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Research on the Entrepreneurship and Transmission Evolution Mechanism of Platform Enterprises Based on Complex Networks

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Abstract: The new industrial revolution is transforming how businesses operate and innovate. This study uses complex network modeling to simulate structural evolution in different entrepreneurial networks within platform-based enterprises. Key findings reveal that: (1) Network structure and organizational learning positively influence corporate entrepreneurship, with distinct learning patterns emerging across development stages; (2) Hub-and-spoke networks drive broader entrepreneurial participation, while market-oriented networks accelerate entrepreneurial transmission. Simulations confirm that under identical initial conditions, hub-and-spoke networks yield more entrepreneurial firms than hybrid networks, which in turn outperform market-oriented networks. When controlling for startup proportions, market-oriented networks achieve transmission stability fastest, followed by hybrid networks and then hub-and-spoke networks—demonstrating the inherent logic of entrepreneurial evolution; (3) Both startup size and platform-initiated entrepreneurship catalyze entrepreneurial transmission, collectively accelerating business development.

Keywords: Complex networks; Platform-based enterprises; Corporate entrepreneurship; Entrepreneurial transmission; Mechanism evolution

The new industrial revolution is quietly transforming enterprises' production and innovation models. With their unique organizational structures, platform enterprises achieve rapid growth and have become leading players in entrepreneurship in the new era. For example, Haier Group has fostered differentiated unicorn enterprises. It has built three platform models.

These models are an empowerment platform, an incubation platform and a mass entrepreneurship and innovation platform. By doing so, Haier Group has established competitive advantages. It has also driven disruptive innovation in the home appliance industry with Haier at its core.Against this backdrop, how platform enterprises can boost high-quality corporate entrepreneurship, realize industrial value creation and enhance competitive advantages has become a hot topic among scholars in the field of entrepreneurship.

Based on this, this paper focuses on the core issue of platform enterprise entrepreneurship and its transmission effects. It designs three network structure models with the Netlogo 6.1.0 simulation tool to simulate the evolution of the entrepreneurship and transmission mechanism of platform enterprises, and further explores the key factors influencing the evolution of this transmission mechanism, aiming to uncover the black box of platform enterprise entrepreneurship and its transmission mechanism. In terms of research methodology, this paper first sorts out the collected data with the time series analysis method, then builds a multi-agent simulation model through simulation design, and couples it with three complex network models: the scale-free network model, the local-world evolving network model and the random network model, so as to dynamically simulate the evolution of the entrepreneurship and transmission mechanism of platform enterprises. This research is innovative and pioneering for the empirical study of corporate entrepreneurship and its transmission effects.

1.Literature Review

1.1Platform Enterprise Entrepreneurship

Industrial cluster entrepreneurship is the process of transmission and diffusion of entrepreneurship by platform enterprises within an industry (Shuang Huajun, 2012). Current

research is conducted mainly from two perspectives. **The first is the perspective of platform or core enterprise entrepreneurship.** Entrepreneurship of platform enterprises is critical for cluster enterprises to achieve upgrading (Dai Weiqi, Wei Jiang, 2010). Zhao Fuchun and Jiao Hao (2011) suggest that platform enterprises can promote industrial upgrading through product and industrial chain entrepreneurship. The overall development of industrial clusters is closely related to knowledge spillovers (Wang Weiguang et al., 2015), cooperation capabilities (Zheng Shenghua, Chi Renyong, 2017), and innovation-driven effects (Munari et al., 2012) of platform enterprises. Wu Yishuang (2016) points out that leading service-oriented enterprises can promote the upgrading of industrial clusters through three entrepreneurial activities: platform advancement and internationalization, R&D envelopment, and building cluster brand culture.

The second perspective is the entrepreneurial network. Cluster organizational networks can provide lower transaction costs and service costs for enterprises in the industry and make it easier for them to obtain resources and technologies needed for entrepreneurial activities (Gert and Peter, 2003). Therefore, network theory has become an important basic theory to explain the logic of entrepreneurial success (Han Wei et al., 2014). Research on cluster entrepreneurial networks mainly includes two streams. **From the structural perspective**, Hoang and Antoncic (2003) analyze how structural characteristics such as network size and network strength influence entrepreneurial activities, firm performance, competitive advantage, and technological innovation in entrepreneurial networks (Wu et al., 2008). Tolstoy and Agndal (2010) examine the relationship between innovation network structure, response to external environmental changes, and firm performance from the perspective of resource integration and utilization. **From the relational perspective,** Marie et al. (2006) find that strong ties affect

entrepreneurs' cognitive biases and thus promote entrepreneurial activities. Engel et al. (2017) argue that relational ties in entrepreneurial networks play an important role in opportunity identification, opportunity creation, legitimacy acquisition, resource mobilization, and growth of new ventures. Uhlaner et al. (2007) state that trust among organizational members improves the recognition of new firms, and such trust and support enhance firm performance through organizational commitment. Zhu Xiumei and Li Mingfang (2011) propose that accessing external resources through network ties is the optimal choice for new firms and put forward an effective mechanism for new venture network governance from the dynamic perspective of entrepreneurial networks.

1.2 Transmission Mechanism of Complex Networks

The theory of propagation dynamics in complex networks mainly focuses on dynamic behaviors in the transmission process, such as oscillation. In fact, existing studies have explored dynamic phenomena including bifurcation, chaos and general unstable oscillation from the perspective of the propagation equation dynamics of the NW small-world network. Barthelemy et al. (2004) analyzed the time evolution of propagation outbreaks in complex networks with highly heterogeneous distribution. They found low-order dynamic characteristics of virus spread in such heterogeneous networks. If a virus first infects nodes with high degree, it will gradually spread to nodes with lower degree in the network. The NW small-world network was first proposed by Newman & Watts (1999). They described the propagation process on a d-dimensional NW small-world network. Moukarzel (1999) provided a more detailed analysis based on this work and established the propagation principle of this network. Yang (2001) argued that there is a time delay in the spread of the NW small-world network due to waiting

time in reality. He then proposed fractal, chaos and bifurcation features in the dynamic propagation equation of the small-world network. Hayashi (2004) used the SIR model in homogeneous and heterogeneous networks to study the spread of computer viruses. He also compared network evolution with and without immunity measures.

In summary, current research on entrepreneurship and transmission among platform enterprises mostly focuses only on the level of core enterprises. It discusses the impacts of focal firms and network structure on entrepreneurship, and some scholars have also conducted valuable explorations on corporate entrepreneurship from an evolutionary perspective. However, none of the above studies adopts a systematic perspective to examine platform enterprise entrepreneurship. Moreover, few existing studies investigate the transmission of platform enterprise entrepreneurship from the perspective of complex networks. Most studies on the transmission of corporate entrepreneurship start from the perspective of network relationships and have preliminarily explored the composition of entrepreneurial networks, which provides a sound foundation for further research on platform enterprise entrepreneurship. Nevertheless, existing research rarely classifies entrepreneurial networks according to their transmission modes and targets. Therefore, research that distinguishes how different types of entrepreneurial networks affect transmission modes and targets can further effectively reveal the mechanisms underlying platform enterprise entrepreneurship and transmission.

