ON THE SPATIAL EMBEDDEDNESS OF INNOVATION NETWORKS: AN EXPLORATION OF THE PROXIMITY EFFECT

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I. INTRODUCTION

In recent years, a growing body of research in regional science has focused on networks, innovation and proximity. In this research, different theoretical frameworks are used. Some refer to old theoretical approaches like the Marshallian industrial district and externalities (Becanttini, 1989), and some refer to more recent developments like the innovative milieu approach (Aydalot and Keeble, 1988; Maillat, 1991), the 'New Industrial Spaces' (NIS) approach (Scott and Storper, 1992; Storper, 1997), the network approach (Camagni, 1991; Fisher, 1999), and the literature on national and regional systems of innovation (Lundvall, 1992; Gregersen and Johnson, 1997; Morgan, 1997).

In a discussion and evaluation of these approaches, Oerlemans, Meeus and Boekema (2000) conclude that there is a general agreement on the importance of spatial proximity for innovation. Moreover, emphasis is placed on patterns of social or economic relationships which enable or constrain economic action in general and innovation in particular (Florida, 1995; Cooke, Gomez Urganga and Etxebarria, 1997, Morgan, 1997). Moreover, the importance of 'tacit' knowledge and the interactive character of the development of technical knowledge and innovation are stressed. The basic assumption in theoretical literature is that geographical distance affects the ability to receive and transfer knowledge. In general, firms' innovations are presumed to be more dependent on local than on distant linkages. However, there is little consensus as to how and why this occurs (Audretsch, 1998).

A vast body of literature discusses the relation between R&D, knowledge spillovers, and proximity. Mowery et al. (1996), for example, conclude that proximity to a network of other firms, universities, and business services remains critical to innovations. Jaffe et al. (1993) and Feldman (1994) found that product innovations exhibit a clear tendency to cluster geographically. This is especially true for urban regions in which the concentration of individuals, occupations, and industries facilitates communication and speeds up the flow of information that leads to innovations. This spatial concentration is related to the level of university R&D and industry R&D spending, as proxies for knowledge spillovers. In sum, this research concludes that R&D spillovers are sensitive to distance and have a tendency to cluster in space.

Recent publications criticise R&D spillover literature (Audretsch, 1998). The important role that knowledge spillovers within a given geographic location play in stimulating innovative activity is acknowledged. However, the main contribution of this literature is simply to shift the unit of observation away from firms to a geographic unit (state, region). This shift has also some methodological and theoretical consequences. Correlating specific characteristics of the geographic unit (e.g., private or university research expenditures, sectoral structure) and measures of regional innovative output (e.g., patents), is the way insights in the spatial dimensions of knowledge spillovers are derived (Audretsch, 1998; Caniëls, 1999). It is simply assumed that the presence of certain elements in regions is a sufficient condition for generating spatial interactions between actors. However, this is not obvious because availability does not necessarily imply utilisation.

By taking the geographical unit as the unit of observation, the behaviour of innovator firms becomes a black box, and spatial interaction is faceless. As a result, there is a detachment between the theoretical mechanisms explaining the relationships between innovation and proximity on the one hand, and measurement of these relationships on the other. In our view, it is actual interaction between actors that facilitates the transmission of knowledge, and not just a high endowment of production factors in a region (Saxenian, 1990). Therefore, we argue that theorising on the relation between networking, innovation, and proximity from a firm-level perspective and a sound theory-driven measurement should come into focus again. Knowledge and resource flows have to be researched at the micro-level to find out how the proximity effect actually works.

In innovation literature, it was B-Å Lundvall (1992) who gave an advanced account of these flows from a firm-level perspective. Lundvall explains the relation between innovation and proximity primarily through the concept of complexity of innovative activities. Lundvall conceptualises innovation as an informational commodity, and he gives a Schumpeterian interpretation of innovation profits as transitory. It is therefore essential for actors to acquire and protect information in order to innovate and to profit from innovation, which explains the emergence of linkages, as well as the importance of control. Lundvall's starting-point is that a broader range of technological opportunities and a higher changeability of user needs give rise to a higher rate of innovation. Since innovation is, by definition, the creation of qualitatively different, new products and technologies involving new knowledge, the chances and threats of technological opportunities, besides changing user needs, have to be evaluated in order to find out whether they can be translated into new product/process features. This feasibility check demands close cooperation between users and producers, since users provide the necessary information for producers. It is radical innovation, in particular, that erases existing communication codes between users and producers. New codes have to be developed on a trial and error basis, which requires more intensive interactions between users and producers as compared with incremental innovations. This implies basically that the more radical the process of technological innovation, the less codified are the information and knowledge communicated and the more important spatial proximity between users and producers becomes. Moreover, 'subjective' elements, such as trust, a common language, and mutual friendship are decisive factors in these relationships. These elements are not easily transferred across space, resulting in a strong proximity effect.

