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Innovation network trajectories and changes in resource bundles☆

Sharon Purchase [b,*], Doina Olaru [b], Sara Denize [a]

[a] The University of Western Sydney, Locked Bag 1797, Penrith, NSW 2751, Australia
[b] The University of Western Australia, UWA Business School, Stirling Highway, Crawley 6009, Australia

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ABSTRACT

This paper reports on an investigation into how changes in network resource bundles influence the success of innovation networks and how they change trajectories over time. Innovation networks are complex adaptive systems, and this paper uses a fuzzy set theory simulation methodological approach to capture complexity. The findings indicate that the interdependencies between knowledge variables and financial resources are the greatest contributor to high performing innovation networks, whereas the loss of social capital and its interdependency with the environment are the largest contributors to declines in innovation network performance. The paper suggests a more nuanced role for social capital within innovation networks and, importantly, highlights the sequencing of knowledge contributions, which take low performing innovation networks to high performing innovation networks.

1. Introduction

Innovation networks are business networks that create new products or processes, which in turn radically change the current value chain (Ferrary & Granovetter, 2009). Information is shared widely in innovation networks, particularly where a culture of open science and cooperation prevails (Ferrary & Granovetter, 2009; Owen-Smith & Powell, 2004). Thus, participating in successful innovation networks benefits all actors, even those who do not have direct relationships with the most innovative organizations in the network (Powell, White, Koput, & Owen-Smith, 2005). Despite the importance of innovation networks, there is a lack of understanding of how organizations know which innovation networks are likely to be more successful, and what network behaviors are likely to improve performance. This paper begins to address these issues by reporting on observed differences between successful and unsuccessful innovation networks.

Successful innovation networks are likely to efficiently mobilize and re-configure network resources (Andriani, 2011; Dougherty & Dunne, 2011; Lichtenstein & Brush, 2001). Yet, previous research has tended to ignore the network level and focus on resource exchange within dyads or in intra-organizational resource development (Dougherty & Dunne, 2011). However, recent research highlights the importance of interdependencies between resources within inter-organizational networks (Land, Engelen, & Brettel, 2012). Although the importance of resource interdependencies has been discussed (Håkansson, 1989), few have attempted to investigate the influence of these interdependencies on network success. The present research contributes by evaluating the relative extent of interdependencies in successful and unsuccessful innovation networks.

Powell et al. (2005, p. 1133) call for more research on innovation networks, to analyze their "momentum, sequences, turning points and path dependencies" and to focus on the evolution of entire networks. The present research answers this call by considering how changes in resource bundles influence future network trajectories. In other words, the paper considers the changes in network resource combinations that lead unsuccessful innovation networks to become successful over time and vice versa. The research builds on the notions of technological trajectory (Dosi, 1982; Jenkins & Floyd, 2001) and path dependence (Andriani, 2011; Arthur, 1989).

Innovation networks are complex adaptive systems (Andriani, 2011; Ferrary & Granovetter, 2009; Jack, 2010; Lichtenstein, Carter, Dooley, & Gartner, 2007; Lichtenstein, Dooley, & Lumpkin, 2006; Ritter, Wilkinson, & Johnston, 2004) and the complexity perspective corresponds well to social reality. Furthermore, the fuzzy set theory simulation methodology used in this study is particularly suited to complexity approaches (Byrne, 2012; Häge, 2007; Rezaei & Ortt, 2013). Although fuzzy set theory simulation methods are not common within business network research, examples within the marketing and management fields include customer relationship management (Meier & Donzé, 2012), human resource management (Kvist, 2007), supplier selection and segmentation (Chou & Chang, 2008; Rezaei & Ortt, 2013) and many others (see Bojadziev & Bojadziev, 1997, for further examples). Incorporating fuzzy set theory simulation methods, the present

* Corresponding author. Tel.: +61 864881812; fax: +61 864881004.
E-mail addresses: sharon.purchase@uwa.edu.au (S. Purchase), doina.olaru@uwa.edu.au (D. Olaru), s.denize@uws.edu.au (S. Denize).

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research is sympathetic with a complexity approach and allows easy incorporation of non-linearity, numerous variable interactions, ambiguous and noisy data in the simulation model of the innovation network.

Given the research gap relating to innovation research conducted at a network level (Jack, 2010; Parkhe, Wasserman, & Ralston, 2006; Powell et al., 2005), especially from a complexity perspective (Andriani, 2011; Dougherty & Dunne, 2011; Ferrary & Granovetter, 2009), this research paper focuses on the following questions:

RQ1: What differences in network resource bundle combinations distinguish between successful and unsuccessful innovation networks?

RQ2: How do changes in network resource bundles influence changes in the trajectories of innovation network clusters?

By taking a holistic, compositional approach to innovation networks this paper contributes by highlighting the influences of research bundle interactions in distinguishing between successful and unsuccessful innovation networks and examines the changes in resource bundles that lead to innovation network trajectory changes.