Meanwhile, existing studies on entrepreneurship and transmission among platform enterprises only use social network analysis. In fact, interactions among elements of entrepreneurial networks form complex network relationships. Social network analysis cannot fully describe the internal complex relationships among these elements or quantitatively

measure such complex network structures. Thus, it cannot deeply reveal the mechanisms of entrepreneurial transmission. However, existing complex network studies have fully explored network dynamics, transmission mechanisms, and network failures, which provide a solid theoretical foundation for research on entrepreneurship transmission among platform enterprises. Based on the above literature review, we believe that research can use tools from complex network theory to describe the structure of entrepreneurial networks. According to complex network theory, the entrepreneurial network structure of platform enterprises consists of nodes and edges. Nodes represent the number of enterprises in the cluster, and edges represent relationships between enterprises. Complex network theory highlights the characteristics of aggregation, nonlinearity, and interaction among heterogeneous individuals through these nodes and edges. It also shows distributed control, information sharing, knowledge transfer and learning, diverse behavioral characteristics, innovation capabilities, as well as complex relationships and structural evolution among actors (Auyang, 1998; Holland, 1995; Lane, 2001). Meanwhile, this representation of complex networks provides a basis for computer simulation technology and offers a new perspective for the study of entrepreneurship and transmission among platform enterprises.

2.Network Classification and Architecture Design

2.1Network Classification: Hub-and-spoke,Market-type, and Hybrid Network Models

Multi-agent simulation modeling serves as a vital methodology in social simulation research. This approach effectively captures emergent phenomena within groups of enterprises characterized by competitive and collaborative relationships,

proving instrumental in informing entrepreneurial network formation.

Iansiti (2004) conceptualizes entrepreneurial networks as dynamic ecosystems comprising four distinct agent types: core network players, dominant controllers, beneficiary players, and niche specialists. Thomas's (2014) framework categorizes network structures by connection patterns—including internal corporate relationships and external configurations linking suppliers and rivals through one-to-many, many-to-one, or many-to-many arrangements. Examining Europe's top 20 automakers, Lampón et al. (2017) observed non-integrated network cores and proposed modular architectures. Collectively, these studies reveal that while entrepreneurial network classifications lack standardization, they consistently reflect two defining platform enterprise features: 1) platforms bridge connections among diverse agents, and 2) interactions between these agents generate network value through direct, indirect, and cross-side effects.

Based on extant research and case studies examining three developmental stages of entrepreneurial networks, this study categorizes such networks into three structural types: hub-and-spoke networks, hybrid networks, and market-oriented networks (See Table 1).

[Table 1 near here]

Market-Oriented Networks (See Figure 1): This entrepreneurial network structure consists of multiple enterprises with comparable market positions. Within the network, firms engage in randomized resource exchanges, market transactions, and strategic collaborations within highly homogeneous industries. Supply and demand

relationships form through stochastic connections among participants, exhibiting low bilateral dependency—characteristics aligning with the initial developmental stage observed in case studies.

[Figure 1 near here]

Hybrid Networks (See Figure 2): This entrepreneurial network structure features several incubated platform enterprises (independent entities) and enabling firms developed by a core platform company. Resource allocation occurs through enablement mechanisms connecting both the core platform and its incubated platforms. These incubated platforms operate within distinct yet limited business domains, exhibiting moderate heterogeneity. Partner enterprises access specialized resources from different core and incubated platforms, while the relatively small pool of cross-sector participants creates discernible demand characteristics. This configuration yields moderate network diversity, allowing firms greater selectivity in partnerships and reducing dependence on singular entities—characteristics aligning with the second developmental stage identified in case studies.

[Figure 2 near here]

Hub-and-Spoke Networks (See Figure 3): Centered around a single platform enterprise, this entrepreneurial network connects diverse supply and demand stakeholders through internal platformization. The platform features a flattened organizational structure—categorized into distinct functional units—compared to traditional hierarchies. Serving as the central resource hub, the platform enables partner firms to access specialized resources such as capital, technical expertise, and

proprietary information services. High dependency on the core platform creates strong network effects, while the platform's aggregation capacity attracts heterogeneous participants, resulting in maximal network scale. These characteristics correspond to the third developmental stage observed in case studies.

[Figure 3 near here]

2.2Architecture Design: Architectural Models and Attributes of Three Types

2.2.1Model Architecture Design

First, this paper argues that the individual enterprises in entrepreneurial networks specifically refer to Agent entities with the capabilities of learning, absorption, and adaptation.These firms constantly seek higher cooperative benefits. While doing so, they gain market resources, space, and information to drive entrepreneurship. Based on the classification of entrepreneurial network structures, this section matches the three network types with corresponding models from complex network theory. This helps build a network classification framework for this research.

（1）Market-Type Networks and the ER Model

The ER model in complex networks was developed by Erdos et al. It is a purely random network where nodes connect randomly based on set probabilities. Market-type entrepreneurial networks develop naturally. Firms in these networks choose partners randomly for collaboration or resource sharing—they don't specifically pick influential ones. This leads to equal status among firms, which matches the random nature of the ER model.The ER model has two key features that align with market-type networks: first,the degree distribution is nearly uniform; second,nodes form links randomly at a

fixed probability.These features directly match the characteristics of market-type networks.There are two types of architectural designs for this model.

①Random Graph with Fixed Edge Count: Given n nodes and m edges to be added, randomly select a pair of nodes without an existing edge and add an edge between them. Repeat this process until m edges are established.

②Random Graph with Fixed Edge Probability: Given n nodes and m edges to be added, randomly select a pair of non-adjacent nodes and add an edge between them with probability P . Repeat the process until all nodes are connected. The probability P is defined in Equation 4.1:

$$P = \frac{1}{N(t)} \tag{4.1}$$

（2）Hybrid Networks and the LN Model

The Local-world Evolving Network (LN) model describes nodes operating within specific subnetworks or localized domains, where inter-node connections dynamically evolve. In this model, businesses stay rooted in their local areas and face some limits. They pick partners that either have skills they lack (complementary) or are similar to them. This helps them get resources.

The architectural design of this model is as follows:

①Growth: The initial network consists of m nodes and e_0 edges. Each time, one node is added along with m edges.

