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DRUID Working Paper No. 10-08

On the Determinants of the Reach of Innovation-related Collaboration in Small Firms

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Abstract:
This paper takes as its starting point an item of relatively recent academic orthodoxy: the insistence that '…interactive learning and collective entrepreneurship are fundamental to the process of innovation' (Lundvall, 1992, p. 9). From this, academics have frequently taken "interactive" to imply "inter-organisational" and, whilst one might be concerned by this too casual conflation, there is a growing consensus that firms' embeddedness in collaborative networks matters for their innovative performance (Gilsing et al., 2008).

Keywords:

Jel codes:

ISBN 978- 87-7873-290-3

1. Introduction

This paper takes as its starting point an item of relatively recent academic orthodoxy: the insistence that '…interactive learning and collective entrepreneurship are fundamental to the process of innovation' (Lundvall, 1992, p. 9). From this, academics have frequently taken "interactive" to imply "inter-organisational" and, whilst one might be concerned by this too casual conflation, there is a growing consensus that firms' embeddedness in collaborative networks matters for their innovative performance (Gilsing *et al*., 2008).

Following this, and on the back of a commendable amount of empirical research establishing the importance of innovation-related collaboration, a growing literature has begun to investigate 'who cooperates for innovation, and why' (Tether, 2002). From these studies, the identified determinants of collaborative innovation are frequently shown to include: industry sector and firm size (Miotti and Sachwald, 2003); differences in innovation strategies (Bayona *et al*., 2001); internal resources (Lee, Lee & Pennings, 2001) and, more specifically, absorptive capacity (Fritsch and Lukas, 2001). Unfortunately, however, the bulk of these studies are marked by insensitivity to the central feature in popular expositions of innovation networks – viz. geography. With few exceptions (e.g. Drejer and Vinding, 2007), the concern has been with explaining (or, strictly, predicting) collaborations irrespective of the location of partners.

Yet, a central problem in understanding the manner in which collaborative relations are formed and governed is in the way in which geography 'matters' (Moodysson and Jonsson, 2007). To this end, Gertler and Levitte (2005, p. 489) draw a common inference from our opening 'orthodoxy': "if innovation as an activity has become increasingly interactive and socially organized…, then geographical concentration of the relevant actors will facilitate this process of learning-by-interacting". This, of course, is consistent with observations on the spatial concentration of *innovations* (Asheim and Gertler, 2005). Paradoxically, empirical studies are unequivocal in demonstrating that innovation-related collaborations are frequently dispersed (Kaufmann and Tödtling, 2000; Freel, 2003; Drejer and Vinding, 2007). Even within prototypical innovative regions (such as the San Francisco Bay area and Baden-Württemberg) innovation networks have been shown to extend more and less spatially. Indeed, there is some suggestion that extra-local networks may be more important than local networks. For instance, in their study of Germany mechanical engineering SMEs, Grotz and Braun (1997, p. 549) noted that "local sub-contractors mainly perform low-level production operations", while the "more crucial and innovation-oriented ties are very often national or international in character". Clearly, understanding the differences between locally and globally networked firms has important implications for business executives and for policy makers charged with national or regional development.

Accordingly, and drawing upon data from the 4th UK Innovation Survey, the current paper attempts to discriminate firms on the basis of the reach of their innovation networks. Both structurally and strategically, what characterizes firms collaborating with more distant partners, relative to their locally embedded counterparts? To this end, the paper is structured as follows: Section 2 briefly outlines the theoretical inspiration for our interest in near and far collaborations; section 3 describes the parent dataset and our specific interest here; section 4 details the rationale for our model and provides a variety of descriptive statistics; section 5 presents our principal analyses; and section 6 concludes, discussing the implications of our findings.

2. Background

Much of the contemporary interest in innovation-networks appears to flow from developments in a variety of related literatures. Most obviously: new industrial districts (Brusco 1982, Becattini 1978 and 1990); innovative milieux (Maillat, 2001); new industrial spaces (Scott, 1988); spatial systems of innovation (Freeman, 1987; Lundvall, 1992; Nelson; 1993); and clusters (Porter, 1990). These literatures define innovation networks, to a greater extent, spatially. That is, they:

> '…emphasise the spatial organisation of the market by different players (firms essentially), the inter-relation between these players and, eventually, the diffusion of economic growth from a given set of players to the rest of the geographic area" (Andréosso-O'Callaghan, 2000, pp. 70-71)

And the extent of the "geographic area" is invariably restricted. Of course, in many respects a local territorial focus may seem reasonable. Discussions are often framed in terms of 'common social culture' and 'industrial atmosphere' (e.g. Bianchi, 1998). And, whilst one might wonder about the extent to which this represents 'old wine in new bottles' (Harrison, 1992), such trust creating mechanisms and local specialisation may sensibly provide the basis for innovation networking. In other words, that external resources are liable to be sourced locally is thought to relate to the apparent importance of social proximities for effective cooperation, and *their* essential immobility. Cappellin (2004, p. 216) captures this latter point well:

> 'In a world of freely moving capital and increasingly freely moving people, it is only social capital that remains tied to specific locations'

In a related argument, researchers have tied the importance of geographical proximity for innovation to the concept of 'localized knowledge spillovers' (e.g. Jaffe et al., 1993; Audretsch & Feldman, 1996). As Feldman and Audretsch (1999, p. 410) hypothesise; "new economic knowledge may spill over, but the geographical extent of such knowledge spillovers is bounded". Central to this line of argument is the contention that successful innovation relies upon accessing external (tacit) knowledge, rather than (codified) information (Rothwell, 1991). Whilst the ICT revolution allows information to be transferred over great distances at relatively low cost, the efficiency and efficacy of knowledge transfer continues to revolve around face-to-face contacts, naturally facilitated by spatial proximity (Romijn and Albu, 2002). Indeed, some authors have been remarkably precise about the spatial extent of spillovers – Varga (1998), for instance, places the extent of US academic spillovers at 75 miles[1]. In part this reflects the view of collaboration as just one mechanism of knowledge diffusion. Alternative mechanisms include the mobility of workers between organizations and informal meetings. However, regardless of the mechanics (and many studies elide these), empirical analyses frequently confirm a positive relationship between geographical clusters of firms, knowledge transfer and realized innovations (e.g. Audretsch & Feldman, 1996; Baptista, 2000; Bottazzi and Peri, 2003).

In contrast to this apparent assurance, there is a growing stream of literature which charges that the bulk of existing empirical work has tended to 'fetishize' local links (Amin and Cohendet, 1999) – 'focusing on processes and conventions *within* clusters, rather than the transfer of critical knowledge through extra-local connections' (Bunnell and Coe, 2001, emphasis in the original). The starting point is often the empirical observation that, while innovation activities appear to be highly concentrated in space, interactions and exchanges between firms within 'clusters' are often fairly limited (Barthelt *et al*. 2004). For example, in their study of six European opto-electronic clusters, Hendry and colleagues (2000) concluded that there existed "proximity without intimacy or interaction".

