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Managing Innovation Networks for Knowledge Mobility and Appropriability: A Complexity Perspective

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Abstract: Despite widespread recognition that an enterprise's critical resources may extend beyond the enterprise's traditional boundaries, with the focal enterprise drawing upon the resources of other firms and institutions through networks, there is a dearth of empirical research on knowledge mobility and appropriability patterns among innovative Australian small and medium-sized enterprises (SMEs) through the lens of complexity science. We address this gap, by examining what, how, and why innovation-related knowledge flows from networks into SMEs, and how SMEs protect intellectual property (IP) and appropriate value. Based on a survey of 838 SMEs, we find patterns of internal and external knowledge flows with SMEs searching for ideas internally, and via market-based networks, with internally sourced ideas having the strongest impact on innovativeness. The results also show SMEs are most likely to network with market-based agents relative to localised learning networks. Further, networking with suppliers increases innovativeness, as does sourcing knowledge as part of a package with the purchase of new equipment, underscoring the importance of the vertical supply chain network. Despite limited interaction with localised learning networks, outsourcing R&D to these networks increases innovativeness. We also find that informal IP, in particular, secrecy, complexity of product design, and frequent and rapid changes to products/services increases innovativeness, as do formal copyrights and trademarks. In addition to protecting IP, these practices are product market strategies, enabling SMEs to

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commercialise innovations and appropriate value. But while appropriability mechanisms provide innovation benefits to individual agents, from the perspective of complexity science, IP mechanisms act as barriers to effective knowledge flows (e.g. information sharing) preventing innovative networking through the mechanism of a positive feedback loop to evolve to the state where distributed intelligence comes into play and facilitates break-through innovations.

Keywords: complex systems, innovation, knowledge mobility, knowledge appropriability, networks

1 Introduction

Recent developments in complexity theory (Allen 2013; Arthur 2013; Cooke 2013) conceptualise innovation as a complex phenomenon giving rise to unpredictable emergence of new products, knowledge and business models as a result of the interactions of innovative agents (Dougherty and Dunne 2011). Small and medium-sized enterprises' self-organisation, in particular self-organisation in the collaborative process, has become an imperative to overcome resource limitations and [to be provided] to achieve innovation. This was previously recognised in the seminal work by Schumpeter (1942), where he identified the evolutionary process in which shocks of discontinuities destroy old sources of competitive advantages and are replaced by new ones (McKelvey 2004). Despite complexity theory increasingly being used as a lens to look at national and regional innovation systems (Cantner, Meder, and Ter Wal 2010; Cooke 2013) and technological innovations diffusion (Frenken 2006), there are aspects of innovation research where complexity theory is yet to be utilised, including to provide a dynamic perspective of self-organised order creation on how networking behaviour gives rise to innovations.

It is generally accepted that an enterprise's critical resources may extend beyond the enterprise's traditional boundaries, with the focal enterprise drawing upon the resources of other firms and institutions (Tomlinson 2010; Tomlinson and Fai 2013). Small and medium-sized enterprises (SMEs) – defined as enterprises comprising less than 200 employees – in particular, are increasingly accessing additional, substitute and/or complementary knowledge, skills and other resources from external agents in order to overcome resource constraints, and enable them to innovate (Teirlinck and Spithoven 2013) and/or improve innovation performance (Cooke 2013; Gronum, Verreynne, and Kastle 2012; Laursen and Salter 2006; Teirlinck and Spithoven 2013; Wyncarczyk 2013). Thus SMEs operate in an interrelated, complex network, a fundamental characteristic of complex systems. Knowledge mobility is recognised as one of the main

components of the innovation network organisation (Dhanaraj and Parkhe 2006). Knowledge mobility refers to “the ease with which knowledge is shared, acquired, and deployed within the network” (Dhanaraj and Parkhe 2006, 660). Despite it being widely acknowledged that innovation is an outcome of the interaction of a number of different agents within the innovation system, most research focuses on the processes or outcomes of individual firms, not the behavioural patterns, activities and relationships among these agents (Malerba and Nelson 2011; Woodside and Biemans 2005).

The second main component of the innovation network organisation is innovation appropriability which is a mechanism “to ensure value is distributed equitably and perceived as such by network members” (Levén, Holmström, and Mathiassen 2014, 159). Although IP management is critical to appropriating value and securing return on investment (Di Minin and Faems 2013), how an SME in an open exchange of knowledge protects itself while trying to acquire knowledge has not received much attention in the literature. While some studies have explored the influence of the type of network agent on IP strategies in SMEs (e.g. Leiponen and Byma 2009; Thomä and Bizer 2013), or how an enterprise’s degree of openness is related to the strength of their appropriability strategy (Laursen and Salter 2014), there is a dearth of research on the patterns of protection and appropriability mechanisms employed in the innovation process, especially in Australian SMEs. The small amount of empirical evidence examines formal IP practices only (Jensen and Webster 2006), despite recognition that SMEs often rely on informal, non-legal appropriability mechanisms (Jensen and Webster 2006). A deeper understanding is required on patterns of appropriability arising from SMEs’ use of these practices. This issue is particularly salient in Australia, where researchers and policy-makers acknowledge that both large and small businesses perform poorly on a range of innovation metrics relative to other developed countries (see Cutler 2008). For example, compared to EU countries, Australia ranks poorly in the introduction of new to market goods/services (9% versus 17% and 26% respectively for Germany and Sweden). Moreover, Australia’s introduction of new to market goods/services has declined over time (Department of Industry 2014).

The purpose of this research is to fill these gaps through an empirical study of knowledge mobility and appropriability patterns among innovative Australian SMEs through the lens of complexity science. In so doing, we address the following question: *What, how and why does innovation-related knowledge flow from heterogeneous agents in general, and market-based networks and localised learning networks in particular, to SMEs; how do SMEs protect and appropriate value, and to what extent do these factors and patterns affect SME innovativeness?*

The study contributes to prior research in three ways. First, it adds to the few field studies that have investigated knowledge mobility patterns for innovation among SMEs using complexity theory perspective (Foster 2005). Specifically, the research contributes to our understanding of different active agents' patterns of participation within the system and their contribution through networking activities to the innovation system in a regional Australian SME context. While there are a number of conceptual and empirical studies looking at inter-organisational networks as complex adaptive systems (e.g. Boschma and Frenken 2010; Ter Wal 2013), the effects of innovator networks on regional innovative systems (Cantner, Meder, and Ter Wal 2010) and innovations complexity (Cooke 2013; McKelvey, Lichtenstein, and Andriani 2012), there is a dearth of research on the patterns and nature of innovation-related knowledge flows from market-based networks (i.e. customers, suppliers and competitors) and localised learning networks (i.e. universities, higher education institutions and related providers such as research institutes) especially in the regional SME context. This is despite widespread acknowledgement that SMEs, which comprise the majority of firms in most economies, including Australia (ABS 2015), rely heavily on external knowledge for innovation (Ortega-Argilés et al. 2009; Rammer et al. 2009), and that the networks that facilitate knowledge flows within and across regions are a central source of innovation and growth (Huggins and Johnston 2009). Thus our study attempts to overcome the limitation of many innovation studies that occur at the national level and therefore ignore significant variations among different regions. As Huggins and Thompson (2015) observe, regions are increasingly considered to be important sources of economic development and organisation (Scott 1995; Cooke 1997; Amin 1999; Werker and Athreye 2004; Malecki 2007). Innovation networks also have the capacity to contribute to the economy and are increasingly recognised as a key factor underlying the future growth trajectories of regions (Reynolds et al. 2001, 2002; Fritsch and Mueller 2004).