A comparable line of thought on the relation between innovation and proximity is developed in the '*milieux innovateurs*' approach (Maillat, 1991). Maillat argues that the importance of the local environment for the innovation process depends both on the type of innovation and on the innovation strategies of the firms. For incremental innovators, the local production environment is of little importance. Resources necessary for incremental innovation can often be found in the firm itself. Radical innovators, however, develop more relations with the local production environment if they have an insufficient supply of internal resources to realise this type of innovation. This is basically a resource deficits argument (Meeus, et al., 2000).

Lundvall and Maillat agree on the relation between innovation and proximity: more radical innovations demand localised ties. However, they have different views on the explanation of this link. Lundvall takes a knowledge and communication perspective, whereas Maillat takes a resource-based perspective.

However, Lundvall and Maillat underspecify the relationship between innovation and proximity. Firstly, they do not sufficiently specify the comparative advantages of local as compared to non-local links. Secondly, as Lundvall considers only user-producer relationships, he ignores the importance of suppliers to the innovation process. Maillat takes the view that his proximity argument is valid for every type of firms' external relationship, regardless of the type of external actors. Thirdly, they only give a few clues on how to research their theoretical claims empirically. Fourthly, they overlook the absorptive capacity argument made by Cohen and Levinthal (1990). The absorptive capacity of innovators refers to the ability to learn, assimilate, and use knowledge developed elsewhere through a process that involves substantial investments, especially in in-house R&D. As a result, R&D activities play a dual role: developing innovations on the one hand, and enhancing the learning capacity on the other. Hence, in order to learn from external actors, innovators must have the capabilities to do so. Fifthly, both theoretical accounts state that local ties are important to firms with radical innovations; but radicalness is used as a rather broad concept, conflating characteristics of innovation processes and outcomes, which makes the concept highly problematic.

This paper tries to penetrate the black box of geographic space and concentrates on unraveling the proximity effect in innovation networks. We want to deepen the theoretical and empirical discussion of the relation between networking, innovation, and proximity. After all, this relation is anything but automatic. Firstly, if given the option, most organisations prefer to establish a minimum number of inter-organisational relationships inasmuch as these relationships may constrain their subsequent actions (Hage and Alter, 1997). However, some of the resources needed for innovation are outside the firm. Consequently, firms become dependent on their environment. Balancing these two demands could be called an autonomy-dependency dilemma. Secondly, it is well-known that a great deal of human knowledge is context-bound, highly firm-specific, and tacit in nature (Smith, 1995). Moreover, there are limits to which knowledge can be effectively articulated, transferred, and utilised (Lam, 1997). Thirdly, the transfer of knowledge in networks encourages imitation and diminishes the returns from innovation. Fourthly, the probability that local ties can offer all complementary resources is low. Fifthly, the assumed importance of localised ties is counterintuitive in the context of globalisation combined with the ICT revolution. Both developments reduce the importance of proximity, so it is often assumed. These five considerations lead to our research question: *Why would innovating firms wish to engage in localised networks?*

In this paper, we develop a theoretical line of reasoning which combines resource and knowledge-based organisation theory in economics and sociology with elements of regional economic theory on innovation, thus viewing organisational and spatial embeddedness as two dimensions of innovation networks.

The remainder of this paper is divided into 5 sections. In the second section, an explanatory model is presented and hypotheses are put forward. The third section briefly discusses some methodological issues and characteristics of the region under investigation. In the fourth and fifth sections, the results of the empirical analyses are described. The final section summarises and discusses the most important findings of our analyses.

II. INNOVATION AND EMBEDDEDNESS: AN EXPLANATORY MODEL AND HYPOTHESES

The study of innovation and networks is basically a variation on an old theme in the social sciences: the problem of structure and action. Granovetter (1985: 482), for instance, stated that behaviour and institutions are so constrained by ongoing relations that to view them as independent is a serious misunderstanding. Economic action of actors is embedded. Embeddedness refers to the fact that economic action and outcomes, like all social action and outcomes, are affected by actors' dyadic (pairwise) relations and by the structure of the overall network of relations (Granovetter, 1992: 33). He calls this the relational and structural aspects of embeddedness.

