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RESEARCH ARTICLE

Incubation Network Structure, Risk Propagation Effects, and Incubation Network Health: From Complex Network Perspective

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ABSTRACT

Risk propagation in the incubation network affects the health of the overall incubation network, which, in turn, may lead to a high entrepreneurial failure rate and a low growth rate of clusters of incubating enterprises. In order to achieve effective network governance, taking the actual network formed by the national incubator as an example, with the help of theoretical analysis of complex networks, statistical methods are used to test the research hypotheses, and to explore feasible solutions to alleviate the risk propagation effect and improve the health of the network. The research shows that there is a significant correlation among the incubation network structure, risk propagation effect and network health, and the risk propagation effect will reduce the health level of the incubation network; the level of structural visualization helps to reduce the risk propagation effect in both network structures.

INTRODUCTION

Under the circumstances of innovation-driven development, the incubation network can make up for some limitations of a single incubator, such as the resources shortage, and using the agglomeration effect, it can carry out extensive networked cooperation to promote the growth of entrepreneurial enterprises, which has become an important measure to promote high-quality economic development. But behind its booming development, there are many problems, the hatched enterprises experience a high failure rate and a low growth rate. According to the 2020 data from GEM (Global Entrepreneurship Observatory), only 20-30 out of every 100 entrepreneurial enterprises can survive for one year, and no more than 10 can continue to run for following three years. To investigate the reasons, the risk propagation in the incubation network is an important incentive (Marián & Romualdo, 2002). The so-called risk propagation means that a few of enterprises in an incubation network generate risks, the potential risks in the cooperative enterprises will be triggered due to the intricate cooperative relationship among the member enterprises in an incubation network. A trigger situation is created which will lead to an outbreak of risk propagation in an network (Zhang & Yang, 2018). With the risk propagation, incubating enterprises will be unlikely to resist risks and they are doomed to be a failure in the end, which brings a greater uncertainty to an incubation network.

The degree of impacts of risk propagation on an incubation network is largely determined by the network structure itself formed by incubators, incubating enterprises and related entities (Battiston et al., 2012). The laws of risk propagation are different within different structures, which will inevitably lead to different health levels of incubation network. In order to effectively prevent the occurrence of risk propagation in an incubation network, and to minimize the impact of the risk propagation effect on the health level of the incubation network, this paper is armed to analyze the interaction among incubation network structures, the risk propagation effect and the health level of an incubation network. So first, we should analyze the characteristics of different types of network structure, then we would get to know the relationship between network structure and the laws of risk propagation, and the ways to improve the health of the incubation network.

In the fields of the characteristics of different network structures, a large number of studies on the following fields in network structure types (such as small-world networks, scale-free networks), in static indicators (network size and density, centrality, structural holes, etc.) and also in its evolution laws provide a new approach to the studies of promoting collaboration and optimizing the network when social network analysis methods have been gradually accepted among the scholars in academic circle. In addition, a further exploration of the relationship between static characteristic indicators and entrepreneurial performance also gains an insight into revealing the evolution of network structure on network governance. However, the above studies only partly explained the phenomenon of a high failure rate and a low growth rate of the hatched enterprises in an incubation network, and those studies cannot analyze and examine this phenomenon thoroughly.

The research on the relationship between network structure and risk propagation started from the exploration of network connectivity by Allen and Gale (2000), who believed that a sparse network is more conducive to risk propagation, because dense network nodes can disperse network risks. However, Blume et al., (2011) proposed that a dense network structure would act as an amplifier for risk propagation, bringing about the contagion effect of "dominoes", that is, a network structure with strong connectivity will reduce the elasticity of system risk. Gai et al., (2011) drew on the phase transition theory of contagion and generalized the above conclusion as the "robust and fragile" nature of network risk propagation. With the deepening of research, the structural features in the entity network have gradually captured the increasing attention of scholars. Gaccioli et al., (2012) believed that the financial network with scale-free features had better resilience to shocks, and its infection rate is higher than that of random networks. Li and Zhou (2015) conducted simulations based on enterprise association networks, and proposed that small world networks help nodes share risks with each other, so that risk propagation has a delay effect. Shen et al., (2019) found that the spatial correlation network of local financial risks in my country would be a typical scale-free network. In the network structure, the improvement of the degree centrality index can reduce the level of risk propagation. Wang and Zhou (2018) explored the risk propagation path of the high-dimensional network of listed banks in China and the United States with the help of the cluster coefficient, network density, small-world effect and other indicators in the network structure. The above studies provide a basic theoretical perspective for observing the relationship between risk propagation and network structure, but those studies rarely focus the field of incubation networks, and incubation network structure and risk propagation have been never put into the same study framework, and also there is no important findings in the fields of the relationship among incubation network structure and risk propagation in incubation network especially under the specific contexts (e.g. based on the perspective of structural visualization).

In the field of network health research, most of the researches center around the health of the innovation ecosystem itself. Mageau et al., (1998) took the lead in pointing out that health is in a good operating state in a system which has an ability to self-regulate and recover, and which can maintain the balance of various internal elements. Since then, scholars have supplemented the connotation of network health, emphasizing that the stability, sustainability, and maintenance of organizational structure are important indicators of health of a system (Blome & Schoenherr, 2011). Domestic scholars have used FAHP, principal component analysis, entropy, etc. to measure the health of innovation networks from the perspectives of health assessment, suitability, and performance assessment. Most of the above studies refer to the static evaluation of ecosystem health, but those studies have not interpreted the incubation network health levels with the different initial health states by using the dynamic evolution of nodes with specific network structures.

In view of the above research, with the help of the concept of bionic management, we borrowed the word "health" into the research of network status, and explored the network risk propagation mechanism with the incubation network structure as the carrier, and analyzed the simulation results data simulation. Regression analysis was conducted to verify the research hypothesis of the main effect between incubation network structure, risk propagation and the health level of the incubation network. At the same time, it analyzed the moderating effect of specific situations on the health level of the incubation network, in order to provide valuable suggestions for the managers of the incubation network in terms of decision-making and organizational governance.

The innovation of this paper is to implant the theory of complex network into the incubation network research in hope to reveal the impact mechanism of the incubation network structure and risk propagation effects on the health of the incubation network. Taking improving the health level of the incubation network as the starting point, the paper attempts to study the interaction of the visualization level of the incubation network structure on the incubation network structure and risk propagation effects, hence providing a reference for the incubation network managers to manage risks and improve the efficiency of network operation.

