

## Knowledge flow and inter-firm networks: The influence of network resources, spatial proximity and firm size

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The objective of this paper is to analyse the characteristics and nature of the networks that firms utilize to access knowledge and facilitate innovation. The paper draws on the notion of network resources, distinguishing two types: social capital – consisting of the social relations and networks held by individuals; and network capital – consisting of the strategic and calculative relations and networks held by firms. The methodological approach consists of a quantitative analysis of data from a survey of firms operating in knowledge-intensive sectors of activity. The key findings include: social capital investment is more prevalent among firms frequently interacting with actors from within their own region; social capital investment is related to the size of firms; firm size plays a role in knowledge network patterns; and network dynamism is an important source of innovation. Overall, firms investing more in the development of their inter-firm and other external knowledge networks enjoy higher levels of innovation. It is suggested that an over-reliance on social capital forms of network resource investment may hinder the capability of firms to manage their knowledge networks. It is concluded that the link between a dynamic inter-firm network environment and innovation provides an alternative thesis to that advocating the advantage of network stability.

**Keywords:** inter-firm networks; knowledge networks; network resources; network capital; social capital; innovation; regions; network dynamism

### 1. Introduction

The rapid growth of research on inter-firm networks, as well as networks between firms and other organizations, has led to such networks becoming increasingly recognized as important assets for securing competitive advantage (Kogut 2000; Owen-Smith and Powell 2004; Dyer and Hatch 2006; Lavie 2006; Gulati 2007). Taken together, the resource-based view of the firm (Wernerfelt 1984; Barney 1991) and inter-firm network theory suggest that firms have a dual necessity to form and manage external networks producing knowledge and information of value, as well as possessing the internal capabilities to profitably exploit this knowledge. The objective of this paper is to empirically assess the characteristics and nature of the networks that firms utilize to access knowledge and facilitate innovation.

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The paper seeks to analyse the inter-firm and other knowledge networks external to firms from a number of perspectives, including the rationality and motivation for network development, the nature of the firm, the type of network participants, the dynamism and stability of networks, and their spatial scope. In particular, the paper draws on the notion of *network resources* (Lavie 2006; Gulati 2007) to better understand those assets that firms have at their disposal to facilitate knowledge-based interactions and relationships. In seeking to distinguish different forms of network resource, we integrate the concept of *social capital*, which we argue largely concerns resources related to the social relations and networks held by those individuals within a particular firm. As a means of describing and identifying network resources that are more strategically held by the firm as a whole we introduce the concept of *network capital*.

Overall, the paper addresses the following issues: the types of organizations from which firms most frequently source their knowledge; the types of organizations firms most commonly collaborate with to innovate; the spatial proximity of network actors; the types of resources firms invest in to develop and sustain their networks; the extent to which knowledge network configurations change over time; the influence of firm size on the nature of engagement in knowledge networks; and the relationship between the knowledge networks of firms and their innovation performance.

Drawing on a review of relevant literature, we initially develop a framework to characterize inter-firm knowledge networks (section 2), followed by a delineated framework to characterize network resources (section 3). In section 4 we review the role of space and regional proximity in relation to knowledge network development, and in section 5 we outline the role of firm size and growth on network development. Section 6 details the methodological approach, which consists of a quantitative analysis of data gathered from a sample survey of firms of all sizes. As the focus of our research concerns the role of knowledge in network activity, our sample survey of firms is drawn from those operating within sectors with a relatively high level of knowledge intensity. Following a discussion of the key findings (sections 7–9), we conclude (section 10) by highlighting some of the challenges for firms in managing their knowledge networks and for public policy-makers in facilitating effective knowledge network development.

## **2. Inter-firm networks and knowledge**

Knowledge can be defined as information that changes something or somebody, either by becoming grounds for action or by making an individual or an institution capable of different or more effective action (Drucker 1989). Unlike simple information, knowledge concerns action and is a function of a particular stance (Nonaka and Takeuchi 1995). Knowledge is often described as a public good, where use by one actor does not preclude its use by others. However, as Oliver (1997) argues, in reality it is no longer possible to think of knowledge as a truly public good that can be easily reproduced and diffused, but at best a quasi-public good where reproduction and diffusion cannot be taken for granted. Seely Brown and Duguid (2001) distinguish between ‘sticky’ and ‘leaky’ knowledge, with sticky knowledge being that which is difficult to move, while leaky knowledge refers to the undesirable flow of knowledge to external sources. In general, network scholars stress that

innovation, be it undertaken internally or externally, is a complex process which may require knowledge flow between firms and other actors (Meagher and Rogers 2004; Lichtenthaler 2005; Sammarra and Biggiro 2008). Increasingly, this process is viewed as a systemic undertaking, i.e. firms no longer innovate in isolation but through a complex set of interactions with external actors (Chesbrough 2003). Therefore, inter-firm knowledge networks and networks with other external actors are potentially an important aspect of the innovation process.

We distinguish two forms of knowledge network: (1) *contact networks*, through which firms source knowledge; and (2) *alliance networks*, through which firms collaborate to innovate. Networks in the form of alliances usually concern formalized collaboration and joint ventures, and other 'contracted' relationships resulting in frequent and repeated interaction. Firms gain competitive advantage from alliances by accessing the knowledge of its alliance partners. This means that the competitive advantage firms are potentially able to gain is dependent upon the resource profiles of their partners (Stuart 2000; Ireland, Hitt, and Vaidyanath 2002; Grant and Baden-Fuller 2004). A key feature of most of the extant network literature concerning alliances is the focus on 'repeated' and 'enduring' (Podolny and Page 1998) or 'sustained' (Huggins 2001) interactions or relationships. Yli-Renko, Autio, and Sapienza (2001) find that knowledge exploitation for knowledge-based firms depends on repeated and intense interaction, as well as the willingness of firms to share information. As Gulati (1999) argues 'most alliances involve prolonged contact between partners, and firms actively rely on such networks as conduits of valuable information' (p. 401).

Converse to alliances, contact networks consist of non-formalized interaction and relationships between firms and other actors. The structure of these networks is often more dynamic, as firms continually update and change their contacts (Burt 1992; Huggins 2000, 2001; McEvily and Marcus 2005; Grabher and Ibert 2006). For both alliances and contact networks, the focus of the network is on accessing, rather than acquiring, knowledge. This is consistent with the knowledge-based view of the firm, which considers inter-firm networks as principally a means of utilizing the knowledge of others, rather than necessarily seeking to internalize such knowledge within the firm (Grant and Baden-Fuller 2004). Although firms may seek to acquire knowledge through inter-firm networks, it is more likely that the internalization of knowledge will be achieved through other modes related to hierarchical integration, such as firm mergers and acquisitions (Grant and Baden-Fuller 2004).

