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## **Social network and radical innovation: evidence from the U.S. pharmaceutical and biotechnology industry**

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**CHAPTER 1**  
**General introduction**

## 1.1 Introduction

Innovation is a key driving force of economic growth and social progress (Schumpeter, 1942). It plays an essential role in firms' competitiveness and long-term success (Anderson et al., 2014; Kock et al., 2011; Kraft & Bausch, 2018). For example, Schumpeter (1942) considered firm innovation as the “fundamental impulse that sets and keeps the capitalist engine in motion” and coined the term “creative destruction”, a process that new innovation “revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one.” However, innovations come in different types, ranging from run-of-the-mill innovation that bring incremental changes to existing technologies to radical innovation that break from existing trajectories (Anderson & Tushman, 1990; Verhoeven et al., 2016). For example, Anderson and Tushman (1990) distinguished between competence-enhancing and competence-destroying technological discontinuities. Dahlin and Behrens (2005) emphasized three defining features of radical innovation: novel, unique, and having a major impact on future technology. Funk and Owen-Smith (2017) and Chen et al. (2021) viewed radical innovations as those that destabilize existing technology trajectories or create new directions. Following previous literature, this PhD dissertation focuses on the technological perspective of innovation, and defines radical innovation as innovation that brings intensive destruction and changes technology trajectories.

Radical innovation has received a lot of attention from innovation scholars and practitioners, and it is considered as the core of entrepreneurial activity and wealth creation (Ahuja & Morris Lampert, 2001; Schumpeter, 1942; Verhoeven et al., 2016). For example, the turbojet engine is a radical innovation compared with the traditional propeller engines, which opens up new directions for many subsequent innovations and realizes considerable growth in the aviation industry. Considering the importance of radical innovation, unpacking the determinants and consequences of radical innovation is of major interest to academia and industry.

Prior studies have extensively investigated technological origins of radical innovation. However, we know relatively little about the social determinants of radical innovation in the organizational and social environment. In social network literature, there is a long discussion about the advantages and disadvantages of different types of network structure on creativity and innovation, in particular

debates between strong and weak ties, and between network cohesion and structural holes (Burt, 1992; Coleman, 1988; Granovetter, 1982; Uzzi, 1996, 1997). Competing theories are developed and empirical evidence is also mixed. Some researchers highlight the benefits of weak ties and structural holes, while others suggest advantages of strong ties and network cohesion for radical innovation (Burt, 1992; Coleman, 1988; Granovetter, 1973; Nahapiet & Ghoshal, 1998). This dissertation (Chapter 2) separates two faces of weak ties and structural holes: their informational advantages in accessing the diverse knowledge that is needed for radical innovation, and their relational disadvantages linked to a weaker shared understanding and trust. More importantly, this dissertation (Chapter 2) explores how weak ties and structural holes collectively effect on radical innovation, which provides a promising direction for reconciling competing theories about network effects.

Another reconcile direction is to examine different stages of the creative process, and the common wisdom is that information diversity provided by weak ties and structural holes are particularly beneficial for generating novel ideas, while reciprocity norms, trust, and fine-grained information exchange offered by strong ties and network cohesion are advantageous for idea implementation, transfer, and adoption (Burt, 2004; Fleming et al., 2007; Perry-Smith & Mannucci; Reagans & McEvily, 2003; Tortoriello & Krackhardt, 2010). Building on this line of literature, this dissertation (Chapter 3) explores how collaboration network for idea production affects the diffusion of the produced idea and highlights that the same social structure that is conducive for producing a creative idea might hamper its diffusion. Investigating differential effects of network structure on idea production and diffusion provides valuable insights into the complex network effects. Moreover, this dissertation (Chapter 3) examines the moderating effect of innovation radicalness, considering the fundamental differences between radical and incrementation innovations. This complements the innovation research about the contingency effects of innovation types.

In addition to examining the contingency effects of innovation, this dissertation (Chapter 4) also investigates radicalness as the independent variable. Exploring how radicalness affects the private value for the innovating firm, this dissertation (Chapter 4) provides empirical evidence that radicalness has important influence on firms' private value. Considering the diverse approaches for conceptualizing and operationalizing radicalness, this dissertation (Chapter 4) differentiates between two

dimensions of radicalness: destructiveness and dissimilarity. This dissertation (Chapter 4) provides a useful approach for reconciling seemingly conflicting empirical findings in previous literature and makes an original contribution to the literature of radical innovation by unpacking the novelty concept into two components.

