Knowledge context, learning and innovation: an integrating framework

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ABSTRACT

In this paper we develop a framework to identify those elements of firms' knowledge context which are important for innovation, and the mechanisms through which that knowledge impacts on firms' innovation performance. We make four main contributions to the existing literature. First, our characterisation of knowledge context provides the basis for a more specific identification of which elements of firms' knowledge environment are important for innovation, discriminating between spatial, industrial and network influences. Second, we reflect the role of innovation ambition in shaping firms' knowledge search strategies. Third, we differentiate between firms' interactive and non-interactive knowledge search activities and recognise that these may be complemented by unanticipated and serendipitous knowledge spillovers. Finally, we introduce the notion of encoding capacity to reflect firms' internal ability to assimilate and apply external knowledge. Our framework provides an integrating mechanism for existing empirical studies, suggests a number of new research directions related to the determinants of innovation performance and the heterogeneity of innovation outcomes.

Keywords: Knowledge, innovation, spatial, industry, learning.

1. INTRODUCTION

Contextual influences on innovation have attracted significant recent attention (Carney et al. 2011), with strategic implications as firms search to establish coherence between their organisational strategies and their context, and maximise the value of organisational assets and capabilities (Akgun, Keskin, and Byrne 2012; Vaccaro et al. 2012). The notion of 'context' is itself complex, however, comprising distinct spatial, social and relational elements. Despite this in much of the empirical literature on innovation, attempts to allow for the various elements of context are often represented by simple regional and/or industry shift dummies. For example in their widely cited study of open innovation in UK manufacturing firms Laursen and Salter (Laursen and Salter 2006) use a series of industry dummies, while Fritsch and Franke (2004) (Fritsch and Franke 2004) use regional dummy variables to explore inter-regional differences in knowledge spillovers in Germany.

This type of approach makes to two implicit assumptions, at least in linear regression models. First, it implies that contextual factors (whether these are industrial, regional or both) have a separable and additive effect on innovation over and above any firm-level influences. Second, it assumes that any contextual influences have the same innovation impact for firms which share a common context. Neither assumption is likely to be valid. Within industries, for example, firms differ markedly in terms of their R&D investments, a key element of absorptive capacity, and firms' capability to take advantage of external knowledge resources (Griffith, Redding, and Van Reenan 2003). Similarly, variations in firms' human resources can also create significant differences in their ability to capitalise on regional knowledge resources (Roper and Love 2006). Simple shift dummies may therefore fail to reflect the potential moderating or mediating effects of firms' capabilities on contextual influences. Perhaps equally important, however, they provide little or no help in identifying which elements of firms' context are actually most influential in shaping performance.

In this paper we develop a framework within which it is possible to identify those elements of firms' knowledge context which are important for innovation, and the mechanisms through which that knowledge impacts on firms' innovation performance.[1] The argument proceeds in three stages. First, we focus on the knowledge context itself, and those external influences which might shape the external knowledge base available to a firm. This is the focus of Section 2 which combines spatial, network and industrial elements of context and also explores the various conjunctions between these factors. Secondly, we consider the range of potential mechanisms through which the external knowledge surveyed, accessed, absorbed, and used by firms in their commercial activities will impact on innovation performance. Specifically, we consider strategic – interactive and non-interactive – mechanisms, and non-strategic or serendipitous spillovers. Thirdly, we consider issues which may influence the relationship between the knowledge environment and firms' innovative outputs. Individual firms may not only react very differently in terms of their strategic response to a given knowledge context, but may also vary in their capacity to take advantage of the external knowledge that is available. Firms' innovation strategies may, for example, shape their willingness to invest in external relationships and knowledge search, while their internal capabilities may moderate the relationship between external knowledge and its effect on innovation performance. These capabilities – which we call encoding capacity – vary markedly between firms, forming part of what economists describe as 'unobserved heterogeneity'.

We make four main contributions to the existing literature. First, our characterisation of the knowledge context provides the basis for a more specific identification of which elements of firms' knowledge context are important for innovation. Second, we reflect the role of innovation ambition in shaping firms' knowledge search strategies (Ritala et al. 2013). Third, we

[1] Love and Roper (2013) in their review of the firm-level evidence on the key 'external enablers' of (SME) innovation and exporting also note the potential importance of external resource enhancing or augmenting factors which may help firms to overcome internal resource constraints.

recognise that firms may benefit from interactive and non-interactive knowledge search activities (Glückler 2013) as well as unanticipated and serendipitous knowledge spillovers. Finally, we introduce the notion of encoding capacity to specifically reflect firms' ability to assimilate and apply external knowledge from whatever source it originates.

2. KNOWLEDGE AND INNOVATION

Definitions of innovation vary, but generally stress the commercialisation of new knowledge or technology to generate increased sales or business value. The US Advisory Committee on Measuring Innovation, for example, defines innovation as: 'The design, invention, development and/or implementation of new or altered products, services, processes, systems, organisational structures or business models for the purpose of creating new value for customers and financial returns for the firm' (Advisory Committee on Measuring Innovation in the 21st Century Economy 2008, p. i). The link between innovation and knowledge is more explicit in the following definition of innovation developed by the UK House of Lords Select Committee on Science and Technology in 1991: innovation is the 'commercial application of knowledge or techniques in new ways or for new ends. It may involve radical innovation or incremental innovation. In each case the innovator achieves a competitive advantage, at least until another company catches up or goes one better'. Implicit in both definitions is a broad view of the knowledge necessary for successful innovation including technical, commercial and market data, both codified and tacit. The profile of knowledge needed will also depend significantly on the nature of the innovation and the stage of development of any innovation. Radical innovations are likely to require more new technological knowledge than more incremental change. Different types of innovation – product, process or service will also require different types of knowledge (Roper, Du, and Love 2008). Knowledge search among customers, for example, might impact most strongly on product innovation (Su, Chen, and Sha 2007), while search with suppliers or external consultants might impact most directly on process change (Horn 2005; Smith and Tranfield 2005). Early, exploratory, stages of an innovation process may involve 'the pursuit of knowledge, of things that might come to be known,' while subsequent elements of the innovation process focussed on exploitation may require more market focussed knowledge as part of 'the use and development of things already known' (Levinthal and March 1993, p. 105).

Hansen and Birkinshaw (2007) suggest that the innovation process can be represented as an innovation value chain (IVC) comprising three stages. The first of these includes firms' efforts to source the bundle of different types of knowledge necessary for innovation (Hansen and Birkinshaw 2007; Roper, Du, and Love 2008). This may involve firms undertaking in-house knowledge creation – through either design or R&D activities – alongside, and either complementing or substituting for, external knowledge sourcing (Pittaway et al. 2004)[2]. The next stage in the innovation value chain is the process of transforming this knowledge into new services or business processes. This 'encoding' activity may again involve a combination of firms' internal and external resources (Love, Roper, and Bryson 2011). The final stage in the IVC relates to the exploitation of firms' innovations through product creation and the generation of added value through commercialisation. Each stage of the IVC is likely to require different types of knowledge, and different types of partners (Rosenkopf and Nerkar 2001; Rothaermel and Deeds 2004).

