

# Innovation and knowledge flows in and outside clusters: the Dutch life sciences and computing services

*Roderik Ponds<sup>a,b</sup> & Anet Weterings<sup>b</sup>*

<sup>a</sup> Urban and Regional research centre Utrecht (URU), Faculty of Geosciences, Utrecht University, The Netherlands.

<sup>b</sup> The Netherlands Institute for Spatial Research (RPB), The Hague, The Netherlands<sup>1</sup>

*Draft Version*

## **Abstract**

Networks of inter-organisational contacts are generally seen as an important mechanism for localised knowledge spillovers. Based on this idea, many empirical studies have examined the effect of knowledge flows through these contacts on the innovative performance of firms in clusters. This study builds on this line of literature and contributes to it in two ways. First by comparing the effect of knowledge flows through inter-organisational contacts on innovation between two different industries, life sciences and software services, whereas most studies examine this effect in one industry only. Second, the relation between inter-organisational contacts and innovative performance of firms is analyzed without explicitly differentiating towards spatial scales and including other characteristics of these contacts as well. Our findings suggest that the effect and importance of various types of knowledge flows differ across industries. Knowledge flows through inter-organizational contacts seem to have a positive effect on innovation for firms in case of life sciences but not in the software services industry. Furthermore, although the majority of the contacts in case of life sciences take place at the regional level, there is no additional benefit in having a higher share of regional contacts. The type of organization with which the firm has contact seems to be more important than at which spatial scale these contacts are occurring.

---

<sup>1</sup> Correspondence address: Roderik Ponds, Netherlands Institute for Spatial Research (RPB), P.O.Box 30314, 2500 GH, The Hague, The Netherlands, r.ponds@geo.uu.nl

## **Introduction**

The spatial concentration of industries and clusters points to the existence of positive localized externalities. The analysis of these externalities or agglomeration advantages is a central issue in contemporary economic geography and regional economics. A key element in the research on agglomeration economies is the concept of localized knowledge spillovers, which is based on the idea that newly generated knowledge circulates more easily among organizations located in the same region than among organizations located at longer distances. Firms located in clusters would benefit from spatial proximity to other firms and relevant research institutes since this enhances the probability of knowledge flows to occur. This would then result in a better innovative performance of these firms compared to firms located outside a cluster.

The topic of clusters and localised knowledge spillovers has been extensively researched during the last decades. Empirical studies are ranging from spatial-econometric studies till in-depth case studies of specific regions. Although fundamentally different in their underlying theoretical assumptions, both type of studies generally conclude that knowledge externalities are to a large extent spatially bounded, resulting in specific advantages for firms located in clusters. Based on these outcomes, many researchers and policymakers have emphasized the role of the region for knowledge, innovation and economic development. Recently however several scholars have criticized this sometimes assumed encompassing importance of the region for several reasons (Breschi & Lissoni 2001, Martin & Sunley 2003). The concept of localized knowledge spillovers often remains a black box, used as a general argument for the explanation of the existence of clusters, without any reference to specific mechanisms. Furthermore the implicit or explicit assumption that all firms benefit in an equal way from being located in a specific region or cluster can be questioned, given the large variety between individual firms in the same industry and region. Finally the explicit focus on the importance of the region tends to overlook the possible importance of knowledge spillovers over longer distances. This has resulted in the current notion of several authors that in order to truly understand the relation between the (innovative) performance of a firm and its location, a firm level approach is necessary (see for example Beugelsdijk 2007, Boschma & Frenken 2006).

Based on these critical notions, several empirical studies are focussing on the regional dimension of the mechanisms behind knowledge externalities at the level of the firm (see for example Guiliani 2007) or the inventor (Breschi & Lissoni 2003). In this line of research, much attention has been given to the structure and the effect on firm performance of local networks of relations and knowledge exchange, which is generally considered to be one of the key-mechanisms behind localized knowledge spillovers. The outcomes of these studies generally confirm the importance of the firm as the proper unit of analysis since there are large differences in the extent that firms participate and benefit from these local networks (Boschma & Ter Wal 2007, Cantner & Graf 2006 and Guiliani & Bell 2005).

This study builds on this literature and tries to analyze the importance of knowledge flows based on contacts with other organizations for the innovative performance of firms. Although cluster studies on this topic generally focus on the role of the spatial dimension of these relations, other characteristics are regarded at least as important according to studies in other fields, like innovation or business studies on this topic. Therefore it seems that in order to determine the role of the spatial dimension of these contacts for the innovative performance of firms it is necessary to take several other characteristics into account as well.