Thus our study examines SMEs in South Australia, which has lagged in terms of economic growth compared to other Australian states (Spoehr 2005). In so doing, it builds on the need to better understand the interactions among network agents for innovation in the context of regions that are comparatively less competitive relative to the larger economy (Huggins and Johnston 2009).

Second, while managing appropriability is seen to be extremely important when firms interact with heterogeneous agents in the innovation process, much of the research has focused on IP in organisations in general (Luoma, Paasi, and Valkokari 2010; Mina, Bascavusoglu-Moreau, and Hughes 2014; Paasi et al. 2010). This study attempts to bridge that gap by examining the role of IP appropriability methods, in particular, how IP patterns influence SME innovativeness.

Finally, this study proposes a conceptual framework that integrates mechanisms of self-organising dynamics of complex networks with innovation concepts to explain SME innovation. This framework establishes relationships between approaches associated with measures traditionally applied in innovation studies with complexity science through network behaviour pattern concepts. By drawing attention to network behaviour of innovative agents we contribute to understanding how innovations emerge from networks pattern dynamics. A limitation of complexity science is that it doesn't underline the objectives of single enterprises or clusters (Dominici and Levanti 2011). Dominici and Laventi (2011) argue for the integration of complexity science with other managerial theories in order to highlight the determinants underlying the behaviour of firms inside the inter-firm network. We address this gap by examining the nature and objectives of knowledge flows.

The paper is organised as follows. We first outline the central tenets of complexity theory and its relevance to innovation. We then review prior literature in the SME context on networks, in particular, the types of networks and behaviours associated with knowledge mobility and methods of IP protection and appropriation. This is followed by an outline of the research method, presentation of results, and discussion of the findings. The paper concludes with limitations and implications for policy-makers and future research.

2 Complexity Theory, Networks and Innovations

The current economy is recognised as a complex system operating out of equilibrium, constantly constructed by a set of institutions, arrangements and technological innovations (Allen 2013; Arthur 2013). As complexity of economic interactions grows, traditional frameworks become much less relevant in explaining the tendencies in the field of innovation and in offering effective solutions for policy-makers. It has been noticed that the economy is naturally self-organising; however, institutions and regulations are still hierarchical and top-down (Helbing 2013). Cooke (2013) adds that “cognitive dissonance” arises from linearity applied to managing complex organisations. Instead, recognition of the self-organising nature of socio-economic systems could be beneficial in finding effective solutions.

Complexity aspects are not new, having been introduced into innovation studies by Schumpeter (Schumpeter 1934), with radical changes produced by self-organised dynamics. Thus, understanding innovations through the lens of complexity underscores the need to define its elements and their interactions; that is network dynamics. It links traditional agents, such as firms and institutions,

with new agents, such as communities, users and technological platforms. These new innovation networks have generated a network of networks that link together companies, research institutions, inventors, self-organising communities, institutions and technologies (Cooke 2013). In the innovation complexity studies there are two frames of reference that can be distinguished (Frenken 2006): first, complexity can refer to complex interaction structures of components in a technological system, and second, complexity as the structures of interactions between agents in innovation networks (Rzevsky and Skobolev 2014). The focus of this study is on this second frame of reference. Application of complexity laws in innovation studies allows us to recognise inter-organisational networks as self-organised systems emerging naturally and evolving over time (McKelvey, Lichtenstein, and Andriani 2012). Innovations in such systems are products of spill-over effects based on diversity and connectivity reinforced by positive feedback loops (Lindsay 2005). In order to innovate, SMEs are embedded within an external environment which includes many stakeholders operating in a complex system. The systems dynamic allows SMEs to readapt their operations to a very competitive and changing environment (Dominici and Levanti 2011).

This dynamic is possible only if the social-economic system operates at the “edge of chaos” (McKelvey, Lichtenstein, and Andriani 2012) or “melting zone” (Kauffman 1993), which is the state in a complex system at which knowledge flows seamlessly among network agents giving rise to “self-organised distributed intelligence” (McKelvey, Lichtenstein, and Andriani 2012; Uhl-Bien and McKelvey 2007). Such behaviour produces large-scale effects that manifest themselves in positive externalities associated with enhanced innovative ability of network agents. It is noted that the emergence of innovation takes place when a critical threshold of density of transactions and variety of agents is achieved, giving rise to sustained communication patterns within innovation networks (Andriani 2003a; Andriani 2003b; He, Rayman-Bacchus, and Wu 2011). These interactions result in innovative projects, new ventures, and start-ups. Obtaining a critical mass, such innovative endeavours give rise to new industrial streams or technological paths which crystallise in the form of new institutions, and eventually industries, providing input for existing businesses thus creating positive feedback loops. This continuous transformation leads to transformation of regional systems and, in turn, innovative outcomes (Arıkan 2010).

Recognition that the static and linear nature of prior research related to social networks (e.g. Burt 1997; Granovetter 1973) gave rise to the new perspective on factors affecting innovative capacity, shifting the focus to network dynamics and evolution (Han and McKelvey 2008). This alternative view based on complexity science gave new insights into adaptability of complex inter-organisational networks to changing environment through changing their

configurations and recognising repeating patterns of self-organisation within complex networks resulting in scale-free structures (Barabási, Albert, and Jeong 2000; McKelvey et al. 2012). Such complex networks involve many interconnected and interdependent agents that operate at multiple levels. The agents, in our case, SMEs, are proactive, self-organised and readapt their behaviours as a result of changes in the global volatile economic environment (Dominici and Levanti 2011). Referring to Kauffman's "edge of chaos" concepts, Han and McKelvey (2008) show that spontaneous order creation takes place when three necessary conditions exist: (1) heterogeneous agents, (2) connections among them, and (3) motives to connect.

The role of formation and performance of inter-organisational networks draws on the stream of new organisational research involving the complexity sciences – an approach that offers useful insights into the dynamics of innovation (Clifton et al. 2010; Crespo, Suire, and Vicente 2014; Huggins, Johnston, and Stride 2012). For example, Clifton et al. (2010) show that learning and thus innovation often occurs via highly interactive, iterative, network-based processes. Crespo et al. (2013) relate regional resilience associated with ability to innovate with the structural properties of local inter-organisational knowledge networks. Huggins and Thompson (2015) found that the relationship between entrepreneurship, innovation and regional growth is governed by a series of network dynamics. Network capital, in the form of investments in strategic relations to gain access to knowledge, is considered to mediate the relationship between entrepreneurship and innovation-based regional growth. Breznitz and Taylor (2014) relate success of innovations with rich multiple, locally centred social networks as an essential prerequisite to growth and regional development. In summary, inter-organisational networks are seen as an important dimension of innovation (Chiaroni, Chiesa, and Frattini 2011; Fichter 2009; Vanhaverbeke and Cloudt 2006).

