

# **Innovation-Led Entrepreneurship and Inter-Organizational Knowledge Flow: The Formation of Network Capital**

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## **Abstract**

Firms utilise inter-organizational networks to manage flows and access knowledge to enhance expected economic returns. In particular, inter-organizational networks are an important aspect of the innovation process. The aim of this paper is to analyse the formation and role of inter-organizational networks in facilitating the flow of, and access to, knowledge from the perspective of innovation-led entrepreneurial firms. The paper utilises and builds upon the concept of network capital, which seeks to recognise that investments in inter-organizational network facilitating access to knowledge are a capital asset in their own right for firms. Drawing on a series of in-depth case studies of entrepreneurial firms, the paper attempts to theorise the relationship between network capital and inter-organizational network formation and innovation-led growth, particularly in the entrepreneurial context and environment. Overall, the findings suggest the importance of network capital for generating innovation-led growth among entrepreneurial firms. It is found that there are multiple mechanisms underlying the formation and development of inter-organizational networks by entrepreneurial firms, and it is through a range of complementary networks that firms are able to appropriately access and apply knowledge, and subsequently develop innovative goods and services. The findings also suggest that the formation processes of network capital for these firms possess certain particularities which are likely to be less common or pronounced among larger more established firms. From a public policy perspective, it is argued there may be a role for government intervention in educating firms in the art of network management, as well as providing entrepreneurial firms with appropriate support to establish a high performing network structure that allows them access to the knowledge they require.

## **Introduction**

Firms utilise inter-organizational networks to manage flows and access knowledge to enhance expected economic returns. In particular, inter-organizational networks are an important aspect of the innovation process, with network scholars stressing that innovation is a complex process often requiring knowledge flow between organizations. (Meagher and Rogers, 2004, Lichtenthaler, 2005; Sammarra and Biggiero 2008; Tomlinson, 2010; Bergenholtz and Waldstrøm, 2011). 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 other organizations (Chesbrough, 2003).

Emerging theories of the firm such as the knowledge-based view (Grant 1996) and extensions of the resource-based view (Eisenhardt and Schoonhoven, 1996; Lavie 2006) recognize that knowledge accessing, acquisition, exchange and creation are a key reason why

firms build or enter networks with other organizations. These networks concern the interactions, relationships and ties existing between firms, and may arise through the need to access new assets and skills, and keep pace with competitors (Ahuja 2000). In general, although significant attention has been given to understanding the nature and role of firm resources in providing competitive advantage, less attention has been given to network resources resulting from membership or participation in inter-organizational networks (Barney 1991; Eisenhardt and Schoonhoven, 1996; Gulati 2007; Lavie 2006). The ‘network’ focus is pertinent given the evidence suggesting that with the exception of knowledge protected by property rights, such as patents and copyrights, knowledge is not generally accessible or appropriable by means of market transactions (Grant, 1996; Malecki, 2010). Inter-organizational networks in this context are defined as consisting of the interactions and relationships organizations utilise to access knowledge.

The aim of this paper is to analyse the formation and role of inter-organizational networks in facilitating the flow of, and access to, knowledge from the perspective of innovation-led entrepreneurial firms. The paper utilises and builds upon the concept of network capital (Huggins, 2010), which seeks to recognise that investments in inter-organizational network facilitating access to knowledge are a capital asset in their own right for firms, and differs significantly from the type of social capital held by firms.

The paper is structured, therefore, around understanding the processes of network capital formation. Drawing on a series of in-depth case studies of entrepreneurial firms, the paper attempts to theorise the relationship between network capital and inter-organizational network formation and innovation-led growth, particularly in the entrepreneurial context and environment. The key questions the paper seeks to address are: (1) what is the rationale and motivation for engagement in inter-organizational networks by innovation-led entrepreneurial firms? (2) how do firms search for and select organizations with which to form networked relationships? (3) what are the characteristics and underpinning interaction mechanisms of these networks? and (4) what is the nature of the knowledge accessed and applied in order to facilitate innovation? Overall, the findings suggest the importance of network capital for generating innovation-led growth among entrepreneurial firms. However, the findings also suggest that the

formation processes of network capital for these firms possess certain particularities which are likely to be less common or pronounced among larger more established firms. The remainder of the paper is structured as follows: in the next four sections we outline our conceptual framework, which is followed by a presentation of the methodology employed for the empirical study. The results of the study are followed by a discussion of their meaning and implications, and the overall conclusions we reach.

### **Inter-Organizational Networks**

It is through the networks underpinning systemic innovation processes that organizations access knowledge that they do not, or cannot, generate internally based on their own capabilities. In this sense, it is possible to distinguish two forms of inter-organizational network: (1) contact networks, through which organizations source knowledge; and (2) alliance networks, through which organizations collaborate to innovate (Huggins, 2010). Networks in the form of alliances usually concern formalised collaboration and joint ventures, and other ‘contracted’ relationships resulting in frequent and repeated interaction. Organizations gain advantages from networks by accessing the knowledge of the organizations in their network. This means that the advantage organizations are potentially able to gain is dependent upon the knowledge profile of their network (Stuart 2000; Ireland et al. 2002; Grant and Baden-Fuller 2004).

Knowledge alliances will generally require greater management resources compared with the type of contact networks associated with more general knowledge sourcing, potentially restricting the engagement of entrepreneurial firms (Almeida et al., 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 et al., 2002; Grant and Baden-Fuller, 2004; Goerzen, 2005; Goerzen and Beamish, 2005). Furthermore, accumulated network resources arising from firm participation in prior alliances, firm prestige, as well as any existing interdependence between the potential alliance partners, are likely to be influential in the decision to enter new alliances (Eisenhardt and Schoonhoven, 1996; Stuart, 1998; Gulati and Gargiulo, 1999; Gulati, 1999).

A key feature of most of the extant network literature concerning alliance networks is the focus on ‘repeated’ and ‘enduring’ (Podolny and Page 1998) or ‘sustained’ (Huggins, 2001) interactions or relationships. Converse to alliances, contact networks consist of non-formalised interaction and relationships between organizations. The structure of these networks is often more dynamic, as organizations continually update and change their contacts (Burt 1992; Huggins 2000, 2001; McEvily and Marcus 2005; Grabher and Ibert 2006; Tripp et al., 2009). 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-organizational networks as principally a means of utilising the knowledge of others, rather than necessarily seeking to internalise such knowledge within the organization (Grant and Baden-Fuller 2004).

### **Network Capital**

Some scholars have pointed to networks endowed with social capital – in the form of interpersonal relationships – as a key lubricator of knowledge flow (Iyer et al., 2005; Tura and Harmaakorpi, 2005; Hauser et al., 2007; Lorenzen, 2007; Walter et al., 2007; Tappeiner et al., 2008; Cantner et al., 2009). However, while social capital may explain a degree of knowledge flow across organizations, it does not necessarily account for the large proportion of economically beneficial knowledge (Bathelt et al., 2004; Weterings and Ponds, 2009; Huber, 2011). Instead, network capital, consisting of relational assets in the form of more strategic inter-organizational networks designed specifically to facilitate knowledge flow, innovation, and accrue economic advantage, better explains the means through which economically beneficial knowledge is accessed.

The network capital concept is rooted in the recognition that leveraging of inter-organizational networks is an asset that can be shaped by organizations, and is generated by investments in calculative relations. In recent years, however, the scholars usually identified social capital, in the form of social norms and customs, as the network resource that lubricates the transfer and connection of knowledge (Capello and Faggian, 2005; Tura and Harmaakorpi, 2005). These social norms and customs are embedded in the social environment, and the trustworthiness of any environment is often tacit and specific to each community (Iyer et al., 2005; 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 et al., 2005). However, as Putnam's (2000) finds, although communities, especially business communities, are now more networked than ever, they actually possess less social capital, and 'in some ways social capital may be economically counterproductive' (Putnam, 2000, p. 322).

