from individual enterprises to national innovation subjects, and the evolution path changes from static element theory analysis to dynamic mechanism of action, system operation and results The evolutionary paths range from static factor theory analysis to dynamic mechanism of action, system operation and outcome evaluation. In this paper, we summarize the four levels of innovation ecosystem research: national dimension, industrial dimension, regional dimension and enterprise dimension according to the spatial scope.

Keywords: Innovation ecosystem, Technology innovation, Literature review.

1. Introduction

Today, the world's unprecedented changes are accelerating and the international environment is complicated. Since the 19th Party Congress, the Party Central Committee has always insisted on the core position of innovation in the overall situation of China's modernization, adhered to the innovation-driven development strategy, actively mobilized the enthusiasm of all kinds of innovation subjects, improved the national innovation system and accelerated the construction of a strong country in science and technology. Innovation has become the driving force of enterprise development, and the innovation ecosystem has become a key concern for enterprises and even the country. With the drastic changes in innovation environment, the innovation model, scope, organization and role mechanism have produced new changes, and its model is transformed from closed to open innovation ecosystem, the scope is expanded from Technological innovation to knowledge culture and other innovation paradigms, and the organization is transformed from individual enterprises to national subjects and even global innovation subjects. More and more countries are becoming aware of the importance of creating an innovation ecosystem with a good environment, and innovation ecosystems are developing at high speed from different levels.

In this paper, the four levels of innovation ecosystem evolution are used as the data source, and the CNKI database of China Knowledge Network is used as the data source, and the search period is 2000-2020. The general trend of the number of articles is consistent with the overall trend over the years, and the overall trend of the number of articles over the years is as follows.

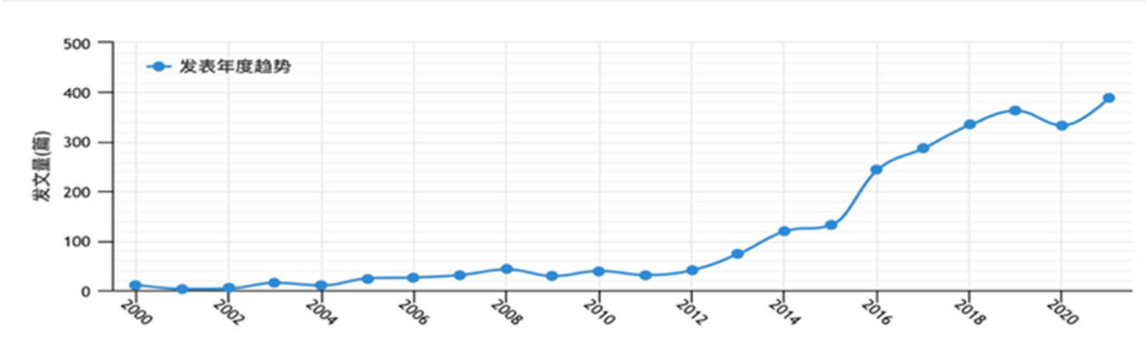

Figure 1. General trend of publications from 2000 to 2020

The number of CSSCI publications on innovation ecosystem has been below 50 from 2000 to 2012, and the fluctuation of magnitude from 2007 to 2008 reflects the growth trend of China's research on enterprise innovation ecosystem, especially in both high-tech enterprises and technological innovation. 2013 has shown an overall fluctuating trend of rapid growth in the number of publications on innovation ecosystem, especially in recent years. The research enthusiasm continues to grow.

2. Current Status of Innovation Ecosystem Research

Recently, the study of innovation ecosystem has attracted wide attention from academic circles, and the research covers the theoretical basis, model construction, mechanism of

action and evolutionary path of innovation ecosystem. The basic theories include the definition of concepts, constituent elements, innovation subjects, system characteristics, etc. The evolutionary paths range from static element theory analysis to dynamic mechanism of action, system operation and result evaluation. Meanwhile, this paper will summarize and outline the four levels of innovation ecosystem research according to the spatial scope: national dimension, industrial dimension, regional dimension and enterprise dimension.