2.1 Complex Systems and Networking Behaviour

There are a number of studies examining the dynamics of self-organising behaviour in complex systems, in particular, forms of inter-organisational networks (Battiston and Catanzaro 2004; Crespo, Suire, and Vicente 2014; Zhao et al. 2011). System behaviour refers to system formation, change and evolution over time (Chauvet et al. 2011; Newman, Barabasi, and Watts 2006). Bellamy and Basole (2013) distinguish three foci in the literature related to network behaviour leading to network formation, change and evolution. These are stimuli, phenomena and sustainability. They recognise that stimuli are driven by agency,

opportunity, inertia and exogenous factors. Agency is seen as the ability to self-organise and adapt to changes within a system and environment, causing changes in the system structure itself. Firms representing autonomous agents although being interdependent have their own interests and goals; therefore, networks emerge as a product of utility-maximising self-interested behaviour. Opportunity represents networking behaviour based on trust and convenience.

Phenomena relate to natural changes in the system occurring over time giving rise to emergence as opposite to control – orderly architecture processes. Sustainability refers to such qualities of inter-organisational network as robustness, responsiveness and resilience (Bellamy and Basole 2013; Newman, Barabasi, and Watts 2006). Zaheer and Soda (2009) showed that network structures emerge out of structural constraints and network opportunities.

2.2 Types of Network

The agency and opportunity perspectives of SME networking behaviour in an innovation context is reflected in motifs for interaction underlying the formation and evolution of different types of complex network structures (Boschma 2004; De Caux et al. 2014; Frenken 2006; Boschma 2014). We examine them drawing on mechanisms of business and learning networks formation as the most crucial in innovations emergence.

We noted earlier that SMEs interact, and establish relationships with external organisations and institutions in order to access resources to facilitate innovation. These resources are typically accessed through the firm's business network (Tomlinson 2010; Tomlinson and Fai 2013). Business networks are particularly important conduits for providing access to complementary inputs, exposing SMEs to novel sources of ideas and, crucially, facilitating the transfer of tacit knowledge and expertise, and technological opportunity (Tomlinson and Fai 2013). Indeed, the premise that underlies much of the literature on SME networks (Tomlinson and Fai 2013) is that through access to, and utilisation of, external resources enterprises can overcome resource constraints (Teirlinck and Spithoven 2013; Terziovski 2010), or reduce some of the disadvantages or liability of their "smallness". We discuss the specific types of networks next.

2.3 Market-based Networks

Business networks can be vertical, involving firms at different points of the supply chain (i.e. buyers and suppliers), or horizontal, between competitors or

potential competitors (known as co-opetition) (Lorange, Roos, and Brønn 1992). Networks based on supply chains, or more generally, market-based networks, are typically closed networks, where network access is restricted to firms engaged in market exchanges with each other (Uzzi 1996). Repeated and exclusive transactions among member firms lead to the development of dense linkages between network firms (Gulati 1995). Dense linkages, in turn, provide the basis for the development of cooperation and trust between member firms, that facilitate the transfer of knowledge and expertise regarding products, technology and production processes (Cooney and Long 2014). Cooney and Long (2014) note the growing importance of networks based upon direct business to business relationships as firms increasingly seek partners with complementary resources to supply services that cannot be supplied internally by the firm (e.g. expertise in marketing and distribution), or a complete package of products and services. For example, the transfer of knowledge and expertise, along with new capital equipment and technology, often forms part of the package of services that accompany technological products.

The advantage of extensive inter-firm networking has been a contentious issue. On the one hand, research (Boschma and Frenken 2010; Ter Wal 2013) indicates that numerous and permanent links associated with high clustering coefficient or “embeddedness” have been found beneficial for innovative capacity of network participants due to high levels of trust and sharing of valuable tacit knowledge. On the other hand, closed networks may become ill equipped for the exploration and creation of new knowledge that leads to the creation of new technologies, new processes, new products and new services – if the network lacks thin, boundary spanning linkages to other networks (Lambooy 2005; Powell, Koput, and Smith-Doerr 1996); in other words, network members become too closed to new ideas due to over-embeddedness (Granovetter 1973). Dense cliques are associated with strong tie effects (Granovetter 1973) reducing agent heterogeneity (Han and McKelvey 2008) and lead to less novelty and technological “lock-in” (Crespo, Suire, and Vicente 2014; Martin and Sunley 2011).

Recent empirical research in the UK (Tomlinson 2010; Tomlinson and Fai 2013) indicates that vertical networks are particularly important for innovation, with higher levels of vertical supply chain collaboration (i.e. suppliers and firms, and buyers and firms), over a range of activities (from joint product design to marketing and distribution) leading to higher levels of innovation, broadly in line with other recent European studies (Lasagni 2012; Nieto and Santamaría 2010). Tomlinson (2010) found that horizontal networks (cooperation with competitors) are also important to innovation, albeit to a lesser extent. In contrast, other UK studies (Freel and Harrison 2006; Tomlinson

and Fai 2013) report that co-opetition had no significant impact on SME innovativeness.

Despite some mixed findings with respect to the relationship between competitors and innovation, we propose the following hypotheses:

H1a: SME cooperation with vertical market-based networks (i.e. clients and suppliers) enhances innovation.

H1b: SME cooperation with horizontal market-based networks (i.e. competitors) enhances innovation.

2.4 Localised Learning Networks

A second type of business network is a localised learning network (Cooney and Long 2014). Local learning networks comprise networks of firms and research institutes, colleges and universities and other institutional bodies which anchor the networks of firms that cooperate in projects to develop new knowledge (Owen-Smith and Powell 2004). These networks tend to be open with a mix of dense linkages (or “tight connections”) and thin linkages (or “loose connections”) between firms and between firms and research institutes, colleges and universities. While dense linkages are important for cooperation and knowledge transfer, linkages in localised learning networks are not exclusive, with multi-party relationships creating the dynamism in the network that leads to innovation. The institutions anchoring the network tend to serve a range of public and private purposes in localised learning networks, enabling the formation of thin linkages. These thin linkages are important as they are often boundary spanning linkages, linking firms to new firms and linking networks to other related networks. These linkages permit knowledge spill-over through and across networks and so are sources of new knowledge leading to innovation (Keeble et al. 1999; Powell and Grodal 2005). SMEs, in particular those that lack the internal resources necessary for the creation of new knowledge, may be relatively more dependent upon local learning networks for the creation of new knowledge vis-à-vis larger firms (Hughes, O'Regan, and Sims 2009; Kirkels and Duysters 2010). Thus we suggest the following hypothesis:

H2: SME cooperation with localised learning networks (universities, higher education institutions and public sector research organisations, government institutions) enhances innovation.