In an entrepreneurial setting, Westlund and Bolton (2003) present a persuasive case concerning some of the negative aspects of social capital among firms, arguing that the strong trust embedded in interpersonal relations can inhibit firm-level development. Most commonly, social capital consists of the perceived value inherent in individual and inter-personal networks and relationships generated through socialisation and sociability as a form of social support (Borgatti and Foster 2003). This leaves us with the question of how to understand and analyse the relational assets held by organizations, rather than those of individuals.

Networks concern investments in 'interaction capability', and as intangible capital structures should be analysed as capital objects (Westlund, 1999). 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). However, when organizations deliberately invest in networks, these networks are different as they concern the development of relationships that Williamson (1993) refers as 'calculative', since they consist of actions motivated by expected economic benefits (Hite and Hesterly, 2001). Investments in inter-organizational networks can be more specifically termed as investments in network capital, consisting of the calculative relations developed by organizations through which they access to knowledge to enhance economic returns, principally as result of innovation. This makes a clear distinction between the two types of relational asset: network capital and social capital, and addresses an explanation as to why social capital may be declining and becoming eroded, even though organizations are often increasing the investment they commit to network development (Coleman, 1990; Putnam, 2000).

The notion of network capital is as a response to the increased recognition that the leveraging of inter-organizational networks can be considered a strategic resource that can potentially be shaped by organizational action (Mowery et al., 1996; Dyer and Singh, 1998; Madhavan et al., 1998; Lorenzoni and Lipparini, 1999; Kogut, 2000; Gulati, 2007). Notably,

research stemming from the field of strategic management has proposed an extension of the resource-based view of the firm to account for external network capabilities, in addition to the internal capabilities of organizations (Eisenhardt and Schoonhoven, 1996; Lavie 2006; Gulati, 1999; Gulati, 2007; Gulati and Gargiulo, 1999; Gulati, Nohria and Zaheer, 2000).

Oliver (1997) suggests that two types of rationality are at play within organizational 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. The source of network capital is rooted in an economic rationality, whereby organizations invest in establishing ‘calculative’ networks to access the knowledge they require.

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 consistent with the view that ‘profits’ from social capital and social networks are not usually ‘consciously pursued’ by the actors within a network (Bourdieu, 1986). The distinction between different forms of network behaviour is not new, and has a long history in sociological studies. Max Weber, for instance, distinguished ‘communal’ (*Vergemeinschaftung*) relationships, based on subjective feelings, from ‘associative’ (*Vergesellschaftung*) relationships, based on rational judgments and expectations, as well as action predicated on ‘custom’ (*Sitte*) or a purely rational orientation (*zweckrational*) (Weber, 1968).

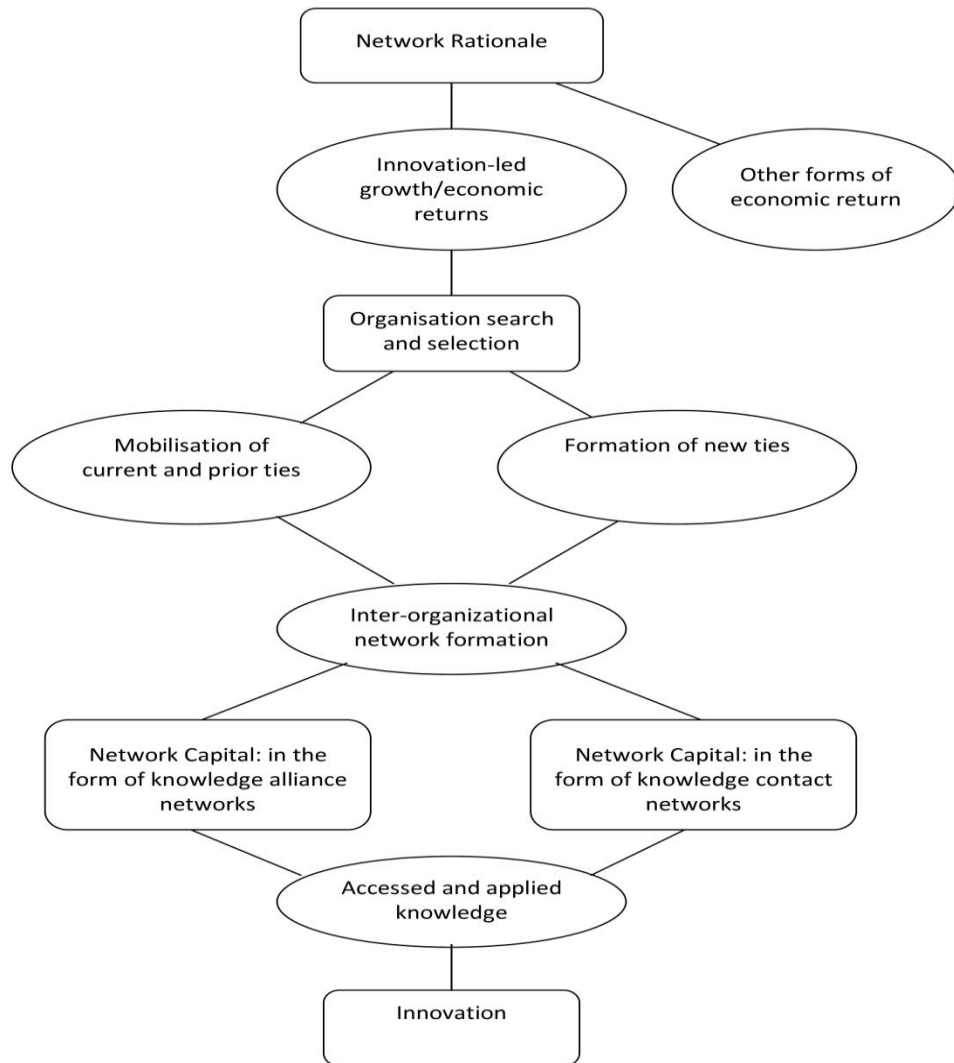
In contrast to social networks, calculative networks provide greater resource availability (Hite and Hesterly, 2001). Network capital is likely to be highly significant to organizations as they seek to access and exploit knowledge. A network capital perspective provides a means of mediating external knowledge exploitation activity. Distinguishing between the network capital and social capital located in networks is a means of understanding the trade-offs, characteristics, function and potential for managing knowledge flows. Such a distinction is again consistent with the knowledge-based view of the firm (Grant, 1996), knowledge management theory (Nonaka and Takeuchi, 1995) and theories of intellectual capital (Stewart, 1997), whereby network capital is an organizational-level resource (with social capital concerning the relationship resources of

individuals). These tradeoffs further highlight the multidirectional flow of knowledge through inter-organizational networks. For instance, a firm may allow another firm access to its research or technology as a means of securing access to knowledge related to the commercialization and innovation of this research or technology (Fosfuri 2006; Lichtenthaler 2005).

In summary, Figure 1 highlights some of the key concepts relating to the formation of network capital. First, the rationale and motivation for engagement, which in this case be related to innovation-led growth of firms, but which may also consist of other forms of economic returns. A key part of the formation process relates to the search and selection of organizations with which to network. This process may be mobilised through the use of current and prior ties or the formation of new ties that are unconnected with current or prior ties. As indicated above, the inter-organizational networks formed are conceptualised as consisting of knowledge contact networks or more alliance-based networks through which knowledge flows. Finally, the forms of knowledge accessed and applied to achieve innovation are important components of the process, and are discussed in more detail in the following section.

**Figure 1: Network Capital Formation: A Conceptual Framework**





## **Networks and Accessed Knowledge**

This section of the paper proposes that the nature of the knowledge flowing and accessed through inter-organizational networks will be an important determinant of the value organizations accrue from their network capital. In particular, the value of network capital to organizations will be determined by the superiority, excludability, and miscibility - the ability to mix/combine different types of knowledge from different sources with their own knowledge stocks - of the knowledge they are able to access through their inter-organizational networks, particularly as a means of triggering innovation. As already indicated, innovation is considered to be at the heart of competitive advantage attainment for both organizations and places and, as Callon (1999) argues, ‘what marks innovation is the alchemy of combining heterogeneous ingredients: it is a process that crosses institutions, forging complex and unusual relations between different spheres of activity, and drawing, in turn, on interpersonal relations” (p. 2, cited in Amin and Cohendet, 2004). For organizations, this means the capability to combine and consolidate knowledge (Prahalad and Hamel, 1990).