Although our underlying premise relates to the potential benefits of inter-firm networks, it is also important to highlight the possibility of negative impacts. For instance, without effective network management knowledge may flow more freely out of a firm than productively into it (Teece 1998; Fleming, King, and Juda 2007). Also, as firms become increasingly familiar with each other's knowledge, negative network effects may emerge, locking firms into low value and unproductive networks, stifling the creation of new knowledge and innovation (Arthur 1989; Adler and Kwon 2002; Labianca and Brass 2006). In order to continue to play a role in the innovation process, knowledge networks are often required to evolve to include new members and configurations to meet changing needs (Hite and Hesterly 2001; Lechner and Dowling 2003).

The stability or dynamism of networks is dependent upon whether or not network actors seek to form additional relationships with actors within an existing

network or new relationships with actors outside a network (Beckman, Haunschild, and Phillips 2004). Networks become unstable when members seek to explore new relationships with new partners, rather than further exploit the resources of their existing network (March 1991; Beckman, Haunschild, and Phillips 2004). In a knowledge-based environment, there is an increasing focus on the dynamic nature of networks and their changeability, heightening the importance of indirect ties and the need for the on-going reconfiguration of networks (Gargiulo and Benassi 2000; McFadyen and Cannella 2004; Levine 2005).

As Gulati (1999) argues, networks are dynamic and change over time, which suggests that networks require diversity in the types of investments made. Unless diversity is sustained, in the long-run networks may reduce firm heterogeneity through the articulation of shared norms, standards, and rules of conduct among firms (Oliver 1997; Monge and Contractor 2003). Westlund and Bolton (2003) present a persuasive case concerning some of the negative aspects of networks, arguing that the strong trust embedded in interpersonal relations can inhibit firm-level development. Although stable networks reduce the transaction costs of knowledge transfer, it may also be the case that knowledge becomes increasingly homogenous and less useful across network actors (Maurer and Ebers 2006). The preponderance of static strong ties may result in firms operating inefficient networks (Lechner and Dowling 2003). Increasingly more fluid and temporary networks, such as one-off project-based collaborations and networks of contacts, have grown in importance as sources of competitive advantage (McEvily and Zaheer 1999; Bell 2005; Salman and Saives 2005; Zaheer and Bell 2005).

### 3. Network resources

The resource-based view of the firm recognizes that a firm's resources, including their application and transferability, are critical factors in creating and sustaining competitive advantage (Wernerfelt 1984; Barney 1991; Rangone 1999). Such resources include the tangible and intangible assets owned or controlled by firms, and are a source of the value creation. These resources are often considered to be concomitant with both the size of firms and their capacity to undertake innovation (Wiklund and Shepherd 2003; Thorpe et al. 2005). However, as Zaheer and Bell (2005) note, scholars with a resource-based view of the firm tend to focus only on the internal capabilities of firms. As a means of addressing this gap, recent research has proposed an extension of the resource-based view of the firm to account for external network capabilities in addition to internal capabilities (Lavie 2006). Gulati (1999, 2007; Gulati and Gargiulo 1999; Gulati, Nohria, and Zaheer 2000) introduces the concept of *network resources* to understand the advantages bestowed by such networks in allowing firms to leverage valuable information and/or resources possessed by their inter-firm network partners.

In this paper we distinguish between two types of network resource. First, *social capital* in the form of social networks established across firms or other organizations through which knowledge may flow. Coleman (1988) defines social capital as consisting of obligations and expectations, which are dependent on: the trustworthiness of the social environment; the information flow capabilities of social structure; and norms accompanied by sanctions. Coleman (1988) argues that social capital is defined by its function and, as with the cases he highlights, this common

function is the creation of localized trust. Second, *network capital*, in the form of more calculative and strategic networks designed specifically to facilitate knowledge flow and accrue advantage for firms (Huggins 2009). We introduce the network capital concept as a response to the increased recognition that the leveraging of inter-firm and other external networks can be considered a strategic resource that can potentially be shaped by managerial action (Mowery, Oxley, and Silverman 1996; Dyer and Singh 1998; Madhavan, Koka, and Prescott 1998; Lorenzoni and Lipparini 1999; Kogut 2000; Gulati 2007).

Social capital has proved to be a popular and powerful mechanism for analysing how knowledge, particularly in its tacit form, can be accessed both within and across organizations (Nahapiet and Ghoshal 1998; Tsai and Ghoshal 1998; Gargiulo and Benassi 2000; Tsai 2000; Kostova and Roth 2003; Oh, Chung, and Labianca 2004; Inkpen and Tsang 2005; Walter, Lechner, and Kellermanns 2007). One of the most important contributions linking social capital to knowledge networks is that of Nahapiet and Ghoshal (1998), which focuses on the importance of social capital within the firm, and the organizational advantages and intellectual capital creation it facilitates through personal relationships fulfilling social motives such as sociability (Portes 1998), approval and prestige. Nahapiet and Ghoshal (1998) point to social capital as consisting of friendships and obligations at an intra-organizational level than cannot be easily passed from one person to another.

Nahapiet and Ghoshal's (1998) work is particularly useful not only because it makes the link between intra-organizational networks, knowledge and social capital, but its focus on the combination and exchange of knowledge in relation to factors such as access, motivation, capability and the anticipation of value. However, it has not gone without criticism. For instance, Locke (1999) argues that there is a potential loss of objectivity in linking business and social relationships, since objective communication means giving information to those who need it, without regard to whether or not they are your friends.

Most commonly, social capital consists of the perceived value inherent in networks and relationships generated through socialization and sociability as a form of social support (Borgatti and Foster 2003). In recent years, however, the social capital literature has come to define a resource where the motivations for investment are largely based on self-interest (Monge and Contractor 2003). This has strayed a long way from Coleman's (1988) assertion that 'social capital is the norm that one should forgo self-interest and act in the interests of the collectivity' (p. 104). It is difficult to reconcile self-interest with social capital's culture of obligation, norms, and trustworthiness. As Dasgupta (2005) argues, the literature following Coleman has gone far beyond their modest claims on the role of interpersonal social networks. Social capital's power is its ability to understand how individuals are able to mobilize their network to enhance personal returns usually within place-bound environments. As Lin (2001) argues, social capital is an 'investment in social relations by individuals through which they gain access to embedded resources to enhance expected returns' (pp. 17–8). In other words, social capital is a *social* and *individually* held capital. This leaves us with the question of how to understand and analyse the networks held by firms and other organizations, rather than those of individuals.