This study contributes to the existing knowledge on the role of networks of knowledge exchange and clusters in two ways. First, this study analyzes what characteristics of knowledge flows matter for the innovative performance of firms in clusters without directly distinguishing between intra- and interregional contacts. Rather the focus lies on the effect of inter-organisational knowledge contacts in general and the possible effect that several characteristics of these contacts might have on innovation. The importance of the spatial dimension, defined as taking place inside or outside the region, of these contacts for innovation is compared with several other characteristics. A distinction is being made between the types of organizations involved; firms, research institutes and other organizations. Furthermore we differentiate between contacts that were based on a social background (such as a spin-off relation) and those that are not.

The second way is by comparing the importance of regional knowledge flows for the innovative performance of firms in two different industries. Until now, most studies have only examined the effect of knowledge flows on the innovative performance of firms for one industry (see for example Giuliani 2007 and Boschma & Terwal 2007). This study focuses on knowledge flows in the life sciences and the computing services in three concentration regions. Both industries are considered to be knowledge intensive and innovative, but differ strongly in their innovation processes. Life sciences have a strong scientific base whereas the innovation processes in computing services is mainly stirred by customer demands. The question is whether knowledge flows through inter-organizational contacts differ in their effect on innovation between these two industries.

This paper continues as follows. In the next part a short overview is given of the literature on the geography of innovation and the recent trend towards a firm level approach. The third part is largely based on the competence-based theory of the firm and focuses on different factors influencing the innovative performance of firms. Also the possible differences between life sciences and computing services with regard to these factors will be discussed. The fourth part will introduce the empirical case of this study and the operationalisation of the different factors. The fifth part discusses the results of the empirical analysis and section six concludes.

## **2. The geography of innovation**

The regional concentration of innovative activities has drawn the attention of a large range of scholars from different subfields. Albeit sometimes different in their theoretical background, ranging from the new endogenous growth theory towards concepts like learning regions (Morgan 1997), one of the central elements in these studies is the argument that knowledge spillovers are to a large extent spatially bounded.

The empirical evidence for the existence of localized knowledge externalities can be found in a large number of quantitative spatial-econometrics studies. Most of these studies are based on the application of a regional knowledge production function introduced by Jaffe (1989) whose findings suggested the presence of localized academic knowledge externalities at the level of US states. In these studies different indicators for knowledge inputs such as R&D expenditures are related to innovation at the regional level. Whereas in the nineties most studies were based on US cases (see for example Audretsch and Feldman 1996, Anselin et al. 2000), over time more and more studies have been performed for European countries as well (see for example Fritsch & Slavtchev 2007 and Del Barrio-Castro & Garcia-Quevedo (2005). In general the outcome is that the spatial range of knowledge spillovers is rather limited and therefore it is often concluded that the existence of localised knowledge spillovers

might be an important driver of the spatial concentration of industries (see for a recent overview Doring & Schnellbach 2006). The theoretical argument is often found in the distinction between tacit and codified knowledge, where the exchange of tacit knowledge is assumed to be eased by spatial proximity due to the importance of face-to-face contacts. In this way knowledge is partly seen as local public good or as specific type of club good, only accessible for organisations located in the physical proximity of the knowledge source. Given the fact that these studies have spatial units of analysis, a well-known critic is that these studies cannot provide insights in the exact mechanisms and causes behind localized knowledge spillovers (see for example Breschi & Lissoni 2001, Martin & Sunley 2003).

Another line of research, which is mainly rooted in economic geography, focuses precisely on the possible mechanisms of knowledge externalities. Most studies are based on a more qualitative case-study approach and generally provide detailed insights in different processes of knowledge exchange inside clusters. This has, amongst other things, resulted in a large number of theoretical concepts like industrial districts (Markusen 1996), regional innovation systems (Cooke 2001) and learning regions (Morgan 1997). A key element in these concepts and studies is the emphasis on importance of the regional level for knowledge exchange and relations between firms, knowledge institutes and governmental organisations. Knowledge externalities are localized here due to the fact that trust-based relations and informal contacts are the key mechanisms, which are in turn assumed to take place within the region. This has resulted in the assumption that the region and especially regional networks can be a crucial factor for the innovative performance of firms (Storper 1997). Some authors (see for example Markusen 2003 and Dicken and Malmberg 2001) however argued that this focus on the structures of relations at the regional level have lead to an 'over socialized' view on economic activities in a region, resulting in an overestimation of the importance of a region for the (innovative) performance of the firm. Furthermore, this focus on the importance of external relations has lead to an underestimating of the role of internal resources and processes for the innovative performance of firms.

