The Effect of Technology Group Coupling on the Failure of Industrial Innovation Network

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Abstract: Recently, innovation has gradually transformed from a single enterprise behavior into a group innovation behavior based on inter-enterprise cooperation. Technology group coupling, a critical element for reducing network failure, has become a common phenomenon in the development of industrial innovation networks. This study discusses the relationship between technology group coupling and innovation network failure at the whole-network level, which responds to the call for the impact of community interaction on network-level outcomes.

1 Introduction

As an institutional arrangement to address systematic innovation (Freeman,1991), industrial innovation networks refer to the network organizations formed by technology subjects with complementary resources through formal or informal cooperative innovation. Most studies have reported that industrial innovation networks serve as important carriers for the flow of innovation resources and provide network support for risk sharing. However, industrial innovation networks are extremely vulnerable and even fail due to elements, such as the failure of hubs, interaction failure between the actors or groups, and external environment shock (Wang. et al., 2010; van der Valk et al., 2011; Ozcan and Islam, 2014; Schilling and Fang, 2014). How to improve the invulnerability of industrial innovation networks to reduce failure has become a major issue and is in urgent need of further exploration (Woolthuis et al., 2005; Corley et al., 2006). Recently, the innovation cooperation between technology subjects has gradually changed to the level of technology groups, which is a concept in the middle level of industrial innovation networks considered a sub-group formed by the frequent interaction of knowledge, technology and resource between technology subjects with similar technology sources (Lyu et al., 2019). The existing literature notes that the coupling between technology groups is a critical element for reducing network failure (Carlsson and Jacobsson, 1997; Woolthuis et al., 2005). Our work responds to the call to explore the effect between subgroups on network-level outcomes (Provan et al., 2007).

2 Literature Review

2.1 Industrial Innovation Networks' Failure and Invulnerability

The existing literature concerning network failure can be divided into dynamic cascade network failure under external motivation and static weak network failure caused by internal failure. On the one hand, network cascading failure occurs when the failure of a few members triggers potential chain failures among the other network members. Zhang and Yang (2014) adopted simulation experiments to analyze the dynamic characteristics, coping or control strategies of cascading failure in R&D networks. Wang et al. (2010) identified three factors of the industrial group innovation networks' failure by establishing a cascading failure model. For example, the numerous SMEs in the Shaoxing textile industrial innovation group of China were on the verge of a devastating and cascading bankruptcy after being hit by the global financial turmoil in 2008. On the other hand, Carlsson and Jacobsson (1997)

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distinguished between strong and weak network failures from the perspective of internal interaction (Carlsson and Jacobsson, 1997). Strong network failure refers to the noncirculation of heterogeneous knowledge in the whole network caused by the lack of bridging between subgroups formed by close interaction, while weak network failure refers to actors' inadaptability to new technologies due to poor, limited or no interaction among actors with complementary technologies (Carlsson and Jacobsson, 1997; Woolthuis et al., 2005; Negro et al., 2012).

Network invulnerability is perceived widely as an effective tool for investigating the network against failure in the field of complex networks (Yang et al., 2015; Wang et al., 2018). Network invulnerability refers to the ability of the network to continue working when it suffers from random failures or intentional attacks (Albert et al., 2004; Yin et al., 2016). Existing studies generally assess network invulnerability from the two dimensions of structural robustness and functional effectiveness, which represent the connectivity and efficiency of the network (Yang et al., 2015; Wang et al., 2018). Much of the literature innovation study introduces network invulnerability to describe the stability or health of the network structure (Cowan et al., 2007; van der Valk et al., 2011; Ozcan and Islam, 2014), while some studies connect the flow of knowledge. For instance, Goerzen (2018) described the paths along which knowledge flow plays a role in network connectivity; Okamura and Vonortas (2006) evaluated the effectiveness of networks through the efficiency of knowledge flow as a channel; Garavelli et al. (2002) stated that the extension of the knowledge span and the increase in knowledge transfer speed are valuable parts of knowledge management.