2.1. Basic Theory

The concept of innovation ecosystem is defined by Moore, who argues that each firm is in an ecosystem where firms are not only in competition or cooperation, but also in co-evolutionary relationships, laying the foundation for the study of innovation ecosystems [1]. Adner considers an innovation ecosystem as a complex network in which the members of the system are constantly stimulated by the external environment to change and generate innovation, and the participating actors play their own heterogeneity while interdependent with other actors to jointly achieve value creation [2]. Zhang Yansheng considers innovation ecosystem as a coevolutionary technological innovation system with high-tech enterprises as the main body and technical standards as the innovation coupling link in a global scale [3]. And Luo Guofeng considers innovation ecosystem as a complex network of synergistic evolution based on the principle of openness between each innovation subject and innovation environment through the mutual influence and constraints of technology, information, capital and talent flow [4].

Iansiti and Levin, from an ecological niche perspective, argue that innovation ecosystems are composed of firms at different levels of the ecosystem that are connected to each other, and that the complex relationships between the subjects form a complex network of innovation subjects intertwined with each other and with their environment [5]. The "four elements" of the innovation ecosystem are customers, core companies, upstream components and downstream suppliers of complementary parts [6]. Some scholars have also subdivided the innovation agents into core agents (universities, research institutions, enterprises, users, etc.), supporting agents (government, financial institutions, intermediaries, etc.) and the innovation environment [4].

From the perspective of innovation ecosystem characteristics, scholars at home and abroad have mostly studied the complexity, symbiosis, and dynamics of innovation ecosystems. The innovation ecosystem is analogous to an ecosystem, in which any enterprise is not only in a cooperative or competitive relationship with other members, but also has the core characteristic of "symbiotic evolution" with the system it is in [1] and the conditions for symbiotic evolution are created by the members of the innovation ecosystem as a loose network [7]. In addition to the common characteristics of natural ecosystems, innovation ecosystems have their own unique properties, such as cohesiveness, inclusiveness, complementarity of interactions and path dependence[8]. On this basis, Li Wan et al. argue that the main characteristics of innovation ecosystem are diversity symbiosis, self-organized evolution, and open collaboration. Diversity symbiosis emphasizes that innovation ecosystems accommodate more ‘innovation gene pools’ and evolve through a complex network of innovation agents based on diverse resources such as knowledge, technology, talent, capital, etc. Self-organizational evolution means that the system interacts, adapts, and even transforms with each other. Open Collaboration considers that all elements in the system are closely related to the outside world [9].

2.2. Innovation Ecosystem Evolutionary Path

The exploration of innovation ecosystems has shifted from the earlier static perspective of focusing on element composition and resource allocation to the analysis of the dynamic mechanisms of interaction among the elements and subjects of innovation ecosystems [9]. Innovation ecosystems evolve from innovation systems, reflecting a paradigm shift in the field of innovation research [10]. It also differs from business ecosystems, which are characterized by value capture, while innovation ecosystems emphasize value creation, and are considered by some scholars as a response to the value capture and competitive strategies that exist in business ecosystems [11]. Also genetic, variation, derivation, and selection as four evolutionary mechanisms of innovation ecosystems, where incumbent firms provide genetic drivers, new firms and users provide variation drivers, government and other stakeholders provide derivation drivers, and selection drivers come from users' responses to innovation outcomes [12].

The innovation ecosystem not only focuses on the composition of elements in the system, but also includes the interaction between elements and elements, and the mechanism of material information exchange between elements and the environment, so that the system is always in dynamic operation. At the same time, with the blurring of knowledge boundaries, the public has begun to participate in the information sharing process of the innovation ecosystem through social platforms such as the Internet, which further improves the mechanism of interaction among system members. The innovation model has expanded from the "triple helix" theory of "university-industry-government" with communication as the core to the "symbiotic evolution" principle of government, enterprises, and government. The innovation model has expanded from the "triple helix" theory of "university-industry-government", which is the core of communication, to the "quadruple helix" of government, enterprises, universities, research institutions and the public, which embodies the principle of "symbiotic evolution"[12]. The "five-helix" innovation model that integrates social ecology and knowledge innovation, which emphasizes university, industry, government, civil society, and natural environment. Based on this, Fei-Fei Wu [13] et al. evaluated the organic nature of innovation ecosystem with high technology industry as the research object, and concluded that the influencing factors are regional differences, degree of synergy, and the positive effect of innovation spiral needs to be further explored. A healthy innovation ecosystem shifts corporate strategies from simple association to collaborative development, product competition to platform port competition, and from independent mechanisms of corporate action to symbiotic evolution [7]. Meanwhile, the evaluation of innovation ecosystem health can be based on three dimensions of productivity, adaptability, and agents (government, financial institutions, intermediaries, etc.) and the innovation environment [14].