In general, the rationalisation offered is threefold: Firstly, authors point to the danger of becoming 'locked in' (Bathelt et al., 2004). Businesses limiting themselves solely to collaboration projects with closely located partners run the

[1] One might usefully think of this as the distance people might be prepared to drive for a meeting and return on the same day. And, of course, this distance will vary in absolute terms across space.

risks of cognitive and functional lock-in (Grabher, 1993). This argument has its roots in social network theory: such that, propinquity encourages strong ties amongst potential partners, characterized by frequent interactions, emotional intensity and extensive reciprocity. Strong tie partners may be suited to make specific contributions to innovation processes, but are typically possessed of similar knowledge of technologies, markets and trends, that they are unlikely to provide the innovating firm with sufficient novelty. Rather, firms may also need weak network ties, located at greater geographical remove, that are 'less confined to the provincial news and views of their close friends' (cf. Granovetter, 1982: p. 106). These 'global pipelines' are developed not solely to exchange products and services, but to benefit from "novel ideas and expert insights useful for innovation processes" (Maskell *et al*., 2006, p. 998).

Secondly, some authors point to the fact that modern information and transport technologies enable collaboration at greater distances (Gallaud & Torre, 2004). This is not to suggest that geographical proximity no longer matters. Simply that geographical proximity should not be simply equated with physical or spatial proximity – that is, with propinquity. Rather, from the perspective of firms (and their locales), geographical proximity is concerned with connectivity and positionality, both objectively (what places may be quickly and affordably reached) and subjectively (what 'feels' near) (Lagendijk and Lorentzen, 2007). In this way, geographical proximity may be realized on a temporary basis; virtually, using modern information and communication devices, or actually, in the form of meetings, conferences or projects – indeed, Barthelt *et al*. (2004) talk of the potential of *temporary* institutions (e.g. trade fairs) as fora for *temporary* proximity. It is quite clear that inter-firm interactions, even for innovation, are typically intermittent. In this light, they are unlikely to require the continuous face-to-face relations, which have underpinned a belief in the importance of spatial proximity (Rychen and Zimmermann, 2008).

Thirdly, is the acknowledgement that colocation is, by itself, insufficient. As Fischer notes (2001, pp. 201), “a proximity that is only geographic in nature can provide the basis for the presence of an agglomeration of firms, but not necessarily for the presence of a system of innovation”. Indeed, given the possible ameliorating effects of other forms of proximity (see Boschma, 2005 for a review), it is not clear that permanent geographical proximity is necessary, let alone sufficient. Nooteboom (1999), for instance, proposed that sufficient ‘cognitive proximity’ was required to facilitate effective communication[2], with the suggestion that greater *cognitive* proximity between partners may require less *spatial* proximity (Torre, 2008). For Torre and Rallet (2005), it is organizational proximities which reduce the need for propinquity, whilst others still emphasise the role of institutional (Kirat and Lung, 1999) or relational (Moodysson and Jonsson, 2007) proximities. In sum, there is a growing belief, evident in the academic literature, that geographical proximity is neither a necessary nor a sufficient condition for effective innovation collaboration. This is not to suggest that geographical proximity is of no import. Simply that, rather than being primary, it may facilitate innovation largely through strengthening other dimensions of proximity. Moreover, and in line with Boschma’s review, (2005, p. 71) whilst geographic, relational (or social), organization and institutional proximities increase the likelihood of partners coming together, it is likely to be *cognitive* considerations that determine whether or not interactive learning processes may take place. We return to these issues below.

Here, in closing this section, we simply note the increasing recognition that innovation networks may be developed at various spatial scales and that the causes and consequences of these networks may vary. As Oinas and Malecki (2002, p. 298) note, “we do not seem to understand the nature and relative significance of proximate and distant connections very well”. Our intention is to contribute to a better understanding of these issues by exploring the determinants of innovation-network reach in a large sample of small firms.

[2] Interestingly, he also suggests that some ‘cognitive distance’ is required to ensure non-redundancy.

3. Data – the 4th UK Innovation Survey (UK CIS4)

The analyses draw on the 4th UK Innovation Survey (hereafter UK CIS4), which was implemented in 2005 and covers the period 2002-2004. The survey is based on the OECD's Oslo Manual (OECD, 2005) and is the UK component of the European Community Innovation Survey. The sample covers firms with over 9 employees across all sectors of the private economy. In order to ensure adequate numbers of responses for analytical purposes, the survey was stratified on the basis of size, industry and region (so, for instance, the survey of firms employing more than 250 employees amounted to a census). Some 28,000 business units received a postal survey, returning 16,446 completed questionnaires (an approximate response rate of 58%). The response rates for different size classes, industries or regions are consistent with the sample frame (see Robson and Ortmans, 2006 for further details).

Although data from UK CIS4 provides the foundation for our analyses, our interest is considerably more truncated. This narrower focus takes two forms. The first is structural: a concentration on small production firms. Collaboration imperatives are frequently applied with particular vigour to smaller firms – as means to resolving resource constraints (Hewitt-Dundas, 2006; Freel and Harrison, 2006). Moreover, small firms are often thought to be more tied to their territories than are their larger counterparts; "their lack of financial or human resources forces them to locate close enough to the organizations with which they need to exchange knowledge" (Torre, 2008). Though this smacks of easy caricature, the distinctions between locally embedded firms and those engaged in more distant collaborations are likely to be particularly revealing in the small firm sector. Certainly, in the current dataset over 90% of collaborating large firms (i.e. with more than 250 employees) list at least one extra-regional partner for supplier, customer and competitor cooperation. Some extra-regionality is the norm for large firms engaging in innovation-related collaborations.

Our focus on ‘production firms’ reflects a desire to avoid confusion –a ‘muddying of the waters’. Whilst the debate on whether innovation processes in services and manufacturing firms vary by degrees or kind continues (Miles, 2008), we set aside service firms in the current analyses. Intriguingly, and by way of an aside, there is some empirical evidence that services, including more dynamic business services, are more local in their focus (Fritsch, 2003; Drejer and Vinding, 2005; see also figure 1).

Secondly, the analyses also only address collaborative innovators. That is, the concern is not with the differences between cooperators and non-cooperators, but with discriminating between those firms engaged in local (intra-regional) innovation-networks only and those whose innovation-networks are more spatially extended. One of the present authors touched upon this issue in a previous paper (XXXX), observing, *inter alia* and rather prosaically, that firm size and export intensity were positively associated with the spatial reach of collaboration. However, this earlier paper employed a more limited set of explanatory variables.

Moreover, no distinction was made in this earlier work between the various partner types. Yet, previous research has consistently identified differences in the characteristics and motivations of firms collaborating with different partners (Frisch and Lukas, 2001; Tether, 2002). For instance, partnering with customers has been associated with a desire to develop radical innovations and expand markets (Tether, 2002), or to develop product innovations (Frisch and Lukas, 2001), whereas partnering with suppliers is more often aimed at production efficiencies, resulting in processes innovation (Frisch and Lukas, 2001; Tether, 2002). Collaborations with competitors, which may often seem paradoxical, are disporportionately motivated by a desire to set standards and/or meet regulations (Tether, 2002). Given that the characteristics of cooperators (relative to non-cooperators) have been shown to vary systematically by innovation partner it appears appropriate to conduct our analysis of network reach separately for each partner.