2.5 Nature of Knowledge Flows through Networks

Localised learning networks (such as universities, higher education institutions and public sector research organisations and government institutions) and market-based networks (suppliers, customers and competitors) have been conceptualised as providing scientific/technical knowledge and market knowledge respectively (Danneels 2002; Du, Leten, and Vanhaverbeke 2012; Mina, Bascavusoglu-Moreau, and Hughes 2014). Drawing on a sample of 221 Belgian manufacturing firms, Faems, Van Looy, and Debackere (2005) provide empirical evidence that universities or research institutes are associated with exploration-oriented collaborations, generating new knowledge, or acquiring knowledge and technology for the development of innovations, while customers and suppliers are associated with exploitative collaborations, exploiting existing knowledge or marketing the innovation. However, other empirical evidence (Tomlinson 2010) indicates that vertical cooperation with suppliers and customers across a range of activities – from joint product design to marketing and distribution – enhances innovation, although this research was not specific to SMEs and did not examine localised learning networks.

In the SME context, some empirical studies (Theyel 2013; van de Vrande et al. 2009; Verbano, Crema, and Venturini 2011) indicate that SMEs are most likely to network in the technology/development/research and development (R&D) phase, providing a mechanism to overcome their smaller technological portfolio, by engaging in collaborative R&D, or outsourcing/contracting out R&D. For example, in a study of SMEs in regional US, Theyel (2013) found that just over half of the enterprises used joint product and technology development with customers and suppliers, followed by joint commercialisation and joint manufacturing. Verbano, Crema, and Venturini (2011) also found that Italian SMEs are more likely to collaborate on new idea generation, experimentation and design, and if necessary, then in the commercialisation/production phase.

In contrast, Teirlinck and Spithoven (2013) suggest that SMEs have to devote resources to other aspects of the value chain in order to market the internally developed and externally sourced knowledge – for example, in the commercialisation phase. According to Narula (2004) small firms focus on networking for commercialisation purposes because they lack marketing channels and manufacturing facilities. This accords with Lee et al. (2010), who argue that SMEs focus more on commercialisation on the premise that while many SMEs have superior technology for invention, they lack the knowledge, resources and capabilities to manage the entire innovation process by themselves, limiting their ability to commercialise their innovation, with

concomitant adverse implications for innovation performance (Rosenbusch, Brinckmann, and Bausch 2011).

On the basis of the preceding discussion we expect that networking for R&D purposes (which includes idea generation, experimentation and design, through joint ventures, contracting out, consulting, etc.) and – perhaps to a lesser extent – networking for commercialisation and production purposes (through joint ventures, purchase arrangements, etc.) has a positive impact on innovation. Thus we suggest the following hypotheses:

H3a: SME networking for the generation of new knowledge, or acquiring knowledge for the development of innovations (i.e. R&D purposes) enhances innovation.

H3b: SME networking for knowledge for commercialisation and production purposes enhances innovation.

2.6 Managing Innovation Appropriability

From the complex network behaviour perspective, appropriability represents a protective mechanism that substitutes for lack of trust and acts as a constraint for seamless knowledge flow within an innovative network. It might also be conceptualised as “inertia” – norms and rules that moderate formation of new ties leading to knowledge creation and innovations. However, from the firm perspective a key incentive to innovate is to appropriate returns from their innovation activities (Levin et al. 1987) necessitating robust value appropriation mechanisms. The term “appropriability mechanisms” refers to the formal IP rights (such as patent, trademark, or copyright protection) and informal IP mechanisms (e.g. developing high trust relations, lead times/first mover advantages, and lock-ins) that allow a firm to protect its knowledge and intangibles and profit from them (Teece 1986).

While both formal and informal IP methods for innovation appropriation exist (Dahlander and Gann 2010; Pisano 2006; Teece 1986) and work well in the context of large firms, SMEs are assumed to be disadvantaged in their ability to utilise formal IP rights (IPRs) – on the basis that IPRs are both costly to acquire and to enforce – and instead rely on informal, non-legal appropriability mechanisms such as secrecy and first-mover advantages (Jensen and Webster 2006). Yet a recent empirical study by Jensen and Webster (2006) found that Australian SMEs actually have higher rates of patent, trade mark and design usage vis-à-vis large firms, once industry effects are controlled for. This may suggest that SMEs have more incentives relative to large firms to obtain IP protection: for example,

if more of their transactions occur through the external market rather than within the firm, and a lower level of trust between transacting parties makes legal contracts more attractive to both parties (Jensen and Webster 2006).

But while an emphasis on legal appropriability methods provide managers with the confidence to network widely with external partners – allaying fears of opportunistic behaviour from these partners (Teece 2002) – too much emphasis on appropriability may be associated with reduced efforts to draw in knowledge from networks (Laursen and Salter 2014). Conversely, if the firm has no strategy in place to realise the value from its innovative efforts, it might choose to go it alone, thereby reducing opportunities to develop and commercialise their innovations.

Olander, Hurmelinna-Laukkanen, and Mähönen (2009)) argue that the size of small firms intensifies this knowledge protection/sharing dilemma: the limited resources of SMEs relative to large firms create a greater need for them to disclose some of their knowledge in exchange for resources that they lack, but they must simultaneously protect their most valuable intellectual assets in order to succeed commercially, despite limited resources making it more difficult for them to use expensive, complex formal IP mechanisms. As noted above, this is because the range of appropriability mechanisms available to various sized firms may differ (Olander, Hurmelinna-Laukkanen, and Mähönen 2009) with SMEs disadvantaged vis-à-vis large firms in their ability to use formal IP to appropriate returns from innovation (Jensen and Webster 2006; Spithoven, Vanhaverbeke, and Roijakkers 2013) and instead rely on informal, non-legal appropriability regimes (Jensen and Webster 2006). Agostini et al. (2015) find that informal appropriability regimes are most important to protecting innovations and realising economic benefits in the form of higher profitability.

Research also indicates that the type of network influences the type of protection and appropriation strategies employed by SMEs. In a qualitative study involving vertical networks in Finland and in the Netherlands, Paasi et al. (2010) found that contracting is the most important method to protect the IP of the firm, with trust perceived as complementary to contracting. Informal methods, particularly secrecy, were also among the most preferred ways to protect IP. Formal methods, especially patents and trademarks, protected innovation outcomes, which also received more management attention.

In contrast, quantitative evidence from a study of small, innovative Finnish firms with horizontal networks, together with firms with substantial vertical networks, indicates that speed rather than secrecy is key to protecting

innovation returns (Leiponen and Byma 2009). Secrecy is perceived to be beneficial to firms that do not engage with networks. Formal IPRs are unlikely to be emphasised by small firms as important IP mechanisms, with the exception of small R&D-intensive and science-based enterprises networking with science-based partners (e.g. universities), which identify patents as the most important method of appropriation (Leiponen and Byma 2009).

