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The role of diverse knowledge in creating knowledge within industry networks ¬¬–A study in the Victorian biotechnology industry

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Knowledge creation through diverse knowledge networks

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Abstract

Inter-organizational knowledge networks have been considered vital for the knowledge economy, particularly for small and medium size enterprises in knowledge-based industries, since knowledge creation often happens within those networks. Hence an interesting question to explore is: how do knowledge networks serve to contribute to knowledge creation? Beyond the role of network structure, which has dominated the knowledge network literature, our research highlights the need for the consideration of other factors like knowledge content. First by reviewing the literature, we propose a hypothesis that predicts a positive association of content and knowledge creation. Then, focusing on patent co-authorship networks of the biotechnology industry in Victoria, this research used an explanatory multiple case study approach to test the formulated hypothesis. By introducing new emergent constructs, the results provide more insight on the positive association of knowledge content and knowledge creation. Based on the emergent constructs, rival hypotheses are also developed for further research.

Keywords

Knowledge networks, knowledge creation, diverse knowledge

INTRODUCTION

Knowledge-intensive or high-tech industries are widely regarded as important for overall national economic growth and competitiveness (National Science Foundation 2012). In knowledge-based industries, one mode of knowledge creation is through collaboration with peers and other partners. Such collaborations are sometimes called knowledge networks (k-networks). The high pace and radical innovation projects in knowledge-based industries emphasise the need for research in the area of k-networks, particularly in the biotechnology industry (Plum and Hassink 2011).

The need for networking seems even more relevant to knowledge-intensive small and medium enterprises (here-after SMEs) (Szarka 1990). The networking phenomenon for SMEs seems primarily as a competitive response (Hanna and Walsh 2002), since the delicacy of such firms can be off-set by the supporting environment provided by a resilient network (Szarka 1990). Meanwhile, most of the actors in knowledge-intensive industries like the biotechnology industry are SMEs (e.g. Owen-Smith and Powell 2004). Given the key importance of SMEs, more studies are needed in k-network research to focus on SMEs' k-networks (Phelps, Heidl and Wadhwa 2012).

As the k-network is considered as a means of knowledge creation, an important question to explore is: how do knowledge networks serve to contribute to knowledge creation by SMEs? Our review of the research highlights how different theories, level of analysis, and themes are focused on the structural configuration of k-networks (e.g. Phelps et al. 2012) to explain collaborative knowledge creation in k-networks. Hence our study has focused on content as an important construct that is not mentioned sufficiently in the current k-networks literature.

This literature, however, is mainly focused on large organizations through quantitative research. Based on a thorough literature review, in this paper we propose that collaborative knowledge creation of the actor in a k-network will be positively associated with the diverse knowledge possessed by the actor. Then, using an explanatory multiple case study approach, we examine this hypothesis in SMEs within the Victorian biotechnology industry–as an example of a knowledge-intensive industry. By introducing new constructs, the results provide more insight on how knowledge content of SMEs may influence their knowledge creation positively.

The rest of the paper is structured as follows. First, we position our research within the k-network literature by clarifying the dimensions of this research, which leads to the literature review and also the proposed hypothesis about the role of diverse knowledge on knowledge creation. Next, the Australian biotechnology industry as the setting of the research is introduced and the explanatory multiple case study as the research approach is discussed. Finally, the results are presented and discussed, followed by the conclusion.

THEORETICAL BACKGROUND OF THE K-NETWORK RESEARCH

In this section, first the relations that this research bears to previous and contemporary treatments of the k-network research are discussed by defining the position of our research. Then, content as a construct of k-networks is discussed from the two specific theories that have been introduced in the first part, and finally the hypothesis is formulated.

Theoretical position of this research

There is an increasing volume of research published on networks (Borgatti and Foster 2003) and k-networks (Phelps et al. 2012). To position our research within this substantial body of literature, and to reduce the complexity inherent in the network research (Carpenter, Li and Jiang 2012), first we define our research in terms of focus, level of analysis, themes and areas of research.