In this instance, our focus is on the role of knowledge and differentiating social capital, in the form of investments in social networks at an interpersonal level to secure individual advantage, from the advantage firms gain from investments in

inter-firm and other external networks. As Westlund and Nilsson (2005) argue, ‘when these investments are made in social networks, it is logical to say that they amass a form of “social capital”’ (p. 1081). If firms deliberately invest in networks, these networks are likely to concern the development of relationships which Williamson (1993) refers as ‘calculative’, since they consist of actions motivated by expected economic benefits (Hite and Hesterly 2001). We define these inter-firm assets more specifically as *network capital* consisting of investments in calculative relations by firms through which they gain access to knowledge to enhance expected economic returns (Huggins 2009). This definition makes a clear distinction between the two types of network resource: network capital and social capital.

Table 1 highlights the key characteristics differentiating network capital from social capital. The criteria underlying the choice of these characteristics are based on four critical factors of capital creation: (1) the source of the capital; (2) the mechanisms through which the capital is created; (3) the objects of the capital; and (4) the impact of the capital. A key difference between these two forms of network resource concerns the rationality of the actors, and whether or not actions are motivated by behaviour seeking to directly accumulate either economic or social returns. Oliver (1997) suggests that two types of rationality are at play within firm resource selection processes: economic rationality based on systematic and deliberate decision processes oriented towards economic goals; and normative/social rationality based on habitual and unreflective decision processes embedded in norms and traditions.

Table 1. Network capital and social capital characteristics of inter-firm networks.

Dimensions	Characteristics	Network capital	Social capital
Source	Rationality	Economic	Social/Normative
	Network	Calculative networks, although social networks emerge as a by-product	Social networks, although calculative networks may emerge as a by-product
	Investment	Relationship investments by firms	Relationship investments by individuals
Mechanisms	Interaction	Based on a logic of business and professional expectations	Based on a logic of sociability and social expectations
	Stability	Mix of dynamic and stable networks	Mainly stable networks
	Trust	Reflective	Blind
	Management	Can be strategically managed by firms	Difficult for firms to strategically manage
	Spatial proximity	Network actors not necessarily spatially proximate	Higher propensity of spatial proximity to other network actors
Object	Key object	Firms	Individuals
	Firm size	Large and growing firms	Small and new firms
Impact	Network returns	Principally economic, although social returns may emerge as a by-product	Principally social, although economic returns may emerge as a by-product

Source: Huggins (2009).

The source of network capital is rooted in an economic rationality, whereby firms invest in establishing calculative networks to access the knowledge they require. The source of social capital is based on a social rationality, whereby individuals invest in social networks to access embedded resources relating to sociability and social expectations. This differentiation is consistent with Bourdieu's (1986) view that social capital is not conceived as a calculated pursuit of gain, but in terms of the 'logic of emotional investment'. In contrast to the implicit social and emotional logic underlying the creation of social capital, the mechanisms through which network capital are established are rooted in a business and economic logic, whereby access to knowledge is sought as means of increasing economic returns. This is again consistent with the view that 'profits' from social capital are not usually 'consciously pursued' by actors within a network (Bourdieu 1986).

Furthermore, the intensity of interaction required to establish social capital means that the networks within which it is established tend to be spatially bounded. Without such interaction network ties may become dormant, eroding social capital (Putnam 2000). In this case, social capital can be re-ignited through new investments in interpersonal social networks. Ties established through network capital may also become dormant, but can be re-ignited by new investments arising from a requirement to access knowledge. In general, both network capital and social capital are stronger when networks are active (interactive) rather than dormant, since relationship investments are maintained rather than falling into disrepair. In terms of the object of the capital, a key distinction is that network capital is a firm-level resource, while social capital concerns the relationship resources of individuals. Of course, the social capital of individuals may be mobilized as a means of securing returns for the firm, but this is most likely to be of proportionally higher importance in small firms (section 5). In these firms, the social capital of the entrepreneur may be more highly developed than the network capital of firm. In relation to impact, the effect of network capital primarily relates to economic returns secured through access to knowledge, and social capital to social returns, although in both cases other returns may emerge as a by-product, such as the unintended access to useful knowledge often facilitated through social networks.

#### **4. Regions and the proximity of network actors**

Within debates concerning inter-firm networks, the role of space and place are recognized as increasingly important features of network structure and operation (Pittaway et al. 2004; Davenport 2005; Iyer, Kitson, and Toh 2005; Giuliani 2007). As a means of understanding these spatially-defined networks, scholars have applied the concept of social capital to identify the social norms and customs that lubricate the transfer and connection of knowledge (Capello and Faggian 2005; Tura and Harmaakorpi 2005; Hauser, Tappeiner, and Walde 2007). These social norms and customs are embedded in the social environment, with the trustworthiness of any environment often tacit and specific to each community (Brökel and Binder 2007; Lorenzen 2007). The more trustworthy a community is, the likelier it may be to facilitate the transfer and connection of knowledge, in turn reinforcing the cycle of knowledge creation (Iyer, Kitson, and Toh 2005). This highlights the place-based nature of social capital as a force influencing the connection of knowledge across

organizations through the generation of localized trust by individuals (Westlund and Bolton 2003; Capello and Faggian 2005; Lorenzen 2007).

Inter-firm knowledge networks are considered to be a crucial element underlying the economic success and competitiveness of regions (Asheim et al. 2003; Bathelt, Malmberg, and Maskell 2004; Cooke, Heidenreich, and Braczyk 2004; Rutten and Boekema 2007). Typically, it is argued that the existence of established spatially proximate knowledge networks is one of the key reasons why a number of the most successful localities and regions throughout the world have become or remained more competitive than those that have not adopted a networked approach (Storper 1997; Lawson and Lorenz 1999; Huggins 2000; Owen-Smith and Powell 2004; Knoblen and Oerlemans 2006). A feature of this discourse has concerned the increased attention given to the role of external institutions within the innovation process (Keeble et al. 1999; Cooke, Heidenreich, and Braczyk 2004; Huggins and Izushi 2007). This has led to the innovation process at a regional level being conceived as systemic, resulting from both formal and informal networking with other knowledge actors such as universities, R&D labs and other firms (Seely Brown and Duguid 2001; Chesbrough 2003; Cooke, Heidenreich, and Braczyk 2004).

Cooke (2004) suggests that regional innovation systems consist of interacting knowledge generation and exploitation sub-systems linked to global, national and other regional systems, which stresses the importance of both regionally internal and external linkages. This conceptualization addresses the potential problem that only those firms and organizations located in a contextual geographic environment rich in relevant knowledge sources can take competitive advantage of the co-location of other knowledge actors. Also, as Watts, Wood, and Wardle (2003) find, many firms in close proximity do not necessarily share face-to-face interactions through either social or business contacts, reducing the scope for knowledge access.

Despite the recognized importance of proximity to network development, there is an increasing emphasis on the importance of understanding networks and knowledge flows in an environment that is simultaneously local and global (Andersson and Karlsson 2007; Lorentzen 2008; Van Geenhuizen 2008). Many firms do not acquire their knowledge from within geographically proximate areas, particularly those firms based upon innovation-driven growth where knowledge is often sourced internationally (Davenport 2005). If applicable knowledge is available locally, firms and other institutions will attempt to source and acquire it, if not they will look elsewhere (Drejer and Lund Vinding 2007).