The emphasis on informal practices was established in an early study of SMEs in the UK (Kitching and Blackburn 1998), in which most small business owners place more importance on informal methods, which are seen as more familiar, cheaper, less time-consuming and importantly, effective in protecting IP. Moreover, these practices enable SMEs to commercialise innovations, and thus are seen as product market strategies rather than IP practices *per se* (Kitching and Blackburn 1998). Thus sharing information can build trust and facilitate innovation, but still protect the “crown jewels” (Tapscott and Williams 2006).

In a large-scale study of innovative small enterprises in Germany, Thomä and Bizer (2013) found that informal IP is the dominant protection mechanism. However, for many the main issue is not whether to use IPRs or not, but whether to protect their innovations from imitation at all. Thomä and Bizer (2013) also found that formal and informal appropriation practices are employed jointly. Thomä and Bizer (2013) conclude that the relevance of specific appropriability mechanisms depends, in part, on innovativeness. On the basis of the preceding, we investigate how SMEs protect and appropriate IP and the extent to which these factors affect SMEs’ innovativeness.

H4a: Informal IP mechanisms enhance innovation.

H4b: Formal IP mechanisms enhance innovation.

3 Conceptual Framework

Based on the preceding discussion, Figure 1 describes the conceptual framework that depicts the complexity attributes of emergence of spontaneous order in the state of “melting zone” (Kauffman 1993), and self-organised criticality (Bak 1996) applied to innovative networks orchestration framework (Dhanaraj and Parkhe 2006) acknowledging the existence of external factors (such as law, policy, environment and economy) which may influence the agents’ behaviour (who are involved in the formation of dynamic network patterns resulting in innovative outcomes) (Gorod et al. 2015).

Figure 1: Conceptual framework.

Note: Although the presentation of the model suggests a linear sequence (read from left to right), this illustration has merely been adopted to facilitate interpretation of the model, and is a practice adopted in prior research on complex systems (White et al. 2014). As White et al. (2014) note, a linear mindset is seldom effective with complex systems.

In the next section, we present the research method employed to test the hypotheses and answer the research questions.

4 Research Method

4.1 Survey Design, Sample and Constructs

The study used a self-administered questionnaire conducted via the internet to survey SME owners/managers in the Adelaide metropolitan area of South Australia. Adelaide is the capital of South Australia, with a population of around 1.3 million people. The questionnaire was an adaptation of the Australian Innovation Survey (ABS 2003) which was based on the Organisation for

Economic Co-operation and Development's (OECD) *Oslo Manual* (OECD 2005). Some minor modifications and additional questions were introduced in some sections to meet the study's research objectives.¹

4.2 Sample

The population for the study consists of all SMEs in the Adelaide Metropolitan area. The South Australian State Government supplied the dataset from which the sample was selected. A subset of records was extracted from this database that met the following criteria: active businesses in the Adelaide Metropolitan area; annual turnover of more than \$50,000; Australian Business Number registration for taxation purposes; and an email address. The sample was further restricted to commercial enterprises. This population subset comprises 14,206 Adelaide businesses. Of these, 33.7% of the email addresses proved to be inoperable. This resulted in a final Adelaide population dataset comprising 9,418 active firms.

An (email) invitation to participate was sent with a link to the survey. A total of 1,226 questionnaires were received; however, only 838 were used in the analysis because some questionnaires contained missing data. An analysis of the sample in comparison with the population revealed no apparent differences between the two groups. Thus, the active response rate was 9% (Neuman 2000) and compares with an expected rate for internet surveys of 11% (Saunders, Lewis, and Thornhill 2007).

4.3 Constructs

The unit of analysis of this research are SMEs (units or nodes) which interact with other agents in the economic system (through linkages or ties) (Rzevsky and Skobolev 2014). The analysis will focus on structure and actor diversity in order to interpret the SMEs' behaviours through identification of patterns of relations. These patterns underlie the SMEs' preferences use in knowledge and appropriability methods.

4.3.1 Dependent Variable

Firm innovativeness: the survey questionnaire asks about four types of innovation output as described in the *Oslo Manual* (OECD 2005): product innovation,

¹ A copy of the survey is available from the corresponding author.

operational process, organisational/managerial methods, and marketing methods. In order to simplify analyses, we measure SMEs' innovativeness by constructing a count of innovation types (ranging from 0 to 4), according to the number of different types of innovation launched in the last two years. Mina, Bascavusoglu-Moreau, and Hughes (2014) constructed a similar measure of innovation output.

4.3.2 Independent Variables

4.3.2.1 Heterogeneous Active Ties heterogeneity (diversity)

Ties heterogeneity or diversity measure as an index of multiple types of agents used in complex inter-organisational networks research (Powell, White, Koput, and Owen-Smith 2005), our independent variables, heterogeneous ties, can be broadly categorised into two major groups: market-based and localised learning ties. The first group includes three types of agents who are part of the market-based networks which were subdivided into two subgroups. The first subgroup includes vertical network ties (clients and suppliers) and the second subgroup includes horizontal network ties (competitors). The second group involves four types of agents in localised learning networks (universities, commercial laboratories/R&D enterprises, private, not-for-profit research institutes and other institutional bodies). In each case, we use dichotomous values (if the tie exists, there is a value of one assigned or it is a value of zero if it doesn't exist)

4.3.2.2 Nature of Knowledge Flows

SMEs network to source knowledge from agents in market-based networks and localised learning networks for purposes that can be broadly categorised into those related to the generation of new knowledge, or acquiring knowledge for the development of innovations (hereafter referred to as R&D-related purposes for convenience), or for commercialisation and production related purposes. We use nine items to measure knowledge flows related to R&D-related purposes: used research facilities of HEI or research institutions, used patents, designs, or other IPRs initially from these HEI or research institutions, used consultants from HEI or research institutions, and contracted out R&D to HEI or research institutions, or joint R&D, or informally sourcing ideas internally, from market-based actors, from institutional actors or from "other" actors. We use four items to measure knowledge flows for commercialisation and production purposes as part of a package with the purchase of new equipment or technology for producing goods or services, joint marketing and distribution, joint manufacturing, joint R&D and other joint venture. Again, we use dichotomous values (if the tie exist, there is a value of one assigned or it is a

value of zero if it doesn't exists) and those values were summed in order to give a breadth value of the flows.

4.3.3 Managing Appropriability

Finally, we measure four formal methods of IP (patents, registered design, copyright or trademark, and licensing agreements) and three informal methods of IP (secrecy, complexity of product design, making frequent and rapid changes to the goods or services) used by SMEs. Dichotomous values were introduced (if the tie exists, there is a value of one assigned or it is a value of zero if it doesn't exist) and those values were summed in order to give a breadth value of the appropriability methods.

4.4 Data Analysis

The data was analysed with multivariate statistical techniques using Statistical Package for data analysis (Stata). First a descriptive analysis is presented. Second, multivariate regression analysis using Poisson regressions were employed to test the relationship between the explanatory variables and SMEs' innovativeness. Data are expected to "cluster" within firm sizes (FIRMSIZE) and so the robust (clustered) Poisson estimator is used.