Of course, simply because past work on the propensity to collaborate has shown marked differences by partner type, it does not necessarily follow that similar distinctions will mark the geography of collaboration. Indeed, our general introductory discussions largely imply general themes which ought to apply to innovation network reach irrespective of partner type (at least for 'market-partners'). However, undertaking separate analyses seems to be the 'safe' course of action. Accordingly, the paper distinguishes between cooperation with customer, suppliers and competitors, with separate ordered logit analyses conducted for each type of partner. If the equations suggest few differences, then this may suggest the existence (and influence) of the sorts of general effects implied by our reading of the existing literature.

Beyond suppliers, customers and competitors, scope also existed to comment upon 'non-market' partners: in this case, universities, service firms and the public sector. However, on the whole and for a variety of reasons, cooperations with these partners tend to be more spatially concentrated[3]. We believe that fully exploring network reach issues involving these partners would distract from the main thrust of the current analyses. However, their inclusion in figure 1, which details the relative frequency of cooperations at various spatial scales and with various partner types, provides a useful descriptive point of departure for the detailed analyses that follows.

Figure 1 displays the distribution of cooperative relations by partner type. Firms were classed according to the highest spatial level of their collaborative relations for each potential partner. Thus, though firms may have cooperated with both 'regional' and 'international' customers, they will be categorised as 'international'

[3] The local focus of university cooperation, for instance, offers some support for the view that university research programmes are, to a greater extent than usually recognized, locally specialized.

only. The concern is with distinguishing between firms integrated within extra-regional networks and those solely engaged in regional networks. In all cases, excepting universities, extra-regional cooperation is more common than solely intra-regional cooperation. For instance, over 75% of firms cooperating with suppliers for innovation, engaged with a partner outside their home region. Indeed, in the case of customer and supplier cooperation, collaborations involving international[4] partners are more common than solely regional collaborations.

[INSERT FIGURE 1 ABOUT HERE]

4. Modeling considerations & descriptive statistics

Given the paucity of similarly motivated analyses, our investigation is inevitably exploratory. Though a few studies exist, their focus is almost exclusively on one explanatory factor – 'absorptive capacity' (e.g. Drejer and Vinding, 2007). Accordingly, in modeling the reach of collaborative innovation, we take the more general literature on the propensity to cooperate for innovation as our foundation:

Absorptive capacity

Of course, that our interest is broader than simply absorptive capacity does not imply its neglect here. Rather, we anticipate that relative absorptive capacities will play a central role in distinguishing between firms cooperating outside their home region and their locally embedded counterparts. The 'absorptive capacity' thesis holds that a firm's ability to identify, evaluate, assimilate and employ external knowledge is, to a greater extent, a function of the level of its prior related knowledge - i.e. its 'absorptive capacity' (classically Cohen and Levinthal, 1989 and 1990). Empirical studies typically record a positive relationship between the conduct of internal R&D, as the most common proxy for absorptive

[4] The UK CIS4 survey asked firms to identify EU and other international separately. These categories have been combined here.

capacity, and the propensity to cooperate for innovation (e.g. Fritsch and Lukas, 2001; Bayona *et al*., 2001; Tether, 2002). Following this, one might reasonably hypothesise a similar relationship between R&D expenditure and the reach of collaborations. To the extent that organisational search processes are myopically constrained by existing knowledge, R&D may serve to make more things familiar or to make things more familiar. In this way, increasing absorptive capacity is analogous to reducing cognitive distance. As Torre (2008) notes:

> '…firms with higher absorptive capacities within a cluster are those that are most likely to establish linkages with external sources of knowledge. This is explained on the basis of cognitive distances between firms and extra-cluster knowledge, so that firms with high absorptive capacities are considered more cognitively proximate to extra-cluster knowledge than firms with lower absorptive capacity' (p. 874).

Moreover, in addition to extending the reach of search processes, firms with a more developed absorptive capacity may be more likely to view the local environment as an inadequate source of specialised or unusual resources (Oerlemans *et al*., 1998) and to consider themselves constrained by it. Figure 2 records the reach of cooperative relations for R&D performers and non-performers in our sample. At the univariate level the data suggest, quite clearly, that firms performing R&D are more likely to engage in extra-regional collaborations. For instance, 54% of R&D performing collaborators recorded at least one innovation-related collaboration outside of the UK, compared with around 25% of firms not engaged in R&D.

[INSERT FIGURE 2 ABOUT HERE]

Unfortunately, though R&D expenditure is the most common proxy for absorptive capacity, it is unlikely to be adequate when studying small firms (Muscio, 2007).

More often, the innovation emphasis in small firms is on ‘development’ rather than ‘research’, with expenditures spread over a number of operational areas rather than concentrated in a single R&D department (Sterlacchini, 1999). Where R&D activity is distributed, costs are likely to be difficult to clearly discriminate. In tandem with limited managerial resources, the result is a frequent underestimate of small firms’ research capacities where bland statistics on R&D expenditure are relied upon (Roper, 1999). Accordingly, a broader conception of absorptive capacity is required, one which accommodates a more general measure of expertise; emphasizing, in particular, the presence of highly skilled employees and investments in training (Drejer and Vinding, 2007; Xia and Roper, 2008). As Muscio notes:

> “In order to determine SMEs’ capacity to absorb external knowledge and combine it with the knowledge generated by in-house R&D activity – which in many cases is carried out informally in SMEs – it is necessary to investigate the learning capabilities embodied in their human resources (HR). The skills, training and experience of SMEs’ human capital are the foundation of their knowledge bases and contribute extensively to their overall capability to absorb external knowledge” (p. 654)

The UK CIS4 provides data on both employee skills and the occurrence of workforce training. Specifically, the survey asks firms to record the proportion of degree educated staff (distinguishing between science and engineering (SE) graduates and ‘others’) and to indicate whether they had engaged in training specifically to facilitate the development or introduction of innovations. In the former case, international collaborators recorded an average of 11.26% of staff holding SE degree qualifications, compared with 4.97% in locally embedded firms. For ‘other’ degrees, the differences are less marked – 6.49% and 5.23% respectively. In a similar vein, the univariate descriptive statistics suggest a positive link between training and the reach of collaborations: some 70% of firms engaged in extra-regional collaborations had undertaken innovation-specific training, compared with 58.5% of firms engaged solely in intra-regional collaborations.

The geography of markets

There is a further danger, of course, in treating R&D expenditure as a simple proxy for absorptive capacity. The danger is in over-emphasising the learning-face and under-emphasising the innovation-face of R&D (Cohen and Levinthal, 1989). Cohen and Leventhal's original work was explicitly a lament on the tendency to treat R&D as only having one outcome (innovation). Current studies may be repeating this failing in reverse (cf. Drejer and Vinding, 2007). Principal amongst the innovation consequences that are likely to impact upon the reach of cooperation is market location. Given consistent evidence demonstrating a link between the geography of product markets and innovation collaboration (e.g. Arndt and Sternberg, 2000; Freel, 2003; Lagendijk and Lorentzen, 2007) and between innovation and exporting (Roper and Love, 2002), failing to control for market reach will stress the learning face of R&D and neglect the innovation face. In other words, one might propose the reassuringly simple hypothesis that the spatial distribution of innovation-related collaborations is largely a function of the spatial distribution of market relations.