Based on the critics on both types of research, various authors (Beugelsdijk 2007, Boschma & Frenken 2006, Martin & Sunley 2003, Maskell 2001) argue that in order to understand the importance of the region for innovation it is necessary to take the firm as unit of analysis and control for firm-specific characteristics. Empirical research based on these notions can be divided in two categories. First, several authors (Beugelsdijk 2007, Fritsch & Franke 2004, Sternberg & Arndt 2001) test whether specific characteristics of the location of the firm matter for the innovative or economic performance of a firm by taking firm-specific characteristics into account. Methodological improvements have recently been made by the application of multilevel models (see Raspe & Van Oort 2007). Although the impact of the regional environment is tested in a far better way, the region remains a black box here since no insights are given in the mechanisms that are important. The second type of research explicitly focuses on the spatial dimension of one potential mechanism of spillovers and relates this to the innovative performance of firms. Most authors focus on the importance of local knowledge flows and relationships (Guiliani 2007 and Boschma & Terwal 2007) and find that there large differences in the extent that firms participate and benefit from these local networks. The outcomes suggest that the presence of localised knowledge flows is not all encompassing across firms in a region, even when they are located in a cluster. As Boschma and Terwal (2007, pg 20) argue it is necessary to disentangle between the role of firm characteristics, place and networks in order to understand the relation between the innovative performance of firms and being located in a cluster.

### 3. The firm as unit of analysis

As stated above, one of the recent trends in research on the role of geography for innovation is to use of the firm as unit of analysis. As stated by Maskell (2001), this implies that it is necessary to have a theoretical view on the firm in order to determine relevant firm-specific factors that influence the innovative performance. Based on a review of various theories of the firm, he argues that the resource- or competence-based view of the firm (Wernerfelt 1984) seems most promising for economic geography, given that its basis features includes a possible role for interaction between a firm and its environment. According to this view a firm can be seen as a unique set of firm-specific competences and assets. Firms compete with each other on the base of these competences and assets. The most interesting part in this regard, is the fact the development of these competences can be the result of internal resources but also stem from access to external resources, for example by means of collaboration and interaction. In this study, contacts with other organisations through which knowledge is exchanged are considered to be the mechanism through which external resources for innovation are accessed. Since we are especially interested in the role of localized knowledge externalities through inter-organisational contacts, we will analyze the relative importance of the spatial dimension of these contacts in relation with other characteristics. This is done by testing the relation between the number and characteristics of contacts and the innovative performance of firms, controlling for specific characteristics and internal resources of each firm.

The resource based view of the firm focuses on the role of different resources for the innovative performance of firms. Various studies, mainly based in organisational and management literature, have analysed innovation at the firm level from this perspective (see for example Freel 2003). From these studies, different elements influencing the innovative performance can be distinguished. The first and rather clear-cut one, is investments in new knowledge. Firms that invest more in the generation of new knowledge are more likely to be successful in terms of innovation. Besides investments in the generation of knowledge, the quality of the employees, for example in terms of education, might be an important contributing factor. Both the level of investments in new knowledge and the quality of the employees are important factors determining the level and capability of internal knowledge generation. Furthermore, size and age are generally used as control variables. Due to the occurrence of internal economies of scale size can have a positive effect on the innovative performance of firms. However small firms might be more innovative due to a higher flexibility. Older firms are sometimes assumed to be less likely to innovate since new innovative products might interfere with existing products or services that are already in the market.

External knowledge sources can be accessed in different ways. The main focus here lies on the role of access to knowledge through contacts and relations with other organizations, since this is assumed to be among the most important mechanisms of localized knowledge spillovers (see for example Saxenian 1994). Trust and reciprocity over a longer period are generally considered to be key elements of these contacts. As stated earlier, an important assumption in the literature on the role of geography for innovation is the idea that spatial proximity is an important factor enhancing these types of relations. Firms located in clusters would benefit from spatial proximity to other firms and relevant research institutes since this enhances the probability of these type of knowledge flows to occur. As a result most studies on clusters have been focussing on the role of the regional dimension of inter-organisational

contacts and knowledge flows only. However several authors explicitly mention the possible importance of non-local linkages (Bathelt et al. 2004). Based on this, more recent studies have therefore also included extra-regional knowledge flows.

