# Firm clustering and innovation

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# Firm clustering and innovation: Determinants and effects*

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**Abstract.** In this article we ask why innovator firms engage in innovation networks, and which factors explain the spatial dispersion of these networks. Benefits of the use of internal and external knowledge resources for innovative performance of firms were partially confirmed. Especially the utilisation of external competences drawn from buyers and suppliers had stronger effects on innovative performance if complexity of innovation projects was high. Spatial concentration of innovation networks of buyers and suppliers turned out to have a reciprocal, positive relation with interaction intensity between firms. Interaction enhances spatial concentration of relations and vice versa, although the strength of effects differs for ties with buyers and suppliers. Finally we found that higher regional economic embeddedness increases spatial concentration of innovation networks, whereas R& D effort had no effect at all.

**JEL classification:** O31, O32, R11

**Key words:** Organisational and spatial embeddedness, innovation output, networks

## 1 Introduction

In this article we focus on spatial and organisational aspects of innovation networks: two related aspects of embeddedness. We ask why innovator firms wish to

engage in networks in general. This issue is important because strongly contrasting views have been developed. Several authors, (e.g., Porter 2000) emphasise the benefits of networks in terms of gaining access to complementary resources (knowledge, information, money as well as physical resources), risk sharing and synergies of resource sharing. Other researchers stressed the costs of networks in terms of larger dependence, potential constraints on future strategies, and stickiness of knowledge. Especially the authors that have emphasised the constraining aspects of networks in general have introduced the spatial aspect, because a number of constraints are less severe in the case of local relations. A first contribution of this work is to address both issues in tandem. First, we analyse the effects of organisational embeddedness on the innovative performance of firms. Second, we analyse the extent into which these innovation networks are localised networks.

The authors shifting attention to local innovation networks (Lundvall 1992; Maillat 1991; Audretsch 1998) assume that spatially concentrated relations enhance communication and information flows. There are a number of problems with this assumption. First, there is a causality issue in this assumption: does proximity foster communication, or does interaction and communication increase the likelihood of local innovative ties? Second, one can question if only communication and interaction advantages of local innovative ties explain this clustering. Unfortunately, this literature underspecifies the mechanisms explaining the spatial concentration of innovation networks, and considers innovative relations with buyers and suppliers as similar.

The second contribution of this article is that we discern two types of innovative ties: relations between focal innovator firms and their buyers on the one hand, and their suppliers on the other hand. We address the causality issue by exploring the joint dependence of interaction in and spatial dispersion of innovative ties, by means of testing for simultaneity and the application of two stage least squares methods. Finally we extend the explanatory framework, and include regional economic embeddedness, and aspects of the organisation of innovation and R& D of the innovator firms in our model.

The remainder of this work is divided into four sections. In the second section, we review the theoretical literature on firm clustering and interaction in geographical space. In the third section, a production-function is developed in which innovative output depends on the presence and volume of innovative resources and the utilisation of these internal and external resources in the innovation process. This is a necessary first step in our approach: the effects of organisational embeddedness on innovation output have to be determined. The fourth section describes the second step in our analysis. The embeddedness issue is specified, modelling the determinants of spatial dispersion of innovative ties at the dyadic level. The final section summarises and discusses the most important findings of our analyses.

## 2 Theoretical background

In recent years, a growing body of research in regional and organisational science has focused on the clustering of firms. A number of explanations have been advanced to clarify why firms benefit from concentrating in geographical space. Firstly, there is a group of explanations, which stresses the static productivity advantages of clustering (Porter 2000). These include better or cheaper access to such (specialised) inputs as land, components, machinery, business services or personnel, better or cheaper access to information and knowledge, and quicker and cheaper access to institutions and public goods. Moreover, a population of geographically interconnected firms could enhance productivity by facilitating complementarities between the activities of participants. Secondly, scholars emphasise the relationship between firm clustering and new business formation. Because needed assets, skills, inputs and staff are often readily available at a location, they can be assembled more easily for a new enterprise. In this way a geographical concentration of firms lowers entry barriers for new businesses. A third group of explanations for firm clustering concentrates on the benefits of clustering for innovative firms. Clustering enables firms to perceive more clearly and rapidly new technological possibilities, buyer needs, and to learn early and consistently about evolving technology component and machinery availability, facilitated by ongoing relationships and frequent face-to-face contacts.