Implicit in the open innovation variants of the innovation value chain (Love, Roper, and Bryson 2011) is the idea of contingency, i.e. that appropriate strategy decisions and outcomes depend on the market environment in which a firm operates (Scott, 1982)[3]. In studies of business failure, for example, contingency models focus on the effect of the market

[2] Cassiman and Veugelers (2002), for example, find evidence of a complementary relationship between firms' internal R&D and firms' ability to benefit from external knowledge sources. Other studies, however, have identified a substitute relationship between internal knowledge investments and external knowledge sourcing. Schmidt (2010, p. 14), for example, notes that for Germany 'firms with higher R&D intensities have a lower demand for external knowledge than firms with lower R&D intensities. The more R&D is done in-house the more knowledge is generated internally, and the less external knowledge is required'.

[3] Christensen et al. (1998) describe this as an 'integrative perspective'.

environment on the implications of strategic decisions such as the relative timing of technological developments, and the technological complexity of new product offerings (Christensen, Suarez, and Utterback 1998; Bayus and Agarwal 2007; Colombo and Delmastro 2001). In terms of innovation, (Mueller, Rosenbusch, and Bausch 2013) highlight a number of studies which have related innovation success to industry level factors such as R&D intensity, market dynamism and concentration.[4]

A key element of all contingency models is a clear view of the context within which a firm is operating, and on which contingencies will be based. Our focus here is on the knowledge context for innovation. We begin in this section by profiling the spatial, network and industrial elements of knowledge context.

2.1 Locational knowledge specificities

Despite – and in some instances because of - increases in global connectivity, knowledge and information continue to have a specific physical geography. Some nations, regions and local areas remain more 'knowledge rich' than others with potentially important consequences for firms' location decisions (Lorentzen 2007) and the ability of firms in any specific location to develop innovations (van Beers and van der Panne 2011)[5]. In some senses therefore, knowledge is by definition 'local', i.e. it has some dimension of spatial specificity which in any location makes it different to the pool of knowledge available or accessible in other localities. Typically, the spatial specificity of knowledge is linked to its tacit component 'rooted in practice and technical. It is more related to know-how (procedural knowledge as opposite to declarative knowledge, or know-what/why knowledge). Often, the degree of codification in firms is very low, and the experience of more skilled workers is passed on to the newer generations

[4] Mueller et al. (2013) also note the potential moderating effect of firms' internal resources – absorptive capacity – in moderating the effects on innovation of such industry level factors, a theme we return to in later sections.
[5] Discussion of the 'digital divide' and 'digital exclusion' emphasise the spatial and social elements of the same phenomena (Horrigan 2011).

through the word of-mouth mechanism or face-to-face contacts' (Belussi and Sedita 2012, p. 167). In this sense, local knowledge may have the character of a semi-public – or even public good – with local properties of non-rivalry. As He and Wong (2012) suggest:

'local knowledge is thus conceptualized as a semi-public good that is spatially bounded, and access to which requires nothing more than cluster membership. Next, local knowledge exchange is prompt or spontaneous because local firms are assumed to be more willing to share knowledge and exchange ideas with other local actors as a result of shared norms, values, and other formal and informal institutions that hold down misunderstanding and opportunism' (He and Wong, 2012, p. 542).

Localised knowledge may also have other spatially distinct characteristics, reflecting the presence of specific institutions (typically universities, research labs), clusters of industrial activity, and/or concentrations of specific types of human capital. The character of these institutions may lead to very different subject or quality profiles of local knowledge. Universities with particular areas of research strength may intensify local knowledge in particular disciplines or technologies promoting cluster development and sustainability (Calzonetti, Miller, and Reid 2012). Alternatively the presence of large-scale scientific research facilities – such as those linked to nuclear activity, biotechnology or particle acceleration - may create very specific local knowledge conditions and stimulate cluster formation.

Localised knowledge may also be linked to traditional knowledge, however, related to local environmental or agricultural conditions. Cannarella, (2011) argue that such traditional knowledge may also be important in stimulating local innovation – traditiovations – particularly where it is combined with inflows of non-local or distant knowledge. The potential for local knowledge to drive or contribute to global innovation is also implicit in the 'learn local, act global' business strategies of companies such as Toyota (Ichijo and Kohlbacher 2008).

To the extent that local knowledge influences innovation performance, variations in the specific characteristics of local knowledge (both in terms of content and richness) have the potential to shape matching variations in innovation success (Toedtling, Lengauer, and Hoeglinger 2011; Jensen 2004). This also suggests the potential for local, regional or urban strategies to influence the characteristics of local knowledge as a means of driving competitiveness (Asheim et al. 2007;Hewitt-Dundas and Roper 2011).

2.2 Networks

In any specific location the availability of knowledge and information is therefore likely to have some specific characteristics – whether knowledge is tacit, institutionally or industrially embedded or traditional. The accessibility or availability of knowledge, however, is also likely to depend on the density of connections in the area in which a firm is operating and which might facilitate knowledge sharing and diffusion. Wolfe's (2009) conclusions for Canada:

'The mere presence, or absence, of key institutional elements of the local or regional innovation system also affects their innovative capacity and their potential to serve as nodes for cluster development. Many clusters enjoy the knowledge assets and research infrastructure that are necessary for the development of an innovation-based development strategy, but they differ dramatically in their capacity to mobilize these assets in the pursuit of such a strategy' (Wolfe 2009, p. 186).

This is not to suggest – for the moment – that the extent or density of firms' own networks matter for innovation– this is discussed below – but rather that the extent of networking activity in the area in which a firm is located may be influential (Belussi et al. 2011; Spencer 2003). On the basis of an examination of technology diffusion in the flat-screen television sector, for example, Spencer (2003) suggests that[6]:

[6] Comparing the diverse experience of US and Japanese networks Spencer (2003) also suggests that cultural factors may also shape network structure: Corporatist countries are more likely to have greater network density than pluralist countries.

- High levels of network density are likely to be associated with higher levels of innovative activity and competitiveness, and
- Dense or strongly centralised networks are more likely to facilitate convergence on a dominant design than less dense networks.

The suggestion is that network structure as well as the density of connections itself is important in shaping knowledge diffusion and, hence, innovation. In particular, Kesidou and Snijders (2012) find that gatekeeper firms, with strong external connections and extensive networks of linkages within the cluster play a particularly important role. Feldman (2003), Agrawal and Cockburn (2002) calls similar firms "anchor" companies, while Lorenzoni et al. (2010) also highlight the 'anchoring' role of multinational firms and universities.