②Local-world Preferential Attachment: A newly added node randomly connects to m existing nodes, which form its “local world.” The probability of connecting to

these nodes follows Equation 4.2:

$$\prod_{Local}(k_i) = \prod'(i \in LW)\frac{k_i}{\sum_{j\ Local} k_j} \equiv \frac{M}{m_0 + t}\frac{k_i}{\sum_{j\ Local} k_j} \tag{4.2}$$

Here, the local world (LW) is composed of the newly selected M nodes.

（3）Hub-and-Spoke Networks and BA Model

The BA model, proposed by Barabasi and Albert, is a network architecture designed to explain power-law distributions. In real-world networks like the Internet ecosystem, the degree distribution often follows a power-law pattern. This model is characterized by two key features:

① Growth:In the BA network, nodes are continuously added, causing the network to expand indefinitely.

②Preferential Attachment.New nodes prioritize connections with high-degree nodes.These characteristics align closely with the hub-spoke network structure discussed earlier, where platform enterprises occupy central positions enabling learning exchanges among dependent firms. Within this framework, organizations prioritize collaborations with highly competitive and influential partners to access resources or jointly advance entrepreneurship, reflecting the core dynamics of platform-mediated business ecosystems.

The architectural design of this model is as follows:first ,the network starts with m_0 nodes. Each new node connects to m existing nodes ($m \leq m_0$) .The probability Π_i that a new node connects to an existing node i relates to the node's

degree k_i ,as followed in Equation 4.3:

$$\prod_i = \frac{k_i}{\sum_j k_j} \tag{4.3}$$

2.2.2Model Attributes

Networks typically employ three key metrics to assess their structural distribution: degree/degree distribution, clustering coefficient, and average path length. This study primarily focuses on the fundamental statistical metric of degree and degree distribution. A node's degree, denoted as k_i, represents the number of edges connected to that node. Here, k specifically refers to the degree size of an individual enterprise. A higher k value generally indicates more connections to other enterprises, signifying greater network influence and advantage for that enterprise. Conversely, a lower k suggests fewer connections and reduced significance within the network. The average degree, denoted <k>, effectively reflects the network's overall connectivity level. A higher <k> implies denser inter-firm connections, while a lower value indicates sparser relationships. Degree distribution describes the probability distribution of degree values across all enterprises in the network. When degree values are more uniform across enterprises, the network structure is more balanced; greater variation in degree distribution corresponds to increased structural inequality.Specific formulas are provided in Equation 4.4 and 4.5.

The average degree of all nodes in a network, denoted as $< k >$, is calculated according to Equation 4.4:

$$< k >= \frac{\sum_{i=1}^{N} k_i}{N} \tag{4.4}$$

where N represents the total number of nodes;

The degree distribution P(k) , describing the probability that a randomly selected node has degree k , is given by Equation 4.5:

$$P(\mathrm{k}) = \frac{N_{\mathrm{k}}}{N} \tag{4.5}$$

3 Model Algorithm and Rule Construction

3.1Model Algorithm Development

Drawing upon complexity theory, although individual enterprise behaviors within networks may appear stochastic due to multifaceted influences, platform enterprises collectively exhibit discernible evolutionary patterns through entrepreneurial transmission and collaborative exchanges. This facilitates the emergence of structured entrepreneurial networks. Consequently, platform entrepreneurial dynamics and their transmission mechanisms can be effectively modeled using specific complex network algorithms and rules.

Within complex network theory, social transmission refers to the diffusion of phenomena,such as technologies, behaviors, or ideas,through interconnected social structures. Meanwhile, these transmission processes are simultaneously modulated by network topology, potentially yielding divergent behavioral manifestations across distinct entrepreneurial networks (Boccaletti et al., 2006). This section examines the evolution of entrepreneurial transmission mechanisms among platform enterprises under three network typologies, thereby aligning with fundamental principles of complex social network propagation.

3.1.1Algorithm Based on Threshold Diffusion Model

The threshold diffusion model represents a micro-level transmission mechanism within complex network systems. Rooted in individual actors within social networks, this model conceptualizes the adoption of innovations as intentional decision-making processes. It emphasizes that such decisions involve not only individual analysis and judgment but also dynamic adjustments through peer interactions. The model's core premise is that individuals adopt new products or ideas only when influenced by fellow entrepreneurs beyond a critical threshold. This threshold, modulated by network connectivity, diffusion mechanisms, and degree distribution (Morris, 2005), determines behavioral changes. In entrepreneurial networks, platform enterprises' initiatives influence others' entry decisions, while each firm maintains an adoption threshold—aligning perfectly with this model's principles. Therefore, this study employs the threshold diffusion framework to elucidate how enterprises accept entrepreneurial behaviors through organizational learning, thereby enabling entrepreneurial transmission.

Key metrics quantifying the evolution of entrepreneurial transmission mechanisms among platform enterprises include: transmission success rate S (number of enterprises successfully adopting innovations), transmission stabilization time T (duration until entrepreneurial activities reach equilibrium), transmission amplification coefficient E (cumulative entrepreneurial instances within the network), and transmission concentration CV (centralization tendency of entrepreneurial behaviors), with the latter's formulation and average entrepreneurial frequency defined in Equations 4.6 and 4.7.

$$AE_m = \frac{\sum_{i=1}^{m} E_i}{m} \tag{4.6}$$

$$CV = \frac{\sqrt{\frac{\sum_{i=1}^{m} (E_i - AE_m)^2}{m}}}{AE_m} \tag{4.7}$$

AE_m denotes the average entrepreneurial frequency across all enterprises, where m represents the total number of firms within the entrepreneurial network, and E_i signifies the entrepreneurial count of the i enterprise.

The simulation employs thresholds to quantify evolutionary influences: each enterprise possesses an inherent threshold value shaped by network resources and conditions. When other enterprises achieve entrepreneurial success through transmission, the network structure undergoes alterations, generating emergent thresholds (fact-thresholds). Enterprises subsequently evaluate these native and emergent thresholds to determine adoption of observed entrepreneurial behaviors, thereby triggering organizational learning that facilitates entrepreneurial activation.

3.1.2Algorithm Based on Neighbor Effect

Entrepreneurial behaviors within networked enterprises directly influence the entrepreneurial activities and frequencies of connected firms, driving behavioral contagion across the network. The neighbor effect-based transmission model posits that entrepreneurial decisions are significantly shaped by networked peers' choices, primarily examining the probability of such transmission.

The neighbor effect refers to how the decision-making choices of closely connected enterprises influence or alter a firm's original perspectives, prompting adoption or rejection of such decisions to achieve transmission. This effect emerges from inter-firm communication and manifests in both active and passive influence modes. In the active mode, enterprises purposefully promote themselves within the entrepreneurial network—particularly targeting influential firms—to foster communication and collaboration. Here, entrepreneurial entities consciously disseminate innovations to connected partners while providing continuous follow-up, thereby advancing their own innovative activities and enabling entrepreneurial transmission. Within complex network demonstrations, this manifests as node i transferring innovative products or ideas to neighboring node j, subsequently strengthening their relationship and accelerating i's innovation implementation. Conversely, the passive mode involves no deliberate influence attempts; transmission probability depends entirely on rationally evaluated judgments by connected enterprises. In this scenario, enterprise j assesses entrepreneurial i's innovations against its own strategic trajectory before deciding on collaborative engagement. Given this study examines how platform entrepreneurship drives collective innovation through conscious transmission mechanisms, the research exclusively considers entrepreneurial transmission under the active influence paradigm.