Theoretical Background and Hypotheses Development

Theoretical Background

(1) Incubation Network Structure

The incubation network structure is an expression of the networked incubation system. The nodes of the network represent incubators, entrepreneur companies and other innovative entities, and the links between nodes represent the cooperative relationship between those entities. Scholars have found that some incubation network networks have shown a small-world characteristic, which are used to explain the comparatively shorter average path length and high clustering coefficients of incubation networks (Watts & Strogatz, 1998). Research shows that based on common goals and interests in the incubation network, through the cooperation between individual innovation subjects, building a "shortcut" of mutual connection, the incubation network with a small-world characteristic can shorten the distance between innovation subjects, and reduce the barriers to information transmission, thus shortening the average path length of the network (Steen et al., 2011). At the same time, the advantages of the low cost and high performance in the incubating process can attract entrepreneur companies to maintain a relatively stable state of cooperation, and form different cliques with the incubator as the core and bond the interests of various innovation firms together when a tight connection of internal nodes within an incubation network make it possible to increase the level of agglomeration of the incubation network itself. In addition, with the development of the network, new companies continue to settle in the incubator to obtain information and resources, which will lead to a continuous expansion of the node scale of the incubation network. Due to the large differences in the social resources and network status of various entities in the network, when seeking partners, those new firms will give priority to connecting to those core institutions with a better brand reputation and a strong competitiveness, thus showing the "Matthew effect", and in this way some "super nodes" in the incubation network will come into being (Xie & Cui, 2016; Kanval et al., 2024). That is, there are a few central nodes with high-frequency cooperation objects and most edge nodes with a small number of partnerships in the network. Therefore, some scholars believe that the incubation network has the evolutionary process of the scale-free network (Wang & zhou, 2014). Given that random networks are not easily realistic for incubating networks, so random networks only exist as a benchmark against which to compare other networks.

By visiting the website of the Ministry of Science and Technology of China, we select two national incubators as the research objects to verify the structural characteristics of the incubation network. Among them, incubation network A is a professional incubator, with 182 incubating aviation companies, mainly engaged in the production of aviation parts, maintenance and testing, R&D and manufacture of new materials, etc. On the contrary, incubation network B is a comprehensive incubator, with 779 incubating companies with a focus on new energy technology, bio-medicine, integrated circuits, opto-electronics and other fields.

An adjacency matrixis X_{ij} constructed in which the incubator, incubating high-tech companies and other innovative entities serves as nodes and the cooperative relationship between each member as edges by analyzing the data of incubation networks A and B. In the adjacency matrix, X_{ij} represents the cooperative relationship between the member node i and the member node j in the innovation incubation network. If $X_{ij} = 1$, it means that the node has a cooperative relationship, and if $X_{ij} = 0$ vice versa. the network structure diagram is drawing by using Gephi9.2 software (see Figure 1-a, 1-b).

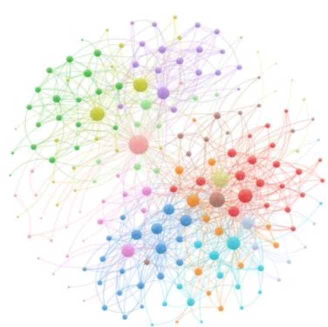

Figure1-a. Topological Structure of Incubation Network A

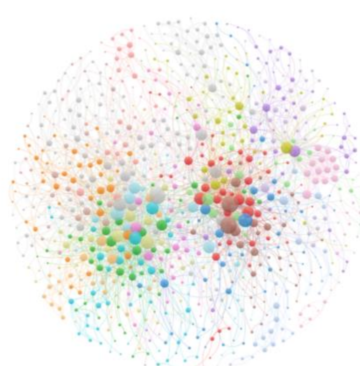

Figure 1-b. Topological Structure of Incubation Network B

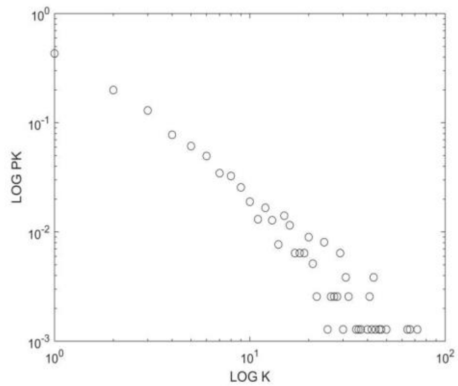

Figure 2. Degree Distribution in Double Logarithmic Coordinate System

Incubation network A has small world characteristics where the rationale is that the average path length is shorter, but the clustering coefficient is higher compared to a random network with the same number of nodes (Newman, 2002; Rashid et al., 2023). By generating a random network with the same 182 nodes and 782 edges, the average shortest path of the small-world of Incubation Network A is shorter (2.635 for the random network and 2.591 for the small-world network sample), but the clustering coefficient is significantly higher than that of the random network (0.042 for random networks and 0.499 for the small-world network). The incubation network B has a great similarity with the scale-free network, and its network contains 779 nodes and 2577 edges. Scale-free networks are characterized by following a power-law distribution. Scholars often plot the degree distribution of the network in double logarithmic coordinates by using log-transformed data to find evidence of linearity (Newman, 2003). The results showed that the incubating network B obeyed a power-law distribution and the log-logarithmic plot was linear (see Figure 2).

Incubation Network Risk Propagation Effects

With the development of complex network theory, Guan et al., (2011) explored the spillover effect and delay effect of network risk contagion, which promoted the academic community's attention to risk dissemination. Based on the simulation model, free from the limitation of computers, taking the innovation network of the marine energy industry as an example, Chen et al.,(2014)mempirically analyzed and verified the influences of incubation network structure and risk propagation effect on network stability from the perspective of network structure and risk propagation effect Yang et al.,(2014) believe that the risk propagation effect often describes the evolution characteristics of risk from the perspective of member nodes in the network. The greater the risk propagation effect, the greater the propagation intensity of network risks in member nodes. Therefore, the research on the incubation network structure has become an important basis for reducing or even avoiding the risk propagation effect, that is, the optimization of the network structure ensures the orderly operation of the network organization. Therefore, this paper proposes that risk propagation should not be defined according to the cause of the risk, but should be defined according to its cooperative relationship. Risk, this kind of behavior that triggers risks with each other continues to form a cascading effect between nodes (Zhang and Yang, 2018; Jam et al., 2014), which eventually leads to the collapse of a considerable number of nodes and even the entire network. This phenomenon is sometimes called Network "avalanche", that is, the effects of risk propagation.