To the extent that networks facilitate knowledge diffusion, they may either strengthen or offset the performance effects of variations in local knowledge. Intra-regional networks may, for example, have positive developmental effects by strengthening local knowledge diffusion, effects epitomised in the literatures on regional and local innovation systems (Shefer and Frenkel 1998; Toedtling, Lengauer, and Hoeglinger 2011). Strong intra-regional networks, particularly where these substitute for more geographically dispersed networks, may also have more negative effects through regional 'lock-in' (Dolfsma and Leydesdorff 2009; Sydow, Lerch, and Staber 2010). Spatially dispersed networks on the other hand may generate inter-regional knowledge flows weakening any locally specific effects either positive or negative. The extent of any such networks are likely to be strongly linked to ownership structures as in multi-national companies, supply chains or collaborative development projects (Breschi and Malerba 2011).

2.3 Industry

The characteristics of the sector may also be important in shaping the knowledge context within which a firm is operating. It has long been observed, for example, that technological opportunity and intensity – measured for example by R&D spending and the average propensity to innovate (both product and process) - varies substantially across industries, but relatively little within industries through time (Levin, Cohen, and Mowery 1985). This has led to the contention that there are some, technology based, sectors in which the opportunities for innovation are intrinsically greater than that in other sectors. The nature of these technological opportunities, however, is often hard to define. Jaffe defines the term as 'exogenous, technologically determined variations in the productivity of R&D' (Jaffe 1986), while Klevorick et al (1995, p. 188) prefer 'the set of possibilities for technological advance'.[7] Defined in either way, the possibility is clear: the nature of technological opportunities in an industry may also shape or limit the type of innovation which is undertaken. The technological opportunities in an industry may also influence the types of innovation opportunities available to firms. For instance, survival and prosperity in low value added industries is often based on high sales volumes, which means firms in these industries might place more emphasis on process rather than product innovation. On the other hand, firms in high value added industries might have more incentive to create distinguishable/unique products.

Two other sectoral characteristics also have potentially important, and interacting, implications for innovation: competition and appropriability. For example, Aghion et al. (2005) show that the relationships between competition, innovation and performance are non-linear. In particular, they show that competition only fosters higher innovation and performance if firms within the industry can appropriate innovation rents. This implies that technology leaders and followers would be affected differently by the level of competition within a sector. (Leiponen and Byma 2009) also demonstrate, however, that significant differences in appropriation

[7] Finding suitable proxies to measure technological opportunities also proves difficult: Jaffe uses relatively simple 'technological cluster' dummies, based around high- and low-tech sectors, a fairly typical approach in the literature. Roper et al (2013) use sectoral R&D intensity partially as a proxy for underlying technological opportunity.

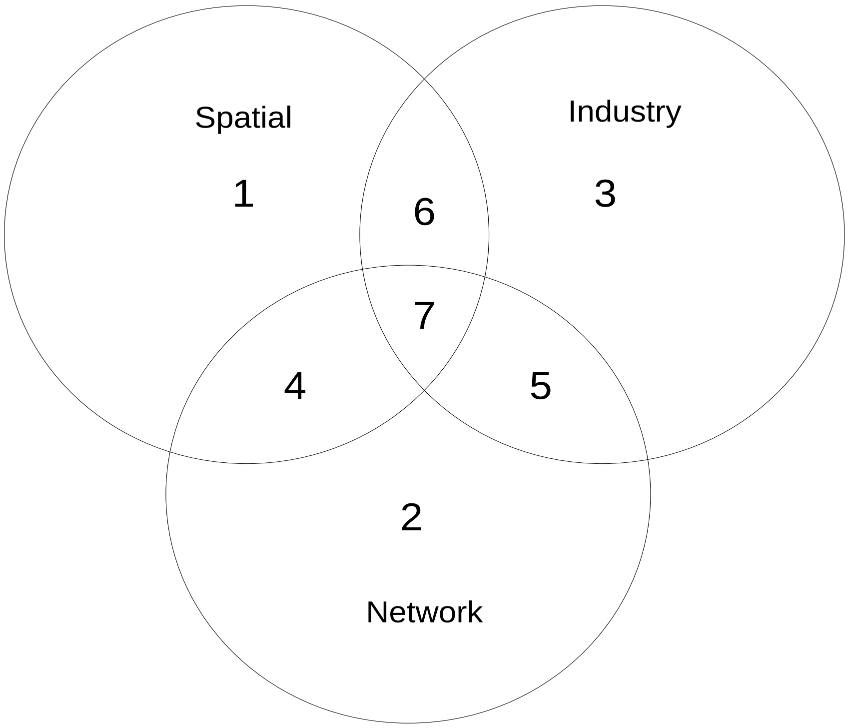
strategies also exist between firms of different sizes and industries; small science-based emphasised formal IP protection strategies such as patents, while most other small firms emphasised strategic appropriation strategies based on secrecy or speed to market.

Profiles of sectoral knowledge will therefore depend strongly on the maturity of the sector, the extent of competition and/or the potential for controlling appropriation either through legal or strategic mechanisms. Each has potential implications for firms' innovation and export behaviour. The interaction of contextual influence of spatial and industry factors has been described in the literatures on industrial districts (Belussi and Sedita 2012; Parrilli 2004) and clustering (Beamish, Craig, and McLellan 1993). Industry networks, trade associations or partnerships initiatives such as standards bodies may reinforce these linkages and enhance the competitive advantage of insiders (Bessant et al. 2012; Carayannis and Campbell 2009).

2.4 Knowledge context – towards an integrated view

The spatial, network and industrial aspects of firms' knowledge context outlined earlier are clearly differentiable (Figure 1). Spatial influences (Area 1 in Figure 1), with specifically locational influences on innovation, have been considered in the literatures on geographical proximity and knowledge transfer (Parjanen, Melkas, and Uotila 2011), regional innovation systems (Braczyk 1998; Buesa et al. 2006), structures and policy, with a particular focus on the impact of regional inequalities (Annex 1). Local contributors to innovation have also been considered (Shum and Watanabe 2008), along with the innovation effects of firms' location in metropolitan environments (Shefer and Frenkel 1998; Shefer, Frenkel, and Roper 2003).