Although an important part of the literature on firm clustering stresses the benefits of clustering, a number of scholars have a contrasting view. They emphasise that clustering and network formation are 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 with which firms have to deal (Meeus et al. 2001). Secondly, it is well known that an important part 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 and clusters encourages imitation and can diminish 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 counter-intuitive in the context of globalisation combined with the ICT revolution. Both developments reduce the importance of spatial concentration, so it is often assumed. In sum, these five points stress the notion that firm clustering is not as obvious as has often been assumed.

These contrasting views on firm clustering and network formation lead to our research question: *Why would innovating firms wish to engage in localised networks?* We draw on economic, sociological and regional economic theories of innovation in answering this research question. Firm clustering, i.e. organisational

and spatial embeddedness are considered as two distinct dimensions of innovation networks.

In regional science different theoretical frameworks are used to study the formation of networks in geographical space. 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). Despite the distinct theoretical starting points, there is general agreement on the importance of geographical space for innovation among these authors on the one hand (Oerlemans et al. 2000). On the other hand one agrees on the constraining and enabling effects of social and economic relationships on economic action in general and innovation in particular (Florida 1995; Cooke et al. 1997; Morgan 1997). The importance of "tacit" knowledge and the interactive character of the development of technical knowledge and innovation (in a regional context) are stressed. The basic assumption in the 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 non-local linkages. However, there is little consensus as to how and why this occurs (Audretsch 1998).

There is a vast body of literature that confirms the relation between R&D, knowledge spillovers, and spatial embeddedness. Mowery et al. (1996), for example, conclude that proximity to a network of other firms, universities, and business services remains critical to innovation. Jaffe et al. (1993) and Feldman (1994a) 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 accelerates the flow of information that leads to innovations. This spatial concentration is related to the level of university and industry R&D spending, as proxies for knowledge spillovers. 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 that insights into the spatial dimensions of knowledge spillovers are derived (Audretsch 1998; Caniëls 1999). That the presence of certain elements in regions is a sufficient condition for generating spatial interactions between actors is simply assumed.

Two questions arise: 1) does availability of resources in a region necessarily imply their utilisation at the level of firms? 2) Do processes that generate spillover effects at the regional level also apply at the level of firms and dyadic relations? By taking the geographical unit as the unit of observation, the behaviour of innovator firms becomes a black box, and spatial interaction is faceless. There is a resulting detachment between the theoretical mechanisms explaining the relationships between innovation and spatial embeddedness on the one hand, and the level of analysis of these relationships on the other hand. 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, in this article we aim at a better match between the explanatory mechanisms of firm clustering and the level of analysis by researching resource and knowledge flows at the dyadic level.

In the 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 gives a Schumpeterian interpretation of innovation profits as transitory. It is therefore essential that actors acquire and protect information in order to innovate and 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 discover 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. In particular radical innovation 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 to 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 concentration of 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, again stressing the importance of spatial concentration of organisations.

A comparable line of thought on the relation between innovation and geographical space 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 geographical space: 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 this relationship. 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 localisation 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 of an organisation on the other. Hence, in order to learn from external actors, innovators must have the capabilities to do so.

It is the aim of this analysis to penetrate the black box of geographic space and concentrate on the specification of the antecedents and effects of organisational and spatial embeddedness at the level of individual firms and their innovative ties.

## 3 Innovation output and organisational embeddedness

### 3.1 Theoretical framework

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), 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). He calls this the relational and structural aspects of embeddedness.

By implication this means that innovative activity is embedded too, and that innovative outcomes are influenced by an actors' relationships with a variety of external actors. This leads to the following research question that will be addressed in this section: To what extent does organisational embeddedness influence innovation outcomes?

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. An actor who improves resources by combining them with other resources performs transformation activities, like innovation. Transaction activities link the transformation activities of different actors. These exchange links can develop into economic network relationships having 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 and performance. Learning is a way to accomplish this. This learning can be done 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).