When considering the connection strength in the network, the transmission probability is defined in Equation 4.8:

$$D_{i-j} = \frac{D_{ij}}{\sum_j D_{ij}}$$

(4.8)

Without considering the connection strength between individuals, the transmission rate under the active influence model is shown in Equation 4.9:

$$D_{i\to j} = \frac{1}{\mathrm{k}_i}$$

(4.9)

3.2Model Rule Construction

In this section, the simulation model rules are set as follows. First, we define the attributes of each enterprise agent in the entrepreneurial network, mainly including whether it has entrepreneurial behavior, entrepreneurial thresholds and fact-threshold), and the number of entrepreneur-times. The attributes of each network link between enterprises include the type of connection .Then, according to different network structures and research needs, we set different conditions (such as different spread sources and initial numbers of entrepreneurial enterprises) for separate simulations. We evaluate the smoothness of the spreading process and its impact on mechanism evolution by outputting four indicators: spreading success rate S, spreading stabilization time T, spreading amplification coefficient E, and spreading concentration CV.

In terms of parameter settings, this study sets the layout size to 45×45, with all connections being undirected. The spreading steps are as follows: first, at each tick (time count), agents calculate their respective degree values; second, agents determine whether they meet the entrepreneurial threshold and whether to accept entrepreneurial spreading; then, if an agent accepts the spreading, it establishes connections with related

enterprises under given conditions; finally, based on changes in connection status, it monitors real-time changes in degree distribution and network architecture, and calculates the spreading amplification coefficient, spreading success rate, spreading stabilization time, and spreading concentration.

4.Simulation Modeling-Basic Simulation and Condition Setting

4.1 Simulation of Three Fundamental Network Models

For the three types of entrepreneurial networks mentioned above, we first assume that each network model contains a maximum of 500 enterprises, equivalent to 500 nodes in the network. Second, we assume that connections between any two nodes are undirected and equal in strength, forming an undirected graph. During the simulation, the entrepreneurial network starts with an initial number of nodes that gradually increase according to the predefined connection rules until reaching 500 nodes. The resulting structures of the three entrepreneurial networks are shown in Figure 4.

[Figure 4 near here]

From Figure 4, we can observe that in the BA model corresponding to the hub-and-spoke network, there are one or a few enterprises with high degree values, indicating the existence of heterogeneous enterprises. The LN model corresponding to

the hybrid network features locally heterogeneous enterprises with relatively tight relationships and moderate overall dependency. In the ER model corresponding to the market-type network, node connections are more random, resulting in lower heterogeneity among enterprises.

Based on the simulations of these three network architectures, this section plots their degree distributions, with the specific results shown in Figure 5.

[Figure 5 near here]

From the degree distribution comparison chart of the three models, it can be seen that in the BA model coupled with the hub-and-spoke network, the degree distributions of the three network structures differ significantly. The minimum degree is 1 with 330 nodes, while the maximum degree is 44 with only 1 node. This shows that most nodes in this network are connected to the node with the highest degree, and there are fewer connections between other nodes. From the node distribution, it can also be seen that nodes in this network are almost spread across the entire range.

In the LN model coupled with the hybrid network, the degree distribution shows a moderate difference. The minimum degree is 1 with 191 nodes, and the maximum degree is 55 with 1 node. Compared with the BA model, the node distribution here is less extreme, with most nodes having degrees between 1 and 5. In terms of node distribution, this network is similar to the hub-and-spoke type, but there are missing nodes within the degree range, and not all degree values are fully covered.

In the ER model coupled with the market-oriented network, the degree distribution shows that node degrees mainly concentrate on 1 and 2, with a total of 258 nodes, while the maximum degree is only 10 with 1 node. In terms of node distribution, this network, similar to the hub-and-spoke structure, covers the entire range of degree values.

The chart also confirms that the BA model tends to connect to high-degree nodes, the ER model features random node connections, and the LN model exhibits connection patterns that lie between the two.

4.2 Simulation of Mechanism Evolution under Different Condition Settings

4.2.1 Impact of Different Spreading Sources on Mechanism Evolution

From the results of the previous section, the spreading influence of platform enterprises on entrepreneurial networks is evident. This section further expands on the

above research findings. Here, the spreading sources are divided into two categories: those dominated by platform enterprises and those using random enterprises within the entrepreneurial network as spreading sources. The entrepreneurial spreading results under different conditions are compared by observing changes in the number of entrepreneurial enterprises within the network. The results of this section are shown in Figures 6, 7, and 8.

[Figure 6,7,8 near here]

4.2.2 Impact of Different Initial Numbers of Entrepreneurial Enterprises on Mechanism Evolution

As mentioned earlier, the neighbor effect also influences entrepreneurial spreading results. In this section, within three network models, we randomly set the first entrepreneurial platform enterprises as target nodes, with the initial number of target nodes set at 5%, 10%, and 15% of the initial nodes respectively. Based on different spreading probabilities under the active influence model in the neighbor effect, we study the spreading results generated by target nodes on their connected nodes. This paper argues that entrepreneurial spreading is a repeated and cumulative phenomenon: after the first spreading act is completed, the nodes affected by entrepreneurial spreading become entrepreneurial enterprises and serve as target nodes for the next spreading, continuing the process. Therefore, on the basis of setting the initial number of target nodes, we observe the impact of multiple entrepreneurial spreadings on spreading results through 50, 100, and 200 spreading processes, output spreading result charts, analyze the differences among S, T, E, and CV, and thus obtain the results in

Table 2.

[Table 2 near here]

[Figure 9,10,11 near here]

From Table 2, it can be seen that through the results of multiple model operations, when other conditions remain unchanged and the number of initial target nodes is changed, the cumulative number of entrepreneurial attempts after 50, 100, and 200 spreading processes under different influence modes in the three types of models show proportional increases. That is, the number of spreading processes has almost no difference on the average number of entrepreneurial enterprises and the average spreading stabilization time. Therefore, this study concludes that the number of spreading processes has no heterogeneous impact on the results of entrepreneurial spreading.