Table 1 The theoretical scope of the research: The types of network theories, levels of analysis, themes and areas of the current research are highlighted

Dimensions	Options			Reference
Theoretical focus of network research	Micro-level	Macro-level		e.g. Galaskiewicz (2007)
	Network as dependent variable	Network as independent variable	Both dependent and independent	e.g. Galaskiewicz (2007)
Level of analysis	Actor	Dyad	Network	e.g. Marsden (2005)
	Interpersonal	Intra-organizational	Inter-organizational	e.g. Phelps et al. (2012)
Themes of research	Origin and Formation of network	Impact of network	Network structure and evolution models	e.g. Ozman (2009)
Areas of research in the theme of Impact of network	Social capital	Diffusion		e.g. Borgatti and Foster (2003)

Given this typology (Table 1), it is possible to define the main focus of this research. First, our study considers the network as an independent construct at the micro-level, since the research concerns the view from the individual firms participating in the network, rather than the view from the whole network. Moreover, the focus is on the "impact" of the inter-organizational network of SMEs (Actor). This impact in an actor level of inter-organizational network may refer to firms' performance and other value-laden outcomes for the actor, like knowledge creation. From the k-network perspective, given the dimensions that are defined in Table 1, there are two main streams of research on social capital: 1. network position research and 2. closed network vs. sparse network research.

1. Network position research

In an inter-organizational network, [inter-organizational] partnerships of an actor define the position of the actor within the network. The more partnerships will push the actor to a central position. The research on effects of network position on knowledge creation mainly considers central position as a favouring factor for knowledge creation (Ahuja 2000; Gibbons 2004; Soh, Mahmood and Mitchell 2004). However , there are other studies that show central position may have weak positive influence (Whittington, Owen-Smith and Powell 2009) or even no influence on patenting as a form of knowledge creation (Owen-Smith and Powell 2004) among firms.

To explain these contradictory results, some scholars found that content of the knowledge could be one contingent factor to explain the role of network position. More specifically, a central position in a network leads to higher innovation, mainly if it leads to higher access to more diverse knowledge (e.g. Baum, Calabrese and Silverman 2000).

2. Closed network vs. sparse network research

Given the context of our research (Table 1), this research deals with actor level and is focused on the effect of social capital within inter-organizational networks. The core concept here is ego-network density or network efficiency (Burt 1995) which is calculated by number of triangles or closure triads divided by n(n-1)/2, where n is the number of the ego's partners (or alters) and closure triads refers to closed relationships between any three actors. From this stream of research, there are two competing views, which are perceived as polar approaches (Burt 2001): closed vs. sparse networks or, as sometimes called, closed network theory (Lavie, Lechner and Singh 2007), which focuses on merits of high dense networks, in comparison with structural-hole theory (McEvily, Jaffee and Tortoriello 2012), which focuses on opportunities in sparse networks.

Theoretical construct and the research hypotheses

This research reviewed the literature on both streams of social capital research, and found that content of knowledge seems important to explain the knowledge creation with the k-network. The idea of content of relationships can be traced back to anthropology as a broad school of thought in social science. Tichy, Tushman and Fombrun (1979) defined the origin of this concept in the exchange theories (e.g. Lévi-Strauss 1971) and distinguished between four different types transactional content including (p.508): expression of affect, influence attempt, exchange of information, and exchange of goods or services. In a network of relationships, however, content may refer to the information, resources, social identity, or authority substance that is conveyed through a relationship (Burt, 1997; Podolny and Baron, 1997, cited by McEvily and Marcus 2005).

In the network research, surprisingly there are few studies that have been focused on the role of content, although the importance of the concept has been emphasized (e.g. Gulati and Westphal 1999). Likewise, there are very few examples in previous empirical studies in k-network research, particularly at the inter-organizational level, that have focused on the content of the network (Table 2).