Despite the appeal of the Håkanssonian approach, his conceptual framework has a major drawback. As many network theorists and economic institutionalists, the relational perspective focuses on the acquisition of and the access to external resources, and neglects the actual internal utilisation of the acquired resources. Of course, acquisition and access extends a firm's resource base, but it does not automatically imply effective utilisation of these resources. We therefore develop a model that allows us to specify the availability and access to resources on the one hand, and the utilisation of internal and external acquired resources in the innovation process on the other hand. Following Feldman (1994b), we use a modified production-function approach in which innovative output depends on the presence and volume of innovative resources and the utilisation of these internal and external resources in the innovation process:

$$INN_i \;=\; RD_i^{B_1} TP_i^{B_2} RDC_i^{B_3} TF_i^{B_4} TA_i^{B_5} PU_i^{B_6} PR_i^{B_7} VC_i^{B_8} \tag{1}$$

where *INN* is innovative output, *RD* R&D effort, *TP* funds drawn from technology policy measures, *RDC* R&D collaboration, *TF* utilisation of the transformation function, *TA* utilisation of the transaction function, *PU* utilisation of the public knowledge infrastructure, *PR* utilisation of bridging institutions, and *VC* utilisation of the value chain.

Innovative output is measured as the average sum score of eight items on results of process and product innovations for a firm $i$, and is modelled as a

function of three groups of innovative inputs. The first group describes a firm's competences in internal resource levels of the innovative firm and encompasses three innovative input variables. The R&D effort of a firm is measured as the number of man-years invested in R&D as a percentage of the total workforce. The other two variables describe externally acquired resources. Technology policy is measured as the total number of technology policy instruments used by an innovator firm, which is a proxy of external funding of innovation activities. R&D cooperation is measured as the number of R&D relationships an innovator firm has with buyers, suppliers, competitors, universities, research labs, and engineering firms. The variables mentioned above are all necessary resources that enable firms to innovate. The function of the internal R&D effort is twofold. Innovator firms need a research and development effort because it is an important source of knowledge to produce innovations. And conversely, this variable defines an innovator firms' "absorptive capacity". As Cohen and Levinthal (1990) argue, firms must have the ability to recognise and monitor the potentials of external knowledge. This is thought to be a function of prior related knowledge. This knowledge is developed through R&D efforts. In order to utilise external resources, it is a necessary precondition that an innovator firm has relationships with external actors. In this sense, having a number of R&D relationships is a resource enabling firms to interact. The second external resource included in the model is technology policy, which is a proxy for financial means provided by government to stimulate innovation.

As Alchian and Demsetz (1972) stated 'efficient production using heterogeneous resources is not a result of having better resources, but knowing more accurately the relative performance of these resources'. In the context of innovation this implies that simply having resources is not enough to produce innovative output. It is also the way these resources are utilised in the innovation process, which determines whether innovative outputs are produced in an effective and efficient way. To capture this idea, we added two groups of variables describing the utilisation of internal and external resources respectively in the innovation process of the focal firm (Arvanites and Hollenstein 1996).

We distinguish the utilisation of the innovator firms' internal transformation and transaction function. $TF_i$ is measured as the extent in which the production and the R&D function is actually utilised in the innovation process. $TA_i$ is measured in the same way, but now for the purchase and marketing/sales function of the firm. Higher scores on these variables indicate higher levels of utilisation of these internal resources in the innovation process. Higher utilisation levels should be associated with higher innovation output levels.

The utilisation of external resources was measured in the same way as in the Community Innovation Survey. Innovator firms were asked to indicate to what extent a variety of external actors, ranging from universities and polytechnics to buyers and suppliers, contributed to the innovation process of the focal firm. A factor analysis (not presented here) resulted in a three-factor solution: (1) Utilisation of the contributions of the public knowledge infrastructure in the innovation process of a firm ($PU_i$). This factor includes the utilisation of (technical) univer-

sities and colleges for professional and vocational training; (2) Utilisation of the contributions of bridging institutions in the innovation process ($PR_i$). Examples of these are innovation centres, business associations and private consultants; (3) Utilisation of the value chain, including the utilisation in the innovation process of contributions of suppliers, buyers and competitors ($VC_i$).

In sum, innovators need internal and external resources to innovate, but it is the extent to which they actually utilise these resources that enable them to innovate with higher results. This leads to our first hypothesis: higher resource levels, and higher levels of utilisation of internal and external resources are positively associated with higher levels of innovation output.

As was stated in the introduction, using relations to obtain complementary resources is anything but automatic. There must be a mechanism that forces 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 internal resource base than routine activities with lower complexity do. 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 to gain access to and obtain necessary complementary resources. This yields the following hypothesis: the number of innovation problems moderates the associations between resource levels, the utilisation of internal and external resource bases and innovation results: higher problem levels induce a more intensive utilisation of external resources.