Under the active influence mode, Figures 9, 10 and 11 respectively show the entrepreneurial conduction results under the initial number of entrepreneurial enterprises of 5%, 10% and 15% in the three network structures. Since the number of conduction times has little influence on the conduction results, this part selects the parameters corresponding to 50 conduction times for further analysis, and the simulation results of 100 and 200 conduction times are only used as comparison and reference. In the BA model—hub-and-spoke network, the conduction stabilization time of 5% initial entrepreneurial enterprises is 102,200 ticks, the conduction amplification coefficient is 450, and the concentration of entrepreneurial behavior is 0.066. The conduction stabilization time of 10% initial entrepreneurial enterprises is 102,000 ticks,

the conduction amplification coefficient is 460, and the concentration of entrepreneurial behavior is 0.059; the conduction stabilization time of 15% initial entrepreneurial enterprises is 101,800 ticks, the conduction amplification coefficient is 461, and the concentration of entrepreneurial behavior is 0.065. In the LN model—hybrid network, the conduction stabilization time of 5% initial entrepreneurial enterprises is 102,110 ticks, the conduction amplification coefficient is 430, and the concentration of entrepreneurial behavior is 0.055; the conduction stabilization time of 10% initial entrepreneurial enterprises is 102,100 ticks, the conduction amplification coefficient is 440, and the concentration of entrepreneurial behavior is 0.055; the conduction stabilization time of 15% initial entrepreneurial enterprises is 1,016,000 ticks, the conduction amplification coefficient is 443, and the concentration of entrepreneurial behavior is 0.05. In the ER model — market-oriented network, the conduction stabilization time of 5% initial entrepreneurial enterprises is 102,000 ticks, the conduction amplification coefficient is 440, and the concentration of entrepreneurial behavior is 0.069; the conduction stabilization time of 10% initial entrepreneurial enterprises is 101,100 ticks, the conduction amplification coefficient is 445, and the concentration of entrepreneurial behavior is 0.052; the conduction stabilization time of 15% initial entrepreneurial enterprises is 101,200 ticks, the conduction amplification coefficient is 445, and the concentration of entrepreneurial behavior is 0.048.

5.Results Analysis and Discussion

5.1 Results Analysis of Mechanism Evolution under Different Spreading Sources

Under the same network structure, using different spreading sources as references,

whether selecting platform enterprises as the spreading source has little impact on the final number of entrepreneurial enterprises. **However, in terms of spreading rate, entrepreneurial spreading with platform enterprises as the spreading source is faster in the early stage. When the spreading progresses to the mid-late stage, regardless of whether platform enterprises are chosen as the spreading source, the difference in spreading speed is minimal**, and entrepreneurial spreading in the network basically proceeds at the same rate. This study argues that the main reason is that in the early spreading stage, the entrepreneurial behavior of platform enterprises sends more direct spreading signals to other enterprises in the entrepreneurial network. Due to the core competitiveness and rich resource advantages of platform enterprises, their entrepreneurial orientation determines the orientation of the entrepreneurial network. Meanwhile, other enterprises can more intuitively receive and imitate the entrepreneurial information from platform enterprises. In contrast, if other enterprises serve as spreading sources, the initial stage suffers from information asymmetry and low status in the entrepreneurial network, limiting the scope of entrepreneurial signal transmission. For the overall entrepreneurial network, only a few other enterprises perceive the entrepreneurial signals or reject spreading in the early stage due to weak signals, leading to slower spreading. However, after a period of transmission, as the number of entrepreneurial enterprises increases, issues like information asymmetry disappear, and the later spreading speed shows no obvious difference compared to that with platform enterprises as the spreading source.

From the perspective of network structure, regardless of whether platform

enterprises or random enterprises within the entrepreneurial network are used as spreading sources, **the BA model has a slight advantage over the other two network models in terms of the final number of entrepreneurial enterprises, with a relatively higher probability that other enterprises accept entrepreneurial behavior and succeed in entrepreneurship. The final number of entrepreneurial enterprises in the ER model and LN model is more balanced,** and entrepreneurial spreading with random enterprises as spreading sources has more advantages in the ER model. The reason may be attributed to the network architecture characteristics of the BA model: whether it is enterprise entrepreneurship or entrepreneurship of other enterprises, inter-enterprise cooperation and entrepreneurial learning mainly unfold through one or several core platform enterprises, making imitation and learning paths easier. An enterprise's entrepreneurial behavior can drive multiple connected enterprises to accept entrepreneurial behavior and promote the development of entrepreneurial activities. In contrast, the ER model and LN model have more diversified network connections and more complex internal relationships between enterprises, so there are multiple reasons for not accepting or failing to receive entrepreneurial signals, leading to no entrepreneurial behavior. In the ER model, using random enterprises as spreading sources results in a higher spreading success rate. Due to the uncertainty of network relationships of random enterprises in the network, there are more channels for entrepreneurial spreading, increasing the spreading probability and thus the final number of entrepreneurial enterprises.

In real life, entrepreneurial spreading involves many factors that need to be

considered. It is necessary to not only take into account the network connection patterns between enterprises, but also pay attention to the strong and weak ties between enterprises and external environmental factors of the entrepreneurial network. However, this study only considered two relatively single factors in the simulation design, namely the structure of the entrepreneurial network and the spreading source. Therefore, there may be certain differences between the simulation results and the actual situation.

5.2Analysis of Results on Mechanism Evolution under Different Initial Numbers of Entrepreneurial Enterprises

Within the same network structure, as the proportion of initial entrepreneurial enterprises increases, the total time for entrepreneurial spreading shortens, and the concentration of entrepreneurial behavior decreases. This indicates that **the number of initial entrepreneurial enterprises can accelerate the spreading speed of entrepreneurial behavior within the entrepreneurial network, enabling faster and more effective dissemination of entrepreneurial behavior and promoting its equilibrium.** This study argues that the main reasons are as follows: First, the scale of initial entrepreneurial enterprises determines the entrepreneurial environment of the network. Entrepreneurial enterprises often possess rich resource advantages and entrepreneurial information. Under a specific network structure, a wider distribution of initial entrepreneurial enterprises means a stronger entrepreneurial atmosphere in the network, increasing the probability that other enterprises can receive new technologies and resources. Enterprises in a healthy entrepreneurial network tend to exhibit stronger learning willingness, thus accelerating the spreading process of the entire

entrepreneurial network. Second, the scale of initial entrepreneurial enterprises also reflects the diversity of entrepreneurial resources. Different entrepreneurial entities often have differentiated innovative development strategies, and the diversity of development strategies can increase the probability of enterprises accepting entrepreneurial behavior and accelerate entrepreneurial spreading.