Even more important, the exact role of spatial proximity itself for knowledge exchange through collaboration and interaction has also been discussed in the recent literature (see for example Howells 2002, Boschma 2005). A central element in this discussion is the issue whether spatial proximity in itself is an important factor for knowledge exchange to occur. Breschi & Lissoni (2003) argue that knowledge is being exchanged between organisations through social networks of individuals tied to these organisations. Knowledge spillovers are localized to the extent that these social networks are localized. Rather than being a prerequisite for knowledge spillovers to take place, spatial proximity seems to play a more 'indirect and subtle role' (Howells 2002) by positively influencing the possibility that relations and contacts are being formed through which knowledge is being exchanged. Other mechanisms of knowledge spillovers such as spin-offs (Klepper 2002) and labour mobility also seem to be more frequently occurring at the regional level. So spatial proximity is important for knowledge spillovers to the extent that the key mechanisms of knowledge exchange take place at the local and regional level. Due to the fact that this does not necessarily have to be the case, Boschma (2005) argues that spatial proximity is neither a necessary nor a sufficient condition for knowledge flows to occur.

In this study the relation between inter-organisational contacts and innovative performance of firms is analyzed without differentiating towards spatial scales. The main reason for this is that the occurrence of knowledge spillovers is assumed to take place through networks of inter-organisational contacts. From a network perspective there might be no reason to expect that networks of knowledge flows are limited to a specific scale or that the effect of these contacts and flows differ across different spatial scales. Therefore the effect of knowledge spillovers through inter-organisational contacts on innovation is analyzed by looking at the effect of the sum of all relations. In order to examine the relation between the spatial dimension of these contacts and innovation, the effect of a higher regional share in the contacts of a firm on innovative performance is tested while controlling for the sum of all contacts. As stated above, several authors argue that geographical proximity can play a role to the extent that social proximity has a local or regional character (Breschi & Lissoni 2003 and Dahl & Pedersen 2004). Therefore the share of relations based on a common social background is also taken into account.

Although studies on the role of networks and interorganisational contacts from a cluster point of view have been focussing on the spatial dimension of these networks, research in the field of innovation and business studies emphasize other characteristics. Especially the importance of various types of organisations where knowledge is being exchanged has been subject of many studies (see for example Klevorick et al. 1995, Freel 2003). The literature on interactive learning emphasized the role of user-producer interaction and feedback (Freeman 1991). Frequent interaction with costumers and suppliers enhances knowledge on the market opportunities, offers ideas for new products and services and provides valuable feedback on new technologies (Tether 2002).

The relative importance of interaction with specific organisations might differ strongly across firms in different industries (Cohen et al. 2002). Various studies emphasize that industries differ strongly in their innovation processes in terms of sources, pace and means of appropriating knowledge (Pavitt 1984). Different authors have come up with conceptual

frameworks as sectoral systems of innovation (Malerba 2002) to describe these differences in a more theoretical framework. It would go beyond the scope of this study to describe in them detail here, but the notion of sectoral variation in innovation is very important here. Given the fact that processes of innovation differ strongly across industries, it seems reasonable to assume that firms in different sectors use different internal and external resources for innovation (Malerba 2004). Therefore the effect of knowledge externalities by means of inter-organizational contacts on the innovative performance of firms can be different across industries. In a similar way, specific characteristics of these contacts might be more important in some industries than in others.

These two sections can be summarized the following. The current line of research on clustering argues that in order to understand the relation between clustering and innovation a firm level perspective is necessary. Based on the often-assumed importance of networks of knowledge exchange within clusters, recent empirical studies focus on the effect of local and non-local inter-organisational contacts on the innovative performance of firms. However, if knowledge spillovers take place through these networks of inter-organisational contacts there is no reason to assume that the effect differs across spatial scales. Moreover studies from the field of innovation and management studies suggest that several other characteristics of inter-organisational relations might be as important or even more important than the spatial dimension. Therefore, in order to examine the role of the spatial dimension of knowledge flows through inter-organisational contacts it seems necessary take other characteristics of these contacts into account as well and to refrain from an a-priori distinction between regional and non-regional contacts.