## 3.2 Data and estimation issues

There are a number of issues to consider with the model estimations. This article draws on a survey on R&D, networks and innovation in the Netherlands. The survey was held in 1995 (relating to firm behaviour in the period 1989-1994) among some 5,500 manufacturing and services firms with more than five employees. The response rate was 8% , i.e. 365 firms. For details on the features of the survey, see Oerlemans (1996). Although the response rate was low, the number of cases is quite sufficient to perform a number of multivariate exploratory analyses. Capello (1999) and Dahlstrand (1999), for example, use 63 and 157 observations, respectively, in their estimations.

Because innovative output may be influenced by sector-specific influences, we defined a dummy variable ($PD_i$) for innovating firms. This variable was formulated along the lines of Pavitt's (1984) taxonomy of innovating sectors.

We expect that firms belonging to the supplier dominated sector (the reference group) have lower levels of innovative output since their innovative capabilities are assumed to be lower in comparison to firms belonging to the other sectors (scale intensive, specialised suppliers, and science based sector).

The resulting equation for estimation is:

$$\ln INN_i = \beta_1 \ln RD_i + \beta_2 \ln TP_i + \beta_3 \ln RDS_i + \\ \beta_4 \ln TF + \beta_5 \ln TA_i + \\ \beta_6 \ln PU_i + \beta_7 \ln PR_i + \beta_8 \ln VC_i + \beta_9 PD_i + \varepsilon_i \quad (2)$$

In order to test hypothesis 2, we constructed the variable 'number of innovation problems' ($NIP_i$), which indicates the complexity of innovative activities of a firm. Using a ranking procedure, innovating firms are divided into two subgroups: firms with low and with high levels of innovation problems. We will use this variable as a moderating variable, which allows us to make estimates for subsets of firms.

An econometric concern in estimating the model is the existence of multicollinearity among the independent variables. In order to check for multicollinearity in our stepwise OLS regressions, we used the so-called variance inflation factor (VIF), which is the reciprocal of the tolerance. As the variance inflation factor increases, so does the variance of the regression coefficient, making it an unstable estimate. Large VIF values are an indicator of multicollinearity (Tacq 1997). The variance inflation factors found in our estimates ranged from 0.92 to 1.15, expressing the fact that no multicollinearity problems occurred.

## 3.3 Empirical results

We present in this section the results of stepwise OLS regressions.

Three stepwise OLS models were estimated: one for the total sample and two for the 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 15% for the total sample model and 19% for the high problem level model.

The total sample model shows that the utilisation of both internal and external resources is positively related to innovative output. The higher the utilisation of the transformation function of the innovator firm (internal), and of the value chain (buyers and suppliers, external), the more positive are the results of innovation. Quite surprisingly it turned out that the variables indicating resource levels showed no statistically significant relationship with innovative outcomes. Evidently, only having resources is not enough to produce innovative output, actual utilisation seems to be far more important, at least for the firms in our sample.

As expected, the sector dummy was statistically significant positive. In other words, innovative firms in the supplier-dominated sector tend to have a lower innovative output, all other variables kept constant.

**Table 1.** OLS stepwise regressions[a]

| Independent variables | Problem levels in innovation (NIP) | | Total sample (n = 160) |
|---|---|---|---|
| | Low (n = 72) | High (n = 88) | |
| Intercept | +0.66*** | +0.66**** | +0.49**** |
| Internal resource levels | | | |
| RD | −0.05 | −0.14 | −0.09 |
| RDS | −0.05 | +0.23** | +0.04 |
| TP | +0.01 | +0.02 | +0.07 |
| Utilisation of internal resources | | | |
| TF | +0.26** | +0.11 | +0.21*** |
| TA | +0.06 | +0.19* | +0.10 |
| Utilisation of external resources | | | |
| PU | −0.08 | +0.11 | +0.08 |
| PR | −0.14 | +0.06 | −0.05 |
| VC | +0.03 | +0.33**** | +0.19** |
| Sector dummy | | | |
| PD | +0.31*** | +0.07 | +0.18** |
| $R^2$ | 0.18 | 0.19 | 0.15 |
| F value | 7.550 | 10.217 | 9.472 |
| Sign. F | 0.001 | 0.000 | 0.000 |

\* $p < 0.10$; \*\* $p < 0.05$; \*\*\* $p < 0.01$; \*\*\*\* $p < 0.001$. [a] *RD* = R&D effort; *RDS* = number of R&D relationships; *TP* = Number of technology policy instruments used; *TF* = Utilisation of transformation function; *TA* = Utilisation of transaction function; *PU* = Utilisation of public knowledge infrastructure; *PR* = Utilisation of private knowledge infrastructure; *VC* = Utilisation of value chain; *PD* = Pavitt sector dummy.