Table 2 Research on content of inter-organizational k-networks in two main streams of social network research

Construct	Network position research	Sparse vs. Closed network research
Content of knowledge in k-networks	Depth and **diversity of knowledge** (Stuart, 2000); timelier access to more diverse information (Beckman and Haunschild 2002); (Wadhwa and Kotha 2006); speed and depth of information transmission (Gibbons 2004)	Knowledge type (McEvily and Marcus 2005);explicit vs. tacit knowledge (Li, Poppo and Zhou 2010); design scope and level of task interdependency (Sobrero and Roberts 2001);the effect of network **diversity of knowledge** (Phelps, 2010), knowledge heterogeneity (Demirkan and Demirkan 2012)

* The **diversity of knowledge** is the common characteristics among both streams of research

In both stream of research studies, there are five characteristics that have been discussed: 1) Depth and diversity of knowledge (Stuart, 2000) and timelier access to more diverse information (Beckman and Haunschild 2002; Gibbons 2004; Wadhwa and Kotha 2006); technological diversity (Phelps, 2010), knowledge heterogeneity (Demirkan and Demirkan 2012); 2) speed of information transmission(Gibbons 2004); 3) Customer vs. supplier knowledge type (McEvily and Marcus 2005); 4) explicit vs. tacit knowledge (Li et al. 2010); and 5) design scope and level of task interdependency of the content (Sobrero and Roberts 2001). However, our research is focused on diverse knowledge, because this is the only characteristic of the content which as illustrated in Table 2, is reflected frequently in both network position research and sparse vs. closed network research.

In the stream of sparse vs. closed network research, Demirkan and Demirkan (2012) highlighted the role of the qualitative characteristics of the network like knowledge diversity that is being shared in the network. They showed a positive effect of having heterogeneous knowledge on innovative performance. Phelps (2010) also discussed the role of diverse knowledge and ego network density on exploratory innovation, which is defined as the creation of technological knowledge by a firm that is novel relative to its existing knowledge stock. He measured exploratory innovation using patent citations, while network technological diversity was evaluated by using the Rodan and Galunic's (2004) measure of knowledge distance. Ego-network density was also measured by the percentage of all possible ties among the ego's alters. His research predicted an inverted U-shaped effect of network technological diversity on firm exploratory innovation. However Phelps (2010) found evidence of a positive linear effect but not a curvilinear effect. Also he showed that network density strengthens the effect of network technological diversity. In his research, network density had a positive and significant effect on exploratory innovation, independent of knowledge diversity. In summary, the research showed that the co-existence of dense ego-networks–wherein a firm's partners are also partners with each other–and access to diverse knowledge may result in combined benefits that increase new knowledge creation.

In network position research, while many studies (Shan, Walker and Kogut 1994; Ahuja 2000; Owen-Smith and Powell 2004; Whittington et al. 2009) considered central position and having more inter-organizational links to others as a factor positively improving organizational performance (mainly in terms of innovation), there are other studies (Beckman and Haunschild 2002; Gibbons 2004; Wadhwa and Kotha 2006) that showed the importance of diverse knowledge and mentioned that the role of central position is mediated by access to diverse knowledge.

In network position research, like ego-network research, the concept of knowledge diversity is reflected in a few studies, even sometimes without testing the constructs. For instance Gibbons (2004) did not test knowledge diversity as a construct, but in her discussion she pointed out the role of diversity of firm's knowledge and mentioned that increasing centrality among firms' partners positively influences diffusion only to the point at which communication with non-adopters overshadows inputs from initial adopters. In other words, this highlighted that the central network only can improve the diffusion of innovation if it provides access to diverse knowledge. Similarly, Beckman and Haunschild (2002) by studying 300 of the large publicly held service and

manufacturing firms in the US, mentioned that the importance of having a central position in a k-network depended on providing timelier access to more diverse knowledge. However, Wadhwa and Kotha (2006) showed empirically that technological knowledge diversity (or knowledge breadth) of 36 corporate firms in the telecommunications equipment manufacturing industry positively moderated the relationship between the number of corporate venture capital investments and knowledge creation. Hence, in all these studies, knowledge heterogeneity seems to be associated with knowledge creation regardless of the centrality or density of the network. Hence we propose:

H1: Regardless of the configuration of an actor's k-network, diverse knowledge possessed by the actor will be positively associated with the actors' collaborative knowledge creation.