As an incubation network, the cooperation of enterprise node with other enterprises generally includes three types: product cooperation, financial cooperation, and R&D cooperation. To clarify the type of cooperation among hatched enterprises, it is essential to identify the type of risk propagation effect. Whenever an enterprise in the industrial chain experiences operational issues, the upstream enterprise cannot sell its products, the downstream enterprise cannot supply its raw materials, and there is no short-term alternative market solution, resulting in an industry risk propagation effect as a result of the product cooperation failure. Likewise, when an incubating enterprise provides commercial credit or financing guarantee for other enterprises, the joint liability for breach of contract will make the guarantee enterprise also bear the corresponding debt liability; Moreover, if the company is liquidated for its own reasons, the accounts payable cannot be paid or accepted, and the creditor's rights company will also have a crisis in the capital chain. This type of risk propagation caused by capital default is called the credit risk propagation effect; When an enterprise fails to complete the technology development of a sub-project, for instance, the technology development of the cooperative enterprise cannot be completed. The failure then spreads to the entire incubation network, which is also termed as the technology risk propagation effect (see Figure 3). In addition to the aforementioned scenarios, there is also the possibility of compound risk propagation. Due to the research environment, complexity, and purpose of classification research, it will not be discussed in this paper.

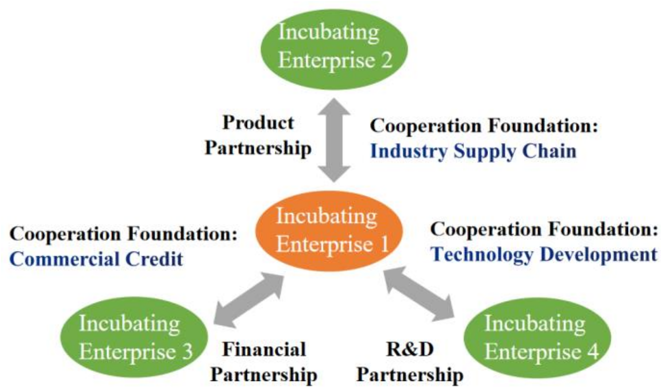

Figure 3. Cooperation Among Incubating Enterprises

Health Level of Incubation Network

"Health" is a biological term describing the state of a system or a specific species. "Health level" is the basic premise for the sustainable development of the incubation network. Only on this basis can the incubation network ensure its future development potential and sustainable development (Song & Chen, 2021). In the past, scholars' research on the incubation network was based on the basic assumption of "health", Because if the incubation network is not "healthy", then many things such as corporate innovation strategy become meaningless. Although in many studies, the "health" of the incubation network is regarded as the basic assumption of the research, in reality, "health" is not possessed by all networks. It has been proved that many innovative networks have gone from prosperity to decline. At present, there are few studies on the health of the incubation network. Iansiti and Levien (2002) first proposed that "health" is an indicator reflecting system performance, which consists of three dimensions: system robustness, productivity, and niche creativity. Then Den et al., (2006) supplemented the evaluation of network health from the enterprise level, pointing out that each member's evaluation of the health of the system is based on their own subjective feelings, including both the health of their own partners and the health of the entire network system. Chen (2014) conducted an empirical study on science and technology parks, and he proposed that the normal operation and stability of the network organization means that the incubation network is healthy. Yao et al., (2019) made a comprehensive assessment of the health of the incubation network in the manufacturing industry in Hunan Province, China with a proposal that a healthy incubation network should have three characteristics, namely, maintaining efficient productivity, continuous adaptability, and presenting rich diversity. To sum up, the health of the incubation network means that the incubation network is reasonable in structure, sound in operational and financial status, highly cooperative in innovation atmosphere with strong strategic synergy among innovative enterprises, where the innovative bodies can interact through materials, information, knowledge and other carriers, they have agile adaptability and diversified competitiveness, and also they can continuously obtain economic output and innovation efficiency.

Structural Visualization Level

The level of structural visualization is a key issue in risk control of the incubation network. The managers of the incubation network can influence the health level and performance of the network through the degree of mastery of the cooperative relationship among member nodes and their partners. The prevention and control measures of large-scale infectious diseases and COVID-19 in human history are good examples in point to illustrate the inhibitory effects of the level of structural visualization on epidemics and risk transmission. In 2020, scholars analyzed the global spread of the COVID-19 with the help of the virus transmission network by selecting seven time nodes, scheming a set of maps and tracing the movement routes of multiple confirmed patients. The visualization data of the trajectory has become an important information resource and basis for epidemic management, which is sufficient to reflect the inhibitory effect of the structural visualization level on the spread of epidemics or risks. Therefore, a good management of an incubating network can also improve its health level and the performance level of the network via better mastery of the cooperative relationship among member nodes. The higher the visualization level of the network structure, the clearer the display results of the network structure and node health status, and the more effective it is to prevent the epidemic from spreading in the shortest time. In the incubation network, the level of structural visualization can improve the network operation efficiency and organizational performance (Amin and Ala, 2016), and it can also promote the decision-making ability of node enterprises, and the enterprise performance will be improved (Caridi et al., 2010; Barratt and Barratt, 2011). When an incubating enterprise only pays attention to the directly related cooperative enterprises, while not aware of the potential chain reaction of risk sources, in this case, the improved level of structural visualization can help identify risk propagation paths on time and more effectively and better isolate risk nodes, thus improving the health. level of incubation network. The level of structural visualization is considered to be a clear display of node interaction relationships and its effect's feedback in the network (Basole et al., 2017; Jam et al., 2013), and it is also the key to network risk control. In fact, it is a risk immunity measure, which enables core node enterprises to more accurately identify risk nodes and prevent risks from spreading in the network.

Hypotheses Development

Incubation network structure and risk propagation effects

The relationship between the incubation structure with small-world characteristics and the risk propagation effects

Risk propagation effects in an incubation network depends not only on infection rates and recovery rates, but also on the structural connectivity among the nodes of the incubation network (Zhang, 2019). Therefore, it is necessary to study the relationship between incubation network structure and risk propagation effects. There are some incubation networks that exhibit a strong small-world effect, that is, higher agglomeration levels and shorter average paths, which makes most nodes in the network exhibit the phenomenon of "small groups" and the phenomenon of "bridge connections". The phenomenon of "small group" reflects the high level of agglomeration of the incubation network, which can enhance the trust among network members and promote the in-depth development of cooperation; "bridge connection" can shorten the distance between network members and make it easier to obtain the trust of other members. As risk propagation effects can be divided into the industry risk propagation effect, the credit risk propagation effect and the technology risk propagation effect according to the cooperative relationship among the incubating enterprises.

Due to those factors such as changes in the industry, market environment, and consumer preferences, the income of incubating enterprises has suffered losses, thus resulting in an industry risk propagation effect, or the incubating enterprise has an adverse impact on the affiliated enterprise due to commercial credit default, or when the R&D of the incubating enterprise fails, the cooperative enterprise will have chain risk credit or technology propagation effect, and these chain risks will be spread among the members of the faction. Cascading failures will occur between node enterprises with cooperative relationships within the same faction. In the network, the higher the strength of the cooperative connection between the incubating enterprises within the faction, the denser the incubating network node enterprises, and the greater the connectivity of the network. The incubator network connectivity is not only conducive to improving the fault tolerance of the network system, but also to improving the stability and survivability of the incubator network. All this shows that the incubation structure of the small world characteristic can reduce the speed of risk propagation in the entire network, which is beneficial to suppress the risk propagation effects.