[INSERT FIGRUE 3 ABOUT HERE]

Figure 3 presents data on the distribution of cooperative activities by market reach. As the data clearly detail, the geography of sales is positively related to the geography of cooperation – for suppliers, customers and competitors. Indeed, 61.2% of cooperative innovators operating in international markets recorded at least one international innovation partner. In contrast, only 9.5% of cooperative innovators selling solely to local and regional markets recorded an international collaborator. The univariate correlation between sales reach and network reach appears strong.

Appropriation Strategy

In addition to input strategies, as an indicator of capacity and capability, appropriation strategies are also likely to influence both the propensity to cooperate and the reach of cooperation. Indeed, in his classic essay Teece (1986) observed that the nature of appropriability regimes influenced the organization of innovation most suitable for "profiting from innovation". In 'loose' regimes integration is suggested, whilst 'tight' regimes with secure legal protection allow firms to pursue partnering strategies in search of specialisation economies. Reflecting on this, Pisano (2006, p. 1124) notes that:

> "In order to help innovators specialize (safely), markets for know-how must work effectively. Networks of innovation thus depend partly on intellectual property regimes. Strong intellectual property regimes would support broader and more diffuse networks of innovation".

Certainly, there is some supporting empirical evidence for this view. For instance, using data from the 1st Dutch CIS, Brouwer and Kleinknecht (1999) observed that both the propensity to patent and patenting intensity correlated with participation in collaborative R&D. From this, it is argued that patents, as a formal and well-defined appropriation mechanism, play an important role in clarifying ownership of the intellectual output of collaborative innovation and limit the scope for disagreement (Arundel, 2001).

In this vein, the UK CIS4 asked firms to record the importance of a variety of methods used to protect innovations introduced in the period covered by the survey (see table 1). Factor analysis of responses to this question identifies two factors which broadly describe formal (registration of design, patents, trademarks, copyright) and informal (secrecy, confidentiality agreements, design complexity, speed) mechanisms respectively. Given the weight of theoretical arguments and empirical evidence, one would anticipate a positive relationship between the importance of formal protection mechanisms and the propensity to collaborate for innovation. We extend this argument, and anticipate a similar relationship with the reach of collaboration. More distant collaborations are likely to be facilitated by clearly defined and legally secure IPRs. Ex ante, the influence of informal mechanisms is not as clear. Whilst the articulation of an appropriation strategy suggests identifiable IP and an appreciation of the steps necessary to protect it, the lack of legal basis to many of the protection mechanisms may limit confidence. It is interesting to note, however, that firms typically view 'informal' protection mechanisms as more important than the formal mechanisms which often dominate academic and policy discussions.

[INSERT TABLE 1 ABOUT HERE]

Innovation Strategy

Whilst identifying what firms do is important, knowing why they do it is a necessary adjunct. That the Community Innovation Survey illuminates the former rather than the latter has been a common criticism. Yet, the survey does provide subjective data on the "effects" of innovation activities. Moreover, the manner in which the question is asked and the cafeteria of choices (table 2) are suggestive of realized intent. For instance, "increased value added" or "reduced environmental impacts" are unlikely to be accidental or, indeed, incidental consequences but rather consciously motivated. Following this, one might note empirical evidence linking motivations and the propensity to collaborate for innovation (e.g. Bayona, *et al*., 2001) and wonder at the relationship between varying innovation motivations and the geography of collaborations. Firms collaborate, not only to access technological knowledge, but also gain access to sales abilities, market information or new markets (Teece, 1992). Moreover, there is some suggestion that while local ties may be important for 'low profile interactions', higher profile knowledge transfer and joint product development activities are less bound by spatial concerns (Grotz and Braun, 1997, p. 550). As with protection mechanisms, factor analysis of responses to this question identify two underlying factors (table 2). Responses to items concerned with increasing the firm's product range, increasing value added and increasing market share load on to the 1st factor and we label this 'expansive' accordingly. Environmental and regulatory 'effects' load on the 2nd factor and we label this 'responsive'[5]. We anticipate that the resources required for 'expansive' innovations are less likely to be found in the local environment, whilst the converse will hold for 'responsive' innovations. In other words, expansive innovators are more likely to collaborate with distant partners and responsive innovators are more likely to be locally embedded.

[INSERT TABLE 2 ABOUT HERE]

Sectoral considerations

Beyond firm-level strategic consideration, one anticipates structural factors bearing on the reach of collaboration. For instance, the persistence of sectoral and size-based variations in innovation activity, generally, and innovation-related collaboration, specifically, are well established in the empirical literature. Because sectoral patterns of innovation are different, one expects to find firms in different sectors using different internal and external resources to innovate successfully (Oerlemans *et al*., 1998; Vega-Jurado *et al*., 2008). In part, this reflects variations across industries in the nature of knowledge (including the relative emphasis on tacit or codified knowledge) (Marsilli, 2002). As noted earlier, the relative significance of tacit knowledge figures large in standard accounts of the importance of proximity for innovation cooperation: "Only by

[5] The other, largely internal, items load equally on to both factors.

being in the same local environment, and by meeting repeatedly in person, can and will such more subtle forms of knowledge be exchanged" (Barthelt *et al*., 2004, p. 32).

Curiously, this argument seems most often to be used to explain the clustering of innovation-networks involving high-technology, science-based firms (e.g. Powell *et al*., 2002). Yet, science-based knowledge tends towards relative codifiability. At the risk of over-simplification, technological development in many science-based areas draws on *know-why* knowledge rather than *know-how* knowledge (Johnson and Lundvall, 2001; Audretsch *et al*., 2005). By and large, the former lends itself to more ready codification than the latter. Accordingly, if transfers of tacit knowledge are the basis for the geographic clustering of innovation networks, one would expect these to be most evident in sectors where *know-how* (acquired through learning by doing) provides the platform for technological development. Science-based sectors are not the ones which spring most readily to mind. Indeed, one might anticipate greater reach on the part of more specialised sectors, as the local environment proves to be an inadequate source of specialised resources.

[INSERT FIGURE 4 ABOUT HERE]

In the current analysis, firms are grouped according to Pavitt's (1984) sectors (figure 4): supplier dominated (n=228); scale intensive (n=151); specialised suppliers (n=116) and science-based (n=138) firms. Given the relative emphasis of supplier dominated and scale intensive firms on process innovations, one would anticipate a greater role for learning by doing (and tacit knowledge). From this, one might anticipate greater embeddedness in local innovation networks as a result of the frequent face to face interaction required. This local focus is likely to be particularly true for the sorts of incremental innovations brought forward by supplier dominated firms. In this case, the requisite knowledge and resources are likely to be available locally (Grotz and Braun, 1997). In contrast, the relative codifiability of science-based knowledge and the reliance upon specific capabilities in development, engineering and design is likely to see specialised suppliers and science-based firms reach further afield for collaborators.