The analysis for the total sample, therefore, shows that utilising internal *and* external resources result in a higher innovative output, thus stressing the importance of including network variables in the analysis of innovation output. Results of estimates made for subsets of firms, distinguished by the number of innovation problems encountered, vary widely. Innovative firms with low problem levels utilise only their internal transformation function. Again, supplier dominated firms tend to have a lower innovative output. Innovative firms with high innovation problem levels utilise their internal transaction function to obtain a higher innovative output. Moreover, a higher number of R&D relationships and a higher level of utilisation of the value chain are positively related to results of innovation. However, there are no sectoral effects in this model.

A comparison of the two estimates made for subsamples of firms lead to some interesting observations. Under the condition of low problem levels, innovator firms utilise relatively more internal resources to innovate successfully. The utilisation of knowledge and experience embodied in the R&D and production (i.e., transformation) function of the firm seems to be sufficient to solve the problems they encounter. In the case of highly complex innovation processes, this inwardness is no longer possible. The number and nature of the innovation problems

force innovators to utilise external resources. This stronger outwardness can be observed in two different ways. First, in the high problem levels model it is the utilisation of the transaction function, which becomes important. In general, in comparison with the transformation function, purchasing and marketing can be considered as the antennas of a firm in the marketplace. Ideas and information relevant to the innovation process can be picked up more easily. Second, suppliers and buyers get involved in the innovation process of the focal firm because they possess relevant process and product knowledge and experience. R&D relationships are the necessary vehicles that make the transfer possible.

## 4 Endogenising the spatial dispersion of innovative ties

### 4.1 Theoretical framework

In the previous section we found support for a generic effect of organisational embeddedness on innovation results revealing that especially the actors in the value chain affect the innovative performance of innovator firms. In this section we specify the embeddedness issue further, by means of modelling the antecedents of spatial dispersion of innovative ties at the dyadic level, which allows for the exploration of the assumption that geographical distance between firms affects their ability to receive and transfer knowledge (Audretsch 1998; Porter 2000). In doing so, we shift the level of analysis to the level of dyads and the geographical distance between actors in the dyads; on the one hand focal firms and their buyers, and on the other hand focal firms and their suppliers. Instead of using proxies such as patent citation as a measure for spillovers and innovative ties, we measure actual features of "real" dyads in the context of innovation.

The research theme of this part of our analysis is one of many that has drowned in the ocean of the conspicuous. Many authors (Porter 2000; Saxenian 1994; Audretsch 1998; Lundvall 1992; Maillat 1991) dealt with the issue of spatial clustering of innovative activities. Often they draw on explanations based on factor advantages, and on the absence of communication barriers (distrust, distinct cultures, distance). Yet the causal direction between spatial concentration and interaction between actors in innovation systems is either not questioned, or left implicit. To our knowledge there is no research that argues that interaction and spatial features of innovative ties should be examined as jointly dependent. One of the contributions of this work is that we do question the causal direction between interaction and spatial dispersion. We examine the following research questions: a) to what extent does spatial dispersion affect the interaction between firms in innovative ties, and b) to what extent does interaction affect the spatial dispersion of innovative ties?

Furthermore, we answer our general research question - why do innovator firms wish to engage in localised networks? – by advancing a model that explains the spatial dispersion of innovative ties and the interaction intensity jointly, as a function of features of the regional embeddedness of the focal firm, and features of the innovation process of the focal firm. This is another contribution of

our analysis. Besides showing the extent to which organisational embeddedness fosters the innovative performance of the focal firms in a general sense, we also try to identify factors that explain the spatial dispersion of the innovative ties in which the organisation is embedded. Our model has the following structure:

$$SDIT = \beta_{11} IIIT + \gamma_{11} RE + \gamma_{12} RAD + u_1 \quad (3)$$

$$IIIT = \beta_{21} SDIT + \gamma_{22} RAD + \gamma_{23} RD + \gamma_{24} RDd + u_2 \quad (4)$$

where *SDIT* is spatial dispersion of innovative ties, *IIIT* interaction intensity in innovative ties, *RAD* radicalness of innovation, *RD* R&D effort, and *RDd* presence of an R&D department.