Table 1: Frequency distributions.

Group description	Explanatory variables	Frequency	Used (percentage)
Innovativeness (count variable including product, operational, organisational/managerial and marketing methods)	NO	245	29
	1 Type	189	23
	2 Types	179	21
	3 Types	117	14
	4 Types	108	13
Heterogeneous Active Agents	Market-based agents		
	Vertical Network Suppliers	371	44
	Clients	402	48
	Horizontal Network Competitors	228	27
	Learning localised agents		
	Universities	69	8
	Government	112	13
	Private non-profit research institutions	31	4
	Commercial laboratories/R&D enterprises	39	5

(continued)

Table 1: (continued)

Group description	Explanatory variables	Frequency	Used (percentage)
Nature of Knowledge Flows Through Networks	Knowledge sourced for the generation of new knowledge, or acquiring knowledge		
	Internal sources of ideas	621	74
	Marketing sources of ideas	515	61
	Institutional sources of ideas	183	22
	Other sources of ideas	400	48
	Used research facilities of HEI or research institutions	37	4
	Used patents, designs, or other IPRs initially from these HEI or research institutions	19	2
	Used consultants from HEI or research institutions	41	5
	Contracted out R&D to HEI or research institutions	19	2
	Joint R&D	92	11
	Knowledge sourced for commercialisation and production		
	Acquired new equipment or technology for producing goods or services	331	40
	Joint marketing and distribution	130	15
	Joint manufacturing	43	5
	Other joint venture	64	8
Managing Appropriability	Informal IP methods		
	Secrecy	237	28
	Complexity of product design	110	13
	Making frequent and rapid changes to the goods or services	76	9
	Formal IP methods		
	Patents	60	7
	Registered design	42	5
	Copyright or trademark	182	22
	Licensing agreements	48	6
Control variablesFirm size (FIRMSIZE)	Micro	575	69
	Small	164	20
	Medium	69	8
Firm age (AGE)	Less than a year	104	12
	1 year to less than 4 years	259	31
	4 years to less than 9 years	181	22
	9 years to less than 19 years	184	22
	20 years or more	109	13
Industry Group(ANZSIC4)	Manufacturing and mining	92	11
	Professional Services	277	33
	Others	469	56
R&D	Expenditure on R&D as a % of total gross income (*)	357	43

Note: (*) continuous variable – 357 companies have some expenditure on R&D.

4.5 Descriptive Results

Table 1 shows that around 70% of SMEs are innovative. While SMEs are most likely to introduce one type of innovation (23%), almost as many enterprises undertake two types of innovation (21%). Enterprises are substantially less likely to introduce three (14%) or four (13%) types of innovation. Table 1 also indicates that SMEs are more likely to interact with agents in market-based networks than agents in localised learning based networks, with suppliers and clients most commonly collaborated with (44% and 48% respectively). In contrast, 10% or less of SMEs interacted with universities, commercial laboratories/R&D enterprises or private not-for-profit research institutes, while just over 10% of enterprises interact with government bodies.

SMEs are most likely to network to generate new knowledge, or acquire knowledge for the development of innovations (i.e. R&D related purposes), by searching for ideas informally internally (74%) or via market-based actors (62%) (see Table 1). SMEs are unlikely to source this knowledge from HEIs, with less than 5% of SMEs utilising any of the methods associated with universities, public sector research organisations, or government institutions (refer to Table 1). While SMEs are less likely to source knowledge for commercialisation/production purposes, 40% of SMEs source knowledge as part of the package with the purchase of new equipment or technology for producing goods or services, while 16% of SMEs undertake joint marketing and distribution.

Table 1 also shows that SMEs are more likely to employ informal than formal IP methods, in particular secrecy, complexity and undertaking frequent and rapid changes to product/service (28%, 13% and 9% respectively). Copyright and trademark are the most commonly used formal IP methods (22%), with patents and registered design employed by only 7% and 5% respectively of SMEs.

4.6 Multivariate Analysis Results

Table 2 presents the results of the Poisson regression used to analyse the influence of the explanatory variables on SMEs' innovativeness. Tests of the model suggest that the potential problem of over dispersion is not present, as the mean (1.589) and variance (1.878) do not differ markedly. In the case of firm size, small and medium-sized firms show significant differences compared with micro firms (IRR, incidence rate ratio = 1.175, $p = 0.009$ and IRR = 1.223, $p = 0.043$, respectively) with small and medium-sized enterprises more innovative

Table 2: Poisson regression analyses: relationship explanatory variables to innovativeness.

Explanatory variable	EXP (beta) = IRR
<i>Heterogeneous Active Agents</i>	
<i>Market-Based Agents</i>	
Vertical Network Suppliers	1.094***
Clients	1.057*
Horizontal Network Competitors	0.941**
<i>Learning Localised Actors</i>	
Universities	1.057
Government	0.955
Private non-profit research institutions	1.002
Commercial laboratories/research and development enterprises	0.953
<i>Nature of Knowledge Flows Through Networks</i>	
<i>Knowledge sourced for the generation of new knowledge, or acquiring knowledge</i>	
Internal sources of ideas	2.107***
Market-based: Marketing sources of ideas	1.235***
Science-based: Institutional sources of ideas	1.028
Other sources of ideas	1.047
Used research facilities of HEI or research institutions	1.086
Used patents, designs, or other intellectual property rights initially from these HEI or research institutions	0.741
Used consultants from HEI or research institutions	1.139
Contracted out research and development to HEI or research institutions	1.207*
Joint research and development	0.888
<i>Knowledge sourced for commercialisation and production</i>	
Acquired new equipment or technology for producing goods or services	1.297***
Joint marketing and distribution	1.228**
Joint manufacturing	1.040
Other joint venture	1.105
<i>Managing Appropriability</i>	
<i>Informal IP</i>	
Secrecy	1.055*
Complexity of product design	1.118**
Making frequent and rapid changes to the goods or services	1.176***
<i>Formal IP</i>	
Patents	0.913
Registered design	1.001
Copyright or trademark	1.111*
Licensing agreements	1.107

(continued)

Table 2: (continued)

Explanatory variable	EXP (beta) = IRR
Control variables³	
FIRMSIZE (Micro)	
Small	1.175**
Medium	1.223**
AGE (less than one year)	
1 years to less than 4 years	1.172**
4 years to less than 9 years	1.087*
9 years to less than 19 years	1.318
20 years or more	1.087
ANSZICGROUP (Manuf and Mining)	
Professional Services	0.884
Others	0.952
R&D expenditure	1.001***
_cons	0.461
N	807
McFadden's R ² ¹	0.118
Good_of_fit ²	0.119