These expectations are borne out by the descriptive statistics in the current study (figure 4). Over 50% of collaborating science-based firms are involved in international networks, compared with less than 20% of supplier dominated firms. Clearly sectoral consideration bear on the reach of innovation networks; whether with suppliers, customers or competitors.

Control variables

Finally, in modeling the propensity to collaborate over distance, we incorporate standard controls for firm size (log of employees), group membership and age (as a binary variable distinguishing firms less than 5 years old). The rationale for the inclusion of these variables is largely resource-based: the argument that "firms must have resources to get resources" (Eisenhardt and Schoonhaven, 1996, p. 137). Larger distances imply more resources to invest in temporary proximities (e.g. transport costs or human resource slack) or in ICTs to effect 'the death of distance' (or, strictly, to lessen the constraints of distance). In the case of firm age, it is the anticipation of a lifecycle effect – with younger firms serving initially localized markets. Table 3 summarises our expectations. As noted earlier, though our analysis will distinguish between cooperations with suppliers, customer and competitors our expectations are largely constant across partner type. This is consistent with both the general themes emerging from our literature review and the evidence implied by the descriptive statistics.

[INSERT TABLE 3 ABOUT HERE]

Analyses

Whilst the descriptive statistics in the previous section are illuminating, there are clear limitations. Specifically, our interest is in the unique contribution of each of the factors to explaining (or predicting) the reach of innovation networks. To this end, estimation of our model takes the form of three ordered logit equations: one each for supplier, customer and competitor cooperation[6]. Clearly, other techniques (such as discriminant analysis) may also have been employed. However, logistic regression makes less stringent assumptions regarding the distribution of the independent (predictor) variables (IVs) and deals, more comfortably, with categorical IVs.

Logistic regression, in common with all varieties of multiple regression, is sensitive to high correlation among the IVs. However, various tests for multi-collinearity (using correlation matrices, and multiway frequency analysis (Tabachnik and Fidell, 2001) – available on request) suggest little problem in this respect. The highest univariate correlation was recorded between sales reach and industry sector (ρ=0.475), with almost 90% of science-based firms engaged in international markets compared to 32% of supplier-dominated firms. As the data in tables 4 indicate, all equations appear reasonable predictors of 'innovativeness' – significantly improving upon 'constant only' prediction at the 1% level and explaining 32-49% of the variance. On the whole, the models seem to have a number of satisfactory properties (table 4).

[INSERT TABLE 4 ABOUT HERE]

Unlike previous empirical investigations into the propensity to collaborate (e.g. Frisch and Lukas, 2001; Tether, 2002), our data on the reach of collaborations do not suggest marked difference by partner type. With few exceptions (discussed below), the signs on the coefficients are the same for each partner type (customer, supplier, competitor), and similar patterns of significance are noted. Of course, this is not to suggest that the influences on supplier, customer and

[6] Multinomial logits were also estimated with broadly similar results.

competitor reach are identical. Rather, that there are important influences on network reach which appear to apply across all three partner types.

In terms of specifics, and addressing our control variables in the first instance: whilst all the coefficient signs are all in the anticipated directions, only in the case of firm size is this observation statistically significant – irrespective of partner type. It would appear that, even in a sample of SMEs, firms size bears on the reach of collaboration.

Beyond this, and in line with recent work on the role of non-spatial proximities, we speculated that a more developed absorptive capacity would serve to reduce cognitive distances and allow firms to collaborate with more distant partners. Certainly, our univariate descriptives strongly supported this thesis for all three of our indicators of absorptive capacity: internal R&D, graduate employment and training. However, when one controls for a variety of other factors – notably market reach – the conduct of R&D no longer distinguishes firms collaborating near and far. Rather, for collaborations involving customers and suppliers, it is the employment of graduate scientists and engineers (SE) which distinguishes reach. Moreover, for supplier collaboration, undertaking innovation-specific training also correlates with cooperative reach. Curiously none of the absorptive capacity indicators correlate positively with the reach of competitor collaboration. Indeed, the proportionate employment of non-SE graduates is negatively related to reach. Certainly, one would expect that competitors are typically cognitively proximate and, in this way, absorptive capacity may not be a distinguishing feature of reach.

As anticipated, the geography of sales correlates with the reach of collaborative innovation for all three partner types – though, and for obvious reasons, most strongly for cooperations involving customers. It seems likely that economic relations are well suited to provide the foundation for deeper ties.

In terms of appropriation strategies, we speculated (following the logic of Teece's (1986) seminal paper) that an emphasis on formal IP protection mechanisms would correlate with reach. Yet, actually, our models suggest that an emphasis on informal protection mechanisms is what most clearly distinguishes firms cooperating near and far – again, for all partner types. Only in the case of customer cooperation is an emphasis on formal mechanisms significantly correlated with reach. Whilst one might speculate that continuing variations in the extent and enforcement of formal IP mechanisms may be at play, this is nonetheless a curious finding which warrants further explication. Importantly, the emphases on formal and informal mechanisms are not mutually exclusive – the signs on the coefficients are positive in all cases.

With regards to innovation strategy: motivation clearly 'matters'. Here the results confirm our expectations. 'Expansive' innovators were more likely to be engaged in international collaborations, whilst 'responsive' innovators were more likely to be locally embedded. The evidence suggests that more proactive and ambitious innovation projects often require expertise outwith the firm's home region. In contrast, the needs of innovation projects reacting to non-market pressures are more often satisfied locally[7].

Finally, and also in line with expectations, science-based firms and specialised suppliers were more likely to have engaged in international collaborations[8]. Strong sectoral variations clearly exist with respect to the reach of innovation networks. However, whilst much of the literature and, indeed, most policies on clusters continue to emphasise technology-based sectors (and local interactions), it is exactly these sectors we find to be most globally linked. In contrast, supplier-dominated firms, in traditional production industries where learning by doing is key to process innovations aimed at serving price sensitive customers, are more locally embedded.

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[7] Perhaps because there remains a national and sub-national flavour to many of these pressures – though less and less so.

[8] In the case of competitor reach this also holds for scale-intensive firms.

Concluding remarks

As Powell and Grodal (2005, p.57) note: “Contemporary studies of industrial performance are replete with reports of a significant upsurge in various types of interorganizational collaboration”. Whilst competence-based theories of the firm have long held firm-level innovation to be reliant upon the development or acquisition of critical resources and capabilities, recent theoretical and empirical work has increasingly recognized that these resources and capabilities may be both internal or external to the individual firm. If they are external, then the next question becomes: *where* are they most likely to be found (Gertler and Levitte, 2005). Until recently, the most common answer has been “locally”. In the academic literature, industrial clustering and local collaboration are familiar explanations of competitiveness (Rees, 2005). Moreover, “the search for synergies between local actors has become the basis for most policies for local development” (Torre, 2008, p. 875). Yet, empirical studies of innovation-related collaboration typically suggest greater spatial dispersion (Barthelt *et al*, 2004; Torre, 2008). This then, provided the inspiration for the current paper.

Employing data from the 4th UK Innovation Survey, the paper sought to explore the factors associated with extra-regional collaboration for innovation. For a variety of reasons, our focus was on small production firms only. In the first instance, the relative frequency of regional and extra-regional linkages bears repeating: As figure 1 details, networks incorporating at least one extra-regional partner were more common than purely intra-regional networks for all partner types, excepting universities. Clearly propinquity is not a necessary condition for innovation collaboration.