RESEARCH DESIGN AND METHOD

This research followed a sequential mixed method, starting with a quantitative phase. This paper, however, reports the explanatory multiple case study as the second qualitative phase. The main aim of such multiple case studies were confirmation, expansion and/or compensation (Venkatesh, Brown and Bala 2012), mainly with the focus on SMEs. Without such qualitative case studies, it would not be possible to provide in-depth insights regarding the results of the quantitative phase. There are several similar mixed method studies with this aim in the literature (e.g. Bhattacherjee and Premkumar 2004). The setting and design of the research are discussed below.

Knowledge intensive SMEs and their k-networks in the Victorian biotechnology industry

K-networks in knowledge intensive industries can be identified in a number of ways, including patent co-authorship (Cantner and Graf 2006). Patenting is used to represent knowledge creation, since a patent, by definition, is evaluated under criteria like, technical reproduction, industrial exploitation and non-obviousness. Thus a successful patent represents creation of new knowledge. The use of patents to protect knowledge is an effective and widely used approach (Arundel and Kabla 1998). Prior research used patents to measure innovation and showed that the number of patents were closely related to new products, innovation and invention counts and sales and growth (Ahuja 2000). Hence the number of patents a firm has published is considered a meaningful measure of new knowledge creation (Wadhwa and Kotha 2006; Markatou 2011).

However, due to the fact that SMEs have the high majority of actors in the knowledge intensive industries (e.g. Owen-Smith and Powell 2004), the knowledge network of SMEs in the knowledge intensive industries is focused. Given the characteristics of SMEs, it is argued that SMEs are not scaled-down versions of larger firms (e.g. Lévy and Powell 2005). SME owner/managers seek a diversity of objectives and have much shorter-term objectives compared to managers in larger organizations. SMEs mainly focus on flexibility to be able to adjust their companies quickly to respond to unexpected changes in the environment. Hence, SME scholars argue that SMEs need their own exclusive research (Lévy and Powell 2005).

Participants in the current research were all the Victorian biotechnology actors who had published at least one patent in IP Australia (AusPat), from 2001–2010. In this network, there were 126 actors, of which 78 were SMEs. These SMEs can be further categorized into two sectors of public research organizations (PRO) like research centres and governmental agencies with 10 actors, and also pharmaceutical bio-firms (PBF) with 68 actors. In the second phase of the research, which is discussed here, to avoid any mixing of results among different types of actors, only the PBF type of SMEs who has collaboration with other actors, was studied in our case studies (i.e. 21 PBF SMEs).

International patent classification (IPC) as a measure for knowledge content: This research focused on the diversity of the knowledge as an essential element of knowledge content (e.g. Rodan and Galunic 2004). In general, SMEs might need different areas of managerial, technological and organizational knowledge (Sammarra and Biggiero 2008), however the singular focus of the current research is technological knowledge. To calculate the degree of heterogeneity of a firm's technological knowledge, the IPC[1] has been considered as a representative indicator. IPC shows the technological knowledge area which firms have created. To calculate the degree of heterogeneity, the Herfindahl index and Simpson's diversity index were applied, as these indices have been used in a variety of fields including KM research (Demirkan and Demirkan 2012).

$$D = 1 - \sum_{i=1}^{N} p_i^2$$

Where; p = proportion of particular knowledge areas (IPCs) in the ego network of firm; i. N = total number of IPCs which are shared by firm i.

1 International patent classification developed by WIPO in 1971: "a hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they pertain" http://www.wipo.int/classifications/ipc/en/

In this regard, knowledge heterogeneity was calculated for all 126 actors including 78 SMEs. The lowest degree of heterogeneity is 0 for firms with only one IPC. And the highest is .929 for the University of Melbourne.