Note: ¹The McFadden's pseudo-R² statistics is acceptable for the model; ²The goodness of fit statistic suggest the null hypothesis of the Poisson model being a good fit to the data cannot be rejected at any conventional level (e.g. p -value is 0.119); the data are not over-dispersed (the Poisson is suitable***, **, * denotes significance at the $p < 0.01$, $p < 0.05$ and $p < 0.1$ levels respectively. An $IRR < 1$ means that that firms innovativeness is lower than other firms: e.g. in micro-sized firms, the variable 'Merger/takeover with/of another business o/s has an IRR of 0.504-firm's with this attribute have lower innovativeness that is about half that of average. An $IRR > 1$ means that firm's innovativeness is higher than other firms: e.g. Used contracted out research and development to these institutions $IRR = 1.243$, firms with this attribute have innovativeness about 1 time more that of the average; ³In the case of control variables, small and medium-sized firms show significant differences compared with micro firms ($IRR = 1.175$, $p = 0.009$ and $IRR = 1.223$, $p = 0.043$, respectively) with small and medium-sized firms more innovative than micro firms. Medium-sized firms are, in turn, more innovative than small firms. With respect to age, firms between one and nine years are more innovative than firms that are younger than one year ($IRR = 1.172$, $p = 0.011$ and $IRR = 1.087$, $p = 0.073$, respectively). R&D expenditure presents also significant results ($IRR = 1.001$, $p = 0.000$). R&D expenditure increases SME innovativeness.

than micro firms. Medium-sized firms are, in turn, more innovative than small firms. With respect to age of firms, firms between one and nine years are more innovative than firms that are younger than one year ($IRR = 1.172$, $p = 0.011$ and $IRR = 1.087$, $p = 0.073$ respectively). This can be interpreted as firms

Table 3: Hypothesis summary.

Hypothesis	Group hypothesis testing	Hypothesis description	Explanatory variable	Hypothesis testing
H1	a) Accepted	a) SME cooperation with vertical market-based networks (i.e. clients and suppliers) enhances innovation.	Suppliers Clients	Accepted
	b) Rejected	b) SME cooperation with horizontal market-based networks (i.e. competitors) enhances innovation.	Competitors	Rejected
H2	Rejected	SME cooperation with localised learning networks (universities, HEIs and related research institutes) enhances innovation.	Universities Government Private non-profit research institutions Commercial laboratories/R&D t enterprises	Rejected
H3	a) Partially accepted	a) SME networking for the generation of new knowledge, or acquiring knowledge for the development of innovations (i.e. R&D) enhances innovation.	Informal ideas from internal sources	Accepted
			Informal ideas from market sources	Rejected
			Informal ideas from Institutional sources	
			Informal ideas from other sources	
			Used research facilities of HEI or research institutions	Accepted
			Used patents, designs, or other IPRs initially from these HEI or research institutions	
			Used consultants from HEI or research institutions	
			Contracted out R&D to HEI or research institutions	Accepted
			Joint R&D	Rejected

(continued)

Table 3: (continued)

Hypothesis	Group hypothesis testing	Hypothesis description	Explanatory variable	Hypothesis testing
H4	b) Partially accepted	b) SME networking for knowledge for commercialisation and production enhances innovation.	Acquired new equipment or technology for producing goods or services) Joint marketing and distribution Joint manufacturing Other joint venture	Accepted Rejected
	a) Accepted	a) Informal IP mechanisms enhance innovation	Secrecy Complexity of product design Making frequent and rapid changes to the goods or services	Accepted
	b) Partially accepted	b) Formal IP mechanisms enhance innovation	Patents Registered design Copyright or trademark Licensing agreements	Rejected Accepted Rejected

become more innovative after they start their businesses; however, over time, they became less innovative. R&D expenditure also presents significant results (IRR = 1.001, $p = 0.000$).

Table 3 provides a summary of each of the individual hypotheses tested and confirmed or rejected based on the significance of the relationships identified in the results appearing in Tables 2 and 3. H1a states that SME interaction with vertical market-based networks enhances innovation. This hypothesis was supported. H1b states that SME interaction with horizontal market-based networks enhances innovation. This hypothesis was rejected as there is a significant but negative effect between SMEs' interaction with competitors and innovation, indicating that interaction with horizontal networks or competitors reduces innovation. H2 states that SME interaction with localised learning networks enhances innovation. This hypothesis was rejected as there was no significant evidence of these relationships. H3a states that SME networking for the generation of new knowledge, or acquiring knowledge for the development of innovations enhances innovation. This hypothesis was only partially supported since there were significant positive relationships between internally sourced ideas

and innovation, marketing sourced ideas and innovation, and contracting out R&D to HEI or research institutions and innovation. H3b states that SME networking for knowledge for commercialisation and production enhances innovation. This hypothesis was partially supported – there was a significant relationship between the acquisition of new equipment and technology and innovation, and joint marketing and distribution and innovation. H4a states that informal IP mechanisms enhance innovation. This hypothesis was supported, with SMEs that use secrecy, complexity of product design and making frequent and rapid changes to products/services innovating. H4b states that formal IP mechanisms enhance innovation. This relationship was partially supported, as only copyright and trademark have a positive relationship with innovation.

4 Discussion

This study set out to understand what, how and why does innovation-related knowledge flow from heterogeneous agents in general, and market-based networks and localised learning networks in particular, to SMEs; how do SMEs protect IP and appropriate value; and to what extent do these factors and patterns affect SME innovativeness.

We find evidence of an interaction pattern involving SMEs networking with agents in market-based networks and to a lesser extent, agents in localised learning networks, as has been the case in prior research (Kang and Kang 2014; Mina, Bascavusoglu-Moreau, and Hughes 2014). The results of the regression analyses show that the patterns of networking with suppliers increase innovativeness, underscoring the importance of the vertical supply chain network. Furthermore, despite the fact that very few SMEs source knowledge from localised learning networks, and in particular, HEIs and related institutions, regression analyses indicate that the pattern of outsourcing R&D to these networks increase innovativeness. This most likely reflects SMEs' limited internal R&D capabilities (Teirlinck and Spithoven 2013), and/or the need for complementary (Teece 1988), cost effective, non-core, applied research (Tidd and Trewhella 1997). Enterprises may prefer to outsource applied R&D to HEI and related research institutions in localised learning networks because of the fear of giving away their technology to a (potential) competitor (Tidd and Trewhella 1997). In this study, results show horizontal networks (i.e. cooperation with competitors) reduces innovativeness, which may suggest that the fear of SMEs giving away their technology to a competitor is well founded.

Our results also indicate a pattern of SMEs networking to source knowledge for R&D-related purposes, with the overwhelming majority of enterprises searching for ideas internally and via market-based agents that have the advantage of providing market-related knowledge, at little or no cost (Kang and Kang 2009; Kang and Kang 2014). The importance of sourcing ideas internally and externally was underlined by the results of the regression analyses which revealed that ideas sourced informally, both internally and through agents in market-based networks, increase innovation, with internally sourced ideas having the strongest impact on innovativeness, indicating that firm-specific knowledge is still very important for innovation. Firm-specific knowledge makes it easier to assimilate knowledge external to the firm and thereby to further innovate. Moreover, it is this combination of firm-specific knowledge and external knowledge forming an innovation that is not directly available to competitors, that yields value through rarity and competitive advantage (Torkkeli, Kock, and Salmi 2009, 180) and *inter alias*, may generate “rents” or superior profits over time (Huang and Rice 2009).