Figure 1: Elements of knowledge context



Pure network effects (Area 2 in Figure 1) are reflected most clearly in studies of business groups and affiliations (Carney et al. 2011; Chang, Chung, and Mahmood 2006), business networks and associations (Balla 2001; Newell and Swan 1995). Such studies are more common in entrepreneurship research rather than innovation studies, however, where the effects of network membership on business growth and ambition have been extensively researched (Watson 2012). Pure industry or sectoral effects on innovation (Area 3 in Figure 1) reflect more traditional Schumpeterian approaches in industrial economics with a focus on industry structure and concentration and their impact on technological development (Harris and Trainor 1995; Levin and Reiss 1984). Such studies have tended also to focus on more traditional drivers of innovation at firm level, however, such as R&D, ignoring the insights of studies of open innovation (Laursen and Salter 2006). More recent studies have however looked beyond industrial structure itself to also include related scientific or educational institutions along with science parks or enterprise zones (Yang and Huang 2005). This broader perspective is most evident in the literature on sectoral innovation systems which integrates Schumpeterian perspectives on firm size with more institutional and historical perspectives on institutional development and inter-relationships (Daim 2005; Malerba 2004).

Situations where pure spatial, network or sectoral effects dominate are, however, relatively unusual in the empirical literature and the majority of studies reflect the interaction or intersection of these effects creating more complex configurations (Figure 1). More specifically:

- Spatial and network elements of knowledge context (Area 4 in Figure 1) interact in the literatures on local, regional or community networks and local linkages whether through alliances, partnerships or along the supply chain (Bae and Koo 2009; Brown and Duguid 2002; Massard 2011).

- Network and industry elements of knowledge context (Area 5 in Figure 1) come together in literatures on trade associations or industry networks, industry based technology development networks such as competence centres (Comacchio, Bonesso, and Pizzi 2012; Vinnova 2004) as well as international supply chain linkages (Ernst 2002).

- The conjunction of location and industry influences (Area 6 in Figure 1) is considered in a number of research studies related to industrial districts and the advantages of industrial co-location, including co-location of firms in the same industry within a given geographic area (Marshallian agglomeration), or co-location of firms in different industries within a given geographic area (Jacobian agglomeration) (Belussi and Sedita 2012; D'Angelo et al. 2013; Munari, Sobrero, and Malipiero 2012).

Finally, the conjunction of all three elements of knowledge context (Area 7 in Figure 1) – spatial, industrial and network – is reflected most clearly in discussion of local or regional industry clusters, networks or partnerships.

Clustering may, for example, generate agglomeration economies either related to regional specialisation or differentiation (Audretsch 1998; Chai and Huang 2007). Clustering may also have a more organisational origin reflecting initiatives such as science parks or special economic zones (Hu 2011).

3. ACCESSING EXTERNAL KNOWLEDGE

Merely being present within a given knowledge environment does not guarantee that a firm will be able to absorb and use knowledge from the environment: some process of learning must occur, either deliberate or unintended. We can identify three main types of mechanism through which firms may access, absorb and use external knowledge which may influence their innovation activity. First, firms may form deliberate, purposive relationships with other firms or organisations as a means of acquiring or accessing new knowledge. These might be partnerships, network linkages or contractually based agreements entered into on either a formal or informal basis. This type of relationship is characterised by strategic intent and mutual engagement of both parties, and may be characterised as a form of interactive learning (Glückler 2013). Second, firms might acquire knowledge deliberately but without the direct engagement of another party. Examples of this type of mechanism include imitation, reverse engineering or participation in network or knowledge dissemination events. Here there is a clear strategic intent on the part of the focal firm but no mutuality in the process, and may be characterised as non-interactive learning. For example, in their analysis of university-business relationships (Hewitt-Dundas and Roper 2011) distinguish between knowledge partnerships 'characterised by a two-way flow of knowledge, e.g. through formal or informal joint ventures or collaborative R&D projects' and knowledge suppliers 'characterised by a more uni-directional transfer of knowledge'.

Thirdly, firms may acquire knowledge vicariously and unintentionally through informal spill-over mechanisms such as social contacts between employees and those in other firms, media publicity or demonstration effects, or through the mobility of labour between enterprises[8]. These pure knowledge spill-overs represent un-priced gains to the firm, effectively increasing the social returns to knowledge. We discuss each mechanism in turn.

3.1 Interactive learning

Interactive learning is characterised by firms strategically building links and relationships with other firms and economic actors (e.g. research institutes, universities and government departments) to capitalise on the knowledge of the linked parties or to cooperate with the linked parties and explore and/or exploit the knowledge together (Borgatti and Halgin 2011). Three characteristics seem important in interactive learning: the number of interactions or relationships the firm has; the mode of interaction adopted; and the nature of the embeddedness of the networks in which firms are involved (Borgatti and Halgin 2011; Glückler 2013).

At its simplest, interactive learning and knowledge acquisition can be positively affected merely by the firms' number of relationships. This is most clearly shown by the analysis of the 'breadth' of external linkages on innovation performance. In purely statistical terms, since the payoff from any given innovation linkage is unknown in advance, the chances of obtaining benefit from any linkage in a given distribution of payoffs increases as the number of linkages increases (Love et al, 2014). Having more linkages increases the probability of obtaining useful external knowledge that can be combined with the firm's internal knowledge to produce innovation (Leiponen and Helfat 2010). The extent or breadth of a firm's innovation linkages may also have significant network benefits, reducing the risk of "lock-in" where firms are either less open to knowledge from outside its own region (Boschma 2005) or where firms in a region are highly specialised in certain industries, which lowers their ability to keep up with new technology and market development (Camagni 1991). However,

[8] Recruitment may also be a strategic knowledge acquisition strategy with positive implications for firms' innovation outputs (Al-Laham, Tzabbar, and Amburgey 2011; Diaz-Diaz and De Saa-Perez 2012).

the capacity of management to pay attention to and cognitively process many sources of information is not infinite, since the span of attention of any individual is limited (Simon 1947). This attention issue means that while the returns to additional linkages may at first be positive, eventually the firm will reach a point at which an additional linkage actually serves to diminish the innovation returns to external networking.

Numerous empirical studies find support for the implied inverted U-shaped relationship between the number of external knowledge linkages (i.e. breadth) and firm-level innovation (Laursen and Salter 2006; Leiponen and Helfat 2010; Grimpe and Sofka 2009; Garriga, von Krogh, and Spaeth 2013). Love et al (2014) find this effect extends through time. Having numerous linkages in previous time periods has a positive effect on the relationship between current linkage 'breadth' and innovation, suggesting that there are learning effects present in terms of innovation linkages. However, this benefit is apparent only for establishments which already had above average 'breadth' in external relationships.

In addition to the number of relationships, the empirical evidence suggests the importance of two other factors in shaping the innovation benefits of firms' interactive learning; the mode of interaction, and the nature of network embeddedness. For instance, a recent empirical study on five UK manufacturing industries reveals vertical co-operative ties with buyers and suppliers has a significantly larger impact on firm-level innovation than horizontal ties with competitors. Furthermore, the positive impact of supply-chain linkages is greater for stronger dyadic relations (Tomlinson 2010). Similar results on the strength of supply-side linkages are found for Irish manufacturing firms by Roper et al (2008). By contrast, there is evidence from both the UK and Norway that linkages with competitors can have a substantially negative effect on innovation (Tomlinson and Jackson 2013), with the Norwegian case finding that association with competitors could reduce radical product innovation by as much as 75 per cent (Fitjar and Rodriguez-Pose 2013).