Under the same proportion of initial entrepreneurial enterprises, **a comparison of the three network architectures shows that the spreading stabilization time in the three models follows the order ER < LN < BA. The stabilization time in the ER model is significantly shorter than that in the other two network structures, indicating that entrepreneurial signals in the market-type network can be transmitted to associated enterprises faster to form a spreading effect.** In terms of the spreading amplification coefficient, the market-type network has the highest cumulative number of entrepreneurial behaviors, suggesting that it is more conducive to entrepreneurial spreading than the other two networks. This study argues that the reason for this result is that the market-type network has more complex relationships and more diversified connections between enterprises compared with the other two networks. As a result, the entrepreneurial behavior of any enterprise in the network can be transmitted to associated enterprises in a multi-chain spreading manner, providing more spreading paths and shorter spreading time. Thus, under the same proportion of initial entrepreneurial enterprises, the market-type platform has the shortest spreading stabilization time, can form a spreading effect faster, and is more conducive to entrepreneurial spreading.

Therefore, this study concludes that within the same network structure, both using platform enterprises as spreading sources and increasing the number of initial entrepreneurial enterprises can accelerate entrepreneurial spreading. The spreading rate of platform enterprises as sources is mainly reflected in the early stage of spreading. When comparing different network structures, the hub-and-spoke network promotes more entrepreneurial activities, while the market-type network accelerates the spreading process.

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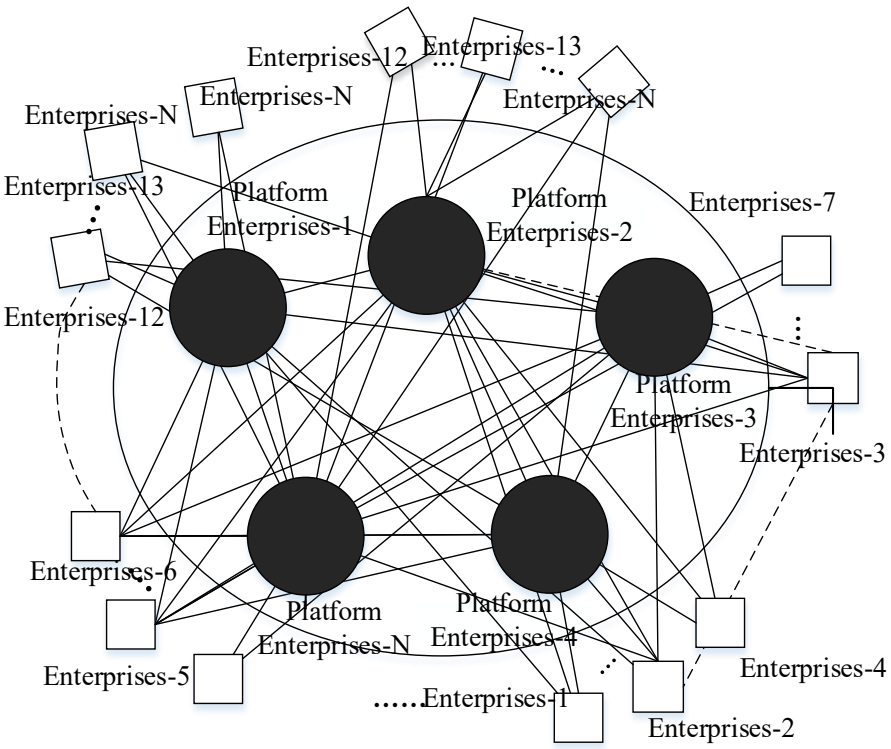


Figure 1: Network structure diagram of market-oriented network

Data Source: Drawn by the author based on relevant literature.

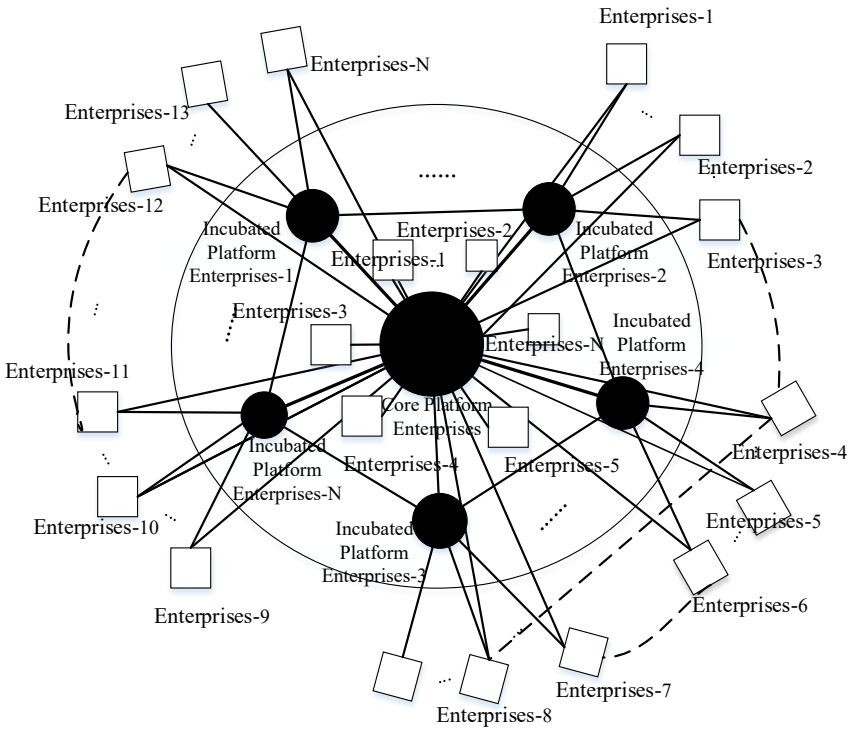


Figure 2: Network structure diagram of hybrid network

Data Source: Drawn by the author based on relevant literature.