Even in those locations possessing a knowledge-rich environment there is evidence of a greater role being played by non-localized networks (Athreye 2004; Doloreux 2004; Garnsey and Heffernan 2005; Saxenian 2005). The key aspect of these developments is that the knowledge base of the world's most advanced local and regional economies is no longer necessarily local, but positioned within global knowledge networks (Wolfe and Gertler 2004; Huggins and Izushi 2007; Lorentzen 2008). There is also a growing school of thought that non-proximate actors are often equally, if not better, able to transfer complex knowledge across such spatial boundaries, providing a high performing network structure is in place (McEvily and Zaheer 1999; Dunning 2000; Lissoni 2001; Davenport 2005; Zaheer and Bell 2005; Palazzo 2005; Teixeira, Santos, and Oliveira Brochado 2006; Torre 2008). Whereas firms with low levels of absorptive capacity (Cohen and Levinthal 1990) tend to



network locally, those with higher absorptive capacity are often more connected to global networks (Drejer and Lund Vinding 2007; Van Geenhuizen 2008).

### **5. Firm size and growth**

There is growing evidence that inter-firm knowledge network development is related to the growth of firms (Freel 2000; Davenport 2005; Knoblen and Oerlemans 2006). In order to compete successfully with large firms, small firms may need to develop external networks to access resources that they do not possess internally (Bennett 1998; Huggins 2000; Kingsley and Malecki 2004). The networks of small firms are often considered to be particularly reliant on social networks such as connections with friends and family (Aldrich and Zimmer 1986; Uzzi 1997; Jack 2005; Thorpe et al. 2005; Lechner, Dowling, and Welpel 2006; Bowey and Easton 2007). Also, small firm networks are considered to be generally localized in their organizational and spatial context (Huggins 2000; Lissoni 2001; Johannisson, Ramirez-Pasillas, and Karlsson 2002). However, as such contexts are necessarily specific, there are competing discourses on the extent of small firm network development within local or regional boundaries (Curran and Blackburn 1994; Keeble et al. 1998; Lublinski 2003).

Although small firms are more likely to be dependent on social capital, as they grow their dependency may shift towards network capital, as networks become more calculative (e.g. suppliers, customers, collaborators and partners become more important) and less reliant on the social networks of the owners (Almeida, Dokko, and Rosenkopf 2003; Thorpe et al. 2005). Also, as firms evolve it can be anticipated that their networks will evolve from more path-dependent social networks – which in the first instance will be highly reliant on the pre-existing social networks of the entrepreneur(s) – to more intentionally managed networks based on reputation and access to relevant resources and partners (Hite and Hesterly 2001). In larger firms, inter-firm networks may become more evident through the formation of alliances consisting of formalized collaboration and joint ventures (Goerzen 2005; Goerzen and Beamish 2005).

Within the mainstream strategic management literature studies on the utilization of strategic alliances often highlight the networks developed by multinational corporations through contractual relationships with the objective of improving resource and knowledge access (Hagedoorn and Schakenraad 1994; Hagedoorn 2002; Kim, Oh, and Swaminathan 2006). The regulation underlying these relationships is often in contrast to small firm environments where there tends to be less ‘red-tape’, resulting in greater flexibility and mobility of network partners, i.e. higher network dynamism (Thorpe et al. 2005).

Entrepreneurs and small business owner-managers build personal networks where individual ties combine calculative and social aspects (Johannisson, Ramirez-Pasillas, and Karlsson 2002; Anderson, Park, and Jack 2007). This is to be expected, since in small and new firms the network requirements of both the firm and the firm’s operator (i.e. the entrepreneur) are likely to coincide, and encompass both his/her social and economic needs and objectives (Jack 2005; Macpherson and Holt 2007). Hite and Hesterly (2001) refer to the different functions and objectives of a network as its ‘compositional quality’. This compositional quality changes in much the same way that the resources required by a firm change as it evolves, with networks

becoming more calculative and less social in terms of expected economic costs and benefits, and more intentionally managed (Hite and Hesterly 2001). However, the nature of networks will also depend upon the size and vintage of network partners. As Lechner and Dowling (2003) find, small firms are often 'forced to share their initial technology base with other and more powerful firms' (p. 21). From the perspective of small firms, network capital may manifest itself through improved performance emanating from the credibility they achieve as a result of having prominent strategic alliance partners (Stuart, Hoang, and Hybels 1999).

## **6. Methodology**

The dataset utilized in this paper was generated through a postal survey of knowledge-based firms based in three regions of Northern England: Yorkshire and Humberside, North East England, and North West England. In defining knowledge-based firms we utilize the OECD's (1999) definition of knowledge-based sectors (those sectors utilizing knowledge as a key input), which consists of all high-technology manufacturing and knowledge-based service sector activities such as IT, computer technology and telecommunications, financial and business services, media and broadcasting. The focus on knowledge-based firms was influenced by two main factors. First, these firms use knowledge relatively intensely within their production processes. Second, knowledge-based firms are viewed as important components in the drive to develop or promote economic development (Huggins and Izushi 2007; Malecki 2007).

The questionnaire was designed to identify how firms source knowledge and engage in knowledge-based collaborations with other organizations as a means of facilitating innovation. The key research questions the survey addressed are: (1) which types of organization do firms most frequently source their knowledge from? (2) for innovation, which types of organization do firms most commonly collaborate with? (3) how do patterns of knowledge sourcing and innovation-led collaboration vary in terms of the spatial proximity of network actors? (4) which types of network resource do firms invest in to develop and sustain their networks? (5) to what extent are the knowledge network configurations of firms subject to change and evolution? (6) how does firm size influence the nature of engagement in knowledge networks? and (7) what is the relationship between the knowledge networks of firms and their innovation performance?

In this case, knowledge is considered to be an objective entity (Ringsberg and Reihlen 2008) and is defined in the questionnaire as 'consisting of research and development, ideas, expertise, and other information that is, or potentially can be, used to make the operation of your company more effective'. The survey gathered data on various aspects of the firms' activities including the frequency and importance of various sources of knowledge and collaboration, the location of network actors (within or outside the regional of the focal firm), the frequency of network membership changes, the motivations underlying network development, and levels of innovation. These factors were mainly measured through 10-point Likert scales, with the exception of innovation which is measured on an actual count basis. Regions are based on the main administrative boundaries of the UK.