Håkansson's economic network approach (1989) is a model to analyse organisational embeddedness in the context of innovation and builds on Granovetter's ideas. The model emphasises the importance of external resource mobilisation for innovation and contains three main elements: actors, activities, and resources. Actors perform activities and possess or control resources. They have a certain, though limited, knowledge of the resources they use and the activities they perform. Two main activities are distinguished: transformation and transaction. Both are related to resources because they change (transform) or exchange (transact) resources through the use of other resources. Transformation activities, like innovation, are performed by an actor who improves resources by combining them with other resources. Transaction activities link the transformation activities of the different actors. These exchange links can develop into economic network relationships, which have a more structural character. Resources can be physical, financial, or human. They are heterogeneous, i.e., their economic value depends on the other resources with which they are combined.

In linking networks and innovation, the heterogeneity of resources and resource mobilisation are the key concepts. Heterogeneity of resources means that knowledge and learning become important. In transforming resources, one has to be knowledgeable about their uses. Learning is a way to accomplish this. This knowledge can be acquired in two ways: internally and/or externally. Learning to use internal resources can be accomplished in various ways, for example through R&D or, learning by using or doing. The external mobilisation of resources can be considered learning by interacting: firms make use of the knowledge and experience of other economic actors (Håkansson, 1993).

Therefore, innovators who are able to mobilise and utilise their internal and external resource bases better are, according to the economic network approach, able to innovate more successfully. This leads to our first hypothesis:

H1: The more innovating firms use their internal and external resource bases, the higher the results of innovation become.

As was stated in Section I, using relations to obtain complementary resources is anything but automatic. There is a mechanism that induces innovators to search for external resources. This mechanism has to do with the complexity of innovative activities, but complexity is not directly linked with radicalness of innovations, which is an outcome-oriented concept. In our view, complexity is a dimension of innovative activity. Synthesising resource-based and activity-based explanations for organisational embeddedness in fact yields a more comprehensive theoretical argument. We contend that the complexity of innovative activities affects the relation between organisational embeddedness of the innovator firm and its innovation results. More complex innovative activities draw more heavily on a firm's resource base than routine activities with lower complexity. These more complex processes increase the probability of problems in the innovation process. Confronted with these problems, innovator firms are forced to enter their external environment in order to get access to and obtain necessary complementary resources. This yields the following hypothesis:

H2: The number of innovation problems moderates the associations between the use of internal and external resource bases and innovation results.

Next, we developed a model explaining the proximity effect in the context of innovation, i.e., the utilisation of local ties beneficial to the innovation process of a focal unit. With this model, we try to explain which features of the structure of the overall network, resources, and dyadic ties explain the probability to benefit from local ties. This enables us to clarify empirically the comparative advantages of proximity for innovation from a firm-level perspective and to deal with a number of flaws discussed in a previous section.

Following Granovetter, embeddedness has a structural aspect. We included two variables (regional purchase ratio and regional sales ratio) describing aspects of the overall network relations of innovator firms, and more in particular the regional economic embeddedness of firms. There is some evidence that webs of local exchange linkages and subcontracting are the basis of agglomeration advantages (Friedmann, 1988; Keeble et al, 1999). Proximity matters because there is a high probability that initial business contacts will be established in the local environment, and these initial ties will develop into a (strong) local network. Firms may take advantage of strong local demand, particularly from related industries. Moreover, buyers are important sources of new ideas and a flow of incremental innovations is generated through localised interaction with buyers (Von Hippel, 1988). Innovator firms also can benefit from localised exchange ties with (specialised) suppliers. As Dodgson (1994) points out, this type of exchange can provide several sets of benefits: increased scale and scope of activities, shared costs and risks, and improved ability to deal with complexity. Furthermore, through the exchanges with suppliers, embodied technologies are imported into the firm as knowledge spillovers (Audretsch and Feldman, 1999).

In the literature, contrasting views on the relationships between resource and knowledge bases and (localised) ties can be found. On the one hand, Cohen and Levinthal (1990) argue that the ability to evaluate and utilise outside knowledge – a firms' absorptive capacity - is largely a function of prior related knowledge, suggesting a positive relationship between the strength of the resource base and external interaction. We already stated that Lundvall and Maillat largely ignore this argument. A spatial version of this view can be found in Thompson (1962). The argument runs as follows. Innovation is a highly cumulative activity, implying that firms located in regions that have accumulated high levels of innovative success and possess a relevant stock of knowledge, such as the region studied in this paper, will be favoured in next rounds of innovation. Firms located in regions that first emerge as centres of innovative activity tend to sustain this advantage over time because the actors in the local system of innovation accumulated a stock of relevant knowledge.