Knowledge can be generally defined as information that changes something or somebody, either by becoming grounds for action or by making an organization capable of different or more effective action (Drucker, 1989). More generally, knowledge is broadly used as a scientific notion for the most important and dynamic driver of the modern economy. Unlike simple information, knowledge concerns action and is function of a particular stance (Nonaka and Takeuchi, 1995). Of course, knowledge takes many different forms, with one of the most familiar typologies suggesting that knowledge is either explicit/codified or tacit. In general, explicit knowledge refers to information that can be easily communicated among individuals, whereas tacit knowledge - such as skills, competence, and talents - is more difficult to directly communicate to someone else in a verbal or other symbolic form (Huggins and Izushi, 2007; Nonaka and Takeuchi, 1995).

The successful recombining of existing knowledge in novel ways through networks (Nelson and Winter, 1982) involving knowledge ‘collisions’ and ‘transpositions’ (Powell and Grodal, 2005) is an example of the effective miscibility of knowledge. Similarly, combining different fields of knowledge creation, such as technology fusion (Kodama, 1992), represents effective knowledge miscibility (Cantwell, 2005). According to Quatraro (2010) knowledge is

the outcome of a combinatorial search activity carried out across a technological space in which combinable elements reside. In this sense, miscibility will be based upon the rates of knowledge coherence and variety (Frenken et al., 2007; Boschma et al, 2009; Quatraro, 2010). In many ways, the notion of the miscibility of knowledge harks back to Schumpeter's (1934) view of innovation as resulting from the carrying out of new combinations.

The excludability of knowledge will be compromised if it is allowed to 'leak' outside a particular network. 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. Without effective network management knowledge may leak more freely out of a network than productively within it (Teece, 1998, Fleming et al. 2007). Effective network management, through strategic and intentional investment in relationships, i.e. network capital building, is a mechanism for ensuring that value is captured rather than lost through inter-organizational networks (Lichtenthaler, 2005; Teece, 1998). Similarly, the superiority of knowledge may be compromised as organizations within a network become increasingly familiar with each other's knowledge, and negative network effects may emerge, locking organizations into low value and unproductive networks, stifling the creation of new knowledge and innovation (Arthur 1989; Adler and Kwon 2002; Labianca and Brass 2006; Molina-Morales and Martínez-Fernández, 2009). In order to continue to play a role in the innovation process, networks are often required to evolve to include new members and configurations to meet changing needs, expanding the network capital of engaged organizations (Hite and Hesterly 2001, Lechner and Dowling 2003).

In general, the search for superior knowledge means 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; Bathelt and Turi, 2011). 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 heterogeneity through the articulation of shared norms, standards, and rules of conduct among organizations (Oliver 1997; Monge and Contractor 2003). Although stable networks may reduce the potential costs of network capital, it is likely that as knowledge becomes increasingly

homogeneous and less useful across network actors the value of network capital may well erode (Maurer and Ebers, 2006).

Network capital investments may become ineffective if there is knowledge equivalence between organizations due to similarities in knowledge profiles, which results in network redundancy (Cowan et al., 2004). These inertial network forces highlight the issue of over-embeddedness, whereby the actors an organization is best connected to may not be best placed to provide solutions to current problems (Krackhardt, 1994; Monge and Contractor, 2003; Maurer and Ebers, 2006).

### **Networks and Entrepreneurial Firms**

Knowledge accessing from external organizations has become increasingly important to small entrepreneurial firms that cannot generate internally all the knowledge necessary for innovation (Teigland and Wasko, 2003; Faber and Heslen, 2004). Within an entrepreneurial firm environment, the role of inter-organizational networks and knowledge sources are increasingly recognised as potentially important assets for creating and sustaining innovation and competitiveness (Lechner and Dowling, 2003). There is growing evidence that network development is related to the growth of firms, particularly networks involving the flow of knowledge (Knoben and Oerlemans, 2006). In order to compete successfully with large firms, entrepreneurial firms may need to develop external networks to access resources they do not possess internally (Kingsley and Malecki, 2004).

Existing evidence suggests that entrepreneurs and small business owner-managers build personal networks where individual ties combine calculative and social aspects (Anderson et al., 2007). This 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). The different functions and objectives of a network can be defined as its 'compositional quality', reflecting the ability of differing network ties to provide needed resources (Hite and Hesterly, 2001). In general, new and small firms are more likely to be dependent on the social networks of the entrepreneurs or

owners of the firm (e.g. the relatives and friends of the owners). As firms grow, their dependency will shift towards strategic networks, 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 et al; 2003). 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, network capital becomes more evident through the formation of strategic alliances based on formalized collaboration and joint ventures, and other ‘contracted’ relationships involving equity and R&D agreements (Goerzen 2005; Goerzen and Beamish 2005; Grant 1996; Grant and Baden-Fuller 2004; Ireland et al. 2002; Stuart 2000). Within the strategic management literature, studies on the utilization of strategic alliances often highlight the networks developed by multinational corporations through contractual relationships with an objective of improving resource and knowledge access (Hagedoorn 2002; Hagedoorn and Schakenraad 1994; Kim et al. 2006). As the cost of searching and maintaining network partners may be proportionately higher for small firms, investments in network capital will tend to account for a greater proportion of total investment in small, as opposed to large, firms (Almeida et al. 2003).

The nature of the networks will also be dependent 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’ (21), which implies relationships based on network, as opposed to social, capital. From the perspective of entrepreneurial firms, this network capital may manifest itself through improved performance resulting from the credibility of having prominent strategic alliance partners (Stuart et al. 1999). In other words, entrepreneurial firms use these networks to develop their reputation as a means of overcoming imperfections in the markets for knowledge (Lichtenthaler and Ernst 2007). Yli-Renko et al. (2001) find that knowledge exploitation for young knowledge-based firms depends on repeated intense interaction, as well as the willingness of firms to share information. The configuration of networks at start-up stage will influence firm performance, which will be enhanced by

developing networks that provide access to diverse information and capabilities with minimum costs of redundancy, conflict and complexity (Baum et al. 2000).

## **Methodology**

The findings presented in the following sections of this paper are based upon a series of 10 case studies of entrepreneurial firms in the UK with a high propensity for engagement in innovation-led growth. The firms were identified via the larger scale postal survey (see Huggins et al., 2012a). The case studies aim to facilitate a better understanding of the role of network capital formation and inter-organizational network development that facilitates access to knowledge in promoting innovation-led growth among entrepreneurial firms.

Our methodology can be broadly situated within the context of 'critical incident' techniques, whereby we have sought to understand in-depth why and how the case study firms became engaged in international knowledge sourcing practices. This approach facilitates a process of inductive theory-building with regard to role of network capital formation in promoting innovation. As Borch and Arthur (1995) argue, there is a need for a more in-depth knowledge of the cultural contexts and socio-economic relations of actors within networks, and suggest the applicability of the qualitative methodological tools associated with disciplines more experienced with human interaction research, such as social anthropology. The critical incidents' technique attempts to explain the motivation for individuals to act in a certain fashion in light of some 'non-routine event' occurring (Curran et al. 1993, Ring and Van de Ven 1994). Curran and Blackburn (1994) and Joyce et al. (1995) both use a critical incidents approach to explore the motivations of entrepreneurial firms to join networks due to occurrences that may potentially destabilize their business. A criticism of this approach is that it appears to assume that decision-making processes associated with network participation occur only during periods of crisis. Nevertheless, the use of critical incidents and other qualitative methods are an important recognition of the need to understand and interpret the characteristics and organization of networks.

The ten cases presented in this paper emerge from an initial sample of 25 entrepreneurial firms identified as possessing innovation-led growth characteristics. The cases presented are

those for which the best possible access was secured. The principal aim of the data collection process was to develop a series of network capital formation biographies for each of the firms set within the context of the critical incidents approach. In general, the case studies aim to capture the following core themes: the rationale and motivation underlying network capital formation; the process of searching and selecting organizations with which to form knowledge-based inter-organizational networks; the types of inter-organizational networks formed and the interaction mechanisms underpinning them; the type of knowledge accessed through the networks and the applications stemming from its sourcing.