Following this, we explored the factors associated with greater collaborative reach. Principal amongst our findings we note the importance of workforce skills. Rather than the standard measure of absorptive capacity (R&D expenditure), it is the presence of highly skilled employees and workforce training which distinguish international collaborators – at least along the value chain. Soh and Roberts (2005), in their study of small computer networking firms, capture the importance of person embodied absorptive capacity well, their interview data suggesting:

> “that getting ‘good engineers’ involved in strategic partnerships is a critical success factor…[and]…the benefits of leveraging the resources of direct partners may be conditioned on the availability of ‘good engineers’ specific to the context of the partnership rather than overall research capacity” (p. 423)

This is reassuringly consistent with the view that any firm-level strategy for innovation must, at its most fundamental, be an employment strategy (Smith, 2000). And the analogous position that any innovation policy portfolio must have, at its heart, the development of skills. For non-technology-based small firms (i.e. most private firms), R&D is likely to be a poor proxy for absorptive capacity.

Beyond this, we noted the importance of identified IP and a clear policy for its protection. Rather surprisingly, it was an emphasis on informal protection mechanisms which most clearly marked firms engaged in international collaborations. This is an intriguing finding which warrants further exploration beyond the scope of the current study. However, one might be tempted to speculate that issues of (limited) disclosure and the uneven enforcement of formal protection mechanisms would be at the root of a preference for informal mechanisms, especially amongst internationally oriented firms.

Perhaps unsurprisingly, we noted significant variations in the reach of innovation networks by sector. However, and irrespective of sales market considerations, it is the higher technology sectors which are least locally embedded. Of course, this should be no real surprise given underlying knowledge differences. Yet, in relation to the spatial concentration of innovation activity, it is common to observe that "the more knowledge-intensive the activity, the more geographically clustered it tends to be" (Asheim and Gertler, 2005, p. 291). Subsequently, this becomes the rationale for searching most intently for local synergies in technology-based clusters. This appears to be misplaced. Empirical evidence elsewhere suggests that the more specialised the project or activity, the less likely it is that managers will find partners within their region (Moodysson and Jonsson, 2007).

More prosaically, we also noted the association between the geography of markets and the reach of collaboration. Clearly, global value chains (in this case proxied by the geography of sales) are major sources of international contacts (Lagendijk and Lorentzen, 2007). Firms may be able to leverage the trust built in economic relations to develop deeper ties as the basis for knowledge exchange. In this way, export policies become an important adjunct to, or component of, innovation policies. Indeed, in the absence of exports, it may make more sense to encourage international sales and purchasing activities – as the basis for global pipelines – rather than direct collaboration.

Limitations

There are, of course, a number of limitations to our study. Of these, two suggest scope for further research. Firstly, in much of the preceding discussion there is the insinuation that international collaborations are in some way 'better' than purely regional collaborations. Certainly, we provide no evidence to support this. Our concern has been with causes not consequences. Much as one might criticize the cluster literature for failing to provide evidence of the superiority of local over non-local linkages (Barthelt *et al*. 2004), this is equally unsatisfactory. Clearly understanding the relative returns to collaborations at different scales is an important part of the story. To this end, figure 5 gives a flavour of the relationships in the current data. From this, it would appear that more distant partners correlate with higher levels of product innovation: for instance, 66% of firms engaged in collaborations with international customers recorded at least one ‘novel’[9] product innovation, compared with 18% of regional only collaborators. Unfortunately, space constraints do not permit formally modeling this (and other) performance relationship here.

[INSERT FIGURE 5 ABOUT HERE]

Secondly, though our concern has been with the geography of collaboration, our analysis has been aspatial in important respects. It is plainly not enough to have a developed absorptive capacity or an appropriate strategy. Rather, the environment must also be rich in the sorts of knowledge and resources that meet specific firm needs (Wenpin Tsai, 2001). These, in turn, are unlikely to be evenly distributed across the space economy, with clear implications for the reach of innovation networks and for the development of firm level capabilities. In peripheral regions, for instance, the development of absorptive capacities may be most pressing (Drejer and Vinding, 2007). Again, space constraints do not permit adequately exploring the bases of spatial variations in the reach of innovation collaborations[10].

Crucially, engagement in extra-regional networks need not be at the expense of regional networking (Rees, 2005). In the current data set, 27%, 30% and 18% of international collaborators with suppliers, customers and competitors, respectively, were also involved in local collaborations with the same partner types. Extra-local networking may be an important mechanism through which external knowledge is transmitted and diffused within the region. These ‘extrovert’ firms (Oinas and Malecki, 2002) may be particularly important for transforming or revitalizing lagging regions.

[9] New to the industry.
[10] Indeed, it is not clear that the data is competent to do so as it stands. Though one may be able to explore regional variations in reach.

Of course, all of the above is not to suggest that proximity doesn't 'matter'. This would certainly be foolish. Not least given evidence of a general preference for local partners where they are available (Moodysson and Jonsson, 2007). This is Feldman's (1994) contention that firms will only look outside their locality if the necessary external knowledge inputs are not locally available. Rather, we merely caution against treating *permanent* geographic proximity as primary. Co-location is clearly neither necessary nor sufficient to foster innovation-related collaborations. Inter-firm interactions, even for innovation, are generally intermittent, which removes the need for a continuous face-to-face (Rychen and Zimmermann, 2008). Following this, we have shown the relative engagement in regional, national and international networks to be conditioned on a variety of strategic and structural factors.

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Figure 1 Patterns of cooperative reach by partner type