2. The resource attributes and resource bundles of innovation networks

Innovation networks need to mobilize and re-configure network resources in order to survive. Notably, it is the combinations of resources or resource bundles in an innovation network that are particularly relevant (Lichtenstein & Brush, 2001). A resource bundle consists of a wide variety of resources that work together: not merely at the firm level but also at the network or market levels. The choice of firm level resources to be included in the bundles comes from Lichtenstein and Brush (2001), who found the following resources important for high technology growth firms: soft intangible resources (social capital), technological resources (knowledge), and capital (financial capital). Network level resources were drawn from the literature, which highlights that environmental munificence is important for technological development (Koka, Madhavan, & Prescott, 2006; Tang, 2008); the requirement for radical technology to offer market value (Dougherty & Dunne, 2011; Panne, Beers, & Kleinknecht, 2003); and the importance of considering network configuration (Ferrary & Granovetter, 2009; Powell et al., 2005). As noted by Parkhe et al. (2006), as with most multi-level research, resources can influence each other across different levels.

2.1. Firm level resources

Social capital is the ability of an organization to access network resources, both at present and in the future, from their business networks (Nahapiet & Ghoshal, 1998). High levels of social capital are associated with significantly enhanced knowledge acquisition (Pérez-Luño, Cabello Medina, Carmona Lavado, & Cuevas Rodríguez, 2011), enhanced ability to integrate tacit knowledge (Cooke & Wills, 1999; Pérez-Luño et al., 2011), provision for higher risk taking ability within relationships, improvement of problem solving abilities (Land et al., 2012), and improvement of overall innovative abilities within organizations (Carmona-Lavado, Cuevas-Rodríguez, & Cabello-Medina, 2009; Partanen, Möller, Westerlund, Rajala, & Rajala, 2008). Other research however suggests that the existence of social capital has marginal significance in facilitating innovation processes (Carolis, Litzky, & Eddleston, 2009) or argues that social capital is a complementary driving force of innovation outputs (Jenkins & Floyd, 2001). Thus, the extant research highlights the importance of including social capital within the resource bundle, but does not consider how the interaction of social capital with other resources influences the innovation trajectory.

Capital investment, as in *financial resources*, significantly influences innovation potential (Ferrary & Granovetter, 2009; Lichtenstein & Brush, 2001). Finance plays an important role in shaping the innovation trajectory (Dosi, 1982). Greater financial capital investment is more likely to facilitate experimentation in the research and development process. Experimentation, in turn, improves innovation capacity (Land et al., 2012) and positively influences long-term innovation performance (Partanen et al., 2008).

Knowledge inputs into the supply side of innovation trajectories are critical for the development of the innovation path (Dosi, 1982; Jenkins & Floyd, 2001). Yet, highlighting the complexity and ambiguity of the knowledge concept (Hoholm & Olsen, 2012), and the conceptualization of knowledge is inconsistent. For example, knowledge has been conceptualized as a process (Hoholm & Olsen, 2012), as learning (Land et al., 2012), a capability (Lichtenstein & Brush, 2001), a resource input (Dosi, 1982), an entity (Pérez-Luño et al., 2011), or as a combination of the above (Jenkins & Floyd, 2001). The present research followed Dosi (1982), including knowledge as a resource within the resource bundle. It should be noted that although Lichtenstein and Brush (2001) conceptualized knowledge as a technical capability, they also included expertise within their resource bundles. This research categorizes knowledge into exploratory and exploitative knowledge, as each requires different resources and skills (Land et al., 2012). *Exploratory* knowledge is used for developing new products, while *exploitative* knowledge is used for improvement, implementation or commercialization of a product (Land et al., 2012). Knowledge *uniqueness* is also addressed, as it is a property of knowledge that pertains to its innovativeness.

2.2. Network level resources and attributes

Environmental munificence influences patterns of network change and plays an important role in the innovation process (Koka et al., 2006; Philippen & Riccaboni, 2007). Munificence describes the 'amount' of resources available to an organization from the environment and indicates the capacity of the environment to support innovation (Koka et al., 2006). In network resource combinations, munificence influences the possible resource combinations available. Munificence also positively influences the ability of entrepreneurs to 'read' the market (Tang, 2008), moderates the radicalness of innovations generated (Barron & Tang, 2011), influences the number of radical innovations generated (Tang, 2008), changes network structures (Philippen & Riccaboni, 2007), and interacts with social capital and network structure to influence learning (Land et al., 2012).

High technology products often generate value through their interconnections with complementary technologies (Andriani, 2011; Dougherty & Dunne, 2011; Jenkins & Floyd, 2001; Sengupta, 1998; Staudenmayer, Tripsas, & Tucci, 2005). *Complementary technologies* develop products that "add value beyond primary product basic function" (Sengupta, 1998, p. 353). Product systems are generated when the products of multiple firms work together as a system to generate a value proposition (Staudenmayer et al., 2005), and the development of complementary designs influences the innovation trajectory and consequently its ability to dominate the system (Jenkins & Floyd, 2001). The importance of complementary technologies across various industries and products is well documented (Dougherty & Dunne, 2011) and they are included as a network resource in this research.

Network configuration influences the flow of information and the shape of the network trajectory (Powell et al., 2005). Others have found that the types of actor participating in the network influence information flow (Hoholm & Olsen, 2012). Ferrary and Granovetter (2009) believe that the number of financial resources firms participating in Silicon Valley's complex innovation network is important for facilitating innovation. Therefore, network configuration is considered via the diversity of actors and is measured as *the proportion of different actor types* within the network.

Therefore, innovation network resource bundles are assumed to include: social capital; financial resources; exploratory knowledge; exploitative knowledge; knowledge uniqueness; environmental munificence; complementary technologies, and network configuration. Consideration of the different combinations of resources and the