The methodology used to capture relevant data consisted of the following key activities: an initial review of publicly available company-level documentation (e.g. website, company accounts, marketing and promotional literature) to gain an overview of key activities and markets; a one-day visit to the firm to interview key decision-makers and executives telephone interviews and email exchanges with those organizations with which the case-study firms network. Also, for those case studies where sourcing is mediated through third parties and other brokers, contact was undertaken with these actors. Follow-up telephone interviews with the firms to investigate any information gaps or to clarify any outstanding issues were also undertaken. Following the initial drafting of the case studies, each report was presented to the respective firm to ensure they contain no points of conflict and that all the material is an accurate portrayal of the firms and their activities.

A summary of the case study firms is shown in Table 1. In many ways, the firms represent a good cross-section of the innovation strengths of the UK economy, in particular its entrepreneurial firms. For instance, there is strong representation for the healthcare sector, consisting of: Easylab; Ingenza; Prosonix; Psynova Neurotech; and QCTR.

Easylab was founded in 2004 by two physicists, the firm currently employs seven people and supplies laboratories, research institutions and universities around the world working in the fields of physics, geophysics, chemistry, and biology. Starting life in an incubation unit at Royal Holloway, University of London in Egham, Surrey, where one of the co-founders had previously done his doctoral research, Easylab quickly outgrew these facilities. The company is currently located in the Science and Technology Centre of the University of Reading, although there are no direct scientific links with the university. Ingenza, an industrial biotechnology company based

at the Roslin Biocentre in Midlothian, started as an Edinburgh University spinout in 2003. The company, which now employs 14 people, provides practical industrial scale methods to manufacture chiral chemicals and biopharmaceuticals. It was acquired by Richmond Chemical Corporation (RC Corp.) a Chicago-based fine chemical company, in 2007.

Prosonix is a small business based in Oxford that specialises in the commercialisation of proprietary pharmaceutical ultrasonic particle engineering technologies and added value ultrasonic process chemistry solutions for the pharmaceutical industry. Psynova Neurotech Ltd is a spinout company, set up in 2005 to build on biotechnology research at Cambridge University. The company develops and tests new hypotheses of the pathological basis of conditions like schizophrenia and bipolar affective disorder. QCTR, based at the Stirling University Innovation Park, is a niche Contract Research Organization (CRO) with a clinical specialism in psychiatry, neurology and orphan diseases. Set up in 2005, the company's 14-strong team provides Phase 2 and 3 clinical trial management, as well as medical writing and regulatory advice services for its pharmaceutical industry sponsors.

Outside of the healthcare sphere, Badley Geoscience Ltd is a small structural geology company, which has 12 employees and specialises in providing high end, technically specialist work for the international oil and gas industry. Biocatalysts Ltd is a wholly independent manufacturer of enzymes used primarily for improving product quality and process efficiency within the food industry. The company, which was founded in 1983, is located north of Cardiff. The firm has 30 employees and a turnover of around £5 million, with 90 per cent of sales from exports. Kinetic Cubed Ltd is a specialist provider of international business solutions to international economic development, trade and investment promotion agencies. The company has its headquarters in the North West of England, with branch offices in Lancaster, Cardiff, New Delhi, Madrid and Barcelona.

Melin Tregwynt is a designer and weaver of traditional woollen fabrics, with its origins in the 18th century Tregwynt mill that became the basis of a family-run business that is now nearly 100 years old. The company employs over 20 local people. Established in 1995, Sitekit is at the forefront of web content management systems development in the UK. The company has a total of 22 employees and more than £1 million in annual revenue. The company is located in the relatively remote and rural setting of the Isle of Skye, Scotland, complemented by a sales office



in Oxford. The company has also recently established a new partner office in Perth, Australia. Sitekit's successes, such as attaining Deloitte Fast 50 status in Scotland for five successive years, highlight its growth and competitiveness.

**Table 1: Summary of the Case-Study Entrepreneurial Firms**

<b>Firm Name</b>	<b>Activity</b>	<b>Number of Employees</b>	<b>Founding Year</b>
Badley Geoscience	Structural geology company that specialises in providing high end, technically specialist work for the international oil and gas industry.	12	2003
Biocatalysts	Wholly independent manufacturer of enzymes used primarily for improving product quality and process efficiency within the food industry.	30	1983
Easylab	Company involved in the design, development, manufacture and support of scientific equipment related to the extreme conditions of ultra-high pressures.	7	2004
Ingenza	Industrial biotechnology company that provides practical industrial scale methods to manufacture chemicals and biopharmaceuticals.	16	2003
Kinetic Cubed	Specialist provider of international business solutions to international economic development, trade and investment promotion agencies.	6	2005
Melin Tregwynt	Designer and weaver of traditionally woollen fabrics.	20	12
Prosonix	Specialist in the commercialisation of proprietary pharmaceutical ultrasonic particle engineering technologies.	17	2006
Psynova Neurotech	Developer of diagnostic products to aid the diagnosis and treatment of psychiatric disorders.	5	2005
QCTR	Niche Contract Research Organization (CRO) specialising in clinical trial management.	14	2006
Sitekit	Company involved in the development of web content management systems.	22	1989

## **Network Rationale**

We begin our analysis of the data stemming from the case studies by aiming to highlight the underlying rationale why the studied firms seek to form network capital. For all firms, it is clear that network capital formation is related to the objectives of innovation-led growth, although this does take different forms. For the majority of firms, the rationale for network capital formation is embedded within the strategic requirements of firms, in particular the requirement to the access knowledge from beyond the boundaries in order to meet the innovation objectives. For instance, in the case of Badley Geoscience the network rationale is considered to relate to the need to ensuring a continual process of innovation enabling the firm to remain at forefront of their industry. According to firm, they build network capital principally as a means of identifying the latest academic research that can be applied to the oil and gas industry, which supports them in their endeavour to develop new tools that can work alongside their current portfolio of software.

Biocatalysts position as a standalone enzyme developer that seeks to act as co-development partner with end-using food producers requires a highly focused network capital development model as part of an effective knowledge-sourcing strategy. In the case of Easylab, maintaining effective links to the global academic community, both as a source of knowledge, and as end-users of their products, is considered to be crucial success factor for the firm.

This model, based around strategic requirement, is replicated in Psynova Neurotech, which collaborates with academics and large pharmaceutical companies, and is a model that is widely accepted in the biotechnology industry, in order to develop diagnostic products to aid the diagnosis and treatment of psychiatric disorders. Also in the healthcare sector, QCTR builds links with with a network of organizations that can provide it with up-to-date, specialist knowledge as and when it is required. Alongside this, they also need to have up-to-date knowledge of processes that will enable them to operate in a streamlined and efficient manner and in compliance with the appropriate regulations when, for example, managing clinical trials.

Although the strategic requirement of these entrepreneurial firms is the central focus of the rationale underlying network development, it is clear that this is often tied to the strategic requirement of their customers, which are often larger concerns. For instance, Ingenza stated that network development is strongly related to the need to constantly develop new, innovative

processes that will help to find solutions to their customers' problems. In other words, Ingenza form part of an outsourced or open innovation, whereby a continual process of knowledge sourcing is required in order to effectively support customers in the development of their own innovative products and processes

Beyond the strategic requirements of firms and their customers, the other underlying rationale for network capital formation relates to the potential to commercially exploit a knowledge-based opportunity. This is most apparent in the case of Sitekit, which is seeking to build network capital through a research arm of the firm – Sitekit Labs - that aims to partner with researchers worldwide to help them commercialise new technologies and rapidly take them to market. The Lab focuses on identifying niche, web-based business applications that have global market potential for Sitekit's partners and customers. Similarly, Prosonix builds network capital to exploring new and innovative techniques that can provide opportunities to develop their position in the pharmaceutical industry through exploiting the latest technology in this globalised industry.