Hypothesis 1: Incubation network structure with small-world characteristics has a negative impact on risk propagation effects

Hypothesis1a: Incubation network structure with small world characteristics has a negative impact on industry risk propagation effect

Hypothesis1b: Incubation network structure with small world characteristics has a negative impact on the credit risk propagation effect

Hypothesis1c: Incubation network structure with small-world characteristics has a negative impact on technology risk propagation effect

The relationship between the incubation structure with scale-free characteristics and the risk propagation effects

In the incubation network with the main body of network nodes presents the phenomenon of growth and preferential connection, which breaks the equilibrium phenomenon of the random network, making its impact on the risk propagation effects different from that of small-world characteristics (Barabási and Albert, 1999). In the face of risk shocks, it shows vulnerability to large-scale nodes or deliberate attacks, resulting in the rapid spread of risks on the incubation network. Therefore, the topology also determines the fact that the risk propagation on the network cannot be effectively eradicated (Pastor and Vespignani, 2001; Boccaletti et al., 2006). In the incubation network, in order to improve the success rate of incubation, the incubator will invite some "star" enterprises to settle in. Such core enterprises have many connections with other enterprises in the network and they have a large number of connection nodes, and thus those core enterprises become become the central hub of the manufacturing and sales links in the industrial chain.

Once faced with the adjustment of economic policies or changes in market demand, it will spread from the core node enterprises to the whole enterprises in the network. If commercial credit or financing guarantee activities are also involved among the incubating enterprises, even if only 5%-10% of the core enterprises have a credit risk, resulting in the paralysis of the incubation network, at this time, the credit risk propagation effect has an impact on the entire network. Just because there are a small number of central nodes with large degrees in the network, multiple "core-edge" structures are formed in the incubation network. The above-mentioned key nodes have become the key engine to promote technological innovation, but also bring huge hidden dangers to network security. Once R&D fails or product development fails to meet expectations, such technology risk propagation effect will spread to the entire network, and even bring about the collapse of the entire incubation network and bring a huge potential danger to the health of the network. To sum up, there is a positive relationship between the incubation network structure of scale-free characteristics and the risk propagation effects.

Hypothesis 2: Incubation networks structure with scale-free characteristics has a positive impact on risk propagation effects

Hypothesis 2a: Incubation networks structure with scale-free characteristics has a positive impact on industry risk propagation effect

Hypothesis 2b: Incubation networks structure with scale-free characteristics has a positive impact on credit risk propagation effect

Hypothesis 2c: Incubation networks structure with scale-free characteristics has a positive impact on technology risk propagation effect

Risk propagation effects and incubation network health level

Although the structure of the incubation network and the connectivity of the incubation network help member companies to achieve resource sharing and innovation cooperation, they are also important carriers of risk propagation, and the level of network risk propagation effects also determines the health of the incubation network (Basole et al., 2016). The incubating enterprise is the main body of the incubation network, and its entrepreneurial success or failure is an important basis for measuring the health level of the incubation network. Since some companies in the incubation network are in the same industrial chain, when they face changes in the external economic environment, they will pass on the impact of these environmental changes to other companies with cooperative relationships. For example, during the COVID-19 pandemic in 2020, consumption in industries such as tourism, film and entertainment showed a cliff-like decline, and the shrinking consumer demand eventually reduced the profits of the entire industry, resulting in a group of companies with weak bargaining power and insufficient liquidity. Falling into bankruptcy will lead to liquidity difficulties for other companies in the entire industry chain. Once the above phenomenon occurs in a large number of incubating companies, the health of the incubation network will inevitably decline. In addition, the higher the status of a core node enterprise in the incubation network, the more partners it has financial cooperation with, the wider the spread of its risks will be. Once the funds break and lead to credit default, it will bring as a result, the default probability of other related companies has increased, the assets and liabilities have deteriorated, and even bankruptcy and liquidation (Song and Liu, 2019). The mass crisis caused by this chain reaction will reduce the value-added efficiency of network incubation and bring about a vicious circle to the incubation network. Third, with the development of the incubation network, the cooperative relationship between enterprise nodes will become more and more stable, and enterprises will use the scale effect and organizational learning mechanism to strengthen the fixed cooperative relationship between each other. On the other hand, the behavior of incubating enterprises will also be constrained by collective behavior. If the technological innovation efficiency of the entire network is low, and the increment of new resources and new knowledge is reduced, then the information acquisition of each enterprise tends to be homogeneous, and the technological Innovation inertia arises from the spread of technological risk due to R&D failures. Once an enterprise fails in research and development, it will pass the negative impact to other nodes, resulting in the reduction of the technological innovation ability of the incubating enterprise, and it is difficult to use new technologies to reduce product costs. Loss of innovation brings product heterogeneity and rarity, resulting in reduced profits and Failure to start a business reduces the health of the incubation network (Liu, 2022).

Hypothesis 3: Risk propagation effects have negative effects on the health level of the incubation network

Hypothesis 3a: The industry risk propagation effect has a negative impact on the health level of the incubation network

Hypothesis 3b: The credit risk propagation effect has a negative impact on the health level of the incubation network

Hypothesis 3c: The technology risk propagation effect has a negative impact on the health level of the incubation network

The structure of the incubation network and the health level of the incubation network

In an incubation network, on the one hand, the network structure can directly affect the speed and efficiency of network information dissemination, and change the depth and breadth of the cooperative relationship between member nodes in the network (Kostopoulos et al., 2011); on the other hand, if the incubator and the incubating enterprise are well adapted to changes in the external environment, and can quickly search, integrate and reorganize internal and external resources, the incubator and the incubating enterprise will form a network system with different structural characteristics, enabling the innovation subject to gain competitive advantages, the incubation network health level presents a differentiated situation (Guan and Shi, 2012). The impact of the incubation network structure with small world characteristics on the health level of the incubation network is reflected in two aspects: first, the higher the clustering coefficient of the incubation network, the closer the relationship between incubating enterprises in resource sharing and knowledge transfer, and the more conducive the enterprises are to communicate and integrate with each other, the incubating enterprises can make use of external resources to make up for the shortcomings in development, the probability of successful entrepreneurship of the incubating enterprises will increase, and the operation of the incubating enterprises and the operation of the incubation network will be healthier; The shorter average path length enables the resources and information possessed by member nodes that are originally far away in geographic space to have high-frequency and deep-level interactions through cooperative behavior, shortening the distance between enterprise groups in social space (Singh, 2005) , easier access to abundant resources, which is conducive to the formation of positive spillover effects in the network (Cowan and Jonard, 2004). Therefore, there is a positive correlation between the hatching network of small-world characteristics and the health level of the hatching network.