Patent counting as a measure for knowledge creation: Patent data are often use to measure technological knowledge, because patents are valid and robust indicators of knowledge creation (Jaffe and Trajtenberg 2005). In some knowledge-based industries, like biotechnology, the use of patents to protect the knowledge is an effective and widely used approach (Arundel and Kabla 1998). Prior research used patents to measure innovation and showed that the number of patents is closely related to new products, innovation and invention counts and sales and growth (Ahuja 2000). Hence, the number of patents a firm has published is considered a meaningful measure of new knowledge creation (Almeida and Phene 2004; Wadhwa and Kotha 2006; Markatou 2011). The patent can be used to represent knowledge creation since a patent by definition is evaluated under three criteria of novelty to the world: technical reproduction, industrial exploitation and non-obviousness. Hence a successful patent application can represent creation of new knowledge.

However, there are some limitations with counting patents to understand knowledge creation. Firstly, the industry type influences product patent propensity (Arundel and Kabla 1998). To avoid this issue, it is recommended to collect data from a single industry—like biotechnology, which actively files for patents (Ahuja 2000). Secondly, the full range of each firm's knowledge creation will not be captured by patents. Some knowledge may not be patentable but still have economic value (Arundel and Kabla 1998). However, patents have been shown to be an important mechanism in the analytical knowledge bases like the biotechnology industry. Moreover, the current research uses the same measure for all participants/actors to understand the role of their k-networks to create knowledge in terms of published patents. Thirdly, the concept of quality of created knowledge is not captured by counting the number of patents. This research does not address the quality of the patents and focuses on whether certain characteristics of k-networks can increase the number of the patents as a measure of knowledge creation.

Explanatory case studies

The case study approach incorporates a group of techniques which emphasize qualitative analysis and includes collecting data from a small number of organizations through methods such as participant-observation, and in-depth interviews (Yin 2003). In this approach, explanatory case study is a type of method used to confirm and explain hypotheses; it is frequently used in information systems research (e.g. Lee 1989; Dubé and Paré 2003). In our research, based on the findings in the first phase, the SME cases were selected and the interview protocol was designed to provide explanation of the findings in the first phase.

Site selection and data collection*:*

To reduce the complexity of research, followed by Yin's recommendation (2003), only PBF-SMEs (21 firms) were selected purposefully as mentioned before. Using binominal regression analysis, followed by the interaction analysis that has been reported elsewhere (Moslehi, Linger and Tanner 2013), these SMEs mapped into three possible configurations:

1. *Favouring configuration:* This configuration of k-network favours the firms' knowledge creation in terms of patents. Regarding the PBF-SMEs, there were only eight firms that could be mapped in this group. Among these SMEs, here we report the study of SME-A. The description of this SME is illustrated in Table 4. Moreover, among the current three personnel, an in-depth interview was conducted with the chief scientist of the company, who had also worked for all the patents that the company owned. However, we did not manage to interview the patent partners of the company, due to their unwillingness to participate.
2. *Mixed impact configuration:* This configuration of k-network seems to provide both positive and negative influences on knowledge creation. Some aspects of the network favour the firms' knowledge creation, while others hinder the firms' endeavours. There were five PBF-SMEs mapped into this configuration, among which, this paper reports SME-B. Of the two management team members, an in-depth interview was conducted with the CEO of the SME, who also had participated in all the firm's patent projects.
3. *Neutral configuration:* This configuration has no particular strong positive or negative influence to favour the firms' knowledge creation. There were eight PBF-SMEs mapped in this configuration .Among these SMEs, here we report the study of SME-C. In this SME, there were three management team members, one of whom was interviewed—the chief business officer.

Reliability and validation of the research design

Given the guidelines of Tashakkori and Teddlie (2008), elaborated by Venkatesh et al. (2012), on validation of mixed-method in IS research, the quality aspects of the research can be understood by quality in design and explanation. Hence, the summary of the methodological rigor in this case study research is illustrated in Table 3.