We also find that the pattern of networking for knowledge for commercialisation/production purposes via joint marketing and distribution has a positive impact on innovativeness. This is important in as much as inter-organisational collaboration for marketing and distribution implies SMEs access complementary assets needed to turn innovation projects into a commercial success (Hagedoorn 1993; Teece 1986).

In addition, our results reveal that SMEs source knowledge for commercialisation/production-related purposes as a by-product of formal economic exchanges or as part of existing business-to-business relationships, in particular, as part of a package with the purchase of new equipment or technology (Cooney and Long 2014), again underlying the importance of vendors in the vertical supply chain network as a knowledge source. Given the resource constraints of SMEs vis-à-vis large firms, SMEs are likely more dependent upon such relationships for this knowledge. This is especially important in light of the regression analyses that show that sourcing knowledge as part of a package with the purchase of new technology increases innovativeness.

Finally, we find that only the minority of SMEs protect IP, suggesting that for many innovative small enterprises the question is indeed not whether to use informal or formal IP protection, but whether to protect innovations from imitation at all (Thomä and Bizer 2013). For enterprises that do, as we would anticipate from prior work (Kitching and Blackburn 1998; Paasi et al. 2010; Thomä and Bizer 2013), informal IP in the form of secrecy is most common, and to a slightly lesser extent, formal copyright and trademark. Moreover, informal IP methods, in particular, secrecy, complexity of product design, and

frequent and rapid changes to products/services, increase enterprise innovativeness, as do formal copyrights and trademarks. While informal and formal practices serve to protect IP, these practices are also product market strategies, enabling enterprises to commercialise innovations (Kitching and Blackburn 1998). For example, a registered trademark provides legal protection for an enterprise's brand, enabling it to stop other firms from trading with it. However, enterprises also use trademarks as part of their marketing and branding strategy, with consumers associating a certain quality, reputation and image with goods/services bearing a trademark, thus differentiating the SMEs' product/service from competitors', and enabling the SME to appropriate returns to their investment in product/service development (Jensen and Webster 2006).

However, IP protection reflects inertia (Bellamy and Basole 2013) in networks formation, reducing network opportunity based on trust and increasing transaction costs, thus impeding innovative outcomes from the systems perspective. In other words, IP constraints do not allow a positive feedback loop effect by means of extensive knowledge diffusion and networking (Andriani 2003b) to occur. We suggest that the nature of interactions among SMEs as innovative agents have yet to evolve to complexity dynamics through positive feedback loops that result in break-through innovation outcomes (Han and McKelvey 2008). One effective way to deal with this form of complexity is with agent based modelling, in parallel with the real world (Rzevsky and Skobolev 2014).

5 Conclusions, Implications and Limitations

This paper presented the results of one of the few field studies to investigate knowledge mobility and appropriability patterns among SMEs using complexity theory perspective. Specifically, the research contributes to our understanding of different active 'agents' patterns of participation within the system and their contribution through networking activities to innovation in SMEs in a regional Australian context. By offering a conceptual framework based on innovative networks orchestration model (Dhanaraj and Parkhe 2006), that acknowledges complexity attributes of emergence of spontaneous order associated with the formation and development of innovative networks, such as the state of "melting zone" (Kauffman 1993), and self-organised criticality (Bak 1996), as well as the existence of external factors (such as law, policy, environment and economy), which influence the agents' behaviour and the formation of dynamic network patterns in the South Australian SME context. Furthermore, it expands the literature on the role of complex systems in entrepreneurial process

(McKelvey 2010), by addressing the role of balancing forces to keep the innovative system in equilibrium: joint initiatives and vertical knowledge exchange using business-to-business relationships as positive feedback leading to its evolution and structural changes, versus appropriability, which acts as a negative feedback mechanism or inertia preventing it from moving to the state of self-organised criticality (Bak 1996) and the role of heterogeneity of innovative agents in co-evolution of the South Australian SME innovative networks (McKelvey 2010). It also contributes to a better understanding of regional innovation systems, and specifically, in the context of regions that are comparatively less competitive to the larger economy, as the research setting was South Australia, in which economic growth has lagged compared to other parts of Australia for the past few decades.

From the perspective of complexity theory we speculate that inertia, in the form of appropriability constraints and a more traditional approach to innovation, characterised by inwardly focused processes and limited interaction with agents in networks, shape innovative networks in the South Australian SME context. This acts as a network constraint (Zaheer and Soda 2009) and does not allow evolution to the state of the “edge of chaos” (Boschma 2010; Han and McKelvey 2008) which is needed in order to enable the full benefits of positive externalities arising from self-organised distributed intelligence (McKelvey et al. 2012) to be achieved, with potential concomitant adverse consequences for regional innovation and growth (Huggins and Thompson 2015). We examine the implications of this below.

Innovation has long been seen as a means for improving national competitiveness, productivity and economic development. However, improvements at the national level can only come about as a result of improvements at the firm level which in turn form part of regional innovation systems. Given concerns about the innovative performance of Australian enterprises, and the high number of SMEs that comprise the Australian economy, this study has implications for policy-makers.

The findings indicate that in the South Australian SME context there are constraints to realising the benefits that arise from spill-over effects due to the network behaviour of innovative agents. Protective attitudes towards IP appropriability and limited networking result in inert behaviour of innovative networks and do not allow crossing the “tipping point” where self-organising behaviour at the “edge of chaos” allows the creation of new structures of distributed knowledge and in turn, innovation. Policy-makers need to understand and incorporate socio-economic complexity and use interaction-oriented instead of agent-oriented viewpoints to encourage change in networking behaviour of SMEs (Helbing 2013), with the aim of encouraging distributed

knowledge creation through network interactions; for example through incentives for collaborative behaviour (Cooke 2013). Helbing (2013) provides a way forward, introducing a new type of economic agent – “homo-socialis” that recognises complex interdependencies and acts accordingly, recognising the interests of its neighbours, as opposed to self-regarding “homo-economicus” thus creating “networked minds”. This can be solved by using complexity techniques. The recognition of network structures would call for new approaches based on network governance that put the emphasis on effective interactions among innovative agents.

Some limitations of the research warrant mentioning so that our research can be interpreted within its constraints. First, we acknowledge the survey is cross-sectional which may affect the explanatory power of the dependent variable which may have lag effects. Future research should incorporate longitudinal data to address this issue. Second, the study uses linear analytic tools to explain complex behaviour of entrepreneurial innovative networks. Further research could be conducted through modelling network interactions using constructs developed in this study supplemented by longitudinal data. Further exploration of order creation mechanisms in entrepreneurial innovative networks such as adaptive tension, phase transitions, and co-evolving causalities operating in an out of equilibrium economy is also warranted.

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