As a means of measuring the network resource investments made by firms with their knowledge sources and collaborators we queried them on the extent to which

interaction occurred outside of the work and business environment, including informal lunch, dinner, drinks, and other recreational, sporting, or leisure activities. This allows us to gauge levels of investment in network resources based on these types of activities. As a means of seeking to differentiate the type of network resource, i.e. network capital or social capital, respondents were asked the extent to which these interactions would continue if they were unable to source the knowledge they require. In this case, *network development* where interaction would continue even if knowledge could no longer be sourced is considered an investment in social capital. In cases where interaction would discontinue, investments are considered to be in the form of *network capital*, since they are maintained on a calculative basis as a means of sourcing required knowledge (Oliver 1997; Hite and Hesterly 2001; Westlund and Nilsson 2005; Grabher and Ibert 2006). Network capital and social capital investment can then be expressed as a proportion (percentage) of overall investment in network resources based on these forms of interaction. Network dynamism (or stability) is measured by asking firms how frequently the members of their knowledge contact and alliance networks change. The innovation measure is based on how many new products or services or adaptations to existing products or services firms had introduced during the previous 3 years.

The initial identification of relevant firms was undertaken using the FAME (Financial Analysis Made Easy) database, which holds financial details of limited companies in the UK. This database provides financial information on each firm based on the latest end of year accounts and also contains the names and addresses of firms as well as the sector in which they operate. In total, over 2500 firms were identified in the sample frame and a random sample of 750 (250 per region) were sent questionnaires via the post. We received a total of 83 responses, a response rate of around 11%, with 74 of these responses usable. Using a chi-squared goodness-of-fit test this distribution was found to be representative of the sample frame, and therefore significant sample bias is not considered to be an issue. Although the dataset is relatively small compared with the population of firms in the three regions, our sample size is comparable with other studies of this nature, which use around 50–75 observations (for example, Keeble et al. 1999; Watts, Wood, and Wardle 2003; Kingsley and Malecki 2004). For the purposes of the analysis, firms are divided into three groups based on the number of employees, i.e. large, medium and small firms. Standard definitions of firm size were used to allocate each firm to one group, large firms are those with over 250 employees (17 responses), medium firms are those with fewer than 250 employees but more than 50 employees (33 responses), and small firms are those firms with fewer than 50 employees (24 responses). In light of the sample size and the type of data collected (ordinal), non-parametric statistical methods were utilized in the analysis, since smaller samples are less likely to be normally distributed. Non-parametric techniques provide robust results for smaller samples and are less likely to provide spurious results. The statistical analysis utilized Mann-Whitney tests of difference to examine the significance of any observed differences between groupings of firms.

## 7. Contact networks

Firms source knowledge from a range of contacts both within and outside their region. As Table 2 illustrates, firms most frequently source knowledge from their

Table 2. Knowledge contact networks – Frequency of sourcing knowledge (1 = never, 10 = very often) by location of contact ( $n = 74$ ).

	Within the region	Outside the region
Customers	5.4	6.5
Suppliers	4.9	5.7
Rival firms	2.5***	4.2***
Public sector organizations	3.2	3.0
Private sector organizations	3.5	2.9
Universities and other higher education institutions	3.1**	2.3**
Members of professional networks	3.8***	2.5***

Note: \* = difference significant at 0.05 level; \*\* = 0.01 level; \*\*\* = 0.001 level (non-parametric Mann-Whitney tests).

customers and suppliers. This highlights the importance of supply-chain contacts as the key means by which many firms access knowledge, especially through the type of untraded interdependencies and knowledge spillovers generated as a by-product of market-based relationships (Storper 1995, 1997; Freel 2000; Tödtling and Kaufmann 2002). In general, customers and suppliers outside the region tend to be utilized more frequently than those within the region. Firms are significantly more likely to use contact networks with rival firms outside their region, as opposed to rivals within the same region, to source knowledge. This suggests that when firms engage with rivals to access knowledge they are more likely to look further afield than their neighbours. The sparseness of local rival firms possessing relevant and accessible knowledge is likely to be a key reason underlying the higher frequency of non-local knowledge network contact with rivals (Davenport 2005; Malecki and Hospers 2007).

Conversely, firms are significantly more likely to source knowledge from both universities and members of professional networks within their region. Universities are increasingly viewed as important sources of knowledge for the business community, with a raft of policy initiatives to develop strong linkages (Kitagawa 2004; Lawton Smith and Bagchi-Sen 2006; Huggins, Johnston, and Steffenson 2008). The focus of these initiatives is usually at the regional level, and while firms are more likely to possess contacts within local universities, rather than in other regions of the UK or overseas, the regional dimension of university-business support development may be a further factor determining this regional bias (Charles 2003; Benneworth and Charles 2005; Coenen 2007; Huggins, Johnston, and Steffenson 2008). Similarly, professional networks in the form of business clubs, chambers of commerce, and other business associations are often co-ordinated on a local and regional basis, making it more likely that firms will source knowledge through members of these networks based in their region (Bennett 1998; Huggins 2000).

Table 3 presents the frequency of sourcing knowledge according to the size of firms. Interestingly, the most significant differences are between small and medium-sized firms. In particular, medium-sized are significantly more likely to source knowledge from local universities, private sector organizations, and professional member networks. This suggests a link between firm size and inter-firm networking propensity (which becomes even more marked in terms of knowledge alliances and collaboration), and to an extent confirms some of the prevailing discourse concerning the culture of small firms and their ‘fortress enterprise’ mentality

Table 3. Knowledge contact networks – Frequency of sourcing knowledge (1 = never, 10 = very often) by firm size (small firms *n* = 24, medium firms *n* = 33, large firms *n* = 17).

	Small firms	Medium firms	Large firms
Customers within region	5.2	5.4	5.6
Suppliers within region	5.0	4.6	4.9
Rival firms within region	2.4	2.6	2.3
Public sector organizations within region	2.9	3.6	2.1
Private sector organizations within region	2.7*	4.2*	2.4
Universities or other HEIs within region	2.5*	3.2*	2.5
Member of professional networks within region	2.8**	4.6**	3.0
Customers outside region	6.1	6.6	8.3
Suppliers outside region	5.7	5.5	7.2
Rival firms outside region	3.5	4.8	4.5
Public sector organizations outside region	2.8	2.9	3.0
Private sector organizations outside region	2.1	3.2	1.8
Universities and other HEIs outside region	2.1	2.1	2.0
Members of professional networks outside region	2.0	2.8	1.6

Note: \* = difference significant at 0.05 level; \*\* = 0.01 level; \*\*\* = 0.001 level (non-parametric Mann-Whitney tests).

Table 4. Network development of knowledge sources (%) (small firms *n* = 24, medium firms *n* = 33, large firms *n* = 17).