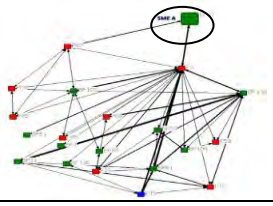
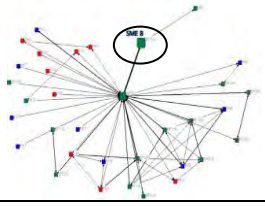
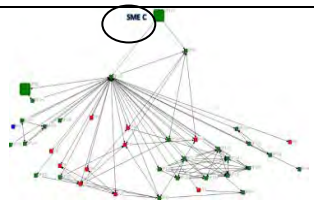
Table 3 Application of methodological rigor Adapted from Venkatesh et al. (2012)

Aspects	Quality Criteria	How the guidelines were followed in this research
Design quality:	Design adequacy: The degree to which the qualitative design components are implemented with acceptable quality–includes credibility and dependability	All possible configurations that were defined based on the results of the quantitative phase, were addressed via interviewing, and three other sources of data including visiting their sites, documents and patent data.
	Analytic adequacy: The degree to which qualitative data analysis procedures/strategies are appropriate and adequate to provide plausible answers to the research questions. Indicators of quality include theoretical validity and plausibility	Using the qualitative phase on SMEs, we were able to get in-depth insights and more comprehensive answers for our hypothesis. The results of this phase were mainly used to confirm and elaborate what was achieved in the quantitative study, mainly for SMEs.
Explanation quality:	Qualitative inferences: The degree to which interpretations from the qualitative analysis closely follow the relevant findings, consistent with theory and the state of knowledge in the field, and are transferable; include credibility, conformability, and transferability	Hypothesis was matched with constructs in the interview protocol and empirical data. After transcribing, the interviewees were asked to check the transcript to make sure that the interviewer's understanding was consistent with their views. Also, the theoretical framework was used to design the coding scheme. Moreover, an external observer was asked to make an independent judgment to validate the coding and conclusions drawn from the case descriptions.

SUMMARY OF THE CASES

Each case was studied through: 1) in-depth interviews with managers/innovators and their partner companies in the network, 2) visiting their sites, 3) reviewing their documents like presentation files and annual reports, and 4) patent data were collected from patent documents provided by AusPat[2]. Here the summary of the case studies are reported to show how these SMEs did feedback on the quantitative findings (Table 4).

Table 4 Major features of the case SMEs – * within last ten years

	SME-A	SME-B	SME-C
Configuration type	Favouring configuration	Mixed impact configuration	Neutral configuration
Number of employees*	3-8 Including 2 managers	5-15 Including 2 managers	7 Including 3 managers
Founded in	1997	2000	2007
Annual revenue*	A$ 180-730 k	A$ 700-800 k	Not reported
Products and services *	Basic R&D, discovery and early stage of development	Basic R&D, discovery and early stage of development	Discovery, and early stages of development
Number of Patents* Mean=8.89 Median=4	High 16	High 14	Low 2
Content—knowledge diversity Mean=.52 Median=.53	High-8 IPCs- heterogeneity=0.77	High-8 IPCs- heterogeneity=0.79	Low- 2 IPCs- heterogeneity=0.5
Ego-network structure			
Centrality Degree- Median=3 Closeness (Reverse):	High centrality 6 1.364	High centrality 8 1.365	Average centrality 3 1.372
Ego network density Geometric mean (Opsahl and Panzarasa 2009):	High dense 1	Low dense 0	High dense 1
H1: positive role of content on collaborative knowledge creation	Confirmed: High knowledge heterogeneity and high collaborative knowledge creation	Confirmed: High knowledge heterogeneity and high collaborative knowledge creation	Confirmed: Low knowledge heterogeneity and low collaborative knowledge creation

DISCUSSION

Focusing on the SMEs' perspective through an explanatory case study approach, this research aimed to test the hypothesis that there is a positive association between knowledge content and knowledge creation.