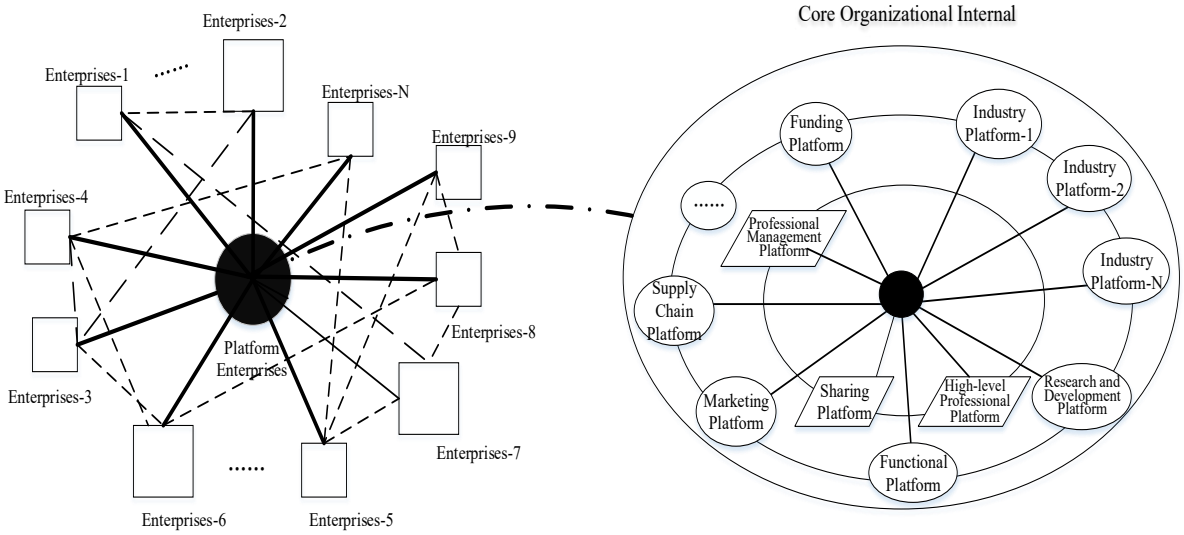
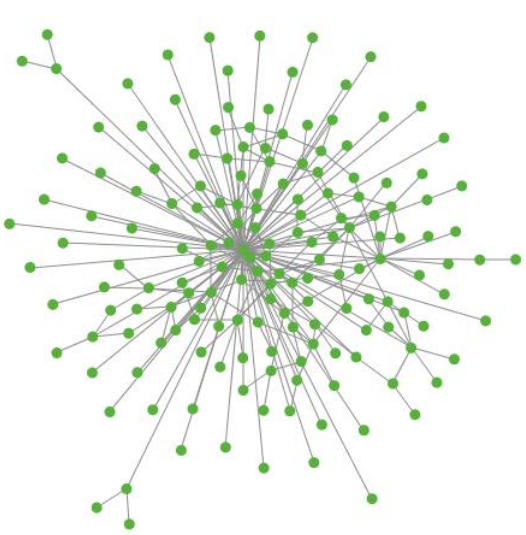
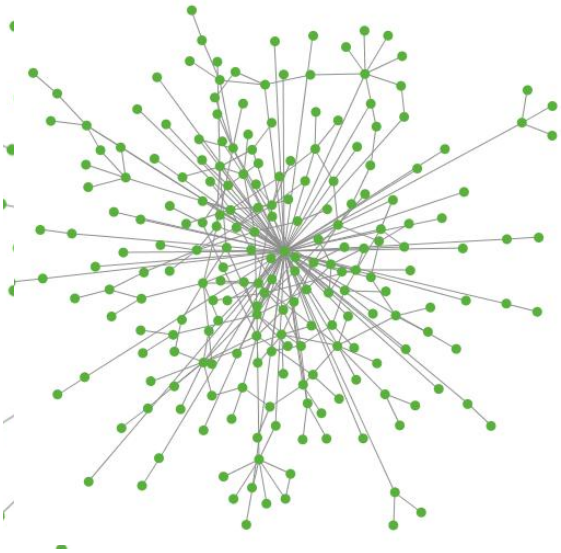


Figure 3: Network structure diagram of hub-and-spoke network

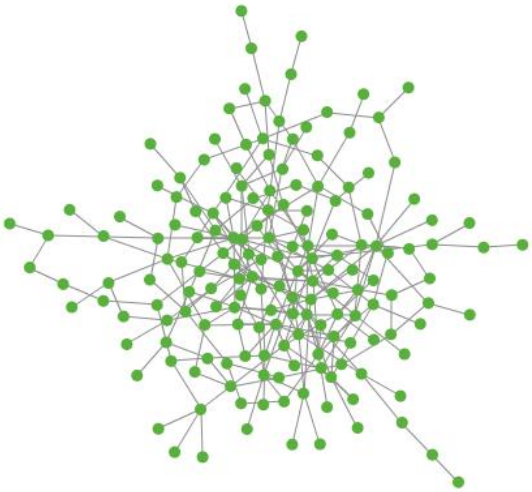
Data Source: Drawn by the author based on relevant literature.



(1)BA Model—Hub-and-Spoke Network



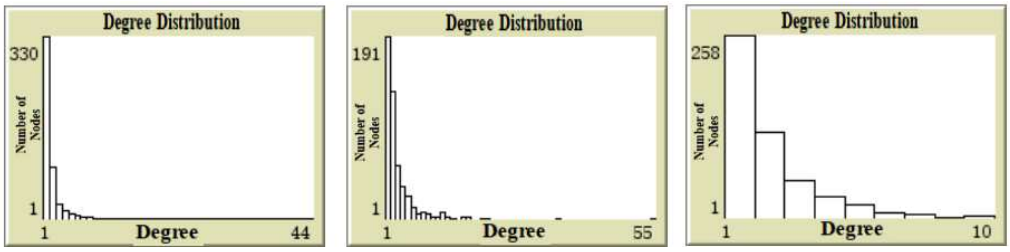
(2)LN Model—Hybrid Network



(3)ER Model—Market-Oriented Network

Figure 1 Simulation Diagrams of Three Network Types(N=500)

Data Source: Drawn by the author



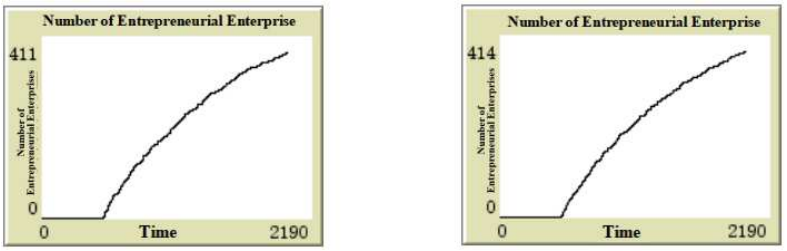
(1)BA Model
Hub-and-Spoke Network

(2)LN Model
Hybrid Network

(3)ER Model
Market-Oriented Network

Figure 2 Comparison of Degree Distributions for Three Network Structures(N=500)

Data Source: Drawn by the author

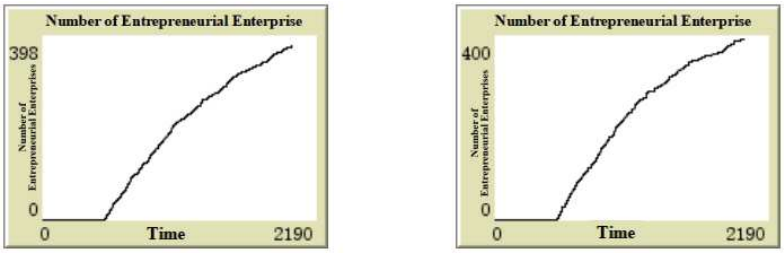


(a)BA Model with Platform Enterprises as Spreading Source

(b)BA Model with Other Enterprises as Spreading Source

Figure 3 Spreading Results of Different Spreading Sources in BA Model

Data Source: Drawn by the author

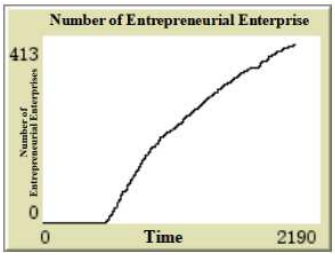


(a)LN Model with Platform Enterprises as Spreading Source

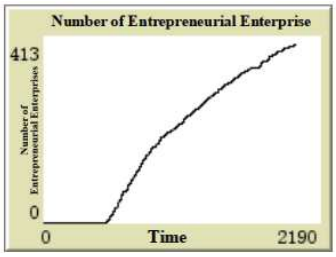
(b)LN Model with Other Enterprises as Spreading Source