The impact of the scale-free network structure on the health level of the incubation network is reflected in three aspects: First, from the perspective of information dissemination and reception, the continuous increase of the node size in the scale-free incubation network leads to the increase of the number of members in the network. The stickiness of cooperation between incubators becomes weaker, new technologies and new knowledge among incubating enterprises are difficult to popularize in a short period of time, and business operations will be polarized, which is not conducive to the healthy development of incubation networks; on the other hand, from the perspective of entrepreneurship learning, the learning and imitation of the entrepreneurial operation process is not only related to the adopter's own decision-making, but it also will be affected by external enterprises. The examples they can learn and imitate from are those they are closely related to in the network. In a sparse and scale-free network, the blocking of communication channels reduces the imitation efficiency of incubating enterprises, and it is difficult to achieve the transcendence from learning and imitation. Therefore, the incubation network with scale-free characteristics is negatively correlated with the health of incubation networks.

Hypothesis 4: Incubation network structure with small-world characteristics tends to improve the health of incubator networks.

Hypothesis 5: Incubation network structure with scale-free characteristics tends to reduce the health of incubator networks.

Mediating role of risk propagation effects

The structure of the incubation network strengthens or inhibits the harmony of the network by affecting the risk propagation effects, which in turn has an indirect impact on the health of the incubation network. Although the structure and connectivity of the network help enterprises to achieve resource sharing and innovation cooperation, they are also important carriers of risk propagation. In the incubation network with small world characteristics, most node enterprsies do not directly establish cooperative relationships, but only indirectly through a few intermediary enterprsies. Maintaining a high degree of network connectivity is an important pre-factor that affects the effects of incubating network risk propagation. The existence of the core node enterprises under the scale-free feature incubation network structure ensures the stability of the network, and at the same time, when it is interrupted by the impact of risks, it will also lead to the maximum contagion of risks in the network, resulting in the collapse of the network. Since the development of the network is inseparable from the coupling effect of the structure and the risk propagation effect (Zhang et al., 2019), it is inferred that the evolution of the network structure through the incubation network will affect the cooperation activities of the node enterprises in the network, and risk propagation effects indirectly affect the health of the network. Existing studies have found that there is a significant mediating effect of the risk propagation effects on the health level of the incubation network. Therefore, the incubation network structure affects the network synergy through the risk propagation effects, which indirectly affects the health of the incubation network.

Hypothesis 6: Risk propagation effects play a mediating role in incubation network structure and the health level of the incubation network.

Hypothesis 6a: The industry risk propagation effect has a mediating role in the relationship between the small-world characteristic incubation network structure and the health level of the incubation network.

Hypothesis 6b: The credit risk propagation effect has a mediating role in the relationship between the small-world characteristic incubation network structure and the health level of the incubation network.

Hypothesis 6c: The technology risk propagation effect has a mediating role in the relationship between the small-world characteristic incubation network structure and the health level of the incubation network.

Hypothesis 6d: The industry risk propagation effect has a mediating role in the relationship between the scale-free feature incubation network structure and the health level of the incubation network.

Hypothesis 6e: The credit risk propagation effect has a mediating role in the relationship between the scale-free feature incubation network structure and the health level of the incubation network.

Hypothesis 6f: The technology risk propagation effect has a mediating role in the relationship between scale-free feature incubation network structure and the health level of the incubation network.

The moderating effect of the structural visualization level

By improving the visualization level of the incubation network structure, it is possible for an enterprsie to have a deeper understanding of the interaction among incubating enterprises, which is beneficial to perceive risks within the enterprises and inhibit the spread of risks in the network (Cowan, 2004). On the contrary, if an enterprise only focuses on the partners it is directly related to, it is unlikely to detect the potential chain reactions of the underlying risks, the failure in lower structural visualization is self-evident. Because the companies failed to identify the others ventures poor performance under the dual pressure of debt scale and economic fluctuations, which triggered the "avalanche" of the entire incubation network.

When an incubator is at a high level of structural visualization or in a network structure with small-world characteristics, the incubator manager has a clearer insight into the "small group"among those incubating enterprises and other innovative entities. When a risk occurs in an enterprise and spreads to the whole network, the incubator can quickly find the main node enterprise of risk sources, isolate the node enterprise from other related main enterprises, and adopt different strategies based on the health level of the main node enterprise and the threshold against risks to help enterprises, which can stop the risk from spreading further. Thus, the level of structural visualization tends to reinforce the negative effect of the incubation network structure with small-world characteristcis on risk propagation effects.

Incubation networks with free-scale characteristics have a heavy reliance on core node enterprises, and they are more vulnerable and less resistable to risk propagation than networks with small world characteristics. Managers can improve the level of structural visualization to detect potential risks in core node enterprises in advance. By supporting and protecting core enterprises greater more influential, managers can establish a risk barrier mechanism to limit the scopes of the risk spread. Incubators can run healthily within those ordinary node enterprises via improving the level of structural visualization to achieve the goal of healthy operation of the entire incubation network. Improving the visualization level of the incubation network structure can enable incubator managers to pay more attention to the degree of visualization of the network structure, and then guide member companies to establish contacts with partners with strong service capabilities, good social reputation, and advanced technology, so that they can find out potential risks in time and timely adopt rescue strategies to improve the success possibility of incubating enterprises. Therefore, the structural visualization level tends to suppress the positive effect of the incubation network structure with free-scale characteristics on risk propagation effects.

Hypothesis 7: The structural visualization level reinforces the negative effects of small-world network structure on risk propagation effects.

Hypothesis 7a: The structural visualization level reinforces the negative impact between small-world feature incubation network structure and industry risk propagation effect.

Hypothesis 7b: The structural visualization level reinforces the negative impact between small-world feature incubation network structure and credit risk propagation effect.

Hypothesis 7c: The structural visualization level reinforces the negative impact between small-world feature incubation network structure and technology risk propagation effect.

Hypothesis 8: The structural visualization level suppresses the positive effects of scale-free network structure on risk propagation effects.

Hypothesis 8a: The structural visualization level suppresses the positive effect between scale-free incubation network structure and industry risk propagation effect.

Hypothesis 8b: The structural visualization level suppresses the positive effect between scale-free incubation network structure and credit risk propagation effect.

Hypothesis 8c: The structural visualization level suppresses the positive relationship between scale-free incubation network structure and technology risk propagation effect.