### **Organization Search and Selection**

In this section the processes and mechanisms underlying the search and selection processes by which firms choose organizations with which to develop network capital are explored. Overall, it is found that there two distinct mechanisms at play: first, the utilisation of prior and current interpersonal and inter-organizational ties held by the firm; and second the formation and utilisation of new ties outside of a firm existing network. In general, the majority of firms utilise a balance between these two forms. For instance, in the case of Easylab the two co-founders of the firm previously worked for Oxford Instruments - a large company in the scientific instruments field with strong links to the academic community – that has provided the firms with a range of prior interpersonal and inter-organizational linkages enabling the formation of networks facilitating access to relevant knowledge. These prior ties have been coupled with the development of new ties outside of the firm's existing network through attendance at trade shows and conferences. Easylab also noted that it has derived some benefit from government programmes such as 'Passport to Export, which has helped with new tie formation.

Kinetic Cubed usually builds on existing networks along with searches for new potential ties from websites, online blogs, databases, conferences and intermediary organizations such as professional/membership organizations. Biocatalysts and Prosonix also attend a wide range of international events, and seek to develop new links with leading universities in the field in the UK and around the world. Collaborative R&D with customers constitutes nearly three quarters of Prosonix's work, and the firm's small business development team are responsible for identifying potential customers through mechanisms such as web searches, web alerts, conference attendee lists, press releases, publicly available company annual reports etc.

Ingenza, similarly, has a strong commitment to attending and presenting at key events in their field, and they have also linked into various international research consortiums that endeavour to advance industrial biotechnology processes. According to the firm, having a short technical presentation that can be delivered at trade shows or symposia is the best way to stimulate networking, which in turn supports future knowledge exchange. Other search and selection mechanisms employed by the firm include current links into a wide range of different organizations; for example a director of the firm has a visiting fellowship at a university. Also, the firm is affiliated to a range of academic research institutes, which helps ensure that it remains up to date with the latest events and opportunities.

QCTR often work with experts in key organizations in the medical community, which it mostly identifies these experts and investigators through existing contacts and networks. Alternatively a web based search or events may provide an opportunity for the firm to meet experts. Initially, the experts will be asked to review QCTR's proposal for undertaking a particular study; critically they will input their knowledge in order to shape the study, for example, by identifying whether it will potentially deliver the 'right results'.

The important role often played by prior ties is highlighted by Kinetic Cubed, which finds that until sufficient networks have been built identifying organizations with the appropriate knowledge can be challenging. A key trend to emerge is the firm's emphasis on informal networks, whether this is through previous clients, associates, friends or professional networks. Alongside the use of informal ties and attendance at networking events, a key mechanism of organization search and selection employed by a number of firms is the utilisation of some form of network broker or intermediary. Kinetic Cubed, for instance, employ a freelance management

consultant to enable sector specific market research in particular providing recommendations for potential key knowledge sources.

Biocatalysts pay an annual retainer for access to the services of Nerac, a US research and advisory firm for companies developing innovative products and technologies. Biocatalysts use the expertise of Nerac in two distinct ways: for customer-specific projects which involve a technical background and IP search around the questions of ‘has it been done before? who is doing it? what’s out there? is it covered by IP?’. This background research provides Biocatalysts with information regarding with whom they should be connecting in order to access the knowledge they require. Similarly, in the case of Melin Tregwynt, although trade shows and exhibitions have played a role in this transition, the most significant factor in facilitating successful access to the knowledge required to new markets has been their linkage with an agent in Japan.

The role of professional membership organizations in generating new ties was highlighted by QCTR, which has joined a number of professional membership organizations, such as the Institute of Clinical Research, the BioIndustry Association (BIA) and the Drug Information Association (DIA). QCTR makes a strategic effort to attend events delivered by these organizations which provide an opportunity for informal networking relating to organization search and selection. However, QCTR also highlighted the fact that network capital formation can involve significant investment, especially for entrepreneurial firms, and the requirement to gauge the extent to which such investments prove to be cost effective.

Finally, it is important to highlight the role of public and government policy in generating network capital. This is most pronounced in the case of Sitekit, whereby the regional economic development agency - Highlands and Islands Enterprise (HIE) - has played an important role in developing the firm’s knowledge sourcing networks. Along with a number of other firms from the region, HIE facilitated a research visit to the Massachusetts Institute of Technology’s (MIT) Media Lab. This visit allowed Sitekit to open a dialogue with key Media Lab researchers, which is now maintained on an on-going basis. Following on from this, Sitekit made a further substantial investment in a field visit to the US, mainly to California, encompassing meetings with research staff at Stanford University in Silicon Valley and large blue-chips such as Johnson and Johnson, as means of making new ties with prospective future US partners and research

contacts to engage with Sitekit Labs. Interestingly, as part of the visit, Sitekit are sponsoring a Californian shinty (traditional Scottish Highlands field hockey game) tournament as means of building visibility and growing relationships with key actors in California.

### **Network Type and Interaction Mechanisms**

This section seeks to indicate the key networks and interaction mechanisms underpinning the inter-organizational networks within the entrepreneurial firms engage. In general, it is found that these largely consist of a mix of networks that can be classed as alliances – largely manifested in the form of collaborative project – and contacts networks, whereby knowledge is accessed through contact with customers, suppliers, universities, etc. The following provides some relevant examples of the network mechanisms and types.

In the case of Badley Geoscience, one of their key alliances is with University College Dublin in Ireland. In particular, the firm collaborates with the University's Fault Analysis Group, which carries out basic scientific research on all aspects of faults and other types of fracture and applies the results to practical problems, principally in the fields of hydrocarbon and minerals exploration and production. According to both parties, the relationship between Badley Geoscience Ltd and the University has worked particularly well, most notably due to its symbiotic nature and the understanding between the core individuals involved in the relationship. Both consider that the fact that there is no direct competition between them – with the University uninterested in writing commercial software or doing bespoke consultancy work of the type undertaken by Badley Geoscience has led to significant returns from the network capital generated.

For the University, working with Badley Geoscience removes the financial risk associated with developing their software commercially. They also have access to the latest software to enable them to conduct relevant, high quality research. In addition, they have gained credit for working with commercialised products, placing them in a better position for future research funding. Through a licensing agreement, the software also generates revenue for the University. Badley Geoscience note, however, a number of challenge in working with universities, such as the requirement to filter through a plethora of information available to identify something that could be of commercial interest to the firm. Badley Geoscience Ltd and

FAG maintain regular contact, through a mixture of face-to-face, telephone and online means, in order to maintain and further develop the software. Alongside this alliance, Badley Geoscience also maintains strong contacts with their key customers- which include BP, Shell, Total, BG Group Plc, Chevron, Petrobras, Conoco Phillips and StatoilHydro – as a means of accessing relevant knowledge.

In the case of Biocatalysts, project-led collaborations with customers are a key source of network capital. According to the firm, it is a case of both sets of scientists working together as a team with the customer being the experts in their processes, while Biocatalysts are experts in enzymes, and putting these two pieces of knowledge together is the key value-added of the relationship. In general, although the larger companies in the industry have people in their own research teams with considerable knowledge of one enzyme product, they do not always have the breadth of knowledge provided by Biocatalysts. For example, it may be that a customer will be trying to do something that has already been done in another market of which they are not aware - Biocatalysts can apply a solution that has already been developed, thus saving resource and development time.

As such, Biocatalysts operates as a co-development partner with end users, rather than as a firm which works on developing new enzymes in isolation. One example of this is the relationship the firm developed with Kraft Foods. At the time, Kraft was focusing its development efforts on enzymes related to improving food flavours. Biocatalysts became aware of a particular enzyme that one of their existing customers had been working with, and Biocatalysts were able to become involved in usage development of this, at first with Kraft, at an early stage. According to Biocatalysts, an open innovation culture within the food production industry has grown in importance in recent years. Major customers - Nestle in particular - increasingly realise they can much more effectively tap into the R&D efforts of small niche firm such as Biocatalysts by providing quite detailed knowledge regarding the technical specifications and requirements of their existing products, as well as those currently in development or anticipated for the future. In general, Biocatalysts has been able to maintain its position as wholly independent co-developer and manufacturer of enzymes for improving product quality and process efficiency within the food industry through the effective use of network capital formation with its leading customers.