The effectiveness of different modes of interaction can also differ significantly depending on industry and innovation characteristics. In a study of Austrian firms (Totdling et al 2006), the adoption of different types of interactive learning mechanism differs noticeably among firms in medium-tech, high-tech and knowledge and innovation-based services. While medium-tech and knowledge and innovation-based services firms engage more in market based linkages (i.e. with suppliers and clients) and informal linkages at regional level, high-tech firms engage more in formal linkages such as R&D cooperation and joint use of R&D facilities (Todtling, Lehner, and Trippl 2006).The value of supply-chain relationships also depends on the complexity of activities: firms may form linkages with their suppliers and buyers only if the innovation task is complex and cannot be accomplished internally (Oerlemans, Meeus, and Boekema 2001).

Network embeddedness can also be a moderator or facilitator of interactive knowledge and learning. Gilsing et al (2008) show that the impact of networks differs significantly depending on the combined effects of firms' technology proximity, location in the network and network density. For instance, either being highly central or highly peripheral could be the optimal choice of network position for a firm to maximise its returns to innovation depending on the structure of the network. When technology gaps among firms in the network are small (large), centrality (peripheral position) is more efficient in generating innovation success (Gilsing et al. 2008).

The relationship between technology heterogeneity and the impact of networks on innovation is not only restricted to central or peripheral firms in a network, but may affect the innovation performance of all firms in the network, regardless of their position. For example, one longitudinal study of global telecommunications equipment firms suggests that technological diversity enhances the positive effect of networks on innovation for all firms in the network. Networks also have a stronger positive effect on innovation success when firms in the network are more technological diverse; diversity which creates more opportunities for learning (Jacobian externalities). The effects of technological diversity are also stronger in more dense networks (Phelps 2010).

The role of geography in interactive learning

In a useful analysis of the links between knowledge, networks and geography, Glückler (2013) identifies four potential mechanisms linking (purposive) networks and space in terms of knowledge flows arising from interactive learning:

- *Geography as a cause* of network formation: here geographical proximity simply makes it more likely that networks will develop.
- *Geography as a moderator* of network effects on knowledge: here, proximity alters the strength of the relationship between networks, interaction and innovation.
- *Networks as moderators* of the effects of geography on knowledge: here consciously developed relationships can mitigate the extent to which knowledge effects decay with distance.
- *Networks as mediators* of the effects of geography on knowledge: here networks explain (partly or in whole) the role of geography on knowledge flows.

Empirical studies rarely explicitly distinguish between all four of Glückler's hypothesised mechanisms but recent literature on interactive relationships and innovation does highlight the importance of geography in the process of interactive learning. For example, Totdling et al (2012) show that the composition of regional and extra-regional knowledge linkages can affect innovation success. In their study of Austrian ICT companies, international and regional interactions have a greater effect on firm-level innovativeness than interactions at national level (Todtling, Grillitsch, and Hoglinger 2012). They attribute the insignificance of national interactions to the small size of Austria and the small scale of the resulting knowledge base. More generally, there is evidence that knowledge linkages with extra-regional and international collaborators are often more productive in terms of innovation than those from intra-regional sources, for countries as diverse as South Africa (Knoben and Oerlemans 2012), Norway (Fitjar and Rodriguez-Pose 2013) and Ireland (Doran, Jordan, and O'Leary 2012).

Echoing Glückler's view of networks as mediators and/or moderators of the effects of geography, Trippl et al (2009) show the value of using formal versus informal knowledge linkages at different geographical level. In their study of firms in the Vienna software industry, firms stimulate innovation by combining knowledge obtained through informal linkages at the local level with formalized R&D partnerships at the local and national level (Trippl, Todtling, and Lengauer 2009). Other studies highlight the importance of the *nature* of the prevailing knowledge in a sector as a key determinant of how geography interacts with knowledge flows. For example, Jensen et al (2007) show that firms in industries with mostly explicit knowledge such as know-what and know-why, and whose innovations are primarily of the Science-Technology-Innovation (STI), type benefit more from global interactions than regional interactions. By contrast, firms in industries with mostly implicit knowledge such as know-how and know-who, and whose innovations arise principally from Doing-Using-Interacting (DUI) benefit more from regional and local interactions (Jensen et al. 2007).

3.2 Non-interactive learning

Non-interactive learning is characterised by the absence of reciprocal knowledge and/or resource transfers between actors. The most frequently discussed non-interactive modes of learning are: imitation, where a firm absorbs the knowledge of other actors through observation of the actions/behaviour of the source actor; reverse engineering, where a firm derives knowledge from the final product of another firm, obtained from the market or through supply chain interaction; and codification of knowledge, where a firm obtains knowledge through knowledge which is a public good such as news, patents and regulations etc. (Glückler 2013). Imitation, for example, may inform second mover or fast-follower type innovation strategies and may suggest alternative market entry modes (Ulhoi 2012) and may generate more significant growth impacts than innovation (Shenkar 2010).

It has been argued that non-interactive learning can intensify the impact of geographical proximity on innovation by allowing firms to more closely monitor their neighbouring firms, especially in the same industry, and to absorb the necessarily knowledge for innovation (Malmberg and Maskell 2002). Moreover, geographical proximity allows firms to share similar cultural, linguistic, education and institution frameworks, which allow them to understand, interpret, absorb and utilise public codified knowledge and information (Bathelt and Gluckler 2005). Furthermore, non-interactive learning can promote information and knowledge transfer without the presence of networks among firms and sometimes can replace the role of network in promoting firm-level innovation activity. In other words, the presence of non-interactive learning could weaken the relationship between network connectivity and knowledge production (Glückler 2013).

Non-interactive learning in the form of attendance at fairs, seminars, congresses and workshops, reading of literature and patents, observation of other firms and the recruitment of skilled workers can complement the impact of networks and formal linkages on a firm's innovation activities. In a study of the Austrian automotive industry, Grillitsch and Trippl (2013) find that more than 75 per cent of firms combine informal interactive and non-interactive learning with market linkages to improve their innovation activities (Grillitsch and Trippl 2013). Non-interactive learning can also weaken the importance of proximity on firm level innovation. For instance, accessing relevant literature and patents allows knowledge transfer at extra-regional levels, and in many case from "global pipelines", which makes firms less dependent on local knowledge base, at the same time reduces the possibility of regional "lock-in". However, this does not mean spatial proximity becomes irrelevant with the presence of non-interactive learning, but rather depends on the different modes employed: for example, non-interactive learning through hiring of skilled labours can still be very much a local phenomenon (Grillitsch and Trippl 2013).