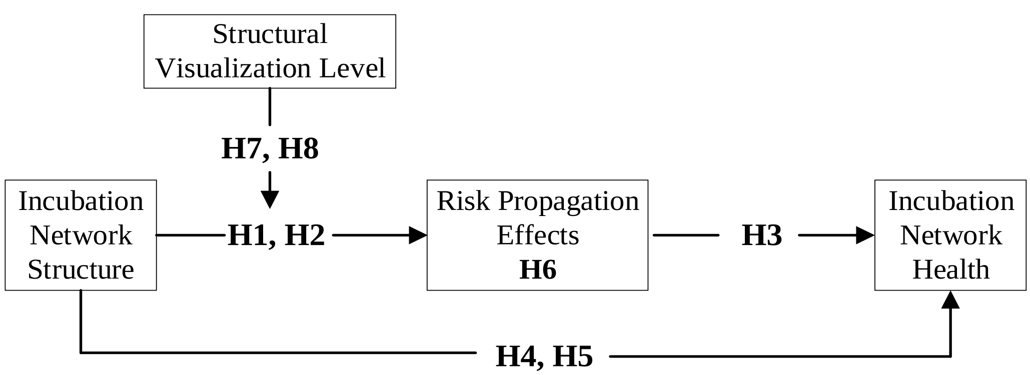

Figure 4. Conceptual Model

Research scheme design

Data Source

The Definition of Research Object

Based on the report by the Global Entrepreneurship Observatory, this paper defines a a start-up enterprise within 42 months as an entrepreneurial enterprise to maintain consistency with the growth cycle of such enterprises in the actual business practices.

Questionnaire design and collection

The data of this research comes from the incubating enterprises of 24 national-level incubators in the Beijing-Tianjin region, the Pearl River Delta, the Yangtze River Delta and the western China as the research object. The questionnaire was completed by middle and senior managers with decision-making authority in the relevant enterprises. A total of 600 questionnaires were distributed, and 461 were returned for a recovery rate of 59.58%; and 357 valid questionnaires were obtained.

Sample Characteristics

In the research samples, the average annual sales of the incubation network range between $5 and $10 million, the average startup lifespan of the incubating enterprises is 2.9 years, and the average number of node enterprises in the incubation network is 812. The specific sample characteristics shown in Table 1.

Table1. Sample characteristics

Characteristics variables	Classification and Proportion		
Enterprise size	Less than 5 million（28.47%）	5 million to 10 million（49.12%）	More than 10 million (22.41%）
Enterprise age	Less than 2 years（20.42%）	2 to 5 years（63.88%）	More than 5 years（15.70%）
Network size	100 to 500（31.65%）	500 to 1000（50.42%）	Over 1000（17.93%）
Network area	Eastern regions（45.32%）	Central regions（14.76%）	Western regions（39.92%）

Variable Design

Mature scale items were used in the design of questionnaire items in this study.And the Likert 5-point scale was used as a data collection tool. Through feedback from in-depth interviews and preliminary research, the questions were revised to ensure that they were clear, simple, precise, and free of ambiguity.

Incubation Network Health. From a microscopic perspective, the evaluation of network node health is based on the research results of Basole and Bellamy (2012), who proposed specific evaluation criteria for physical network health; In terms of meso-level research, the evaluation of network health mainly learn from Xie et al., (2012) research on innovative network operation. Therefore, 15 items are designed in light of the four dimensions of operational health, financial health, cooperation health and strategic health.

Incubation Network Structure. Based on the research of Xie and Li (2014) , Pan and Cai (2014) , two dimensions of agglomeration level and average path were utilized to measure the incubation networks with small-world characteristics, and five measurement questions were formulated. There are three dimensions to the structure of a scale-free incubation network: growth, power-law distribution, and preferential connection. According to sing the study by Albert et al., (2000). (Clauset et al., 2009) and Wang et al., (2014), four measurement questions were set.

Risk propagation effects. According to the cooperative relationship among the incubating enterprises, the risk propagation effect can be categorized into three categories: industry, credit, and technology. In the effect of industry risk propagation, four measurement items are set according to the industry's dependence on enterprise nodes, and based on researches such as Yang and Wang (2021) Capital cooperation between node subjects should be the focal point of the effect of credit risk propagation effect. It measures, on the one hand, the reliance of incubated enterprise nodes on commercial credit within the incubation network. In addition, the ability of the enterprise node to withstand the risk propagation effect should also be reflected. With reference to Zhang and Li (2021), five measurement items are set. The technical risk propagation effect is more pronounced the longer the cooperation time of a single project, the deeper the cooperation, the stronger the difficulty of the cooperation content, the higher the cost of technology development, and the greater the technical risk propagation effect. Three measurement items are set by referencing the study by Zhang et al., (2019), Zhang and Yang (2018).

(4) Structural visualization. Measurement items for structural visualization must center on the cooperation content between node subjects, the scale and operation status of cooperation objects, and the number of partners of cooperation objects. Based on the research of Basole and Bellamy (2014) and Hsiao and Eric (2010), four measurement items were set.

(5) Control variables. The research idea is a design idea combining microscopic and mesoscopic. At the micro-level, two indicators, enterprise scale (C1) and enterprise age (C2), are selected as the enterprise-level control variables; at the meso-level, two indicators, network size (C3) and network area (C4), are selected.

Reliability and Validity Test

The reliability and validity tests were performed with SPSS. In terms of reliability, there were 41 items in the questionnaire, and their overall reliability was 0.744. The reliability test for all the items showed that the α coefficients of the variables are greater than 0.7. This demonstrates that the measurement questionnaire has high levels of reliability and internal consistency, satisfying the statistical requirements of the study).

In terms of structure validity, the KMO value is 0.9, which is greater than the standard of 0.5; Bartlett's sphericity test is significant, and the structure is appropriate for factor analysis of all variables. All scale questions were classed into 10 factors. The factor loading coefficient for each question is greater than 0.5. In addition, the cumulative variance explanation rate of 10 factors was 74.681%, exceeding 60%. The findings proved the validity of the questionnaire structure and the satisfactory compatibility of the data model.

In terms of convergence validity, the average variance extraction (AVE) and combination reliability (CR) were derived from the standardized factor loading. The scale had good convergence validity, with an AVE of all variables higher than 0.5 and a CR of all variables higher than 0.7.

Empirical testing and result analysis

Correlation analysis

It can be seen from the results of the correlation test that the correlation coefficient among the variables is not high, which preliminarily proves that the problem of multicollinearity is not obvious (see table 2). The multicollinearity test was performed again, and the variance inflation factor between items was much less than 10, so multicollinearity could be ruled out. From the calculation results, there is a certain correlation among the health levels of the incubation network and risk propagation effects, and the infection rate and recovery rate of the incubation network.