On the other hand, some authors find a negative relationship between the strength of internal resource bases and external interaction, which can be called the resource deficits argument. The heterogeneity of resources needed in innovation urges firms to actively monitor their internal resource base as well as their financial position and decide how to solve their resource deficits. The strength of internal knowledge resources determines the ability to cope with this heterogeneity. In case resources are occupied or not available, a search for complementary resources starts. In this context, the intensification of existing relationships or the formation of new linkages with other actors are behavioural alternatives enabling innovation strategies. Each external actor can be evaluated with regard to its competencies to complement the resource base of the innovating firm. So the interaction between innovating firms and a wide variety of external actors is the corollary of their needs for heterogeneous resources as well as the ability of external actors to supplement there resource deficits or shortages (Aiken and Hage 1968: 930). Summarising, ties of innovator firms with either their buyers or suppliers permits firms to share resources and thus to overcome resource-based constraints for innovative activities.

Besides the structural aspect, the proximity effect is also affected by features of actors' dyadic relations with suppliers/users (the relational aspect of embeddedness). These features stress the institutional aspects of ties. Spatial proximity can be beneficial for the frequency and intensity of (interpersonal) communication (Malecki, 1997: 150). This is especially true for the diffusion and acquisition of knowledge related to innovation processes. In this respect, a distinction is made between information, which can be easily codified, and knowledge, which is more difficult to codify. While information can be transferred at low (marginal) cost over long distances, knowledge is best transferred via face-to-face interactions through frequent and repeated contacts, all of which are most efficiently managed within local proximity (Audretsch, 1998). Therefore, we include contact frequency, knowledge transfer, and duration of innovative dyadic ties as variables in our model. Next, the economic importance of the tie is included in order to find out whether or not linkages important to innovation are also important in economic terms. Finally, formalisation of the tie is included in the model. The basic idea is that the more informal the innovative ties with buyers and suppliers are, the more important proximity is. The non-exclusive and transitory nature of technical knowledge (Cohendet et al., 1993) makes the acquisition and protection of information a core competence that enables firms to profit from innovation, and explains innovator firms' inclination to formalise innovative ties. On the other hand, the stickiness of technical knowledge (Lam 1997), its range and significance is so difficult to assess, and the outcomes of knowledge exchange and knowledge sharing are so uncertain that any contractual arrangement pursuing a specification of knowledge transactions would become an unworkable straightjacket. Simultaneously, the possibility of opportunistic behaviour is increased in this case. So, informal ties are beneficial to knowledge transfer, but opportunistic behaviour has to be prevented. This can be done more easily in localised ties, because the possibilities of monitoring behaviour of proximal external partners are greater. Hypothesis 3, therefore, reads:

H3: Higher levels of regional economic embededdness, stronger resource bases, and stronger dyadic ties increase the probability to benefit from local ties.

Next, the complexity of innovative activities, as indicated by the number of innovation problems, is introduced as a moderating variable. More complex innovative activities increase the probability of resource deficits, resulting in more innovation problems. Innovating firms are forced into external networking in order to mobilise resources that enable them to solve their problems. As was stated by Lundvall and Maillat, more complex processes probably require the communication of more tacit and non-standardised knowledge. The communication of this type of knowledge is facilitated by proximity. Hypothesis 4, therefore, reads:

H4: The associations between regional economic embeddedness, resource bases, and dyadic ties on the one hand and the probability to benefit from local ties on the other, are moderated by the number of innovation problems.

In the next section, some methodological issues are discussed, followed by an empirical analysis of the hypotheses and the presentation of the results.

III. METHOD

This paper draws on a survey on R&D, networks and innovation in the Dutch region of Noord-Brabant. The survey was held in 1992/1993 (relating to firm behaviour in the period 1987-1992) among some 3,500 manufacturing and services firms with more than five employees. The response rate was 19.6% (689 firms) and was quite even across sectors, although the response of small firms was somewhat less than that of larger ones (for details, see Oerlemans, 1996: 188-191).

The region of Noord-Brabant has some typical features. The region is one of the most industrialised regions in the Netherlands. In 1995, the number of man-years in manufacturing was roughly 800,000, i.e., 24.7% of total employment in the region can be found in manufacturing (the Netherlands: 17.0%). Recent research (CBS, 1999) shows that especially these SMEs contribute significantly to the Dutch innovative performance. About 19% of all Dutch SMEs in manufacturing are located in the region of Noord-Brabant. In terms of innovation-related expenditures, these firms account for 24.4% of all spending in manufacturing in the Netherlands.