3.3 Knowledge spillovers – 'being there'

The richness of local knowledge, and the nature of local knowledge networks and connectivity, will shape the potential for firms to benefit from spillovers. Although the term 'spill-overs' has been variously used in recent studies we use the term here to mean un-priced, and unintentional, knowledge externalities which result from the characteristics of knowledge as a semi-public or public good (Sadri, 2011). In this sense it is the simple presence of a firm within a location, industry or network – being there – which creates the potential for spillovers (He and Wong 2012)[9].

The potential for spillovers depends not only on firms' technological activity but may also be linked to other aspects of local knowledge. For example, a number of studies have examined spillovers from university research on innovation in both the US (Mansfield 1995; Jaffe 1989; Adams 1993, 1990; Acs, Audretsch, and Feldman 1994; Acs, Audretsch, and Feldman 1992) and Europe (e.g. (Fischer and Varga 2003; Arundel and Geuna 2004) generally suggesting a positive linkage between university R&D and innovation levels in different industries. Tassey (2005), for example, argues that knowledge created by firms' research labs, government labs and universities may have some of the attributes of a quasi-public good, and play a significant role in enabling the development of proprietary technologies. Diffusion of such knowledge may be mediated through mechanisms such as social interaction or inter-personal networks, trade publications, professional associations etc. or through firms' direct links with knowledge brokers such as consultants or intermediary institutions. A related literature suggests that there is a strong geographical dimension to this spillover effect, with the impact of university R&D being confined largely to the region in which the research takes place, (Audretsch and

[9] Knowledge spillovers may also play a role in stimulating innovative entrepreneurial activity (Audretsch 2005).

Feldman 1996;Anselin, Varga, and Acs 2000, 1997). Potential spill-over effects may also be industry specific (Jaffe 1989).

The potential for spillovers may also be greater where spatially bounded or concentrated networks facilitate 'buzz', or intensive face-to-face interaction between network members (Breschi and Lissoni 2009; Ibrahim, Fallah, and Reilly 2009; Storper and Venables 2004). In particular, in knowledge intensive industries, the importance of buzz and face-to-face interaction have been emphasised to the diffusion of tacit knowledge or emerging knowledge which has yet to be codified (Asheim, Coenen, and Vang 2007). Combinations of buzz and the availability of knowledge which has quasi-public characteristics – due perhaps to the presence of universities - may be particularly powerful in generating positive spillovers raising firms' innovation productivity above that suggested by their private investments in knowledge creation and external search.

Knowledge spillovers can also be effected by labour mobility, and this too has a spatial dimension. Inter-regional mobility of highly skilled labour has been shown to significantly increase knowledge spillovers among firms in clusters and in the same region, which in turn significantly improves innovation success as measured by patent application (Almeida and Kogut 1999; Breschi and Lissoni 2009). Furthermore, a study of US semiconductor industry patent citations shows that long distance mobility of key inventors and alliances between firms can significantly reduce the effect of long distance on knowledge transfer (Breschi and Lenzi 2010). The mobility of labour can not only bridge gaps between geographic spaces, but can intensify the impact of regional industry clustering on firm-level innovation. A study of IT cluster in Cambridge UK reveals that one key advantage for firms to locate in Cambridge is the potential for the R&D workers to find alternative jobs in the industry without moving house. This helps to keep local talent and encourages the inflow of global talent into the region, which in turn enriches human capital at the firm level and enhances innovation ability (Huber 2012).

4. FROM KNOWLEDGE TO INNOVATION

The context for innovation provides the same opportunities for knowledge acquisition for each firm in a given spatial/industry/network setting. In a situation where firms have similar internal knowledge resources we might expect this to lead to consistent forms of engagement with external organisations and to common profiles of innovation output. This is not what we observe, however, with levels of innovative activity varying widely within any given industry for example (Roper et al. 2009), as well as a variety of different strategies for engaging with the external knowledge context.. What creates this difference in firms' ability – or willingness – to generate innovation in any given context? We consider two factors here – innovation strategies and encoding capacity – both of which might influence the effect of any given knowledge context on firms' innovation activity, and which taken together or separately might create a diversity of innovation outcomes (Cohen and Levinthal 1989).

4.1 Innovation strategy

Ambitious entrepreneurs, who actively seek growth and engage in expansion opportunities for their businesses adopt significantly different strategies to those content with less rapid growth. Gundry and Welsch (2001) for example, identify ambitious entrepreneurs as those who have, among other characteristics, strategic intentions that emphasize market growth and innovation and adopt a wider range of financing sources for the business. More broadly, in the innovation literature a distinction has made between more ambitious innovation-based and imitation-based strategies: "Innovation orientation refers to a firm that has a strategy of developing and introducing innovative new products and services into the market before their competitors… companies with an imitation orientation, try to avoid the exorbitant costs associated with basic scientific investigation and the development of novel technologies and adopt competitor's ideas and technology" (Naranjo-Valencia, Jimenez-Jimenez, and Sanz-Valle 2011, p. 56). Innovation-based strategies focus on either disruptive or radical innovation which is either new to the world or at least new to the market. This type of strategy is likely to involve proactive, interactive and exploratory knowledge search strategies with partner choice depending on the type of innovation objective (i.e. product, process, service). Imitation-based strategies on the other hand focus on new-to-the-firm innovations and may rely purely on non-interactive approaches to knowledge acquisition or knowledge spill-overs.

Firms' innovation ambition may also shape the type of search partners with which they engage as different partners provide very different types of knowledge (Schmidt 2010). One recent study of Finnish firms, for example, relates the search behaviour of different types to firms' strategic orientation, or in other words suggests that strategic orientation may moderate the nature of firms' search behaviour (Ritala et al. 2013). Unsurprisingly perhaps firms with a 'customer relations orientation' emphasise knowledge search relationships with customers while firms with a more technological orientation emphasise links to universities and other technology providers. Firms with more ambitious entrepreneurial orientation – and by implication an innovation-based strategy - tend to emphasise a broader range of search partners.

4.2 Encoding capacity

In the innovation literature discussion around firms' ability to take advantage of external knowledge has focussed on the notion of absorptive capacity (ACAP). Originating with Cohen and Levinthal (1990), absorptive capacity is typically seen as a firm's ability to identify, evaluate, assimilate, and apply external knowledge. In other words ACAP includes firms' ability both to search for and then assimilate and use external knowledge. Here, we are interested in identifying separately the 'search' and 'assimilation' elements of ACAP. Previous sections have identified the three mechanisms through which external knowledge may become available to an enterprise – interactive and non-interactive learning and spillovers. Once acquired, the innovation effect of external knowledge will depend on firms' ability to encode that knowledge into their innovation outputs - or what we might call encoding capacity. The key idea here is that encoding capacity reflects firms' ability to make use effectively of incoming knowledge for innovation, and that encoding capacity will therefore play a moderating role in the relationship between any given level of external knowledge and marketable innovation.