Similarly, collaborating with, and learning from, both customers and the other suppliers of related scientific products through project-led alliances has enabled EasyLab to offer new technical solutions to their customer base. As EasyLab's customers are typically research institutes, the firm is in a good position to learn from these relationships, particularly in terms of potential new applications, improving existing products or developing new ones. One example is the work EasyLab undertook for the National Institute of Standards and Technology (NIST) in the US, which had a need for a particular piece of instrumentation, but wanted an external organization to manufacture and supply this technology. Engineers from EasyLab and NIST collaborated to produce an optimised design. Interestingly, this collaboration was undertaken entirely via video-conferencing, email exchange of CAD drawings and so on. The resulting development is now a product that EasyLab will be able to offer to new customers in the future.

Ingenza's main network capital also pertains to customers, and as well as project-led alliances it also relates to what the firm refers to as a 'natural process of knowledge sourcing' through its ongoing interactions. In general, following work undertaken for a customer, the customer has exclusive use of the technology for their specific application. However, Ingensa owns the general technology and process that can then be used to benefit other customers. As an example, one customer asked Ingensa to develop a method whereby they could determine how efficiently an enzyme was being produced in their system. The resulting method involved the development of a screen, based on constructed growth conditions, which by producing a library of around a thousand isolates would identify whether a particular isolate was being produced more efficiently. According to Ingensa, sourcing knowledge from its customers enables it to better understand how its tools and processes can be applied to different challenges.

A further example of this customer-oriented network capital formation is the case of Prosonix, which although using a range of mechanisms to source knowledge is perhaps most on the way in which it absorbs knowledge from previous and existing customers in order to keep abreast of and learn from industry trends, problems and opportunities. Prosonix stated that it sourced valuable knowledge from its customers, and by helping a customer address a specific problem, the firm learns more about the products they are working with, and the problems they are facing.

Another form of network capital generation is engagement in publically funded collaborative R&D programmes. For instance, Psynova Neurotech is part of an eight member consortium that submitted a proposal to the European Commission (EC) for funding to undertake research into the diagnosis of schizophrenia and other psychiatric disorders. The proposal was successful and the consortium was awarded a three year €2.75 million grant to develop minimally invasive, high throughput, low cost molecular assays for the early diagnosis of these disorders.

As means of accessing knowledge, Sitekit have engaged a number of distinguished academic and industrial Fellows, who have agreed to contribute their expertise to the research work being carried out at the Sitekit Lab. As well as UK-based researchers, other fellows include researchers at Harvard Medical School, Brandeis University in Boston, and at the MIT Sloan School of Management. According to Sitekit, the appointment of these individuals from prestigious national and international institutions provides Sitekit Labs with valuable networks to world-class universities and industrial markets. Furthermore, having both academic and industrial fellows ensures the research into new technologies is directed towards addressing large scale problems that have potentially viable commercial solutions. In collaboration with the MIT Media Lab and Stirling University, Sitekit Labs has further created a PhD research post to study new application of ‘common sense computing’ to enable development of next generation semantic web applications.

### **Accessed Knowledge and Applications**

For the majority of firms the form of knowledge accessed through their inter-organizational networks relates primarily to scientific and technical knowledge, with a smaller number of firms focusing on accessing knowledge related to the development of their market. In general, the scientific and technical knowledge accessed consists of know-how and tacitly held knowledge rather than more codified forms. However, this knowledge is often combined with codified knowledge that the firms access through searches of the relevant literature and publications, as well as sources of codified knowledge. For instance, at regular intervals Prosonix undertakes patent watches to identify technology processes patent that can add value to the coverage of the firm’s existing intellectual property in the pharmaceutical industry.

The applications for the knowledge accessed clearly indicate the role of network capital in promoting innovation-led growth across the entrepreneurial firms, principally through the introduction of products and process either for the firm itself or its customers. In the case of Badley Geoscience, for example, the technical and market knowledge they have accessed through their networks has facilitated the development of their software tools, which comprise of a suite of modules that deliver a focused set of advanced tools for the geological analysis of faults and fault-related processes in the oil and gas sector.

Similarly, the expertise EasyLab has accessed has enabled the development of high pressure as a tool for scientific research; particularly in the field of optical instruments. According to Ingenza, as a result of the knowledge and experience gained through work with its customers, the firm has been able to further develop and expand its enabling technology, allowing a quicker response to customer problems. Also, as result of scaled up the technology for manufacturing, they are able to produce enzymes at ten times lower the original cost.

In the case of Psynova Neurotech, through one of their EU Framework Programme collaborators the firms became aware of Rules-Based Medicine (RBM), which is a US based, biomarker testing laboratory providing pre-clinical and clinical research to pharmaceutical companies, biotechnology firms and research organizations. Psynova Neurotech has subsequently collaborated with RBM on the validation, regulatory approval and manufacture of a diagnostic blood test for schizophrenia. This agreement will leverage the firm's protein biomarker platform and RBM's central lab service to accelerate the delivery of the blood test.

Outside of the scientific arena, the key outcome for woollen product manufacturer Melin Tregwynt is that they have been able to come through a period of severe restructuring within their industry, and successfully diversify away from declining local and low value markets into new areas, both in terms of geography - North America, Europe, Scandinavia and Japan - but also with regard to products i.e. interior design, but also use of the fabric for shoes, clothing, bags, hats and purses, etc.

## **Discussion**

In the preceding sections, the concept of network capital has been operationalised to characterize the more calculative ties held by firms, as distinct from social capital's focus on the social

interrelations of individual firm members. As we have seen, the notion of network capital is more attuned to capturing the role of networks as strategic evolutionary systems, with trajectories which change along with the resources they accrue (Glückler, 2007; Kilduff and Tsai, 2003; Monge and Contractor, 2003). In this sense, evolutionary economic dynamics is guided by knowledge flows (Nelson and Winter, 1982), and networks are key accessing channels facilitating knowledge flow through what Romer (1990) describes as effective mechanisms for supporting collective interests and producing new ideas. In general, the role played by network capital formation has a significant impact on the case study firms via access to knowledge that facilitates – for example - an enhanced understanding of customer demands and market trends, as well as as raising technological capacity and innovation performance. As has been found elsewhere, innovation performance of firms appear to be significantly related to network capital investment in dynamically configured inter-organizational knowledge networks (Huggins et al., 2012b).

Table 2 provides a summary of the key factors determining network capital formation across the case study firms. Overall, the factors shed empirical detail on the conceptualisation of network capital formation in innovation-led entrepreneurial environments. Abstracting from these empirical findings, it is possible to develop some further theoretical implications relating to the dynamics of inter-organizational networks facilitating knowledge access, especially within highly innovative entrepreneurial environments, as presented in Figure 2. First, it is clear that entrepreneurial firms invest in these networks for a range of reasons, which are often overlapping. These motivations consist principally of supporting the firms to meet its strategic requirements, particularly in relation to innovation. However, a further motivation from a number of entrepreneurial firms was to support the strategic innovation requirements of customers, which highlights the dependent relationships small entrepreneurial firms often have with their customers (Lechner and Dowling, 2003). A third motivation found among some firms was a rationale to economically exploit a particular opportunity to access knowledge that does not necessarily relate to the strategic requirements of the firm at that point in time.