Moreover, in the Dutch context this region is considered as a high-tech region where multinational enterprises like Philips Electronics, DAF Trucks, Royal Dutch Shell, and Fuji Film have plants, and which contains important medium-sized international niche players like ASM Lithography, ODME (optical disc equipment), Ericsson, EMI, and General Plastics. The region has two universities (one technical) and three innovation centres. A strong group of key players in internationalised industries and its location near important distribution centres like Rotterdam and Antwerp make this region attractive to foreign investors.

The measurement of the variables used to test the hypotheses is described in Appendix 1. Several techniques were used to produce our empirical results: multivariate OLS regression, descriptive statistics, and multivariate logistic regression models.

IV. INNOVATION RESULTS AND ORGANISATIONAL EMBEDDEDNESS

Our first and second hypotheses concern the relationships between the use of internal and external resources, their impact on the innovative performance of firms, and the extent to which these patterns are moderated by problem levels in innovation (see also Oerlemans et al., 1998).

'Innovation results' is the dependent variable and is measured as the average sumscore of 8 items on results of process and product innovations. Six independent variables are included. Two of them describe the use of internal resource bases (transformation [TF] and transaction [TA] function of the firm). Four external resource bases are distinguished: public (EC1), business (EC3) knowledge bases and knowledge bases embodied in bridging institutions (EC2). The fourth independent variable is 'technology policy': the total number of technology policy instruments used by a firm. This is an external financial resource provided by government to stimulate innovation.

The number of innovation problems (NIP) indicates the complexity of innovative activities and is used as a moderating variable. Using a ranking procedure, innovating firms are divided into three subgroups: firms with low, medium and high levels of innovation problems[1]. This makes it possible to make estimates for subsets of firms.

Four OLS models were estimated: one for the total sample and three for different problem levels. As can be seen in Table 1, all models are significant as indicated by the F-values and their levels of significance. Percentages of variance explained vary between 11% for the medium problem level model and 27% for the high problem level model.

Table 1: OLS estimates with innovation results as the dependent variable and the use of internal and external knowledge bases for innovation as independent variables: a comparison between different levels of innovation problems

Independent Variables	Problem levels in innovation			Total Sample (n=216)
	Low (n=54)	Medium (n=60)	High (n=145)	
Internal knowledge bases:				
TF	0.46***	-0.05	0.03	0.26****
TA	0.11	0.32**	0.21***	0.07
External knowledge bases:				
EC1	-0.12	-0.17	0.01	-0.02
EC2	0.16	0.18	0.22***	0.18***
EC3	0.21	0.02	0.37****	0.24****
TP	-0.05	-0.08	0.18**	0.10
R^2	0.22	0.11	0.27	0.19
Adj. R^2	0.20	0.08	0.25	0.17
F value	13.19	5.56	12.84	16.017
Sign. F	0.001	0.022	0.000	0.000

*p < 0.10, **p < 0.05, ***p < 0.01, ****p < 0.001. TF = Transformation; TA = Transaction; EC1 = use of public knowledge bases; EC2 = use of knowledge bases of bridging institutions; EC3 = use of knowledge bases in the value chain. TP = Technology Policy.

The total sample model shows that the use of both internal and external resource bases is positively related to results of innovation. The higher the contributions of the transformation function (internal resource base), the contributions of the private knowledge infrastructure, and suppliers and buyers (external resource bases), the more positive the results of innovation are. The analysis, therefore, shows that using internal *and* external resource bases results in a better innovative performance, thus stressing the importance of including network variables in the analysis of innovation.

Estimates made for subsets of firms, distinguished by the number of innovation problems encountered, vary widely. Firms with low problem levels only use their internal transformation function to achieve better results. Firms with medium problem levels utilise the resource bases embodied in the transaction function to obtain a better innovative performance. The same is true for firms with highly problematic processes, although in this subset the use of the private knowledge infrastructure, suppliers and buyers, and technology policy instruments is also positively related to innovative performance.

An interesting pattern emerges from these analyses. The more problems firms encounter in innovation, the higher the impact of external resources. This implies that, under the condition of higher problem levels, innovator firms are able to innovate successfully using both internal and external knowledge bases.

Our empirical findings enable us to formulate two conclusions. Firstly, organisational embeddedness is induced by complexity of innovative activities. The patterns of relations and resource flows are strongly influenced by the different problem levels. Therefore, organisational embeddedness cannot be taken for granted. Secondly, it emerges that the involvement of external actors, especially suppliers and buyers (EC3), has a positive influence on the outcome of innovation processes. In sum, hypotheses 1 and 2 are confirmed.