#### **4. The context of this study**

This study focuses on the life sciences and software services industries in three concentration regions. These two industries have been selected since they are both considered to be knowledge intensive and highly innovative but differ strongly in their innovation processes. In this way, the comparison of these industries might provide valuable insights in the relative importance of the role of inter-organisational contacts as a mechanism for localized knowledge externalities. The life sciences industry is a well-researched sector nowadays and can be seen as a prime-example of a science-based industry as defined by Pavitt (1984) and Marsili (2002). Innovation in this industry is primarily based on (scientific) research and is therefore to a large extent science-driven in a way that comes very near the linear model of innovation. Given the fast progress in the scientific research in relevant fields, no individual firm is able to keep up with the development of new knowledge based on internal resources alone. Innovation increasingly depends on the capability to interact and collaborate with other firms (both other life sciences firms and large firms in the pharmaceutical and food industry) and especially scientific research institutes (Powell et al. 1996). As a result, inter-organisational contacts might play an important role as mechanisms for knowledge externalities here. The software services industry can be characterized as one of the most innovative industries within the business services. Firms within this industry generally combine the production and development of software with consultancy services. Frequent interaction with costumers is important since software services firms are often involved in solving costumers specific problems. Since knowledge of the demand of costumers is crucial for a firm to develop new products and services, interaction with costumers is assumed to be amongst the most important external sources of knowledge (Weterings 2006).

Since data on relations at the firm level are generally not available, these kinds of studies are generally based on surveys held in one or more regions (Kaufman & Tödtling 2001, Freel 2003, Giuliani 2005, Boschma & Terwal 2007). In this study we have selected two regions where life sciences firms are clustered and one region where software services firms are clustered. The main reason for selecting two regions in case of the life-sciences was the relative small number of firms in this industry. Although the life sciences industry is among the most intensively researched industries nowadays, in absolute terms it is a rather small industry. In the context of this study a cluster is simply defined as a spatial concentration of firms in the same industry<sup>2</sup>. Following Weterings (2006) the software services industry is defined as the first four sub-sectors within the computer services sector (NACE code 72)<sup>3</sup>. Figure 1 shows the relative spatial distribution of the employment of these four categories. Based on this, the region of Utrecht in the middle of the Netherlands and its surroundings is selected as the region of analyses. The life sciences industry is less easy to define. At this moment, the life sciences are no specific subcategory in industrial classification schemes. In order to select a relevant region, it is necessary to have insights in the spatial distribution of a relevant indicator of (innovative) activity in this industry. Following Acs et al. (2002), the spatial distribution of patents is considered to give a reasonable insight in the regional variations of innovative activity. Figure 2 shows the patterns of patent applications in the life sciences. Based on figure 2 the province of South-Holland and the province of Gelderland have been selected. The region of Leiden in the province of South-Holland and the region Wageningen in the province of Gelderland are well-known life sciences centres.

**Figure 1.** Relative spatial distribution of employment in software services in 2001

**Figure 2.** Relative spatial distribution of patents in life sciences between 1999 and 2001

This study has been based on a telephone questionnaire among firms in the two selected industries in the three regions. The names and addresses of these firms have been provided by two regional life sciences organisations where almost all firms in the two regions were registered. In a similar way a regional network organisation for software service firms has provided a list of firms in the region Utrecht. Although it is possible that there are firms that are not registered at these organisations, these lists represent a large majority of the population of the firms of interest. The questionnaire focussed on the contacts and relations of the firms through which knowledge is being exchanged. Firms were asked if and with which organisations they had contact if they were confronted with a specific problem. The firms were asked only to mention those contacts that significantly contributed to solving the problem. The collection of the data on the relations with other organisations was based on the so-called roster-recall method, stemming from social network methodology (Wasserman & Faust 1994). Firms were sent a list of names of organisations located in the same region and were asked to indicate whether they had contacted this firm if confronted with a problem during the last year (“the roster part”). This list consisted of all relevant research institutes and the most important firms in the region in the industry. Furthermore firms were asked to mention if they had contacted other organisations inside the region not mentioned on the list or organisations located outside the region (“the recall part”). In social network analysis, the roster method is considered to be far better than the recall method. However the roster method

---

<sup>2</sup> Note that there is a whole debate going on the definition of the concept of clusters ranging from authors stating that clusters can be defined as a spatial concentration of an specific industry till authors that argue one can only speak of a cluster in case of the presence of dense network of inter-organisational relations between firms, research institutes and governmental organisations.