2.2 Technology Group Coupling

Technology groups formed by the frequent interaction of knowledge, technology and resource sharing between technology subjects with similar technology sources. The two characteristics are as follows. On the one hand, the internal tight knowledge flow of a technology group is likely to lead to knowledge homogeneity and redundancy (Granovetter, 1973; Burt, 1992), resulting in the negative effects of myopia and inertia (Granovetter, 1985; Andersson et al., 2007). On the other hand, the knowledge sharing between different technology groups tends to be heterogeneous, asymmetrical and complementary, which is driven by coupling across technology groups (Voudouris et al., 2012; Gilsing et al., 2014). According to Pressman (2005), coupling is a measure of how closely two or more modules are connected and the strength of their relationship. In this study, the complementary flow of knowledge is defined as the coupling of any pair of technology groups. At the whole network level, we define technology group coupling as the sum of the degree of coupling of all technology groups in an industrial innovation network.

2.3 Technology Group Coupling and Network Invulnerability

We hold the opinion that technology group coupling positively influences on network invulnerability. On the one hand, technology group coupling increases the network reachability by bridging multiple and heterogeneous knowledge pools (Padula, 2008; Tiwana, 2008; Bergé et al., 2017; Lyu et al., 2019). The bridging ties between technology groups provide a variety of direct routes for knowledge flow across the boundaries of technology groups (Lorenzen and Mudambi, 2012; Zhang et al., 2017). Thus, the actors within technology groups access a broad spectrum of knowledge, which promotes varied knowledge flow in the whole innovation network. On the other hand, technology group coupling stimulates the efficiency of knowledge flow due to the effect of strong bridging ties. Bridges between technology groups shorten the overall distance (path length) of the industrial innovation network, enabling knowledge to spread more rapidly throughout the network (Valente and Fujimoto, 2010). The strength of bridging ties can help foster and accelerate knowledge diffusion by connecting difficult-to-reach knowledge areas (Capaldo, 2007; Tortoriello and Krackhardt, 2010). Based on the above analyses, we argue that technology group coupling not only builds multidimensional routes to expand the scope of knowledge flow but also promotes the diffusion of heterogeneous knowledge of the entire network.

3 Theoretical Contribution and Managerial Implication

This study contributes to the literature concerning innovation network failure by exploring whether technology group coupling reduces the failure of industrial innovation networks (Foxon et al., 2005; Woolthuis et al., 2005; Hu and Hung, 2014). The extant studies of the innovation network have paid inadequate attention to network failure, especially the failure of knowledge flow at the whole network level (Okamura and Vonortas, 2006; Goerzen, 2018), although some literature has described the vulnerability structure of the innovation network. We discuss the impacts of varied and intensive knowledge flow between technology groups on the structural robustness and functional effectiveness of the whole industrial innovation network (Sytch et al., 2012; Jacob and Duysters, 2017; Goerzen, 2018). By doing so, we respond to the call of Provan et al. (2007) to explore the interaction of subgroups on network-level outcomes that a clique's size as well as ties inside and across subgroups have effects on network-level outcomes.

Conclusion

Policy design should be directed towards encouraging the technological knowledge flow across the boundaries of technology groups, which is beneficial in reducing the failure of the industrial innovation network. On the one hand, aimed at reinforcing the structural robustness of industrial innovation networks, we suggest the creation of a wealth of opportunities for heterogeneous technology groups to flow and diffuse complementary technological knowledge. Policy proposals to improve technological interaction between technology groups include the establishment of joint development and research platforms, the hosting of technological innovation forums or seminars, etc. On the other hand, policy proposals related to accelerating the functional effectiveness of the industrial innovation network can be recommended to increase the frequency of interactions of technological knowledge between distinct technology groups to overcome the mutual strangeness of the foreign knowledge base.

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