Until now, the spatial dimension of the innovation networks has been left out of our analysis. In the next section, we research this issue in greater depth.

V. INNOVATIVE TIES AND PROXIMITY: A MULTIVARIATE ANALYSIS

In a previous section, we discussed the disadvantages of the way proximity effects are measured in spillover literature. We argued in favour of taking the innovator firm as the unit of observation and measure actual features of (innovative) ties. In recent empirical literature (Oerlemans et al., 1998; Sivitanidou, 1999; Keeble et al., 1999, Cappelo, 1999), this approach can be found too. In this paper, we chose the same approach.

The (dummy-coded) dependent variable in this analysis is the location of suppliers/buyers most important to the innovation process of the focal unit, stressing the fact that innovator firms benefit from these ties. The variable is coded 1 if suppliers/buyers most important to the innovation process are located in the southern part of the Netherlands, and 0 in all other cases.

In order to test hypotheses 3 and 4, two sets of models were analysed using logistic regression analysis: one for localised innovative linkages with suppliers and one for buyers. In both cases, the number of innovation problems was used as a moderating variable. In order to control for size effects, a size dummy was included in each model.

Table 2: Multiple logistic regression analysis with the location of the supplier/buyer most important to the innovation process as the dependent variable and characteristics of activities, resources, and innovative ties as independent variables: a comparison between different levels of innovation problems

Localised innovative ties with suppliers (y/n)				
Independent variables	Problem levels in innovation, Exp(b)			Total sample
	Low	Medium	High	
Reg. Embedd.:				
RPR	1.21**	1.35	1.33**	1.23***
RSR	1.14	1.09	1.23	1.22
Resources:				
PHE	1.03**	1.01	1.02	1.02**
RDI	1.00	0.97	1.00	1.01
Dyadic ties:				
EI	0.99	0.45**	1.02	0.93
DR	0.73	3.77**	0.76	0.93
CF	1.49*	4.79***	1.38*	1.60***
KT	1.31	0.40	1.20	1.06
FM	0.74	0.42*	0.63**	0.69***
Size:				
SD (dummy)	0.65	0.01**	0.82	0.63
-2LL	96.880	35.133	134.530	291.244
Significance	0.0030	0.0000	0.0012	0.0000
% correct	67.9%	87.1%	69.1%	72.3%
Goodness of fit	81.654	35.081	109.846	257.076
Significance	0.4658	0.7626	0.4511	0.1895
Nagelkerke R^2	14.1%	64.3%	15.6%	18.7%
n	81	62	110	253

Localised innovative ties with buyers (y/n)				
Independent variables	Problem levels in innovation, Exp(b)			Total sample
	Low	Medium	High	
Reg. Embedd.:				
RPR	0.74**	1.03	1.23	0.97
RSR	5.05***	2.26***	4.89***	3.45***
Resources:				
PHE	1.03*	0.99	1.07***	1.03***
RDI	0.98	1.02	0.88***	0.97*
Dyadic ties:				
EI	0.74*	0.98	0.76**	0.83**
DR	0.93	1.49*	1.20	1.13
CF	0.67	1.05	2.05**	1.31*
KT	1.33	1.19	1.25	1.21
FM	1.51	0.67*	1.02	0.96
Size:				
SD (dummy)	2.27	0.32	0.58	0.61
-2LL	87.488	81.291	116.748	312.123
Significance	0.0000	0.0003	0.0000	0.0000
% correct	73.6%	70.0%	80.9%	71.9%
Goodness of fit	76.770	79.216	126.081	303.475
Significance	0.7056	0.1390	0.4216	0.9851
Nagelkerke R^2	45.1%	22.8%	50.0%	35.6%
n	91	70	131	292

*p < 0.10, **p < 0.05, ***p < 0.01; RPR = Regional Purchase Ratio; RSR = Regional Sales Ratio; PHE = Percentage of Higher Educated employees; RDI = R&D Intensity; EI = Economic Importance; DR = Duration; CF = Contact Frequency; KT = Knowledge Transfer; FM = Formalisation; SD = Size Dummy.

Localised innovative ties with suppliers – All (4) models (upper part of Table 2) were found to perform rather well: the percentages of variance explained as indicated by Nagelkerke's R^2 vary considerably between 14.1% for the low problem levels model to 64.3% for the medium problem levels model. In the total sample model, four variables are statistically significant[2]: regional purchase ratio, percentage of higher educated workers, contact frequency, and informality are positively associated with the probability of localised innovative ties with suppliers. The explanatory value of the model is 18.7%.