**Table 2: Summary of Network Capital Formation Factors**

<b>Firm Name</b>	<b>Network Rationale</b>	<b>Organization Search and Selection</b>	<b>Network Type and Interaction Mechanisms</b>	<b>Type of Accessed Knowledge</b>	<b>Knowledge Applications</b>
Badley Geoscience	Requirement for continuous innovation in order to maintain competitiveness in the oil and gas industry	Mobilisation of existing interpersonal ties within the university sector; network search and brokerage by a specialist consultant	Alliance networks with universities and other research group; contact networks with key customers	Scientific and technical knowledge	New product and software development relating to geological fault analysis
Biocatalysts	Requirement to solve a wide range of food processing problems	Pre-existing allegiances in the university sector; search and brokerage through an extensive network of agents and distributors, ties with customers	Alliance networks with customers; contact networks with universities and members of trade and industry associations	Mix of technical and market knowledge	Engagement in open innovation practices with large food producing firms (end users)
Easylab	Continuous access to leading-edge scientific knowledge central to firm's business model	Mobilisation of existing ties within the academic community and customers/suppliers; new tie formation through trade fairs and conferences	Principally alliance networks with universities and customers, supported by contact networks with a group of associates	Scientific knowledge	New product development related to high pressure tools and instruments for scientific research
Ingenza	Requirement to find solutions to the problems of their customers	Existing ties with customers; new ties formation through attendance at symposia and related events; European Commission funded programmes	Principally alliances and contact networks with key customers, coupled with informal contact networks with universities	Technical knowledge	Provision of innovative tools and solutions to customers in the field of industrial biotechnology
Kinetic Cubed	Requirement to source knowledge for customers	Search and brokerage through associates; mobilisation of existing organizational ties; web, conference and database searches for potential new contacts	Alliances with customers and suppliers; contact networks with associated organizations and members of professional organizations	Market knowledge	New trade and investment intelligence provision to customers
Melin Tregwynt	Address the need for market expansion	New tie formation mainly through trade shows, government funded trade missions, and the utilisation of market agents	Principally contact networks with key market agents	Market knowledge	New designs for a range of woollen fabric products
Prosonix	Opportunity to commercially	Mainly mobilisation of existing and	Contact networks with a range of	Scientific and technical	Recombining knowledge to

	exploit accessible knowledge	previous customers, coupled with new tie formation through conferences and trade shows	associated organizations, including venture capitalists; R&D-focused alliance networks with customers	knowledge	solve complex pharmaceutical problems
Psynova Neurotech	Challenge to make scientific breakthroughs in healthcare	Mainly mobilisation of existing ties across the healthcare community	Principally alliance networks with a range of collaborators, some supported by European Commission programmes	Scientific knowledge	New processes to aid the development of biomarkers for clinical blood tests
QCTR	Requirement for very specialist knowledge to improve the treatment of orphan diseases	Mobilisation of existing ties with the university and business community; new tie formation through attendance at events and conferences	Principally contact networks with a range of organizations, including customers, suppliers, members of professional organizations, and regulatory organizations	Scientific knowledge	Improved treatment of orphan diseases
Sitekit	Perceived opportunity to broaden the firm's business model	Mainly new tie formation through engagement in government programmes facilitating access to the global academic community	Establishment of formalised contact networks mainly with key universities	Scientific and technical knowledge	Development of commercial research laboratory

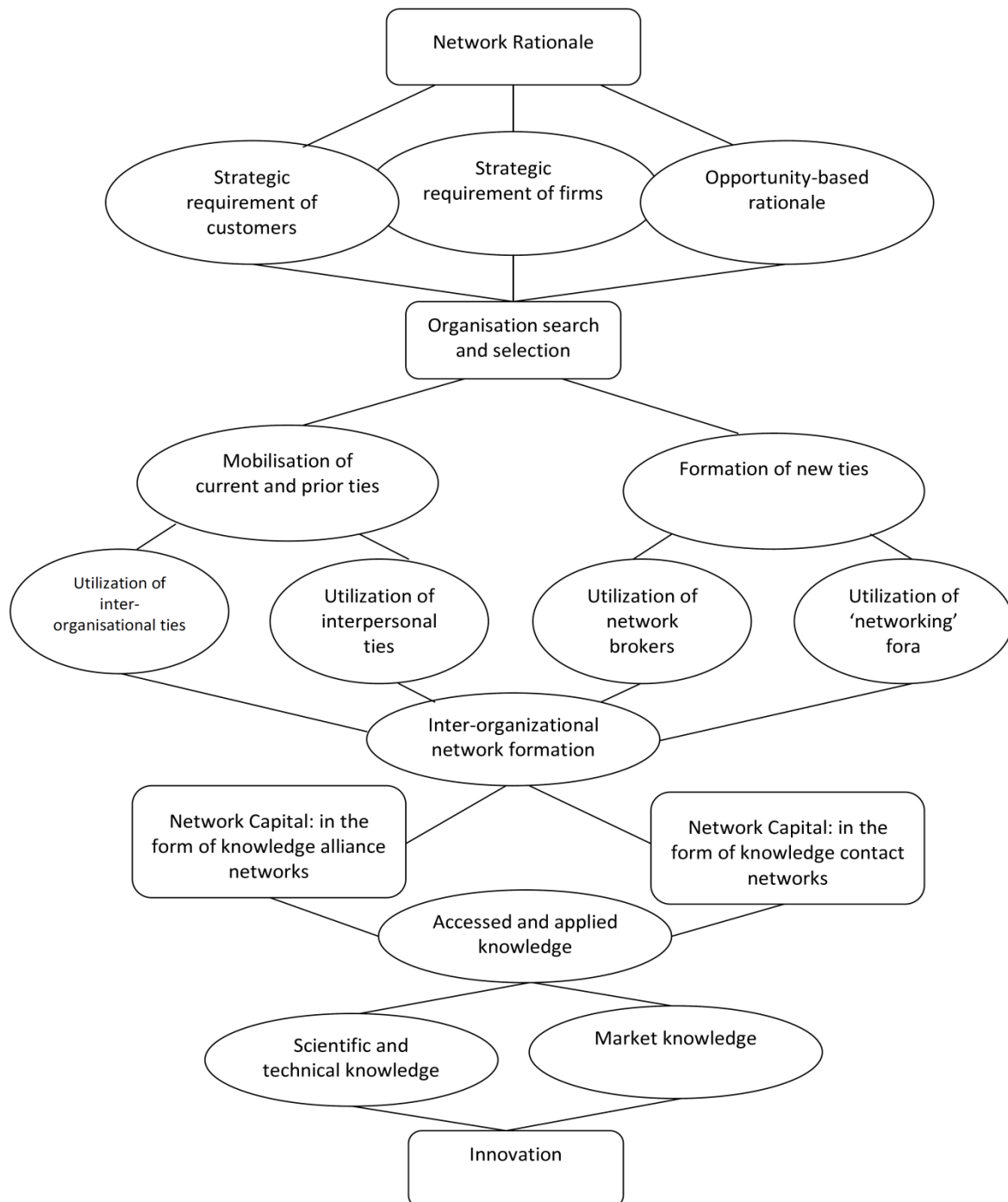
In terms of the search and selection of organizations with which to seek to network development, much of the extant literature has highlighted the role of prior embedded ties, either of an inter-organizational or interpersonal nature (Gulati and Gargiulo; Gulati, 2007). Among entrepreneurial firms these sources were also found to be important, but they are complemented - to a greater extent than that suggested by the relevant literature – by the strong utilisation of network facilitating mechanisms, mainly in the form of intermediary network brokers, such as agents, and networking fora. This is perhaps understandable, given that entrepreneurial firms are less likely to possess the density of embedded social and economic ties compared with larger and more established firms. In particular, new tie formation through network brokerage and network fora highlights how these firms seek to position themselves in the global knowledge networks of their relevant industry and disciplinary communities.

In the case of the firms studied here, it is found that there are multiple mechanisms underlying the formation and development of inter-organizational networks, and firms usually utilise a combination of both knowledge contact and alliance networks. It is through a range of complementary networks that firms are able to appropriately access and apply knowledge, and subsequently develop innovative goods and services. It is this complementary mix that ensures that they keep abreast of knowledge relating to latest industry trends, developments, problems and opportunities. For instance, through strong relationships with academia and customers, in particular, firms are able to engage in a continual process of innovation.

The importance of existing knowledge contact networks should not be underestimated, as they are fundamental mechanisms for building links and identifying suitable organizations with which to develop new networks on an on-going basis. Although stable networks reduce the transaction costs of knowledge transfer, it may also be the case that knowledge becomes increasingly homogeneous 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).