2 The patent database which records all Australian patents published since 1904-http://www.ipaustralia.gov.au/auspat/index.htm

As shown in Table 4, this result was confirmed in all three cases. Those SMEs which were able to acquire more diverse technological knowledge, published more patents than those which tried to reuse their existing technological knowledge. In both SME-A and SME-B, their knowledge was heterogeneous (0.77, .79), because diversity of the knowledge-bases of each was more than the average of the patent-authorship of the Victorian biotechnology industry (.52). Accordingly, numbers of their patents as the measure for knowledge creation was also above the average. However, SME-C, which had more homogeneous knowledge (.50), had only two patents, which was lower than the average. To explain the positive role of knowledge content in knowledge creation in terms of patents, the following themes also have emerged:

Exploration process: Working with different partners on new areas of knowledge can increase both knowledge diversity and knowledge creation. This was the approach taken by SME-A and SMEs B; however SME-C preferred to keep their existing links and exploit them over time.

> *We try to explore new partners, the idea is to collaborate with big pharma [pharmaceutical companies]… it is semi-opportunistic, now we are looking for partnership with 3-4 mid-sized bio-pharma companies overseas, mainly in Europe. The core of the discussion with these companies has started and these collaborations mainly will result in patents* [chief scientist of the SME-A].

This finding is supported by some studies in the literature. For instance, by testing the firm's technology sourcing, Rothaermel and Alexandre (2009) concluded that strong reliance on a partner (exploitation) as a source of technology can have negative performance implications. Likewise, Wadhwa and Kotha (2006) by studying knowledge creation among investors in telecommunications equipment manufacturing, argued that managers need to actively manage and augment their investments with other inter-organizational relationships, in order to be able to unlock the learning potential inherent in their affiliations and generate greater value from multiple relationships. These studies highlighted the role of exploration via partner diversity, though implicitly.

Timeliness: Having timely access to knowledge and protecting it via patenting. For instance, SME-A believed that diverse knowledge works for them to create more knowledge, since their heterogeneous knowledge:

> *…came based on a fundamental idea; in some of these we had good ideas about the core technologies which are the basis of our field and we had studied them very early in 2000. And I think now we have a strong position because of these patents. Since these patents are very fundamental and very early in our field…then we developed upon them.*

It is believed that being a first-mover in the market in terms of access to new knowledge and using patents to protect their position helped SME-A to create more knowledge, and to be more innovative. In theory, this idea sometimes is called a technology-push approach that typically takes place in large companies (Trimi and Berbegal-Mirabent 2012). It means that technological breakthrough can enable the firm to become the first mover in the market. Then, based on the strong position that they have with such diverse knowledge, they are able to create more knowledge later.

Firms' absorptive capacity: The capability of SMEs to create new knowledge seems another important factor to explain this hypothesis. SMEs are widely recognized as companies with limited resources in terms of expertise and finance (Hanna and Walsh 2002). For instance, SME-C mentioned:

> *We've focused on cancer and drug discovery and early stage development of cancer and we do small molecule. I personally think that we are just about right, what we do in the context of Australian research, we are about the right size, right about the amount of funding to do what we can do. If we go any wider, we may become less expert in cancer … and if we go narrower we then probably have difficulty to get enough number of projects each year.*

The capability to get funding and ability to manage new projects seems another construct that influences how this SME uses its knowledge base to create new knowledge. In the literature, also the concept of absorptive capacity (Cohen and Levinthal 1990) was used similarly to explain how heterogeneous knowledge can be used to create new knowledge in intra-organizational collaborations (Tsai 2001), as well as in inter-organizational knowledge creation (Weigelt and Sarkar 2009).

Business strategy: Access to diverse knowledge can help knowledge creation, mainly if SMEs pursue aggressive knowledge. For instance, this was mentioned by an interviewee in SME-A:

> *We always try to be first in the market and provide innovative technologies, we are looking into potential and innovative products, for example in the [….] pain therapeutic area for cancer patients, it was a very innovative strategy to see a very important unmet need, so I think we are a very leading innovative company in gene therapy.*

Business strategy seems another important factor to explain this hypothesis. According to the four types of strategy by Miles, Snow, Meyer and Coleman (1978), prospector SMEs like SME-A, and SME-B, are more interested in developing new products and exploiting market opportunities, which requires more attention to exploring new knowledge than exploiting existing knowledge.