Table 2 also shows the results for subsets of innovator firms distinguished by the number of innovation problems. The results for innovator firms with low problem levels differ only slightly from the total sample model. A higher regional purchase ratio is associated with a higher probability of localised innovative ties with suppliers. However, formalisation is no longer important. If innovator firms experience a medium level of innovation problems, the outcomes of the model change considerably. In comparison with the total sample model, the features of dyadic ties turn out to be particularly important, whereas the variables indicating regional economic embeddedness are not important anymore. Duration and, in particular, contact intensity exert a strong positive influence, whereas economic importance and formalisation have a negative impact on the probability of localised innovative ties with suppliers. Moreover, there is a strong size effect: SMEs tend to use localised ties with suppliers. Taken overall, this model performs very well (Nagelkerke's R^2: 64.3%). In the high problem levels model, three variables are significant. A higher regional purchase ratio, contact intensity, and informality contribute positively to localised ties with suppliers.

Localised innovative ties with buyers – All models of localised ties with buyers most important to the innovation process of the focal firm are significant, with Nagelkerke's R^2 varying between 36.5% and 50.0% (bottom part of Table 2). In the total sample model, it turns out that the higher the regional sales ratio, the higher the probability that a firm has innovative ties with buyers. This indicates that firms already strongly embedded in the regional economy also use these local buyers to acquire necessary knowledge resources. Both resource base indicators are significant. The higher the percentage of higher educated employees and the lower the R&D effort of the firm, the higher the likelihood of localised ties. But the coefficients of these variables differ only slightly from 1, expressing marginal effects. With respect to features of dyadic ties, again contact intensity has a positive impact. Economic importance has a negative impact. This result signifies that ties important to innovation are not necessarily important in terms of sales volume.

The lower part of Table 2 presents the results of the models controlled for the level of innovation problems. For firms with low levels of innovation problems, regional economic embeddedness is of importance, in particular, the regional sales ratio. In the medium problem levels model, regional sales ratio, contact intensity, and informality have positive impacts on the probability of innovative ties with buyers. The high problem levels model performs rather well, in terms of its explanatory value (Nagelkerke's R^2, 50%) and in terms of the number and sign of significant variables. Again, regional sales ratio and contact intensity are particularly important. This is, however, the only submodel in which lower levels of R&D are associated with the proximity effect, but at the same time the percentage of higher educated employees has a positive impact.

Finally, one may conclude from the bottom part of Table 2 that there are no significant size effects. In other words, SMEs have no higher probability for localised innovative ties with buyers than big firms.

VI. CONCLUSIONS AND DISCUSSION

The main aim of this paper was an empirical exploration of the organisational and spatial embeddedness of innovating firms in a Dutch region. The paper developed a *theoretical* synthesis of organisation science (resource-based and activity-based perspective) and regional science (milieu innovateur, systems of innovation) accounting for the proximity effect (benefiting from local ties). The resulting research models enabled us to derive several hypotheses on factors influencing the organisational and spatial embeddedness of innovation networks. The results of the analyses supported most of the hypotheses. Firms using internal and external resource bases innovate more successfully. The importance of including inter-organisational linkages in the analysis of innovation is stressed by this result. Organisational embeddedness was strongly affected by high levels of complexity of innovative activities. This finding can be seen as a confirmation of the autonomy-dependency argument made by Hage and Alter and shows firms engage in innovative networks only if there is a strong internal need to do so.

Regional economic embeddedness, the strength of resource bases, and contact frequency influenced the spatial embeddedness of innovative ties with buyers/suppliers. In general, these empirical findings confirmed our theoretical reasoning on the comparative advantages of proximity. However, the estimates were affected by problem levels in innovation processes, resulting in differing patterns of significant variables and variance explained in the models for buyers and suppliers. We assumed that under the condition of higher problem levels in innovation, i.e., more complex innovative activities, the proximity effect would be stronger. This was found in the case of innovative ties with buyers. This confirms Lundvall's ideas on user-producer relationships. Highly complex innovative activities require localised ties with buyers because existing communication codes between users and producers are erased, and there is a need to communicate more tacit and non-standardised knowledge. This pattern was, however, not found for innovative ties with suppliers. In the case of medium problem levels, the proximity effect was the strongest. If innovative activities exceed a certain level of complexity, it seems that local suppliers are not able anymore to make significant contributions to the innovation process of innovator firms. Perhaps, this has to do with observations of some high-tech producers in the region, who state that the (innovative) quality of suppliers is too low. These producers (Océ Copiers, Philips Electronics) started their own supplier upgrading programmes, subsidised by the Dutch Ministry of Economic Affairs. These findings lead to the observation that spatial embeddedness is sensitive to features of innovative activities and even differs depending on the position of the innovator firm: being a user in a relationship with a producer (supplier) or being a producer in a relationship with a buyer (user).