	Small firms	Medium firms	Large firms
Social capital investment in knowledge sources	27.6	23.5	19.5
Network capital investment in knowledge sources	26.6	26.5	21.7
Social networking	58.3*	44.7	42.6*
Network dynamism	59.4*	48.5	45.6*

Note: \* = difference significant at 0.05 level; \*\* = 0.01 level; \*\*\* = 0.001 level (non-parametric Mann-Whitney tests).

(Curran and Blackburn 1994). However, it is noticeable that the largest firms among the respondents do not source knowledge from these contacts with any greater frequency than their smaller counterparts. This may be partly due to larger firms containing ‘in-house’ the type of knowledge accessible through local networks. Also, larger firms focus more on the supply-chain – especially outside the regional confines – as the most important means of accessing knowledge. This suggests that while large firms may form part of localized knowledge networks, they are also more likely to act as a node of the global pipelines through which knowledge flows into a region (Bathelt, Malmberg, and Maskell 2004; Gertler and Levitte 2005).

As shown in Table 4, small firms invest relatively equally in social and calculative networks with knowledge sources, indicating a balance between network capital and social capital investment. Small firms invest slightly more in network capital and social capital than larger firms, although not significantly so, which partly suggests that smaller firms are more reliant on these network forms as a knowledge source.

Table 5. Network development and the spatial proximity of knowledge sources (%) (high inside the region sourcing  $n = 32$ , low inside the region sourcing  $n = 42$ ).

	High inside the region sourcing	Low inside the region sourcing
Social capital investment	33.8**	16.4**
Network capital investment	23.2	27.1
Social networking	56.3*	42.9*
Network dynamism	55.5	48.2

Note: \* = difference significant at 0.05 level; \*\* = 0.01 level; \*\*\* = 0.001 level (non-parametric Mann-Whitney tests).

In the case of social networking, this is even more explicit, with small firms significantly more likely to engage in social networks and interactions of this kind than large firms. This supports existing arguments concerning the role of external relationship building as a source of small firm competitiveness (Lechner and Dowling 2003; Thorpe et al. 2005; Lechner, Dowling, and Welpé 2006). In general, social networks as a source of knowledge appear to be of greater importance to smaller firms (Hite and Hesterly 2001; Westlund and Nilsson 2005; Bowey and Easton 2007). Smaller firms are also significantly more likely to possess relatively dynamic networks with their knowledge sources, changing contacts on a more frequent basis than larger firms (Das and Teng 2000; Inkpen and Currall 2004). Such dynamism and change indicates that small firms, due to the relative lack of in-house knowledge, have to pay more attention to their networks, and more frequently change their sources in order to ensure access to appropriate and relevant knowledge on an on-going basis (Johannisson, Ramírez-Pasillas, and Karlsson 2002; Anderson, Park, and Jack 2007). As a result of their larger internal resource, larger firms are more inclined to source knowledge through networks that are relatively stable.

Table 5 presents data for the same variables as Table 4, but in this case rather than firm size it assesses differences according to the propensity of firms to access knowledge from sources within their own region. In this case, the respondents have been categorized according to whether or not they source knowledge from within their region on a relatively frequent or infrequent basis (below or above the mean average for all source types), as a means of gauging the spatial orientation of their knowledge contact networks. The view of social capital as a place-based asset, whereby trust is built through face-to-face interactions (Westlund and Bolton 2003; Capello and Faggian 2005; Lorenzen 2007), is strongly supported by the results shown in Table 5. Those firms most frequently sourcing knowledge from inside their region invest twice as much in social capital with these knowledge sources, compared with firms less frequently sourcing local knowledge. Also, high local knowledge sourcing firms are significantly more likely to use social networks as a knowledge source. These findings provide empirical support concerning the importance of social capital and trust-building as a means of accessing localized knowledge, especially among small firms (Coleman 1988; Ostrom 2000; Iyer, Kitson, and Toh 2005). Network capital investments are relatively unrelated to the proximity of knowledge sources, suggesting that these forms of network resource are relatively unbounded spatially (Drejer and Lund Vinding 2007; Huggins and Izushi 2007).

Table 6. Knowledge alliance networks – Importance of external collaborators in the development of new products, services or processes (1=no importance, 10=extremely important) by location of collaborator (*n* = 74).

	Within the region	Outside the region
Customers	5.5*	6.7*
Suppliers	4.3**	5.7**
Rival firms	2.3*	3.1*
Public sector organizations	3.0	2.7
Private sector organizations	3.1	3.0
Universities and other higher education institutions	3.0	2.5
Members of professional networks	3.5*	2.7*

Note: \* = difference significant at 0.05 level; \*\* = 0.01 level; \*\*\* = 0.001 level (non-parametric Mann-Whitney tests).

**8. Alliance networks**

Alliances with more enduring collaborative partners are an increasingly important feature of network development (Podolny and Page 1998; Gulati 2007). Table 6 highlights the most important knowledge alliance partners within the networks of the firms surveyed. These alliance networks consist of formal or informal innovation collaborations undertaken to develop new products, services or processes. As with the sourcing of knowledge, customers and suppliers are the most important knowledge partners, with partners outside a firm’s region considered to be of generally higher importance. In the case of alliances with customers, suppliers and rival firms, collaborations with partners outside the region are considered to be significantly more important than those with similar partners within their own region. Only alliances with members of professional networks are biased to collaborations with partners within the focus firm’s region – echoing the local nature of these networks. The utilization of regionally external knowledge partners indicates that innovation alliances are not spatially constrained within regions, suggesting that those firms possessing these links are not locked-in to path-dependent systems of development (Arthur 1989; Boschma and Frenken 2006; Labianca and Brass 2006; Martin and Sunley 2006). However, to provide more confirmatory evidence would require a longitudinal analysis of changes in the geography of knowledge partners.

In order to further assess the spatial nature of collaboration, it useful to analyse variations by firm size. As firms grow they are generally more likely to place a greater importance on knowledge alliances (Table 7). This is especially the case for collaborations with universities, as well as with actors such as private sector organizations and rival firms located outside of the focal region. Small firms generally consider knowledge partners outside the region to be of less importance than larger firms, indicating that the geographical scope of knowledge partnerships widens as firms grow and the knowledge contained within localized partnerships becomes increasingly homogenous and redundant (Davenport 2005; Thorpe et al. 2005; Maurer and Ebers 2006). Also, innovation alliances will generally require greater resources to manage compared with the type of contact networks associated with knowledge sourcing, potentially restricting the engagement of small firms

Table 7. Knowledge alliance networks – Importance of external collaborators in the development of new products, services or processes (1 = no importance, 10 = extremely important) by firm size (small firms  $n = 24$ , medium firms  $n = 33$ , large firms  $n = 17$ ).