A broad stock of network capital allows firms to respond to emerging trends and adapt to changes in the global market, in order to ensure they remain competitive. For innovation-led entrepreneurial firms, network capital allows them to adapt and augment a product and to better understand the future direction of their key markets, which is critical to success. Although firms may seek to acquire knowledge through inter-organizational networks, it is more likely that the internalisation of knowledge will be achieved through other modes related to hierarchical integration, such as firm mergers and acquisitions, which are often less prevalent among independent entrepreneurial firms (Grant and Baden-Fuller, 2004).

**Figure 2: The Formation of Network Capital Among Innovation-Led Entrepreneurial Firms**





All the firms studied can be said to recognise that the innovation and economic benefits of network capital formation can take time to emerge and required sustained forms of investment. However, the stability or dynamism of inter-organizational 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 an existing network (Beckman et al., 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 et al., 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 ongoing reconfiguration of networks (Gargiulo and Benassi, 2000; McFadyen and Cannella, 2004; Levine, 2005; Huggins, 2011).

The relationships developed by the entrepreneurial firms provides further support for emerging evidence suggesting that 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 (Bell 2005; McEvily and Zaheer 1999; Salman and Saives 2005; Zaheer and Bell 2005). In this sense , the term alliance covers a wide range of interactions, and, as noted by Contractor and Lorange (2002), may be either horizontal or vertical. However, the focus here is generally on non-permanent cooperative alliances, rather than any formal equity sharing or formal merger.

As firms become increasingly familiar with each other's knowledge, negative network effects may emerge, locking firms into the network and stifling the creation of new knowledge and innovation (Adler and Kwon 2002; Arthur 1989; Labianca and Brass 2006). For example, in a study of new biotechnology firms, Maurer and Ebers (2006) found that social capital can impede, as well as enable, organizational adaptation, owing to the inertial forces rooted in what they term as relational lock-in and cognitive lock-in. These inertial forces result in networks becoming a liability, as they impact negatively on the ability of firms to adapt the configuration of their external relationships according to changing information and resource requirements (Maurer and Ebers 2006). Such inertial network forces highlight potential problems of overembeddedness, whereby the actors a firm is best connected to may not be best placed to provide solutions to current problems unless networks are renewed (Krackhardt 1994; Monge

and Contractor 2003). As in Maurer and Ebers's (2006) study, the entrepreneurial firms in the current study showed a strong propensity to develop new ties to match their evolving requirements.

To an extent - although further systematic research would be required to confirm this – network capital formation is related to the particular structure of the industries within which the firms operate. For example, the oil and gas industry within Badley Geoscience is located tends to be a close-knit community with a strong global community of practice, which perhaps is more open to knowledge sharing than the biotechnology sector. In the food industry, for example, it is noticeable that the largest producers - many of which were previously among the most secretive in the world – have themselves adopted open innovation regimes, with the scope for small firms, such as Biocatalysts, to increase engagement through collaboration and cooperation becoming significantly enhanced. Although open and user-led innovation practices are growing, given the competitive nature of the industry, some customers, for example, are still likely to limit the knowledge that they are prepared to share, especially to smaller firms (Lechner and Dowling, 2003).

Previous experience of working with similar customers, products or issues ensures that small firms possess the requisite intelligence to extract the relevant knowledge required. For instance, knowledge accessed from previous or existing customers can be applied in order to enable firms to better support future customers. In general, it appears that some industry sectors have a relatively long history of network capital formation, whereas in others entrepreneurial firms will need to invest more in establishing networks.

Firms clearly utilise considerably more knowledge than that which they have themselves created (Storper, 2000), and the key reason underlying inter-organizational knowledge flows is the search for 'lacking knowledge'. In the first instance, recognising knowledge gaps is the initial challenge that many entrepreneurial firms need to overcome. Once these gaps have been identified, the process of accessing knowledge potentially becomes much more focused. To achieve this, effective absorption of the knowledge accessed through inter-organizational networks is crucial, allowing firms to innovate and stay ahead of competitors. This is considered to require the development of absorptive capacity, defined as the ability to recognise the value of

new, external knowledge, assimilate it, and apply it to commercial ends, i.e. the process of innovation (Cohen and Levinthal, 1990).

Absorptive capacity is often history-dependent and reflects how much an organization has invested in the area of expertise it specialises in, and largely depends upon a organization's investment in innovation efforts (Cohen and Levinthal, 1990; Zahra and George, 2002). Good in-house capabilities in R&D, design, and engineering help to capture and appropriate knowledge, in both codified and tacit forms, in the process of learning from external sources (Howells, 1996). The mutual reinforcement of in-house commitment to innovation efforts and complementary commitment to external knowledge accessing is particularly evident in technology-based sectors. In sectors such as biotechnology, successful firm invest in their in-house capabilities while accessing other economically beneficial knowledge from external sources at the same time (Arora and Gambardella, 1990). In this line, Audretsch and Lehmann (2005) refer to the knowledge filter, which is the gap between new knowledge and that which Arrow (1962) refers to as economic knowledge or commercialisable knowledge, which requires intentional and often complex efforts to access and assimilate. Indeed, knowledge, but especially combinatorial knowledge, underlies the complexity of economic systems (Jensen et al., 2007; Martin and Sunley, 2007; Mattes, 2011).

## **Conclusion**

This paper has established both a theoretical and practical framework to better understand how strategically formed networks act as an asset underpinning knowledge flow and innovation-led growth across entrepreneurial firms. Network capital clearly requires significant levels of management and investment if it is to be effective. The growth of new knowledge formation across the globe suggests an enhanced requirement to manage network capital, since it is often becoming increasingly difficult to establish relationships with appropriate knowledge sources (Hagedoorn 2006; Hung 2002; Parise and Casher 2003). The push toward the strategic management of networks, and the potential financial rewards associated with effective management, almost paradoxically suggests the establishment of markets for network capital. This strategic view may further infer the outright commodification of networks whereby information on key contacts may be stored, exchanged or even stolen (Grabher and Ibert 2006).

Finally, from a public policy perspective, there may be a role for government intervention in educating firms in the art of network management. There is a growing applied and professional discipline related to the management of networks and knowledge flows, which should be supported through public policy. Our key recommendations for consideration by policymakers consists of providing entrepreneurial firms with appropriate support to establish a high performing network structure that allows them access to the knowledge they require. Policy should help identify and map key communities of practice, and then make firms better aware of these communities.

In recent years we have witnessed the predominance of cluster policies as key mode of government intervention in this arena (Porter, 1998). In a network sense, cluster policy has concerned the promotion of social capital - through network initiatives seeking to promote long-term stable relationships, but often lacking clear objectives - and the formulation of spatially bounded inter-organizational networks. Our findings suggest that in the case of knowledge-based network environments, investments in network capital and the formulation of relatively dynamic network configurations are also of importance. Therefore, distinguishing between social and network capital development may have implications for policy-makers, particularly in the field of economic development, who have tended to focus on facilitating firms and organizations in building and utilizing social capital (Huggins, 2000). These efforts need to be complemented with facilitating the generation of network capital.

This is not to suggest that policy-makers should seek to disinvest from business development programmes with a high focus on social activities, but that network capital development programmes focused on the business community must also be supported. Policy-makers often appear to expect that innovation and economic benefits will spillover from these networks as a by-product of the development of socialized interaction (Huggins, 2000; Pittaway et al., 2004; Casson and Della Giusta, 2007). Business network programmes must also encourage the development of networks with a clear strategic, and often task-specific, focus to their activities. More generally, there needs to be far more intelligence concerning exactly how effective and successful inter-organizational knowledge networks are formed, and to what extent these can be supported or orchestrated (Batterink et al., 2010), through policy. This should consist of facilitating the development of both the type of enduring knowledge networks required

for effective collaborative innovation and the dynamic networks required to access the most relevant and up-to-date knowledge. There is need to build upon existing policy strengths, and in Europe, for example, the European Commission's initiatives represent a growing opportunity for entrepreneurial firms to access knowledge through inter-organizational networks.

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