Endogenous variables in our structural model are "spatial dispersion of innovative ties" (Equation (3)) and "interaction intensity in innovative ties" (Equation 4). *SDIT* is measured as the geographical distance between firms, their customers and suppliers. The value of *SDIT* ranges between 0 and 3. The lowest score means that the buyer/supplier that is the most significant contributor to the focal firm's innovation processes is three borders removed from the focal firm. The highest score means that the focal firm and its most significant contributor are located in the same region, and hence they need not cross borders in order to have face-to-face contact.

*IIIT* is a compound variable (Cronbach's $\alpha = 0.89$ for innovative ties with users, and 0.85 for innovative ties with suppliers) of two indicators: contact frequency and intensity of the knowledge transfer related to supplies. Several researchers have reported that especially face-to-face communication between individuals fosters the exchange of knowledge and information and the formation of innovative ties (Saxenian 1990). Because higher contact frequency in tandem with more intensive knowledge transfer has a stronger informational effect, we multiplied the raw scores of the two indicators instead of adding their raw values.

The exogenous variables in our structural model are regional embeddedness (*RE*), radicalness of innovation (*RAD*), R&D effort (*RD*), and finally the presence of an R&D department (*RDd*). *RE* is measured as regional purchase/sales as a percentage of the total purchase/sales and is an indicator for the regional economic embeddedness of the focal firm. *RAD* is a compound variable adding up the newness levels of product and process innovations performed by the focal firms over a five-year period (1989 – 1994). For the measurement of *RD*, see Sect. 3.1. *RDd* is a dummy measuring the presence of an R&D department.

From Equation (3) the following hypothesis is derived: more radical innovations, a higher regional embeddedness, and more intensive interaction between focal innovator firms, buyers and suppliers are associated with a relatively higher spatial concentration of innovative ties.

Many researchers argue for the inclusion of RAD in models explaining innovative behaviour. Both Lundvall (1992) and Maillat (1991) argue – although on different grounds – that more radical innovations demand local ties. Resource availability and low information barriers are the explanatory mechanisms. More radical innovations draw more on the resource base of the focal firm, and invoke resource deficits of many kinds (informational, physical, financial, human).

Because local innovations have the advantage of lower transport costs, less information problems, and smoother knowledge exchange, it is obvious that local firms are preferred above non-local firms. Yet it has to be emphasised that the empirical evidence is scarce and fragmented.

There are contrasting arguments for the effect of regional sales or purchase ratios on the spatial dispersion. Some researchers, (e.g., Fagerberg 1998) suggest that higher regional economic embeddedness increases the likelihood of local innovative ties. The explanation is that suppliers or customers representing large accounts provide the most knowledgeable feedback about product functions and quality. Moreover this feedback is linked with strong economic incentives, and such firms are therefore more likely to develop a preference for local innovative ties. However Granovetter's (1973) "weak ties" argument – not strong but poorly developed relations provide new ideas and information – offers an alternative perspective. In that case low regional embeddedness is supposed to increase the probability of local innovative ties.

The effect of interaction intensity on innovative ties can be explained in process terms. Without contacts, interesting partners cannot be found, subsequently innovative ties cannot develop, and finally knowledge cannot be transferred. Hence the interaction intensity constitutes the formation of innovative ties, and guides the search process for partners as well as the development of innovative ties. Nevertheless, it is difficult to specify a straightforward link between interaction and the spatial dimension of innovative ties without the introduction of additional assumptions.

From Equation (4) the following hypothesis was derived: more radical innovations, a higher absorptive capacity, the presence of an R&D department in the focal innovator firms, and higher spatial concentration of innovative ties intensify the interaction between focal firms and their innovative partners.