The notion of 'encoding' has been discussed elsewhere as the link between an external knowledge search process and the commercialisation of firms' innovation outputs (Love, Roper, and Bryson 2011). Encoding capacity itself is likely to be determined by a range of factors related to organisational culture, structure and resources. More open organisational cultures which facilitate internal knowledge sharing and creativity may facilitate the encoding of external knowledge, whereas more closed or rigid cultures may make this more difficult (Lucas and Goh 2009). Attitudinal differences, reflecting a not-invented-here syndrome, may also create barriers to encoding potentially useful external knowledge (Agrawal, Cockburn, and Rosell 2010). Structural factors may also be important in shaping encoding capacity. The number of individuals with boundary-spanning roles, for example, may shape firms' ability to share knowledge effectively within the firm and their encoding capacity (Johri and Ieee 2008). Similarly, the use of cross-functional development teams may help to distribute and apply knowledge effectively within a firm maximising encoding capabilities (Ernst, Hoyer, and Rubsaamen 2010; Love and Roper 2009; Atuahene-Gima and Evangelista 2000). Resource availability may also be important in shaping encoding capacity, with investment in IT systems, for example, supporting knowledge diffusion within the firm.[10]

This range of influences mean that encoding capacity will differ markedly between firms (even within a given industry or region) and that any given firms' ability to encode different types of incoming knowledge may also vary

[10] The effects of IT investment on innovation are not always straightforward, however. In their study of Canadian manufacturing SMEs, for example, Raymond et al. (Raymond, Bergeron, and Croteau 2013) find positive effects from IT investment on growth-driving innovations but negative effects on productivity.

significantly (Schmidt 2010). For example, as both boundary spanning and knowledge diffusion capacities are likely to be greater in larger firms, this may mean that larger firms have greater encoding capacity. This is perhaps reflected in recent empirical evidence which suggests that small producers adopt open innovation practices significantly less than medium sized ones (van de Vrande et al. 2009).

Levels of encoding capacity may also have implications beyond the firm itself as firms – and other organisations – with effective boundary-spanning capabilities can also absorb knowledge then act as a gateway to that knowledge for other networked or linked firms. For example, in the Chilean Colchagua Valley wine cluster, those firms with a higher number of technical qualified personnel, a more experienced professional staff, and a higher intensity of experimentation have wider linkages with organisations both outside and inside the cluster (Giuliani and Bell 2005). Similarly, a study of firms in Italian furniture districts reveals that the leading firms absorb external knowledge then spread it to their clients and suppliers in their own network (Morrison 2008). Universities can also play a similar gateway role. For example, one study of German regional innovation networks emphasised the central position of local universities and the linking role of each university between local and international networks (Kauffeld-Monz and Fritsch 2013).

5. INTEGRATING FRAMEWORK

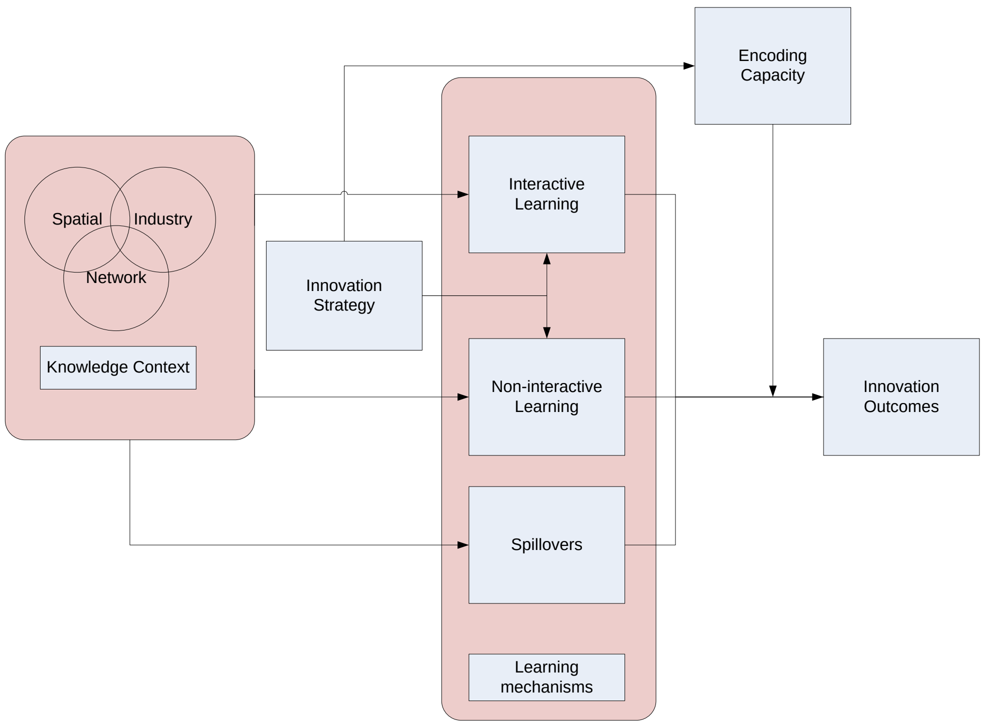
Knowledge – of markets, new technology and opportunities – is a key input to innovation. New knowledge may arise from inside the firm, through discovery or invention, but in most cases is likely to originate outside the enterprise. The potential for such external knowledge to drive innovation arises from the properties of some forms of knowledge – as a public good and being non-rival – which create the potential for knowledge diffusion between firms and other organisations. The characteristics and richness of the knowledge context within which a firm operates will, however, depend significantly on its spatial, network and sectoral position (Figure 2). Specific locations may, for example, be knowledge rich depending on the presence of universities or other development organisations. This may positively influence local innovation (Lorenzoni, Russo, and Ferriani 2010). Industries differ too both in their technological and innovation intensity and the extent of knowledge diffusion (Raider 1998). Finally, network characteristics, and firms' individual position within any given network, will also contribute to shaping innovation potential (Oerlemans, Meeus, and Boekema 1998; Grabher 2001; Massard 2011).

Here, we also identify three very different mechanisms through which external knowledge may influence firms' innovation: interactive learning, non-interactive learning and spillovers. Interactive learning – the formation of contractual or informal partnerships with an element of mutual benefit – is a strategic activity and will be influenced by the nature of firms' innovation strategy (Figure 2). The extent of such relationships will significantly influence firms' ability to benefit from ambient knowledge. The extent of non-interactive learning (e.g. imitation, reverse engineering) will also be influenced by firms' innovation strategy and again will influence firms' ability to benefit from ambient knowledge. Spillovers also provide a mechanism by which firms may benefit from ambient knowledge (Figure 2). This mechanism is serendipitous, however, rather than strategic, with learning resulting primarily from social interaction. (Of course, valuable interactions are more likely in some locations, industries and networks than others and a firm's choice of 'location' in each dimension may therefore have implications for the extent of knowledge spillovers).