The aim of this PhD dissertation is to integrate radical innovation and social network literature to broaden theoretical understanding, especially contribute to the literatures of social networks, creativity, and innovation, and inform innovation management by unpacking the drivers and effects of radical innovation.

We study the network effect on radical innovation in the context of multinational corporations' internal R&D collaboration networks. Overseas R&D is playing an increasingly important role in the R&D networks of multinationals, and the competitiveness of the firm relies on its ability to coordinate its R&D activities across the globe (Alcácer & Zhao, 2012; Almeida & Phene, 2004; Belderbos et al., 2021; Du et al., 2022; Kuemmerle, 1997). While prior studies have systematically investigated drivers of R&D location decisions and strategies for coordinating subsidiaries, it has not yet studied how the network structure affects radical innovation at a particular R&D location. To test hypotheses, we construct a panel dataset consisting of 16,011 unique sites (i.e., firm-locations) belonging to the 93 most innovative U.S. pharmaceutical and biotechnology companies according to the EU Industrial R&D Investment Scoreboard.

## **1.2 Structure and research questions of this PhD dissertation**

To advance our understanding about the existing innovation literature, this dissertation investigates the determinants of radical innovation and its social and economic impact. Specifically, Chapter 2 studies the social driving forces of radical innovation; Chapter 3 demonstrates the social impact of network structure and the role that radicalness plays in their relationships; Chapter 4 explores the economic impact of different dimensions of radicalness. To summarize, Chapter 2 to Chapter 4 aim to answer the following three research questions:

***Research Question 1: How does network structure affect innovation radicalness?***

The innovation and social network literatures have long highlighted the importance of network structure for individual and organizational innovation performance. The literature among researchers exhibits varying perspectives on the influence of tie strength and network structures in promoting radical innovation (Burt, 1992; Coleman, 1988; Fleming et al., 2007; Granovetter, 1973; Nahapiet & Ghoshal, 1998; Perry-Smith, 2006; Rost, 2011). For example, the brokerage view, which is grounded on Burt's (1992) structural hole theory, contends that sparse networks which full of structural holes can benefit innovation because of the nonredundant information. By contrast, the bonding view which builds on Coleman's (1988) view, argues that cohesive network facilitates innovation because of cultivate trust, common understanding, and reciprocity. This dissertation aims to reconcile these competing theories. Chapter 2 explores how network structure affects radical innovation in the context of corporate R&D networks. Specifically, Chapter 2 separates two faces of weak ties and structural holes: their informational advantages in accessing the diverse knowledge that is needed for radical innovation, and their relational disadvantages linked to a weaker shared understanding and trust. To test hypotheses, Chapter 2 builds a unique panel dataset consisting of 19,343 firm-location-time observations for 16,011 unique firm-locations belonging to 93 U.S. pharmaceuticals and biotechnology companies on the EU Industrial R&D Investment Scoreboard. Following Funk and Owen-Smith (2017), radicalness is measured as the extent to which the focal patent family destabilizes existing technology trajectories. Tie strength between two R&D locations is captured as their frequency of co-inventing patent families, and structural hole is calculated as the share of missing ties in an egocentric network excluding the ego itself. Findings of this chapter provide empirical evidence of how tie strength and structural holes collectively affect innovation radicalness at a location within an innovation firm. More specifically, findings of this chapter demonstrate that the informational advantages of structural holes can be mobilized if there are strong ties for mitigating the relational disadvantages of structural holes. Similarly, network cohesion is needed for mobilizing informational advantages of weak ties. This chapter provides a promising direction for reconciling competing theories about network effects.

***Research Question 2: How does collaboration network structure influence the adoption and future use of its innovation? Would their relationship condition on innovation types (e.g., incremental innovation and radical innovation)?***