More radical innovations (*RAD*) intensify interaction due to the fact that the innovator firms are more uncertain about product specifications and the preferred and feasible functions and quality (Teubal 1976; Von Hippel 1976, 1988). No communication codes exist and 'wording' of new functions and interfaces is a key problem. The information and knowledge needed to solve the related problems are mainly provided by the contacts with suppliers and buyers (Lundvall 1992). The internal resources and structures sustaining R& D are measured with two indicators. R&D effort (*RD*) indicates a knowledge quantity, which allows a firm to perform R&D and to monitor and evaluate developments in its technical and market environment (Cohen and Levinthal 1990). The efficacy of R&D efforts turns out to be highly dependent on adequate R&D management (Eisenhardt and Tabrizi 1995). The translation of R&D into project plans is basically information processing. A formal R&D department responsible for this process will introduce project management in order to make these processes manageable. Therefore we expect that the presence of an R&D department will intensify the interaction with internal and external actors engaged in the focal firm's innovation projects (Rutten 2000; Wynstra 1998). Local innovative ties are expected to intensify interaction relatively more compared to non-local ties because one of the most

important barriers limiting face-to-face communication – geographical distance – is set to nearly zero. Moreover, in case of interaction in local innovative ties there is considerable less negative impact of cultural and trust factors. Hence we expect that spatially concentrated innovative ties have higher interaction intensity than spatially dispersed innovative ties (Porter 2000; Audretsch 1998).

## 4.2 Data and estimation issues

The data used were already described in Sect. 3.2. In our analyses we estimated two sets of simultaneous equations. Two stage least squares (2SLS) methods were applied for several reasons. Firstly, we cast serious theoretical doubts on the one-way or unidirectional cause-and-effect relationship between *SDIT* and *IIIT*. As a consequence, this two-way, or simultaneous, relationship blurs the distinction between *SDIT* and *IIIT* as dependent and independent variables. Given these jointly dependent variables, OLS estimates suffer from a simultaneity bias that makes the obtained estimators inconsistent (Gujarati 1995; Johnson and Wichern 1998). To apply 2SLS one needs to have at least one over-identified equation, which applies for Equation (3).

One of our theoretical purposes was to clarify the simultaneity of *SDIT* and *IIIT*. For that reason we used the Hausman test. The unstandardised predicted and residual values obtained by estimating Equation (3) were included in Equation (4) to find out if the correlation between the residuals and the disturbance term $u_1$ is zero. If this correlation differs significantly from zero there is simultaneity.

In Table 2 the findings for the two structural models are displayed. Models 2a and 2b relate our estimates to innovative ties with buyers, whereas Models 3a and 3b do the same for suppliers.

## 4.3 Empirical results

Table 2 presents the results of our 2SLS estimates of the hypothesised structural model.

As shown in Model 2a, two out of three predictors have the expected significant positive impact on the spatial concentration of innovative ties with buyers. More intensive interaction between focal firms and buyers, as well as a higher regional sales ratio is associated with higher spatial concentration of innovative ties with buyers.

The findings as to Model 2b reveal that two out of four predictors significantly intensify the interaction of focal firms with their buyers. Local innovative ties and more radical innovations intensify the interaction of focal firms with their buyers. The significant Hausman test shows that spatial dispersion of innovative ties and the intensity of interaction in innovative ties are jointly dependent for the buyer model.

Results in Model 3a show that all predictors have significant impacts on the spatial dispersion of innovative ties with suppliers in the expected direction. More

**Table 2.** Two-stage least square estimation results[a]

| Independent variables | SDIT Model 2a buyers (n=106) | IIIT Model 2b buyers (n=106) | SDIT Model 3a suppliers (n=117) | IIIT Model 3b suppliers (n=117) |
|---|---|---|---|---|
| Endogenous variables | | | | |
| SDIT | — | 0.41* | — | 0.37 |
| IIIT | 1.03**** | — | 0.57**** | — |
| Exogenous variables | | | | |
| RD | — | 0.01 | — | −0.03 |
| RDd | — | 0.21 | — | 0.40** |
| REsr/REpr | 0.12*** | — | 0.17*** | — |
| Rad | −0.16 | 0.29* | 0.22* | 0.14 |
| F value | 446.64 | 98.86 | 218.23 | 100.22 |
| Sign. F | 0.001 | 0.001 | 0.001 | 0.001 |
| Hausman test | t = 2.97*** | | t = 3.07*** | |

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$.
[a] SDIT = Spatial dispersion of innovative ties; IIIT = Interaction intensity of innovative ties; RD = R&D effort; RDd = R&D department; RE = Regional Embeddedness Sales/Purchase Ratio; Rad = Radicalness of Innovation.

intensive interaction, higher regional purchase ratios and more radical innovation significantly increase the spatial concentration of innovative ties with suppliers. The estimation of Model 3b shows the poorest fit with our theoretical expectations. Only one out of four predictors had the expected impact on interaction intensity in innovative ties with suppliers. The presence of an R&D department intensifies the interaction of the focal firms with their suppliers. For this set of equations, the Hausman test was significant as well. So the spatial dispersion of innovative ties with suppliers and the interaction intensity between the focal firms and their suppliers are also jointly dependent.