<sup>3</sup> Nace codes 72101, 72102, 7220 and 7230

is based on the assumption that all potential 'partners' are known. Since this is hardly ever the case, the roster method is generally extended with a recall part (Wasserman & Faust 1994). For each contact with another organization, firms were asked to give information on the location of this organisation and the type of organisation (a distinction is being made between a research institute, a firm and a governmental organisation). Furthermore it was asked whether there was a common social background on which this contact was based. This has been defined as being a being former classmate or a former colleague or employee (Agrawal et al. 2006).

At the firm level, information on the size of the firms in number of fte employees and age have been collected as most important control variables. The quality of the workforce has been measured by the share of employees having a university or PhD degree. The choice of the indicator for knowledge inputs and innovation is more difficult. During the consultation of several experts in life sciences and computing services on the questionnaire it became clear that it was impossible to have the same indicators for both industries given their fundamental differences. This is in line with the literature on the appropriateness of specific innovation indicators for different industries (see for example Kleinknecht et al. 2002). The most straight forwarded indicator for innovation seems to be the one that is defined in the OECD and used in the community innovation studies (CIS); the share of new products and services in the turnover of a firm. This indicator can be relatively easy applied for the computing services sector, but is more problematic in case of the life sciences. Most dedicated life sciences firms, at least in the Netherlands, are mainly focussing on R&D activities for future products that are generally being developed in collaboration with larger firms. Turnover figures are not very useful here since most firms are not (yet) in the stage of development, let alone the stage of bringing these products to the market. If firms are at that stage their entire turnover is stemming from new products or services, which makes it not a very useful indicator here. However results of R&D activities are generally patented and licensed to larger firms. Given the fact that most firms are not very willing to give information on the income through licensing of their patents, the best option here seems to be the number of patents of a firm as indicator for innovation. Although the use of patents as indicator is widely discussed in the literature (see Griliches 1990), in case of life sciences it is generally considered to be a fairly good indicator of the innovative performance of firms. The investment in knowledge generation by a firm is measured by the share of employees devoted to R&D in case of life sciences and the development of new software or services in case of the software services.

The telephonic questionnaires have been conducted in the spring of 2006 among the owners or managing directors of the firms. This means that the data on the relations and contacts with other organisations refer to those organisations recognized by the director or owner as valuable. Needless to say that it is possible, especially in larger firms, that employees might have valuable contacts with other organisations that are not known by the director or owner. Some firms were removed from the original research population since they ceased their activities, moved or were listed more than once. The final research population consisted of 350 firms in the computing services sector and 120 life sciences firms (35 located in the province of Gelderland and 85 in the province of South-Holland). The response rate was relatively high with 38,8 % in case of the software services and 57 % for life sciences in Gelderland and 44.7 % in South-Holland. This resulted in a final research sample of 135 firms for Computing services and 57 for the life sciences. Unfortunately hardly any information was available on the firms that did not participate in the questionnaire, so it is difficult to perform a goodness of fit test whether the sample is representative for the population.

## 5. Results

The innovative output of a firm is here modelled as a function of the size of the internal resources, the external resources accessed through inter-organisational contacts and the moderating firm characteristics; size, age and sector. The main goal is to analyze the effect of the number of inter-organisational contacts and the characteristics of these contacts on the innovative performance of firms. The effect of the size of knowledge externalities is analyzed by relating to the total number of contacts with innovation without differentiating between spatial levels. The several distinguished characteristics have been taken into account by analyzing the effect of the share of the contacts that have the characteristic of interest. The effect of the spatial dimension of these contacts is taken into account by analyzing the effect of the share of regional contacts in the total number of contacts. Besides the spatial dimension, the effect of the share of contacts that are based on a common social background and the share of the contacts with research institutes and firms are taken into account. With this analysis some insights are given in the relative importance of the spatial dimension of inter-organisational contacts controlled for the total number of contacts and other characteristics.

Table 1 and 2 summarize the variables, their definition and the descriptive statistics of respectively the Computing services sector and the life sciences sector. Not all firms were willing or able to give an indication of their internal knowledge sources or their innovation input. This has resulted in a final number of 110 observations in case of the Computing services and 44 for the life sciences.