Innovation starts from creative ideas, but not all creative ideas will turn into successful innovation that is being adopted and used by others, and it takes multiple steps to develop a creative idea into a successful innovation (Anderson et al., 2014; Baer, 2012; Bharadwaj & Menon, 2000; Fleming et al., 2007; Lavie & Drori, 2012; Obstfeld, 2005; West, 2002). The prior literature has categorized various steps in the creative process (Csikszentmihalyi, 1997; Perry-Smith & Mannucci, 2017). One important separation is between an initial production stage where a creative idea is being generated and a latter diffusion stage where a creative idea is being adopted and used by others (Fleming et al., 2007; Lee et al., 2015; Wang, 2016). These studies have highlighted that the social structure for producing the idea not only shapes the inherent characteristics of the initial creative idea but also influences the diffusion of the initial creative idea beyond the social structure in which it was produced. More importantly, the same social structure that is conducive for producing a creative idea might hamper its diffusion. Therefore, exploring differential effects of network structure on idea production and diffusion provides valuable insights into the complex network effects. Building on this line of literature, Chapter 3 investigates how social structure for producing a creative idea influences its diffusion and make a novel contribution by exploring how this effect is contingent on the radical nature of the creative idea. The empirical analysis is based on a unique panel dataset of 93 most innovative U.S. pharmaceuticals and biotechnology companies from 2001 to 2013, with a total number of 19,343 location-time observations. Innovation success is measured as the average number of patent family citations that a focal location received. Tie strength is operationalized as the frequency of collaboration, and network cohesion is calculated as the share of collaborating ties in one location's egocentric network. The radicalness index adopts from Funk and Owen-Smith (2017). Findings of this chapter highlight the contingent effect of radical innovation.

***Research Question 3: How does the private value of a patent depend on its radicalness? Would destructiveness and dissimilarity have the same effect on private value?***

Studying how the radicalness predict future economic value, especially the different aspects of radicalness, is a very interesting research topic in innovation literature. However, the empirical evidence is mixed considering there are diverse approaches for conceptualizing and operationalizing innovation radicalness (Arts et al., 2021; Verhoeven et al., 2016). Chapter 4 investigates the association between the private

value of a patent for the innovation firm and its technological radicalness by differentiating between two important dimensions of technological radicalness: destructiveness and dissimilarity. Using a dataset consisting of 1,066,637 USPTO granted patents, Chapter 4 adopts the private value of individual patents based on abnormal stock market return, developed by Kogan et al. (2017). Following Funk and Owen-Smith (2017), the destructiveness of patents is measured by using citation networks and more specifically the extent to which a patent destabilize the existing trajectories. Following Arts et al. (2021), the dissimilarity of patents based on to what extent the text of a patent is dissimilar to prior patents. Findings of this chapter confirm that the different dimensions of radicalness have distinct effects on private value. More importantly, this chapter provides a useful approach for making sense of the diverse and sometimes competing theories and evidence about technological radicalness.

Chapter 5 summarizes and discusses the main findings presented in chapters 2 to 4. Based on these research findings, the theoretical and practical implications are illustrated for advancing future study. The limitations are also discussed in this chapter.

### **1.3 Potential contributions**

Given the existence of competing theories and the mixed nature of empirical evidence, this dissertation endeavors to reconcile the conflicting viewpoints between social network and innovation studies. By unpacking the drivers and effects of radical innovation, this dissertation contributes to the literatures of social networks, creativity, and innovation. Chapter 2 contributes to the social network and radical innovation literature by proposing a two-faced view of network structures separating informational and relational aspects, and investigating the interaction between different network properties. The conceptual model and empirical findings acknowledge that the same network structure (i.e., weak tie, structural hole) may present both informational advantages and relational disadvantages at the same time. In addition, the informational advantages of weak ties can be mobilized if there are network cohesion to mitigate the relational disadvantages of weak ties. Similarly, the informational advantages of structural hole can be mobilized if there are strong ties to mitigate the relational advantages of structural holes.



Chapter 3 investigates how collaboration network for idea production affects the diffusion of the produced idea and explores how these effects are contingent on the radical nature of the innovation. Reciprocity norms promote cooperation but at the same time sanction behavior that is not aligned with cooperation, and such “non-reciprocal” behavior might be more desirable for some agents in some contexts, for example, not providing information for an information provider (Gargiulo et al., 2009), and adapting their networks for a manager in a changing environment (Gargiulo & Benassi, 2000). Chapter 3 extends previous literature and sheds further insights into the complexity of network effects, by showing that reciprocity norms are not always beneficial but can become a burden for some agents in some contexts, where the desirable behavior misaligns with reciprocity norms. In particular, the adoption of radical innovation is hindered because of its destructive impact on existing technologies and the collaboration network.

Chapter 4 expands the literature on radical innovation. Chapter 4 highlights the importance of unpacking different dimensions of innovation radicalness (i.e., destructiveness and dissimilarity), which have distinct effects. Unpacking innovation radicalness also provides a useful approach for making sense of the diverse and sometimes competing theories and evidence about radical innovation.