Table 2. Correlation Analysis of Main Variables（N=357）

	C1	C2	C3	C4	SW	BA	IRP	CRP	TRP	NH	SV
C1	1										
C2	0.453***	1									

C3	-0.069	0.005	1								
C4	-0.095	-0.005	0.054	1							
SW	0.016	0.13*	0.059	0.039	1						
BA	0.072	-0.114*	-0.1	0.025	-0.223***	1					
IRP	0.197***	0.017	-0.159**	0.095	-0.193**	0.262**	1				
CRP	0.209***	0.078	-0.155**	-0.013	-0.307***	0.355***	0.458***	1			
TRP	0.156**	-0.076	-0.171**	-0.029	-0.263***	0.45***	0.53***	0.49***	1		
NH	-0.071	0.103	0.135**	0.035	0.452***	-0.384***	-0.413***	-0.49***	-0.42***	1	
SV	0.021**	-0.095	-0.11*	0.086	0.046	0.085	0.309***	0.206***	0.156**	-0.081	1

*p<0.05，**p<0.01，***p<0.001

Regression analysis test

Main effect

Model 1a, Model 2a and Model 3a respectively verify the influences of control variables on the risk propagation effects; Model 1b, model 2b and model 3b respectively verify the main effects of the incubation network structure on risk propagation effects; Model 4 verifies the influence of control variables on the health level of the incubation network; Model 5 verifies the influence of the incubation network structure on the health level of the incubation network; Model 6 verifies the effects of risk propagation on the health of the incubation network (see table 3 for details).

The results show that the incubation network with small-world characteristics has a significant negative impact on risk propagation effects; the incubation network structure with scale-free characteristics has a significant positive impact on risk propagation effects. The incubation network structure has a significant impact on the health of the incubation network. Among them, the incubation network structure with small world characteristics has a significant positive impact on the health level of incubation network, and the incubation network with scale-free characteristics has a significant negative impact on the healthy level of incubation network. The risk propagation effects have a significant negative impact on the health level of the incubation network.

The reason is that the "linking mechanism" in the incubation network with scale-free characteristics promotes the formation of "super node" enterprises and undertakes overloaded resource allocation. Once the risk exposure of the "super node" occurs, it will lead to quicker spread of risks in the incubation network. Furthermore, there are many closely connected and cooperative small groups of cliques in an incubation network with small world characteristics. Once a node enterprise generates a risk, it will first affect the inside of the clique, and then pass it on to firms outside the clique, which will inevitably slow down risk-spread throughout the network.

Mediation effect

Model 8a, Model 9a, and Model 10a in Table 7 verify the influence of the small-world characteristic of the incubation network structure on the three dimensions of the risk propagation effects. Model 8b, Model 9b, and Model 10b verify the mediating effect of the risk propagation effects. From Table 7, the incubation network structure of independent variable small-world characteristics has a significant negative impact on the industry risk propagation effect, credit risk propagation effect, and technology risk propagation effect; industry risk propagation effect, credit risk propagation effect, and technology risk propagation effect have a significant negative impact on the health level of the incubation network. After adding the risk propagation effects of the mediator variable, the impact of the small-world characteristic of the incubation network structure on the health level of the incubation network decreases, while the three dimensions of the risk propagation effects still have a significant negative impact on the incubation health level. Therefore, the risk propagation effects have a partial mediating role in the positive relationship between the small-world trait incubation network structure and the health level of the incubation network, supporting hypotheses H6a, H6b, and H6c (see table 4 for details).

Model 12a, Model 13a, and Model 14a in Table 8 verify the impact of the scale-free incubation network structure on the three dimensions of risk propagation effects. Model 12b, Model 13b, Model 14b verify the impact of risk propagation effects on the health level of the incubation network. The regression results show that the independent variable scale-free incubation network structure has a significant positive impact on the three dimensions of the risk propagation effects; that the scale-free incubation network structure has a significant negative impact on the health level of the incubation network; that the three risk propagation effects have a significant negative impact on the health level of the incubation network. After adding the mediator variable, the influence of scale-free incubator network structure on the health level of the incubator network decreases, while the three dimensions of risk propagation effects still have a significant negative impact on the health level of the incubator network. Therefore, the risk propagation effects have a partial mediating role in the positive relationship between the scale-free trait incubation network structure and the health level of the incubation network, supporting hypotheses H6d, H6e, and H6f (see table 5 for details).

Moderating effect

Models 15, 16, and 17 in table 9 verify the moderating effect of structural visualization level between the incubation network structure with small-world characteristics and the risk propagation effects. The regression results in table 9 show that the level of structural visualization strengthens the negative effect of the incubation network structure with small world characteristics on the industry risk propagation effect and the credit risk propagation effect. Therefore, it is hypothesized that H7a, H7b are validated by the data, but H7c is not (see table 6 for details).

Models 18, 19, and 20 in table 10 verify the moderating effect of the level of structural visualization between scale-free incubation network structure and risk propagation effects. It can be seen from the regression results in table 10 that the level of structure visualization inhibits the positive effects of the scale-free incubation network structure on the industry risk propagation effect, credit risk propagation effect and technical risk propagation effect. Therefore, it is assumed that H8a, H8b, and H8c are validated by the data, and the test is passed (see table 7 for details).

Table3. Regression Analysis - Main Effects

Variable	IRP		CRP		TRP		NH		
	M1a	M1b	M2a	M2b	M3a	M3b	M4	M5	M6
C1	0.240***	0.204***	0.207***	0.152**	0.226***	0.16**	-0.135*	-0.075	0.012
C2	-0.091	-0.033	-0.015	0.075	-0.178**	-0.084	0.164**	0.055	0.117*
C3	-0.149*	-0.123*	-0.142*	-0.102*	-0.155**	-0.112**	0.124*	0.079	0.026
C4	0.126*	0.122*	0.014	0.01	0.0001	-0.011	0.017	0.017	0.045
SW		-		-0.25***		-0.162**		0.378***	
BA		0.196***		0.286***		0.382***		-0.28***	
IRP									-

CRP									-
TRP									-0.140*
R^2	0.081	0.15	0.064	0.232	0.075	0.265	0.044	0.301	0.32
? R^2	0.081	0.069	0.064	0.168	0.075	0.19	0.044	0.257	0.276
F Value	7.806***	10.306***	6.005***	17.591***	7.163***	21.042***	4.034**	25.079***	23.476***

*p<0.05 **p<0.01 ***p<0.001

Table 4. Regression Analysis——Mediating Effects（1）.