	Small firms	Medium firms	Large firms
Customers within region	5.0	5.5	6.1
Suppliers within region	3.9	4.4	4.7
Rival firms within region	2.2	2.3	2.5
Public sector organizations within region	2.9	2.9	3.2
Private sector organizations within region	2.5	3.3	3.7
Universities or other HEIs within region	2.0***	3.0	4.5***
Members of professional networks within region	3.0	3.5	4.2
Customers outside region	5.4	7.2	7.5
Suppliers outside region	5.4	5.9	5.7
Rival firms outside region	2.5*	3.0	4.1*
Public sector organizations outside region	2.8	2.1	3.6
Private sector organizations outside region	2.4**	2.6	4.5**
Universities and other HEIs outside region	2.1**	2.0	4.0**
Members of professional networks outside region	2.8	2.6	2.7

Note: \* = difference significant at 0.05 level; \*\* = 0.01 level; \*\*\* = 0.001 level (non-parametric Mann-Whitney tests).

Table 8. Network development and the spatial proximity of collaborators (%). (High inside the region collaborators  $n = 27$ , low inside the region collaborators  $n = 47$ ).

	High inside the region collaborators	Low inside the region collaborators
Social capital investment	27.3**	13.2**
Network capital investment	24.5	20.9
Network dynamism	54.6*	44.1*

Note: \* = difference significant at 0.05 level; \*\* = 0.01 level; \*\*\* = 0.001 level (non-parametric Mann-Whitney tests).

(Almeida, Dokko, and Rosenkopf 2003; Lechner and Dowling 2003; Thorpe et al. 2005). More generally, the propensity to engage in formal knowledge-based collaborations heightens as firms grow (Stuart 2000; Ireland, Hitt, and Vaidyanath 2002; Grant and Baden-Fuller 2004; Goerzen 2005; Goerzen and Beamish 2005).

The relationship between investment in social and network capital with collaborators and the propensity to collaborate with local partners is shown in Table 8. Network capital investment is largely unrelated to whether or not their partners are regionally located. Social capital investment, on the other hand, is more than double among those firms with a relatively high quotient of important knowledge partners located within the same region. This confirms the spatially bounded nature of social capital, whereby investment predominately occurs with actors within physical proximity (Monge and Contractor 2003; Tura and Harmaakorpi 2005). In this instance, firms are utilizing social capital to develop and sustain knowledge-based collaborations. It is also likely that new forms of social



Table 9. Network development and innovation (Innovation high firms  $n=38$ , Innovation low firms  $n=36$ ).

	Innovation high firms	Innovation low firms	Scale
Social capital investment in knowledge sources	26.5	21.2	%
Network capital investment in knowledge sources	25.5	25.3	%
Social networks as knowledge sources	52.0	45.1	%
Network dynamism for knowledge sources	56.6*	45.8*	%
Inside the region knowledge sources	4.1	3.5	1–10
Outside the region knowledge sources	4.6**	3.5**	1–10
Social capital investment in collaboration	22.4*	14.1*	%
Network capital investment in collaboration	23.7	20.7	%
Network dynamism in collaboration	54.6**	41.0**	%
Inside the region collaboration	4.0*	3.1*	1–10
Outside the region collaboration	4.6**	3.5**	1–10

Note: \* = difference significant at 0.05 level; \*\* = 0.01 level; \*\*\* = 0.001 level (non-parametric Mann-Whitney tests).

capital are created as a by-product of strategic alliance and partnership development (Tsai 2000; Koka and Prescott 2002). This a significant finding, highlighting how social capital within a localized environment facilitates the connection of knowledge (Capello and Faggian 2005; Tura and Harmaakorpi 2005).

Firms with a propensity to collaborate locally are also significantly more likely to possess dynamic networks, changing or adding new collaborators more frequently than those with a lower propensity to engage locally. Stronger social capital and network development at the local level allows firms access to a wider pool local of firms with which to potentially collaborate than firms engaged in more distant collaborations. This suggests that social capital actually facilitates access to alliance partners at the local level. The dynamic nature of networks and their changeability confirms the need for the on-going reconstitution and reconfiguration of networks (Gargiulo and Benassi 2000; McFadyen and Cannella 2004).

**9. Innovation**

Finally, the extent to which network development and investment are related to the innovation capability of firms is analysed. On average, small firms introduced 11.3 innovations over the 3-year period, which is slightly higher than the medium-sized firm average of 11.0, but significantly lower than the 21.7 innovations introduced by large firms. Splitting the firms into two groups – ‘innovation high’ and ‘innovation low’ (based on the mean average) – reveals a number of interesting characteristics (Table 9). Firms with more dynamic configurations of both contact and alliance networks have a significantly superior innovation performance than those firms with more stable configurations. This indicates that more innovative firms are more likely to develop new contacts and alliances as a means of accessing and utilizing the most appropriate and state-of-the-art knowledge. Therefore, although network stability is usually considered to be a positive feature of knowledge networks (Podolny and Page 1998), it appears that more innovative firms are avoiding the type of network inertia

(DiMaggio and Powell 1983; Kim, Oh, and Swaminathan 2006) and lock-in (Arthur 1989; Adler and Kwon 2002; Labianca and Brass 2006) that may stifle innovation. Firms with a higher propensity to establish contact networks with knowledge sources outside the region in which they are located also have significantly higher rates of innovation.

Those firms investing significant social capital in relationships with collaborators are significantly more innovative than firms making little investment. In recent years, the role of social capital as a facilitator of innovation has been explored at both a micro and macro level, resulting in growing prominence within policy circles (Cooke and Wills 1999; Maskell 2000; Capello and Faggian 2005; Obstfeld 2005; Tura and Harmaakorpi 2005). Our findings suggest a clear connection between innovation and social capital investment made in collaborative alliances. However, it should be noted that the same relationship does not hold for social capital investment in contact networks. This highlights that the importance of social capital to innovation processes varies according to network type. Also, firms with more developed alliance networks, both inside and outside the region, achieve significantly higher levels of innovation than those firms placing less importance on collaboration. This indicates that, in general, network-oriented firms tend to enjoy superior innovation performance. This adds weight to evidence on the link between the inter-firm network activities of firms and their innovation capabilities (Powell, Koput, and Smith-Doerr 1996; Stuart 2000; Pittaway et al. 2004; Obstfeld 2005). However, it is also clear that firm size impacts on innovation capabilities. In reality, it is likely that as firms grow not only does their capacity to innovate, but also their capacity to manage inter-firm networks, allowing them to leverage both calculative and social relationships facilitating greater access to the knowledge required to innovate.