Although the reciprocal relation between spatial concentration of innovative ties and interaction intensity within these ties is supported for both buyers and suppliers, we also found significant differences between the results of the buyer and supplier models. First, the reciprocal effects are stronger in the buyer models than in the supplier models. This finding can be interpreted in terms of a user-bias in innovation processes. To determine the feasibility of innovations, firms are more sensitive and eager to anticipate the demands and needs of users. Hence innovator firms are inclined to intensify their interaction with users more than with suppliers. Second, the effect of *IIIT* on *SDIT* is significantly stronger ($\beta$'s 1.03 and 0.57) than the effect of *SDIT* on *IIIT* ($\beta$'s 0.41 and 0.37). This can be explained by the fact that we included spatial embeddedness in Equation 3 as an exogenous variable. Under the condition of higher regional sales and purchase ratios, a stronger spatial embeddedness probably reinforces contact frequency and knowledge transfer, and so the likelihood of the emergence of local innovative ties is larger. This interpretation is supported by the significant effect of spatial embeddedness in Model 2a and 3a.

## 5 Discussion and conclusion

In this article we have developed two different theoretical models. The first model specifies the effect of organisational embeddedness on innovation output (Equation (2)). The second model (Equations (3) and (4)) deals on the one hand with the simultaneity of the spatial dispersion of innovative ties and the interaction in these ties. On the other hand the second model tries to identify the antecedents of the two jointly dependent endogenous variables.

The results of the model on organisational embeddedness and innovation output yield two conclusions. Firstly, firms using internal and external resources more intensively have higher levels of innovation output. The importance of including inter-organisational linkages in the analysis of innovation is stressed by this result. Secondly, high levels of complexity of innovative activities affected the impact of organisational embeddedness on innovative output. This finding can be seen as a confirmation of the autonomy-dependency argument made by Hage and Alter and shows that firms engage in innovative networks only if there is a strong internal need to do so. In our view these findings are important because they give a counterbalance against that part of the literature that stresses the generic importance of networks and clusters. Our findings show that a specific mechanism, complexity of innovative activities, is necessary to explain network activity of innovator firms.

In Sect. 4 we reported on the results of the second model. Overall, the results support our theoretical expectations with one notable exception. Our findings of the bi-directional causal relationships between the spatial distribution of innovative ties and the intensity of interaction pose some interesting issues. Prior work has argued that spatial concentration affects the interaction between partners in innovation processes due to reduced communication, cultural and transport barriers. Our findings do not reject these ideas, but they do suggest that the effect is stronger in the opposite direction. Given a stronger regional economic embeddedness, higher interaction intensity facilitates spatial concentration of innovative ties. Obviously, Granovetter's 'weak ties' argument does not explain the spatial dispersion of innovative ties. We therefore conclude that the regional embeddedness seems to define the actor set from which innovator firms select their local innovative ties. The innovation networks we found apparently reflect a self-reinforcing mechanism invoked by innovation. This seems to be a promising research agenda for regional comparison, which would be complementary to the spillover literature.

With respect to the effects of R&D effort, the presence of an R&D department and the radicalness of innovation on our endogenous variables provide mixed evidence. The proposition of Maillat and Lundvall, that more radical innovation demands localised ties, is supported only for the innovative ties with suppliers. Again this allows for a further specification of general notions in innovation and regional studies.

R&D effort is the only variable that did not have the expected effect. Although this indicator has predictive value in many studies on learning (Cohen

and Levinthal 1990), economic growth (Fagerberg 1998), and alliances (Mowery et al. 1996), it has no effect on our endogenous variables. Obviously this important indicator loses its predictive value in models where information processing and spatial dimensions of organisational behaviour are the phenomena to be explained.

In assessing the contribution of our study caution is needed, because there is no prior research available that has empirically explored the antecedents and effects of organisational and spatial embeddedness. Although there is no significant sampling bias in our population, the sample is relatively small. Also caution should be exercised, because an important control variable – regional economic difference – was not included here. Due to the small sample size it was impossible to apply a multi-level analysis that would have allowed us to control for regional differences.

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