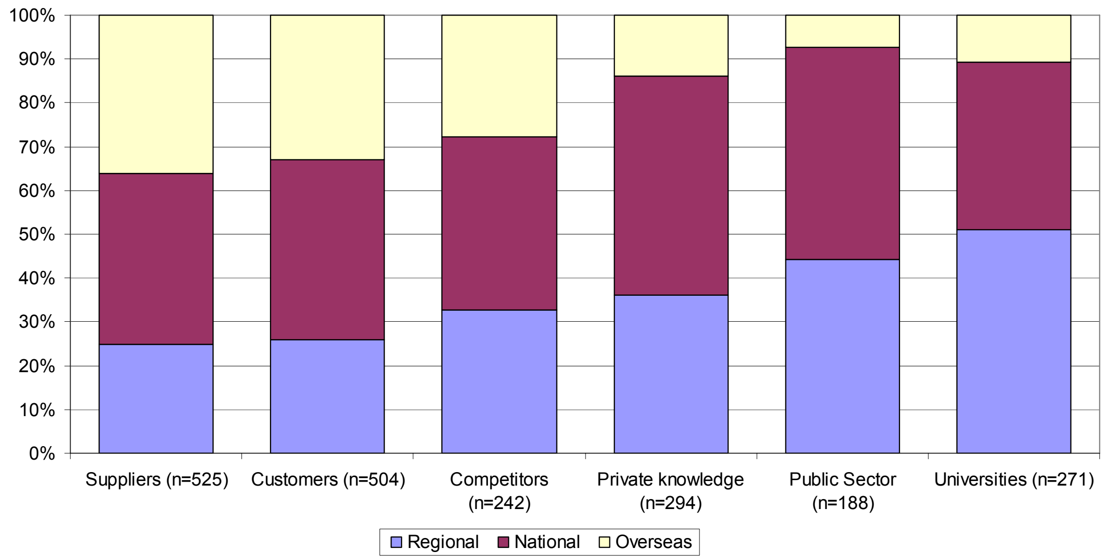

Figure 2 R&D and the reach of cooperative networks

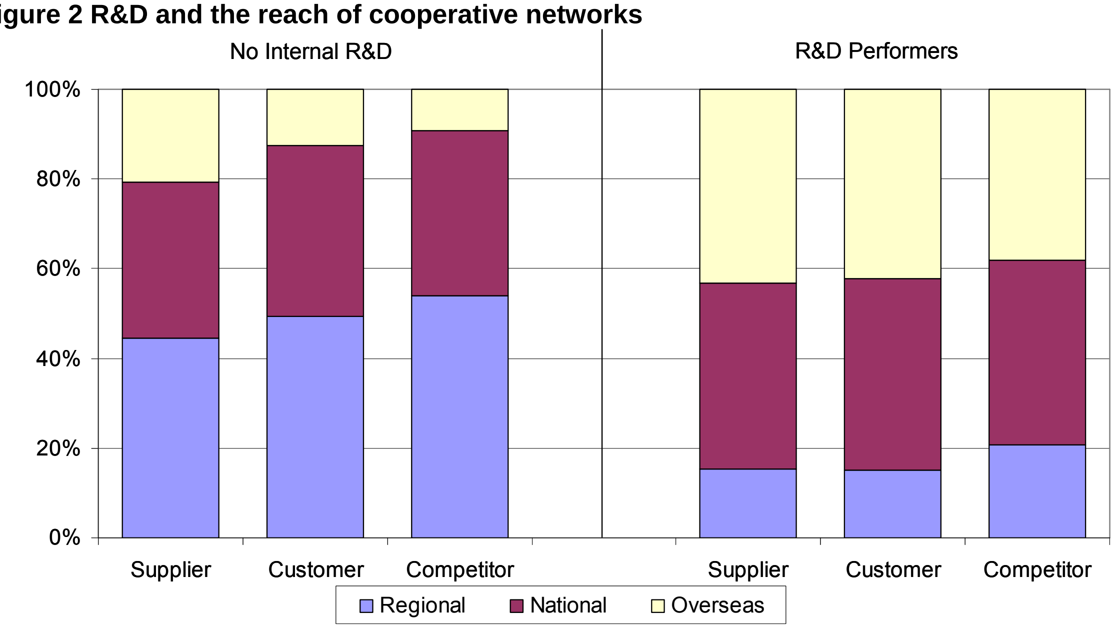

Figure 3 Sales reach and cooperative reach

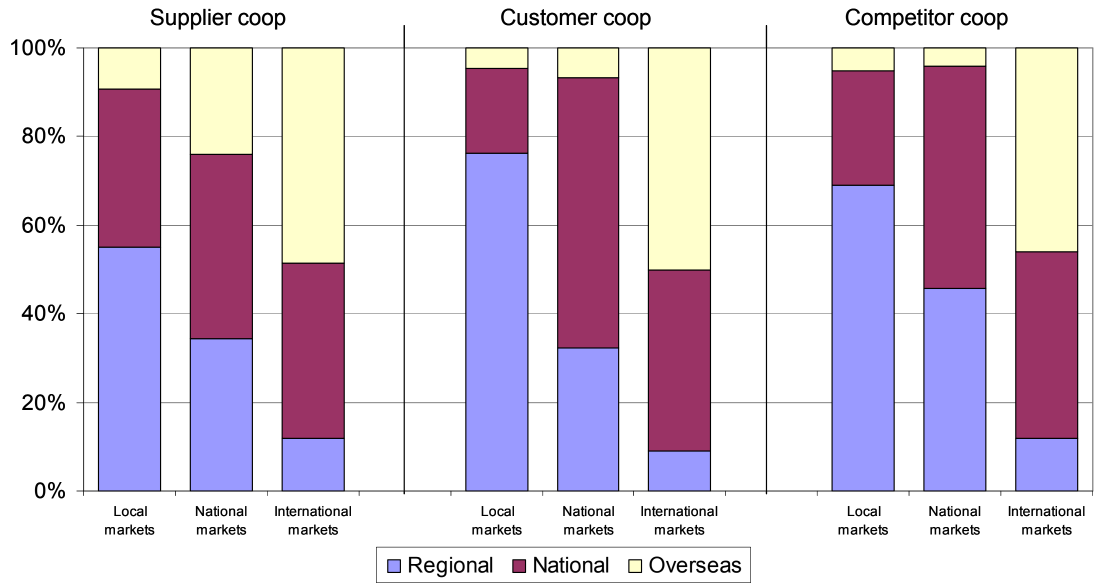

Figure 4 Sectoral variations in the reach of cooperative networks

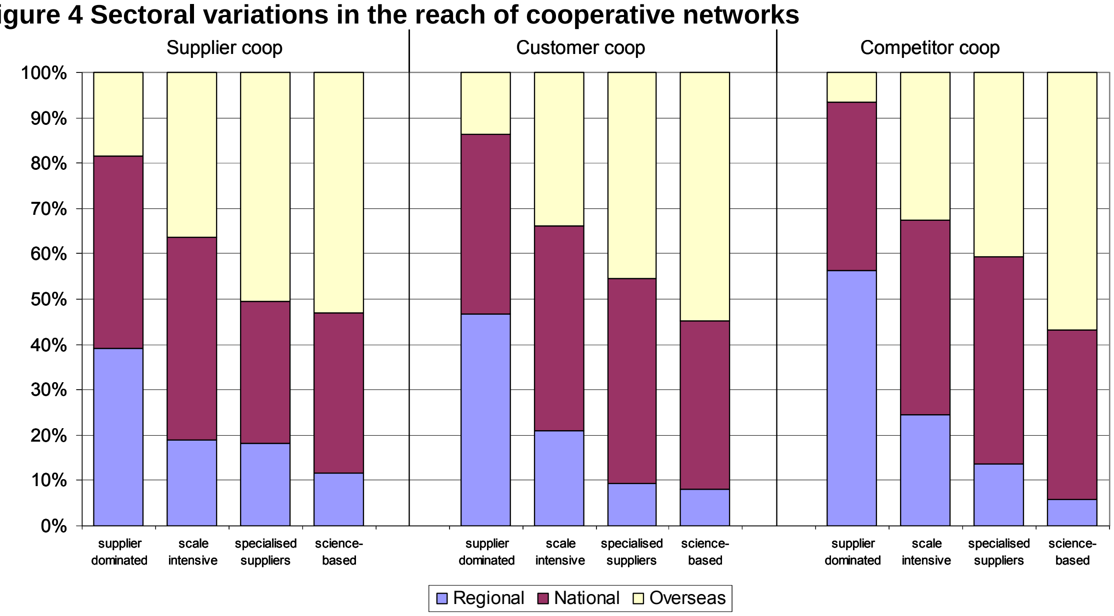

Figure 5 Product Innovation and the reach of innovation networks

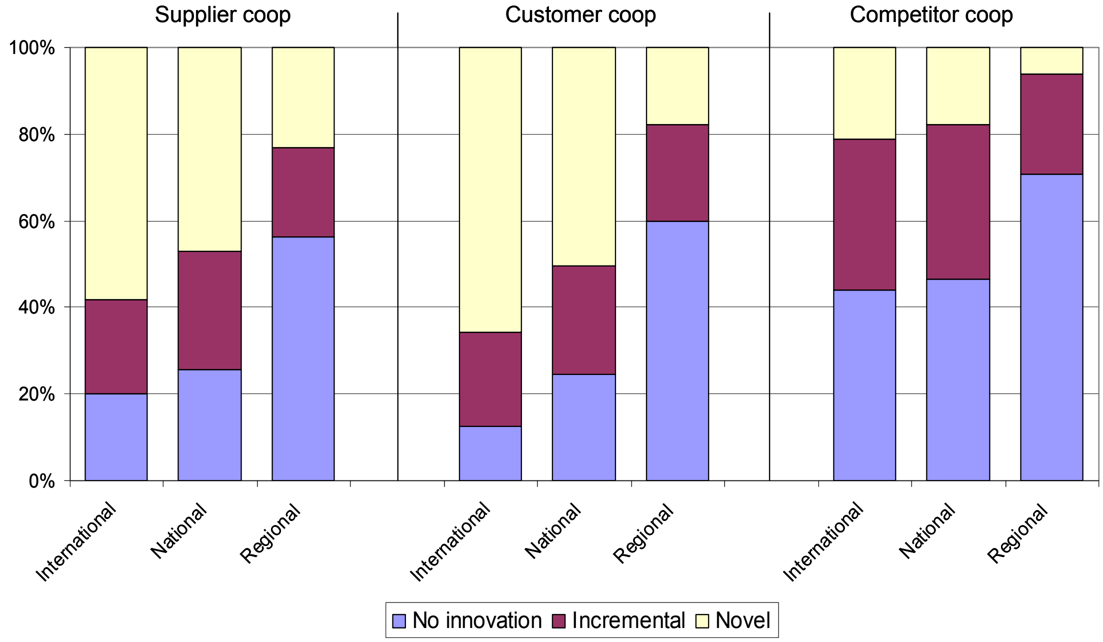

Table 1. Factor analysis of ‘methods to protect innovation’ items

Item	Factor Loadings		
	Factor 1: Formal IP	Factor 2: Informal IP	% “high”
Registration of design	**0.845**	0.219	12.2
Trademarks	**0.812**	0.231	14.7
Patents	**0.830**	0.248	18.0
Confidentiality agreements	0.421	**0.698**	30.1
Copyright	**0.647**	0.369	11.9
Secrecy	0.320	**0.809**	21.9
Complexity of design	0.260	**0.830**	13.9
Lead-time advantage on competitors	0.143	**0.816**	27.8
Eigenvalues	4.524	1.119	
Percentage of total variance explained	70.54		
N = 631			

PCA with Varimax rotation
Respondents were asked to rank on a scale of 1-4 (1=Not used and 4=High) the importance of the above items as means of protecting innovations during the three-year period 2002-2004.

Table 2. Factor analysis of ‘effects’ of innovation items

Item	Factor 1: Expansive	Factor 2: Responsive	% “high”
Increased range of goods	**0.820**	-0.084	35.9
Entered new mkts or increased mkt share	**0.807**	0.006	37.5
Improved quality of goods	0.547	0.524	39.0
Improved flexibility of production	0.527	0.535	27.3
Increased capacity for production	0.505	0.488	24.8
Reduced costs per unit produced	0.504	0.479	32.8
Reduced environmental impacts	0.018	**0.834**	24.8
Met regulatory requirements	0.045	**0.790**	31.9
Increased value added	**0.600**	0.418	35.7
Eigenvalues	3.997	1.306	
Percentage of total variance explained	58.92		
N = 627			

PCA with Varimax rotation
Respondents were asked to rank on a scale of 1-4 (1=Not relevant and 4=High) the effect on the above items of their product and process innovations introduced during the three-year period 2002-2004.