## **10. Conclusions and discussion**

This paper has sought to analyse differences in the knowledge networks utilized by firms. It has focused on differences in the types of networks according to the size of firms, the location of networks actors, the types of networks developed, and the nature of investments made in these networks. Although the study has acknowledged limitations in terms of the number of observations upon which the findings are based, it is nevertheless possible to draw some general conclusions regarding the role and development of the external knowledge networks of firms. For instance: (1) firms frequently use local networks to source knowledge and undertake innovation, but for some network types and actors – such as competitors, customers, and suppliers – interactions are more likely to concern actors outside the region of location; (2) social capital investment and social network development is more prevalent among those firms frequently interacting with actors from within their own region; (3) social capital investment is related to the size of firms and the spatial configuration of their networks, while network capital appears to be largely independent of these factors; (4) firm size plays a role in knowledge network patterns, with larger firms more likely to engage in alliance networks with actors outside the focal region; and (5) network dynamism appears to be an important source of innovation, with such dynamism often more apparent among small firms.

In general, as firms grow they are more likely to be linked to the global pipelines through which knowledge flows into a region (Bathelt, Malmberg, and Maskell 2004), with their reliance on social networks as sources of knowledge weakening (Bowey and Easton 2007). The networks through which they source knowledge tend to become more stable as firms grow (Anderson, Park, and Jack 2007), with them becoming more likely to establish knowledge-based alliances with external partners. Furthermore, firms reliant on local knowledge networks are more likely to invest in social capital. A dynamic inter-firm network environment, based on fluid and temporary interactions and relationships, such as one-off project-based collaborations and networks of contacts, provides an alternative thesis to that advocating the advantage of network stability (Teece 2000; Monge and Contractor 2003; Salman and Saives 2005; Zaheer and Bell 2005). The significant relationship this study finds between network dynamism and innovation indicates a requirement for future research in this area to be more attuned to capturing the role of networks as evolutionary systems with trajectories that change along with the resources they accrue (Kilduff and Tsai 2003; Monge and Contractor 2003; Glückler 2007).

Proximity remains significant for establishing effective knowledge networks. However, in some cases non-proximate actors appear to be better 'placed' to transfer knowledge (Boschma 2005; Davenport 2005; Palazzo 2005; Zaheer and Bell 2005). In general, the pattern of knowledge networks utilized by firms conforms to the model proposed by Bathelt, Malmberg, and Maskell (2004), whereby non-local linkages, or pipelines, provide access to relevant and useful knowledge, but it is primarily local linkages, or 'buzz', which provide the environment for establishing the social relations that remain of importance for effective collaborative or 'open' innovation practices (Chesbrough 2003). These patterns also resemble the types of regional innovation systems proposed by Cooke (2004) and others (Asheim 2002; Fritsch 2002; Doloreux and Dionne 2008), whereby interaction is systemized through both regional and spatially wider networks.

The complementary evolution of firms and their external knowledge networks underlines the need for models of these networks to be dynamic across space and time (Hite and Hesterly 2001). More generally, it also highlights the requirement for existing theories of the firm, such as the resource-based view (Barney 1991), to more rigorously account for the changing nature of firms and their network resource requirements. In general, firms invest in a balance of both network capital and social capital as means of sourcing knowledge and innovating. Network capital's emphasis on the business and professional aspects of networks echoes Granovetter's (1973) notion of 'work-related ties'. However, while Granovetter (1973) aligns work-related relationships with his concept of weak ties based on relatively infrequent contact (as opposed to strong ties based on frequent contact often amongst friends), the network capital-social capital approach is not cast in terms of distinguishing the amount of time network actors spend with each other. Rather, it is primarily concerned with distinguishing the reasoning network actors interact, which as Granovetter (1973) indicates is related to network content.

Smaller firms utilize social capital in the form of social networks with actors such as friends and family more frequently than larger firms do so to source knowledge, and are also more likely to change the contacts through which they source knowledge. Firms develop knowledge networks with actors both within and outside their regional vicinity, but the networks of small firms tend to be more localized than

those of larger firms. Firms with relatively well-developed local networks invest significantly more in social capital development compared to firms with less well-developed local networks. Larger firms have better developed knowledge networks in the form of innovation-based alliances. Networks are most commonly formed with supply-chain actors (i.e. customers and suppliers), with firms investing more in their knowledge networks appearing to enjoy higher levels of innovation.

Smaller knowledge-based firms clearly have a stronger reliance on social capital investment for accessing knowledge and innovation. This suggests that while small firms may effectively manage certain forms of knowledge networks, other important networks are embedded within the social capital of 'members' of the firm (i.e. employees, directors, etc.), which to an extent are beyond strategic management. Although firms can strategically influence their network capital resources, they are less able to influence social capital resources, and for managers actually distinguishing between networks based on network capital or social capital may facilitate a greater understanding of the complexity of knowledge-based interactions. Such an approach would assist a better understanding of the (potential) value of particular knowledge networks as well as the rationality (economic or social) underlying their construction. Without such an understanding managers may be unable to make important judgments as to which networks they should, and are able, to invest in.

Potential solutions could take the form of developing systems to understand a firm's network resources in terms of: motivation – why particular interactions and relationships are initiated; function – what role they serve for the firm; processes – how and when do interactions occur; structure – which individuals and organisations are involved; outputs – what outputs are gained for the firm as a direct consequence of network development or as additional by-products; sovereignty – to what extent would/could interactions continue without those individuals currently involved; and evolution – how are the above changing over time. Such a framework has the potential for assessing those networks a firm can or cannot manage, or invest in, to meet its requirements.

Our findings cannot be said to be representative of all firms located within the surveyed regions, but are likely to be biased towards the most progressive firms within these regions. From the literature, it can be suggested that firms operating in lower-value added sectors would exhibit a stronger bias toward more localized network connection with customers and suppliers, while also experiencing lower innovation performance. This suggests a requirement for further research to analyse differences in network resources across different firms and sectors, and in different regional settings. More generally, the overlap of firm and individual level network assets suggests a requirement for further empirical delineation if we are to better understand how firms secure advantage and rent from networks.

Finally, increasing the innovativeness of firms, and promoting the development and enhancement of knowledge networks and regional innovation systems, has been described as the 'high road of regional competition' (Malecki 2004). Some of the key challenges and barriers identified as restricting the innovation and growth capabilities of firms, especially SMEs, include their heavy reliance on knowledge tacitly held within the firm (Smallbone, North, and Vickers 2003). For instance, the propensity of firms to engage in networks is often related to the characteristics of individual entrepreneurs, which will be shaped by the underlying social and

business culture in the region (Asheim and Isaksen 2003; Watts, Wood, and Wardle 2006). In general, there is a need to expand the empirical base of research on knowledge networks among the wider strata of 'ordinary regions' and examine the context in which the majority of firms exist. While there may be no 'ideal model' for innovation policy, policy-makers world-wide have expended considerable efforts in pursuing policies that aim to emulate the conditions in successful regions (Boschma 2004; Tödtling and Trippel 2005; Hospers 2005, 2006). Part of the problem appears to be in developing and utilizing the soft and more difficult to measure infrastructure such as knowledge networks.

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