In summary, innovation ecosystems have undergone a three-stage evolution from early closed innovation systems 1.0 to open innovation systems 2.0 to symbiotic innovation ecosystems 3.0 [15]. Innovation ecosystems evolve from low

to high levels, following a broader transformation path from technology substitution, consumer preferences, infrastructure, cultural policies, while high level innovation ecosystems embody the rule order [16].

2.3. Innovation Ecosystem Framework Level Research Analysis

In the era of globalization, countries, industries and enterprises are no longer competing in a single dimension, but in a synergistic and symbiotic evolution based on an innovation ecosystem, where any element plays an irreplaceable role in the system. The concept of sustainable development is deeply rooted in people's minds, and promoting green development has become an important mission of innovation ecosystems [9]. At the same time, the model construction is related to the spatial scope of different regions, and the research mainly proposes different level of national innovation ecosystem (macro level), industrial innovation ecosystem and regional innovation ecosystem (meso level), and enterprise innovation ecosystem (micro level) [17]. In recent years, with the gradual enrichment of research theories at different levels, diversified and innovative research perspectives, and case studies becoming the dominant method to explore the mechanism of inter-subjective action of innovation ecosystems, the theory of innovation ecosystems at different levels has been further improved. This section will elaborate on the four levels of innovation ecosystem classification.

2.3.1. Status of Research on National Innovation Ecosystems

The OECD (Organization for Economic Cooperation and Development) defines a national innovation system (NIS) as a network of various institutions in the public and private sectors whose interactions shape a country's ability to diffuse knowledge and technology and influence the innovation performance of the country as a whole [18]. In the context of rapid development of Informa ionization and globalization, the national innovation system has gradually evolved into a national innovation ecosystem, whose basic components include the innovation environment, innovation subjects, and the dynamic flow of information resources between the environment and the subjects [19], highlighting the concept of sustainable development. At the same time, China started to study the national innovation system in depth since 2003, and it has made outstanding achievements so far. In recent years, the research focuses mainly on the construction of the national innovation ecosystem, the characteristics of key elements, and the exploration of the effects of government policies and behaviors on the development process of other innovation subsystems. The construction ideas mainly range from creating a favorable innovation atmosphere, strengthening alliances and cooperation among innovation agents, and constructing an open innovation system with government policies as the leading factor and enterprises as the core [20]. Zhang summarized the research characteristics of the national innovation system theory with Chinese characteristics, firstly, emphasizing the core subject position of enterprises in the innovation system, secondly, valuing the collaborative innovation mechanism among the subjects of industry, university and research based on system endogeneity, and thirdly, building a regional innovation system based on inclusiveness through central-local duality domination [21]. Su Nan et al. quantitatively studied the dynamic changes of China's national innovation system by using social network analysis [22]. Chen Jing proposed to further improve the national innovation system through openness and synergistic symbiosis led by national strategy and institutional innovation, and to form a "university-research institution-enterprise The foundation construction and good operation of the national innovation ecosystem directly determine the comprehensive national power and scientific and technological competitiveness of China [23].

2.3.2. Current Status of Industrial Innovation Ecosystem Research

Industrial innovation ecosystem is an innovation community formed by the interaction of industrial chain, innovation chain, value chain and ecological chain, which is an ecosystem of coexistence and coexistence of innovation subjects and innovation resources.[24] is located in the middle of enterprise and national innovation system and plays an important role.