Figure 4 Spreading Results of Different Spreading Sources in LN Model

Data Source: Drawn by the author



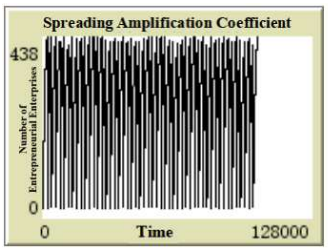
(a)ER Model with Platform Enterprises as Spreading Source



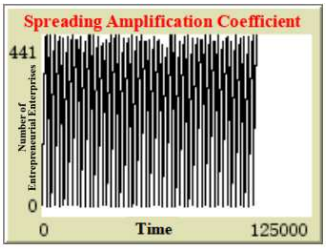
(b)ER Model with Other Enterprises as Spreading Source

Figure 5 Spreading Results of Different Spreading Sources in ER Model

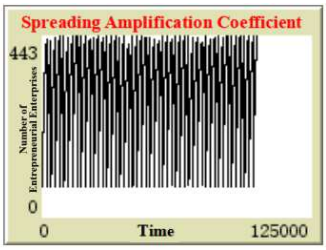
Data Source: Drawn by the author



(a)5% Initial Number of Entrepreneurial Enterprises



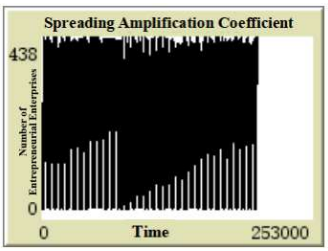
(b)10% Initial Number of Entrepreneurial Enterprises



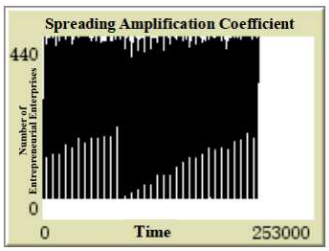
(c)15% Initial Number of Entrepreneurial Enterprises

Figure 6 Entrepreneurial Spreading Results of Different Initial Numbers of Entrepreneurial Enterprises under Active Influence (BA Model—Hub-and-Spoke Network)

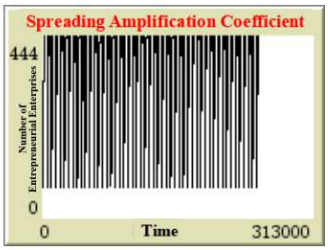
Data Source: Drawn by the author



(a)5% Initial Number of Entrepreneurial Enterprises



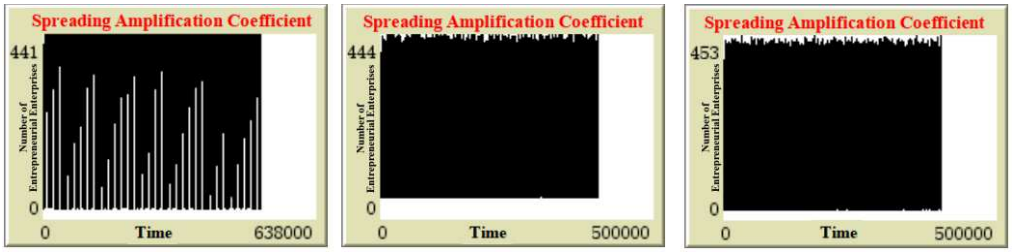
(b)10% Initial Number of Entrepreneurial Enterprises



(c)15% Initial Number of Entrepreneurial Enterprises

Figure 7 Entrepreneurial Spreading Results of Different Initial Numbers of Entrepreneurial Enterprises under Active Influence (LN Model—Hybrid Network)

Data Source: Drawn by the author



(a)5% Initial Number of Entrepreneurial Enterprises (b)10% Initial Number of Entrepreneurial Enterprises (c)15% Initial Number of Entrepreneurial Enterprises

Figure 8 Entrepreneurial Spreading Results of Different Initial Numbers of Entrepreneurial Enterprises under Active Influence (ER Model—Market-Oriented Network)

Data Source: Drawn by the author

Table 1 Comparison of Three Network Types

Indicator Characteristics \ Network Type	Market-oriented networks	Hybrid Network	Hub-and-spoke Network
Network Scale	Small	Medium	Large
Network Diversity	Single	Moderate	Rich

Data Source: Collated by the author.

Table 2 Spreading Results of Different Initial Numbers of Entrepreneurial Enterprises

Network Classification	Simulation Input Parameters		Simulation Output Indicators			
	Initial Number of Entrepreneurial Enterprises	Number of Spreading Times	S（Spreading Success Rate）	T（Spreading Stabilization Time）	E（Spreading Amplification Coefficient）	CV（Concentration of Entrepreneurial Behavior）
BA Model	5%	50	450	102200	10568	0.066
		100	453	203000	51000	0.014
		200	453	407700	102200	0.008
	10%	50	460	102000	25600	0.059
		100	463	200900	51100	0.015
		200	463	405500	10200	0.008
	15%	50	461	101800	25600	0.065
		100	463	202880	50800	0.013
		200	463	404500	101200	0.007

Network Classification	Simulation Input Parameters		Simulation Output Indicators			
	Initial Number of Entrepreneurial Enterprises	Number of Spreading Times	S（Spreading Success Rate）	T（Spreading Stabilization Time）	E（Spreading Amplification Coefficient）	CV（Concentration of Entrepreneurial Behavior）
LN Model	5%	50	430	102110	21750	0.055
		100	435	202000	43800	0.038
		200	435	407000	85600	0.029
	10%	50	440	102100	21800	0.055
		100	440	203000	44000	0.039
		200	440	407000	88800	0.027
	15%	50	443	101600	22250	0.05
		100	443	202000	45400	0.034
		200	442	402000	90400	0.024
ER Model	5%	50	440	102000	25600	0.069
		100	435	201000	51500	0.012
		200	436	405000	102000	0.003
	10%	50	445	101100	25600	0.052
		100	440	200600	51100	0.010
		200	438	405000	88800	0.028
	15%	50	445	101200	22000	0.048
		100	444	199000	45100	0.034
		200	445	401800	87600	0.024

Data Source: Collated by the author.

Supplementary Files

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