Variable	NH	IRP	NH	CRP	NH	TRP	NH
	M7	M8a	M8b	M9a	M9b	M10a	M10b
C1	-0.115*	0.232***	-0.038	0.193**	-0.041	0.215***	-0.05
C2	0.098	-0.063	0.077	0.031	0.11*	-0.142*	0.055
C3	0.101*	-0.139**	0.055	-0.125*	0.053	-0.142**	0.058
C4	0.003	0.132*	0.046	0.024	0.012	0.008	0.005
SW	0.435***	-0.185***	0.374***	-0.308***	0.317***	-0.239***	0.363***
BA							
IRP			-0.331***				
CRP					-0.384***		
TRP							-0.302***
R^2	0.229	0.115	0.325	0.157	0.353	0.131	0.308
$\triangle R^2$	0.229	0.115	0.097	0.157	0.125	0.131	0.079
F Value	20.814***	9.109***	28.135***	13.027***	31.86***	10.605***	25.97***

*p<0.05 **p<0.01 ***p<0.001

Table 5. Regression Analysis——Mediating Effects（2）

Variable	**NH**	**IRP**	**NH**	**CRP**	**NH**	**TRP**	**NH**
	M11	**M12a**	**M12b**	**M13a**	**M13b**	**M14a**	**M14b**
C1	-0.08	0.206***	-0.011	0.155**	-0.016	0.162**	-0.033
C2	0.098	-0.05	0.081	0.047	0.117*	-0.102	0.068
C3	0.092	-0.128*	0.049	-0.111*	0.046	-0.117*	0.058
C4	0.032	0.116*	0.071	-0.0002	0.032	-0.018	0.027
BA	-0.358***	0.226***	-0.282***	0.338***	-0.22***	0.415***	-0.237***
IRP			-0.338***				
CRP					-0.41***		
TRP							-0.292***
R^2	0.167	0.13	0.266	0.173	0.306	0.241	0.231
$\triangle R^2$	0.167	0.13	0.099	0.173	0.139	0.241	0.065
F Value	14.041***	10.528***	21.117***	14.702***	25.693***	22.229***	17.569***
*p<0.05 **p<0.01 ***p<0.001							

Table 6. Regression Analysis——Moderating Effects（1）

Variable	IRP			CRP			TRP		
	M8a	M15a	M15b	M9a	M16a	M16b	M10a	M17a	M17b
C1	0.232***	0.207***	0.206***	0.193**	0.175**	0.173**	0.215***	0.203***	0.203**
C2	-0.063	-0.022	-0.029	0.031	0.061	0.052	-0.142*	-0.112*	-0.123*
C3	-	-0.106*	-0.12*	-0.125*	-0.101*	-0.121*	-0.142**	-0.127*	-0.128*
C4	0.132*	0.103*	0.114*	0.024	0.004	0.018	0.008	-0.006	-0.004
SW	-	-	-	-	-	-	-	-0.249***	-0.25***
SV		0.292***	0.293***		0.212***	0.213***		0.138**	0.138**
SW*SV			-0.105*			-0.14**			-0.012
R^2	0.115	0.197	0.207	0.157	0.2	0.218	0.131	0.15	0.15
F Value	9.109***	14.289*	13.041*	13.027*	14.555*	13.931*	10.605*	10.265***	8.783**
$\triangle R^2$	0.115	0.082	0.011	0.157	0.043	0.019	0.131	0.018	0
△*F Value*	9.109***	35.687*	4.658*	13.027*	18.875*	8.354**	10.605*	7.575**	0.054

$^{*}p<0.05$ $^{**}p<0.01$ $^{***}p<0.001$

Table 7. Regression Analysis——Moderating Effects（2）

Variable	IRP			CRP			TRP		
	M12a	**M18a**	**M18b**	**M 13a**	**M19a**	**M19b**	**M14a**	**M20a**	**M20b**
C1	0.206***	0.186**	0.151**	0.155**	0.143**	0.127*	0.162**	0.155**	0.127*
C2	-0.05	-0.017	-0.02	0.047	0.068	0.067	-0.102	-0.09	-0.092
C3	-0.128*	-0.1*	-0.102*	-0.111*	-0.093	-0.094	-0.117*	-0.107*	-0.108*
C4	0.116*	0.09	0.091*	-0.0002	-0.017	-0.017	-0.018	-0.028	-0.027
BA	0.226***	0.212***	0.15**	0.338***	0.329***	0.3***	0.415***	0.41***	0.361***
SV		0.267***	0.252***		0.173***	0.166**		0.1*	0.088
BA*SV			-0.326***			-0.151**			-0.257*
R^2	0.13	0.199	0.3	0.173	0.202	0.224	0.241	0.25	0.313
F Value	10.528***	14.504***	21.332***	14.702***	14.769***	14.364***	22.229***	19.464***	22.702***
$\triangle R^2$	0.13	0.069	0.101	0.173	0.029	0.022	0.241	0.01	0.063
△*F Value*	10.528***	30.03***	50.089***	14.702***	12.663***	9.722**	22.229***	4.524*	31.838***
$^{*}p<0.05$ $^{**}p<0.01$ $^{***}p<0.001$									

CONCLUSION

Taking the actual network formed by two types of national incubators (professional incubators and comprehensive incubators) as the research object, this paper, with the help of complex network theory, analyzed its network structure characteristics by obtaining the relevant data of the actual network through in-depth research. And, statistical methods were used to test research hypotheses. By exploring the direct effect of incubation network structure on incubation network health, the mediating effect of risk propagation effects and the moderating effect of structural visualization levels, the following valuable findings were obtained:

(1) Different network structures have diametrically opposite effects on the risk propagation effects. The incubation network structure with small-world characteristics has a negative impact on the risk propagation effects; the incubation network structure with scale-free characteristics has a significant positive impact on the risk propagation effects.

(2) There is a significant negative relationship between the risk propagation effects and the health level of the incubation network. With the increase of risk propagation effects, the overall health level of the incubation network will decrease accordingly. The emergence of unhealth or risky enterprises in the network will not only lead to potential risks of enterprises themselves in the process of incubation. And also it will bring a high incubating failure rate and a low incubating growth rate.

(3) Different network structures have diametrically opposite direct effects on the health level of the incubation network. The incubation network structure with small-world characteristics has a positive impact on the health level of the hatching network; the incubation network structure with scale-free characteristics has a significant negative impact on the healthy level of the incubation network. It shows that in the process of incubation network governance, cooperation and exchanges among incubating enterprises should be promoted, and the influence of super nodes in the incubation network should be appropriately controlled, to achieve the goal of diversifying risks and improving health.

(4) The risk propagation effects have a partial mediating effect between the incubation network structure and the incubation network health level, which means that the incubation network structure has a profound impact on the network health level. In the stability management of the network, it is necessary to consider the potential problems caused by the risk propagation effects.

(5) The structural visualization level can strengthen the negative effect between the small-world structure incubation network and the risk propagation effects, and it can suppress the positive effect between the scale-free incubation network structure and the risk propagation effects. That is, the structural visualization level can reduce the propagation of risks and improve the health of the incubation network.

There are still some shortcomings in the research. First, as an innovative network organization, the health evaluation of the incubation network should also be studied from three dimensions: macro, meso and micro. Due to the limited investment in the research, the regional macro level has not been involved. Secondly, the failure to conduct research on the impacts of the cross-risk propagation of the three types of risk propagation effects in the incubation network is worthy of breakthroughs in the follow-up research.

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