The non-strategic nature of potential spillovers suggests that these cannot be influenced by firms' innovation strategy (Figure 2). The effect of spillovers on innovation outputs will, like the innovation returns to both interactive and non-interactive however, be moderated by firms' encoding capacity, i.e. their ability to absorb and utilise external knowledge. This moderating effect may either be positive or negative. Positive moderating effects may occur where internal knowledge and capabilities are complementary to externally sourced knowledge leading to higher levels of innovative activity. There is for example, substantial evidence of the complementary roles of external knowledge and internal R&D (Lichtenthaler and Lichtenthaler 2009; Cassiman and Veugelers 2006; Miravete and Permias 2004). Negative moderating effects may also be possible, however, where internal knowledge sharing is ineffective or cultural barriers such as the Not-Invented-Here syndrome exist to the adoption of external knowledge (Agrawal, Cockburn, and Rosell 2010).

Finally, encoding capacity itself will also be shaped by firms' innovation strategy (Figure 2). Firms adopting play-to-win strategies based on radical and open innovation will need to build greater encoding capacity than firms adopting imitation strategies (Davila, Epstein, and Shelton 2006).

Figure 2: Knowledge context, learning and innovation



6. CONCLUSIONS

In this paper, building on the existing literature on external knowledge effects on innovation, we outline a framework relating firms' knowledge context, their innovation strategy, search behaviours and internal encoding capacity. We make four main contributions to the existing literature. First, our characterisation of the knowledge context provides the basis for a more specific identification of which elements of firms' knowledge environment are important for innovation. Are beneficial spillovers, for example, linked more closely to industry, spatial or network inter-relations? Or, to a combination of these factors? It may also be important to distinguish how each aspect of knowledge context contributes to the extent of interactive and non-interactive learning. Spatial proximity, for example, may facilitate both types of learning as may network centrality or density.

Second, we reflect the role of innovation strategy in shaping firms' knowledge search strategies. More ambitious firms – those pursuing radical innovation rather than imitation strategies – seem likely to have more active search strategies, although previous studies have shown search strategies may also differ in terms of the type of search partner they involve (Ritala et al. 2013). Third, building on the arguments outlined in (Glückler 2013) we differentiate between firms' interactive and non-interactive knowledge search activities and recognise that these may be complemented by unanticipated and serendipitous knowledge spillovers. Together these three mechanisms provide a comprehensive framework within which the extent and determinants of knowledge flows across firm boundaries can be considered. Finally, we introduce the notion of encoding capacity to reflect firms' internal ability to assimilate and apply external knowledge. We also recognise that innovation strategy may also influence firms' willingness to invest in creating encoding capacity.

Our framework suggests a number of potential areas for future investigation. First, in terms of the antecedents of knowledge search activity, the framework highlights the potential importance of different aspects of knowledge context and firms' innovation ambition in shaping the strategic choices between interactive and non-interactive knowledge search methods. The role of innovation strategy in particular has to date received little attention in most innovation studies. Second a series of interesting questions relate to the innovation effects of external knowledge as mediated through interactive learning, non-interactive learning and spillovers. For example, are some types of knowledge better accessed through interactive rather than non-interactive search methods? Similarly, what types of knowledge are most often associated with spillovers? Finally, it will be interesting to explore the moderating role of firms' encoding capacity on the innovation effects of external knowledge.

One further implication follows from our framework relating to the significant role of innovation strategy and encoding capacity – both firm specific characteristics – in shaping the benefits which any firm will derive from its knowledge context. As innovation ambition, strategy and encoding capacity are likely to vary markedly within any specific knowledge context so will firms' ability and/or desire to use external knowledge to benefit their innovation. This will contribute to heterogeneity in innovation outcomes within any given knowledge context. Marked variations may also exist between groups of firms differentiated by size, ownership or age perhaps. Each may shape firms' ambition and the internal resources they have accumulated suggesting the potential value of a differentiated approach to modelling the relationships between knowledge context and innovation outcomes. Future Enterprise Research Centre projects will consider the role of knowledge context in shaping innovation outcomes for different groups of SMEs.

Annex 1: Keywords from the innovation literature

Area 1 (Pure location effect)	Area 2 (Pure network effect)	Area 3 (Pure industry effect)	Area 4 (Interaction between location and network)	Area 5 (Interaction between network and industry)	Area 6 (Interaction between location and industry)	Area 7 (Interaction between location, industry and network)
Regional characteristics	Business affiliation	Industry characteristics	Local network	Trade association	Industry districts	Regional cluster network
Regional factors	Business group	Industry effect	Local channels	Trade network	Industry agglomeration	Informal network within cluster
Regional structure	Business network	Industry structure	Regional network	Industry linkage	Industry diversity	Information network within cluster
Regional development strategy	Business association	Industry environment	Local supply chain	Backward linkage	Marshallian agglomeration	Openness in cluster
Regional diversity	Strategic partnership	Sector characteristics	Local linkage	Forward linkage	Jacob's agglomeration	Social network in cluster
Regional convergence	Social network	Sector effect	Community network	Value added chain	Industry concentration	Cooperation in cluster
Regional institution	Information network	Sector structure	Community interaction	Supply network	Spatial concentration of industry	Value added chain in cluster
Regional inequality	Social media	Sector environment	Innovation system	Social media industry	Regional industry structure	Strategic partnership inc cluster
Spatial effect	Digital media	Industry dynamics		Strategic partnership	Regional industry composition	Membership in cluster
Spatial concentration	Digital network	Industry evolution		ICT industry	Special economic zone	Insider and outside in cluster
Locational factors	Supply chain	Industry development		Network spillover	Science park/ high tech park	Business relation in cluster
Local environment	Value added chain	Sector dynamics			Industry co-location	Personal contact in cluster
Local support	Export participation	Sector evolution			Regional specialisation	Industry cluster
Local structure	Export network	Sector development			Regional diversification	Clustering regions
Local institution	Internationa l linkage	Sector composition				
Co-location	Backward linkage	Industry composition				
Dispersion	Forward linkage	Insider				

Annex 1: Keywords from the innovation literature (continued)

Area 1 (Pure location effect)	**Area 2 (Pure network effect)**	**Area 3 (Pure industry effect)**	**Area 4 (Interaction between location and network)**	**Area 5 (Interaction between network and industry)**	**Area 6 (Interaction between location and industry)**	**Area 7 (Interaction between location, industry and network)**
Urban region	Outsourcing	Outsider				
Rural region	Open innovation	Herding (dominate technology)				
Proximity	Access to ICT	Technical innovation system				
Innovativ e milieu	Adoption of ICT	Sectorial innovation system				
	Membershi p					
	Peer					
	Business relation					

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