At present, the research system of industrial innovation ecosystem in China has taken initial shape, and there are abundant results on analyzing the basic theory, structural characteristics, and model construction of industrial innovation ecosystem in recent years. Wang Na et al. believe that industrial innovation ecosystem is composed of five elements: industrial system (strategic positioning, industrial selection, etc.), hardware conditions (industrial ecological park, infrastructure, etc.), software conditions (innovation atmosphere, brand, etc.), talents (training and exchange, incentive mechanism, etc.) and external environment (government policy support, industrial development trend, etc.)[25], and Li Rui believes that industrial innovation system has self-organizing characteristics of openness, non-equilibrium, randomness and non-linear action, and constructed a self-organizing dynamics model of the system based on system dynamics [26]. Sun Yuan explored the functional structure and operation mechanism of industrial innovation ecosystem under the perspective of symbiosis, and comprehensively considered innovation resources and innovation environment [24]. In recent years, the perspectives of discussing the operation mechanism of industrial innovation ecosystem gradually favor more and more, such as innovation module coupling strategy [27], value creation and value acquisition [28], and innovation governance model of multi-body synergistic symbiosis [29], etc. Some scholars also use ecological chain theory to reconstruct industrial innovation ecosystem and use quantitative analysis to construct industrial innovation efficiency evaluation system [30]. Since any industrial innovation ecosystem may have multiple operating mechanisms, the exploration of the operating mechanism of the system needs to be further explored. The types of industries explored are mainly high-tech industries, creative industries, emerging industries, etc. The directional research on specific industries is relatively scattered, but each industry is both different and connected, and needs to be combined with corresponding application scenarios to form an independent and symbiotic industrial innovation ecosystem [31]. Further improve the industrial innovation ecosystem.

2.3.3. Current Status of Regional Innovation Ecosystem Research

Regional innovation ecosystem emphasizes the distance in spatial scope, which is a complex network system formed by the interaction and interdependence of technological innovation subjects and technological innovation environment in a certain spatial scope through the flow of

innovation material energy and information [32]. The basic research on regional innovation ecosystem mainly includes the basic concept, elemental subjects and characteristics, and regulatory functions. Su Yi et al. believe that regional innovation system has complex system characteristics such as nonlinearity, uncertainty and self-organization, and is a social system with rich functions and complex structure [33]. From the system, the suitability, effectiveness, health and performance of regional innovation ecosystem are evaluated, and the evaluation indexes are mainly selected from innovation subjects, innovation resources, innovation environment and innovation results. In recent years, the research is no longer limited to the system theory, but gradually focuses on the theoretical application of regional innovation ecosystem and conducts evaluation research in the context of specific regions and specific development, for example, Wang Deqi uses the composite system synergy and coupling coordination model to evaluate the operation level of Beijing-Tianjin-Hebei innovation ecosystem [34]. Innovations are also made in research perspectives, such as considering the coordinating role of intermediary organizations such as governmental actions or combining regional innovation ecosystems with current hot innovation research. Wu Cui explores the relationship between regional innovation ecosystems and industrial synergistic agglomeration and analyzes the suitability of regional innovation ecosystems based on ecological niche measurement [35]. At the same time, the construction of regional innovation system is strongly characterized by the binary dominance of the central government, and the government has introduced the regional innovation policy with pairs of levels and multiple dimensions, which is an important instrument tool to promote the construction and development of regional innovation ecosystem, giving great autonomy to each local area, mobilizing the enthusiasm of each factor in the regional innovation system, and well enhancing the innovation performance [21], In addition, some scholars also propose to pay attention to rural innovation system In addition, some scholars have proposed to pay attention to the research and development of rural innovation systems to realize a regional innovation ecosystem built by synergizing urban and rural innovation ecosystems [18].