A further comparison of the outcomes of the models leads to some interesting observations. Regional economic embeddedness seems to be a strong driver for localised ties, and these ties are generally not influenced by size effects. The strength of resource bases seems to be of little importance, given marginal effects of the variables. Consequently, neither the absorptive capacity argument nor the resource deficits argument are convincingly confirmed in our models. Knowledge transfer was not of any importance at all. This is a striking result in view of the emphasis that is put on this issue in nearly every theoretical approach. Of course, this finding can be the result of the way we measured because our variable reflects more the intensity of the knowledge transfer than the type of knowledge exchanged. In several models, the economic importance of a tie had a negative impact. This signifies that local dyadic linkages beneficial to innovation are less important in financial terms. Finally, one may conclude that structural as well as relational aspects of embeddedness affect the proximity effect, but no general model explaining the proximity effect can be found.

The findings reported here highlight the importance of synthesising complementary theoretical perspectives as a fruitful avenue to developing the theoretical and empirical explanation of the proximity effect. Moreover, the findings emphasise that organisational and spatial embeddedness is anything but automatic. Researchers of these two dimensions of network structure have to give more explicit theoretical accounts of the mechanisms influencing the formation of innovative ties with external partners.

Notes:

1. A rank procedure categorises firms in (3) groups. The values of all respondents on a variable are ranked in ascending order. The first 33% of the firms are grouped in subgroup 1, the second 33% in subgroup 2 (medium levels) and so forth. Here, subgroup 1 (low levels) has 0 problems (n=144), subgroup 2 (medium levels) has 1 problem (n=110), and subgroup 3 (high levels) has 2 to 6 problems (n=252).
2. The interpretation of the significant coefficients [Exp(b)] in a logistic regression differs only slightly from OLS regression. An Exp(b) > 1 indicated a positive effect, whereas an Exp(b) < 1 denoted a negative impact on the dependent variable.

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Appendix 1: Variables used in the analyses

Variable	Description	Indicators
IR	Innovation results	Average sum score of items: cost price reduction; quality improvements of products and processes; increased production capacity; delivery time improvements; sales increase; profit increase. 5-point Likert scale
NIP	Number of innovation problems	Total sum score of items: exceeding time planning; product deficiencies; technical production deficiencies; exceeding budgets; bad timing; wrong partners; reaction of competitors; insufficient market introduction efforts
TF	Use of knowledge base of the transformation function of a firm	Average sum score of items: Contributions to innovation by (a) R&D function, and (b) production function. 5-point Likert scale
TA	Use of knowledge base of the transaction function of a firm	Average sum score of items: Contributions to innovation by (a) marketing/sales function, and (b) purchase function. 5-point Likert scale
EC1	Use of public knowledge bases	Contributions to innovation by technical universities and colleges for professional and vocational training
EC2	Use of knowledge bases of bridging institutions	Contributions to innovation by Innovation Centres, Chambers of Commerce, trade organisations, Centres for Applied Research (TNO), and private consultants
EC3	Use of knowledge bases in the value chain	Contributions to innovation by important buyers, suppliers, and competitors
TP	Technology policy	Number of technology policy instruments used by a firm
LS LB	Location supplier Location buyer	(1) southern part of the Netherlands (SN), (2) elsewhere in the Netherlands (EN), (3) foreign countries (AB)
RPR	Regional purchase ratio	Regional purchases as a percentage of turnover
RSR	Regional sales ratio	Regional sales as a percentage of turnover
PHE	% higher educated	Percentage of workers with higher education
RDI	R&D intensity	Ratio of R&D personnel to total workforce
EI	Economic importance of innovative relation	Percentage of total purchases/turnover supplied by/sold to the supplier/buyer most important to the innovation process
DR	Duration of innovative relation	Number of years that the innovative relationship has existed
CF	Contact frequency of innovative relation	Every: (1) six months, (2) quarter, (3) month, (4) week, (5) day
KT	Knowledge transfer	Supplier/sales are accompanied by the transfer of knowledge: (1) never, (2) sometimes, (3) regularly, (4) often, (5) always
FM	Formalisation of innovative relation	(1) no formal contract, (2) one-off contracts, (3) short-term contract, (4) long-term contract
SD	Size of firms	Dummy coded variable, (1) equal to or less than 100 employees; (2) more than 100 employees