Table 3 Anticipated influences on the reach of innovation collaboration

Variable	Influence
Internal R&D (binary variable)	+
Science and Engineering graduates (as % of all employees)	+
Other graduates (as a % of all employees)	+
Innovation-specific training (binary variable)	+
Market reach (2 binary variables)	+
Importance of formal IP protection strategies	+
Importance of informal IP protection strategies	+/-
Expansive innovation	+
Responsive innovation	-
Pavitt Sectors	Various
Firm size (log of employment)	+
Age (binary)	-
Group membership	+

Table 4. Ordered logit models of the reach of innovation networks.

	Supplier Reach	Customer Reach	Competitor Reach
Log Employment	**0.360 (10.532)**	**0.344 (8.548)**	**0.307 (2.857)**
S&E grads	**0.020 (7.416)**	**0.013 (4.026)**	0.008 (0.822)
Other grads	0.005 (0.421)	0.001 (0.022)	**-0.018 (2.986)**
Expansive motivation	**0.299 (8.279)**	**0.361 (10.286)**	**0.487 (8.709)**
Responsive motivation	**-0.181 (3.816)**	-0.135 (1.793)	**-0.405 (7.335)**
Formal IP	0.030 (0.111)	**0.180 (3.302)**	0.025 (0.030)
Informal IP	**0.246 (5.472)**	**0.308 (7.737)**	**0.502 (8.491)**
Internal R&D	0.157 (0.507)	0.181 (0.534)	0.093 (0.061)
Training	**0.443 (4.894)**	-0.006 (0.001)	-0.376 (1.228)
[i]International sales	**0.899 (8.878)**	**2.265 (37.740)**	**0.931 (3.737)**
[i]National Sales	0.379 (1.620)	**1.188 (11.901)**	-0.197 (0.170)
[ii]Science-based	**0.503 (3.347)**	**0.669 (5.375)**	**1.638 (13.446)**
[ii]Specialised-suppliers	**0.510 (3.559)**	**0.549 (3.427)**	**0.935 (4.187)**
[ii]Scale-intensive	0.155 (0.397)	0.080 (0.091)	**0.838 (4.372)**
Age	-0.209 (0.611)	-0.086 (0.099)	-0.373 (0.802)
Group membership	0.245 (1.475)	0.194 (0.829)	0.343 (1.035)
Nagelkerke R^2	0.320	0.475	0.491
-2 Log-likelihood	937.567	792.106	364.824
[d]χ^2	**170.7[a]**	**268.210[a]**	**148.437[a]**
N	514	492	236

[i] reference group is local/regional sales; [ii] reference group is "supplier-dominated"; [d] full model *versus* constant only model; Figures in parenthesis are Wald χ^2 test statistics; [a] significant at 1% level; [b] significant at 5% level; [c] significant at 10% level