Moreover, the complementary role of content and centrality (Rodan and Galunic 2004) could be another factor. Being in the centre of a network for SMEs, may provide not only more knowledge but also may provide more support to handle their patent projects. For an SME also, having diverse knowledge is associated with higher chance of partnering with more diverse partners, which leads the SME to become more central to the whole network. This combination was true for both SME-A and SME-B, which had a more central position than SME-C, while also having more diverse knowledge heterogeneity compared with that of SME-C.

In summary, it seems that diverse knowledge of SMEs with different configurations is associated with their knowledge creation. Meanwhile, based on the interviews with these SMEs, there are four other constructs that emerged as mediating factors, as discussed above, which may help to explain our hypothesis (Figure 1).

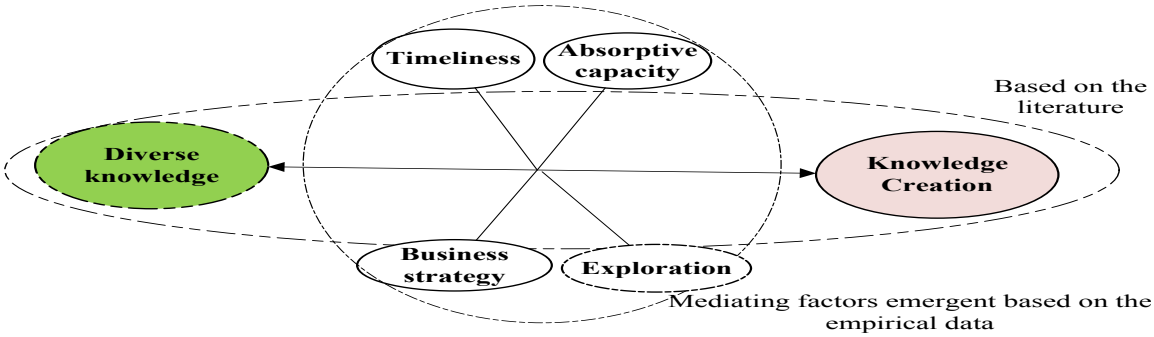


Figure 1 Mediating factors which emerged from the empirical data

CONCLUSION AND IMPLICATIONS FOR FURTHER RESEARCH

To understand the role of k-networks in knowledge creation, existing literature argues that network structure does not provide sufficient explanation per se (Table 2). Also, despite the importance of k-networks for creating knowledge in knowledge-intensive SMEs, this area has not been explored thoroughly in the literature (Phelps et al. 2012). Given our literature review, we proposed content as an important construct to explain knowledge creation in SMEs' k-networks. Using multiple explanatory case studies, this research addressed the impact of knowledge content on knowledge creation within the SMEs' k-networks. The result was consistent with the quantitative research in the whole network (Moslehi and Linger 2013). It seems that diverse knowledge of SMEs with all possible different configurations is associated with their knowledge creation. To explain this result, there are four constructs that emerged in this qualitative research which can provide more insights for future research.

All research studies have their own limitations, and this research is not an exception. Although data were collected on the all three possible k-networks of SMEs, in the Victorian biotech industry, only 21 SMEs had participated in the whole patent k-network and because of mergers and acquisitions, or ceasing of operations even fewer candidates existed to be studied in this research. Among them, three in-depth case studies were conducted; however this relatively low number provides more challenges for analysing the results. Also knowledge creation in this research is narrowed to the patent; however the full range of each SME's knowledge creation cannot be captured by patents only. Some knowledge may not be patentable but still have economic value. Likewise the concept of quality of created knowledge is not captured by counting the number of patents. Therefore this research cannot address the quality of the patents but focuses on whether certain characteristics of knowledge can impact on patents as a measure of knowledge creation.

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