2.3.4. Status of Research on Enterprise Innovation Ecosystem

The most widely studied enterprise innovation ecosystem is a complex network system with openness and dynamism that evolves and forms interdependence and coexistence in order to meet customers' individualized and diversified demands and establish different degrees of cooperation and alliance with other enterprises or individual organizations in the process of production and service innovation [36]. It is the earliest of the four subsystems in the innovation ecosystem, and the research on the components, operation mechanism and evolutionary path of the system is relatively abundant, and the methods are mainly based on case studies and descriptive research. The number of articles published continues to increase. The core of corporate innovation ecosystem is based on the heterogeneity of system members, symbiotic evolution, and the synergy between individual and overall goals. In terms of research content, the early stage mainly focused on high-tech enterprises and technological innovation, but later expanded the depth of enterprises, and state-owned enterprises, central enterprises, private enterprises, and small and medium-sized enterprises were included in the scope of the system to explore the evolutionary path of innovation ecosystem, drivers of innovation dynamics, and performance assessment models of different types of enterprises. Engler et al. simulated the goal expectations and behaviors of different innovation agents by constructing a complex system model to verify the evolution mechanism and profitability of firms in the innovation ecosystem [37]. Li Xiaodi explored the impact effects of enterprise technology standardization driving firm performance, and concluded that collaborative R&D, technology standards, and industrialization of high-tech enterprise technology standardization operate synergistically, and that government actions positively regulate the relationship among the elements of innovation ecosystem [38]. Wen Gao refined the research object and explored the construction mechanism of innovation ecosystem of technology-based SMEs through specific empirical cases and proposed a theoretical framework of innovation ecosystem of SMEs consisting of motivation mechanism, knowledge transfer and sharing mechanism, benefit coordination mechanism, and external governance mechanism [39].

3. Summary

With the expansion of scholars at home and abroad on the concept, functional characteristics, system elements and role mechanisms of innovation ecosystems from multiple perspectives, innovation ecosystems have been evolving, and the macro, meso and micro levels of the system have achieved different degrees of results, and the theoretical framework in this field has been formed, but there are still some shortcomings and gaps in the existing research literature for different dimensions of innovation ecosystems.

For innovation ecosystem, there are still differences in the basic definitions of innovation ecosystem from different scholars based on different perspectives, and there is a need to explore the system essence in depth and form a consistent authoritative interpretation. Meanwhile, in the dynamic study of innovation ecosystem from micro-enterprise innovation ecosystem to meso-industrial innovation ecosystem and regional innovation ecosystem, and even macro-level national innovation ecosystem, the system elements and environment have changed to different degrees, and the symbiotic evolutionary relationship existing at each level makes it more difficult to analyze the evolutionary law of the system as a whole, and a new and comprehensive scientific evaluation model should be constructed. In addition, with the new round of scientific and technological revolution and the deep adjustment of global development pattern, the innovation model has been upgraded and the research perspectives have been innovated and diversified, such as the new "five-fold helix" knowledge innovation ecosystem constructed by adding knowledge culture and natural environment, whose research results mainly focus on the basic theory of knowledge innovation ecosystem. The research results mainly focus on the basic theory of knowledge innovation ecosystem, but we need to explore its mechanism of action, evolutionary path and relevant application-oriented research. Regarding the national innovation ecosystem and the coordination of industrial, regional and enterprise innovation ecosystems, China's original innovation capability is not strong, the efficiency of the innovation system is not high, the integration of innovation resources is not sufficient, and the structure of the talent team needs to be optimized. It is urgent for the government to strengthen the strategic deployment and

mission orientation, pay attention to the interaction effect between subjects in the system and the environment, strengthen the endogenous analysis and inclusive research of the national innovation system, and explore the multi-level research of the national innovation system and the construction law of the system [21], etc. While the openness of NIS is enhanced, the interaction of international organizations is strengthened, and the influence of NIS on global value chain and its mechanism of action are paid attention to. For regional innovation ecosystems, regional innovation development is not balanced, so we can integrate regional characteristics, develop corresponding innovation programs according to local conditions, promote the interaction of regional innovation factors, pay attention to the construction rules and characteristics of regional innovation ecosystems, and explore the operation effects of different regional innovation ecosystems based on different regional scenarios. For industrial innovation ecosystem, although the framework of China's industrial innovation ecosystem has been formed initially, the industrial innovation of different industrial chains needs to be carefully distinguished with the uniqueness of industrial innovation system, in order to strengthen the depth and breadth of industrial innovation ecosystem research, and at the same time enrich the quantitative research of relevant specific industries to enhance the rationality and science of the system. As far as the enterprise innovation ecosystem is concerned, there are abundant example studies of enterprises, and the research samples are biased toward high-tech and other enterprises, so we can focus on the research combining quantitative and qualitative analysis, establish the status of enterprise innovation subjects, enhance the innovation momentum of enterprises, explore the interaction mechanism of subjects in the system based on different levels [40], accelerate the construction of innovation consortium led by leading enterprises, supported by universities and institutes, and coordinated by various innovation subjects, and form a strong enterprise innovation ecosystem.

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