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A study of knowledge supernetworks and network robustness in different business incubators

Haihong Zhang, Wenqing Wu *, Liming Zhao

College of Management and Economics, Tianjin University, Tianjin 300072, China

HIGHLIGHTS

- We describe the heterogeneity of incubating firms using a knowledge supernetwork.
- Knowledge interaction and network evolution show cyclical fluctuation in incubators.
- Different incubators are similar with respect to the stability of network structures.
- Specialized business incubators have stronger network communication abilities.

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ABSTRACT

As the most important intangible resource of the new generation of business incubators, knowledge has been studied extensively, particularly with respect to how it spreads among incubating firms through knowledge networks. However, these homogeneous networks do not adequately describe the heterogeneity of incubating firms in different types of business incubators. To solve the problem of heterogeneity, the notion of a knowledge supernetwork has been used both to construct a knowledge interaction model among incubating firms and to distinguish social network relationships from knowledge network relationships. The process of knowledge interaction and network evolution can then be simulated with a few rules for incubating firms regarding knowledge innovation/absorption, social network connection, and entry and exit, among other aspects. Knowledge and networks have been used as performance indicators to evaluate the evolution of knowledge supernetworks. Moreover, we study the robustness of incubating firms' social networks by employing four types of attack strategies. Based on our simulation results, we conclude that there have been significant knowledge interaction and network evolution among incubating firms on a periodic basis and that both specialized and diversified business incubators have every advantage necessary in terms of both knowledge and networks to cultivate start-up companies. As far as network robustness is concerned, there is no obvious difference between the two types of business incubators with respect to the stability of their network structures, but specialized business incubators have stronger network communication abilities than diversified business incubators.

1. Introduction

Business incubators (BIs) are popular tools that have been established worldwide to foster and accelerate the process of creating successful firms and entrepreneurs. Today's third-generation BIs typically focus on new-technology-based

* Corresponding author. Tel.: +86 15522235789.
E-mail addresses: haihongz@tju.edu.cn (H. Zhang), wenqingw@tju.edu.cn (W. Wu), zhaolm@tju.edu.cn (L. Zhao).

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firms [1], which contrasts with the first-generation of incubators that emphasized companies associated with real estate (e.g., infrastructure, shared resources) [2–5], and the second-generation, which emphasized companies that provided intangible services (e.g., business experience, marketing skills) [6–10]. Because of the knowledge-intensive nature of new-technology-based firms, the knowledge factor has become increasingly important in BIs. Knowledge is recognized as a critical resource to gain and maintain a competitive advantage in business [11]. Neves et al. [12] analyze micro and small firms in Brazilian incubators and conclude that knowledge is essential to conduct activities that encourage innovation. In the context of university-based incubators, Rothaermel et al. [13] argue that BIs should facilitate knowledge flows from the university to these incubator firms. Kai et al. [14] explore the relationships among social capital, knowledge acquisition and knowledge exploitation and find that social capital has a positive effect on an incubating firm's knowledge acquisition.

BI development has now entered a period of networked incubators, and BIs' knowledge networks play an important role in promoting the growth of incubating firms. Some studies indicate that networks can emerge among incubating firms and external actors [15–17] and are used for knowledge sharing purposes [4,18]. A communication and knowledge-based view of the firm has been used to examine how incubating firms communicate in BIs [19]. Incubating firms' expectations for dynamic informal communication are inspired by their proximity to one another [20]. Proximity to the other members of an incubator in the network increases the likelihood that tacit knowledge will be transferred [21]. Cooper et al. [22] use a combination of network analyses to determine the motivations of incubating firms with respect to participating in networking activities. Soetanto et al. [23] believe that incubating firms are more likely to develop networks to access intangible as opposed to tangible resources. Another facet of BI knowledge networks that is advanced from the micro perspective involves analyzing knowledge nodes [24].

BIs are typically divided into diversified business incubators (DBIs) and specialized business incubators (SBIs). The degree of heterogeneity among incubating firms in terms of knowledge is different in diverse types of BIs. Chan et al. [2] suggest that homogeneity increases the likelihood of knowledge sharing among incubating firms. Tötterman et al. [25] find that too much diversification impedes communication and exchange relationships. Schwartz et al. [26] argue that incubating firms in DBIs show poor performance, whereas those in SBIs demonstrate better performance. However, other studies find that networking and cooperation efforts are not necessarily more effective with SBIs than with DBIs and that SBIs are not superior to DBIs in certain aspects [27,28]. The knowledge supernetwork, which can be applied to various fields to describe knowledge and information transfers [29–33], is an effective way to demonstrate the heterogeneity and compare the performance of two types of BIs. To study the characteristics of a knowledge network, Yu et al. [34] and Li et al. [35] propose a supernetwork model of knowledge resources that includes a network of persons, a material network and a knowledge network. In addition, many complex networks exhibit a surprising degree of tolerance for errors, and Albert et al. [36] remain convinced that error tolerance and attack vulnerability constitute generic properties of communication networks. Thus, we also consider the robustness of networks that emerge among incubating firms as an important factor that can affect the performance of the BIs. The robustness of different networks has been widely studied and is often evaluated by indicators such as the size of the largest connected component and network efficiency [37,38].

Although the previous literature has studied knowledge networks among incubating firms in BIs, these studies are typically confined to knowledge learning and diffusion within a homogeneous network. Such a network structure cannot demonstrate the heterogeneity of the incubating firms or depict the double network formed by an incubating firm's knowledge relationships and social relationships. In this paper, we constructed a knowledge interaction mechanism among incubating firms based on a knowledge supernetwork and used a simulation tool to show the emergence process of knowledge and networks from a micro perspective. Moreover, we compared the performance of knowledge supernetworks from DBIs versus SBIs and studied network robustness.

The remainder of this paper is organized as follows. Section 2 describes the model's construction. Section 3 provides statistical indexes of knowledge and network features. The simulation results and system performance are shown in Section 4. We discuss network robustness in Section 5. Finally, we briefly discuss our conclusions in Section 6.

2. The model

2.1. General description of the knowledge supernetwork model

We cannot explain the heterogeneity of incubating firms solely in terms of a social network or knowledge network; however, a type of supernetwork known as a knowledge supernetwork [34] can solve this problem. In this paper, the knowledge supernetwork consists of two subnetwork layers, i.e., the K–K knowledge network and the P–P social network. In addition, there are two types of nodes in the knowledge supernetwork: incubating firm nodes and knowledge nodes. According to the hypergraph theory, the model can be presented as follows:

$$G = \left(G_p, G_k, E_{p-k}\right), \tag{1}$$

where $G_p = \left(P, E_{p-p}\right)$ is the undirected social network among incubating firms, $P = \{p_1, p_2, \ldots, p_m\}$ denotes the set of incubating firms (knowledge owners), m is the number of incubating firms, and $E_{p-p} = \left\{(p_i, p_j)|e(p_i, p_j) = 1\right\}$ is the set of edges that denotes relationships between incubating firms. $G_k = (K, E_{k-k})$ is the directed knowledge network that can be generated with knowledge points, $K = \{k_1, k_2, \ldots, k_n\}$ denotes the set of knowledge points, n is the number of knowledge