**Table 1.** Definition and descriptive statistics of the variables for the software services sector

**Table 2.** Definition and descriptive statistics of the variables for the life sciences

Some interesting differences between both industries can be observed when comparing table 1 and 2. On average a firm in life sciences is smaller and younger than a firm in the software services. Furthermore the share of employees with a university or PhD degree is on average higher in life sciences, which is probably related to the fact that R&D activities in life sciences are based on scientific research. This is also reflected in the fact that research institutes such as universities are far more important for inter-organisational contacts in life sciences than in software services. Finally it is noteworthy to mention that life sciences firms seem to be more regionally orientated than software services firms. Altogether these differences indicate that sectoral differences might play an important role in the relation between knowledge externalities through organisational contacts and the innovative performance of firms.

In both life sciences and computing services the variables size, age and the number of contacts have been transformed by taking the log. Table 3 and 4 show the correlation matrices of these and the other variables. For most variables the correlations values do not seem to imply potential problems of multicollinearity. In case of life sciences there is a high negative correlation between the share of contacts with firms and the share of contacts with research institutes. The main reason for this is the fact these firms in life sciences have hardly any contacts with other organizations types than these two, whereas a considerable amount of software services firms do, for example with regional branch organizations or governmental organizations. Within life sciences a negative correlation between size and quality of the workforce can be observed. Possibly, the reason for this is that there are many young and

small firms in this sector that cannot afford supporting employees such as a secretary or research assistants.

**Table 3.** Correlation matrix life sciences

**Table 4.** Correlation matrix Computing services

Table 5 and 6 presents the results of the main regression models of respectively the software services and the life sciences. Due to the differences in the way the dependent variable is measured two different types of regression models have been estimated. Since innovation in the Computing service sector is measured as share of new products or services in the total turnover, the value of this variable is limited between values 0 and 100. As a result a two-sided Tobit model seems to be the most appropriate estimation technique. In case of life sciences, the dependent variable is the number of patents, which has a count data character. Therefore a Poisson model is applied here. In order to account for potential differences between the two regions from which the firms in life sciences are pooled, a regional dummy is included here.

Several models have been estimated for both industries. The first model includes only the internal resources and the firm specific control variables size and age. For computing services, internal knowledge sources, measured by input and quality of the workforce, have a positive effect on the innovative performance<sup>4</sup>. Larger and younger firms also appear to have a higher innovative performance. In case of the life sciences knowledge inputs also has a positive effect on the innovative performance whereas the quality of the workforce has no significant effect. A possible reason for this might be the earlier mentioned fact that the majority of the work is related to scientific research, resulting in a relative small variation of this variable across the firms as can be seen in table 2.

**Table 5.** Regression results for computing service sector

**Table 6.** Regression results for life sciences

The second model includes the number of contacts. The main goal is to test the influence of the size of knowledge externalities through inter-organisational interaction without taking any of its characteristics into account. In case of computing services no significant effect of the number of contacts has been found, indicating that firms with more inter-organisational contacts are not more innovative. The number of inter-organisational contacts does have a positive significant effect on the innovative performance of firms on life sciences. This suggests that in case of life sciences knowledge flows through inter-organizational contacts is an important source of knowledge externalities. A finding that is in line with other studies on this issue (see for example Powell et al. 1996). There may be a possibility of a reverse causality (more innovative firms have more contacts) seems to be present. From a resource-based view of the firm however it seems plausible, at theoretical grounds, to assume that after controlling for internal resources firms that have more inter-organizational contacts are more

---

<sup>4</sup> Since the depended variable in case of the software services is defined as the share of new products and services in total turnover, there is a risk of a bias towards young firms since start-up firms by definition have a 100% share of new products and services in their turnover. This is partly taking care of by the control variable age. In order to check the robustness of the results we also estimated the models for firms older than three year only. With the exception of the insignificance of the variable age, the outcomes are similar.

innovative. This is also in line with empirical findings on collaboration and innovation in life sciences (Shan, 1994).

In order to verify whether these results are robust and the effect of knowledge exchange through inter-organizational knowledge relations does not differ across spatial scales, the third model includes regional and non-regional contacts separately. The outcomes indicate that the number of regional contacts and the number of non-regional contacts have indeed the same effect on the innovative performance of firms as the total number of contacts. Therefore in models 4 till 7 we test for the effect of three distinguished characteristics, controlling for the total number of inter-organizational contacts. Given the fact that in case of computing services the number of contacts did not have any significant effect and this holds as well for the different characteristics, we focus on the result for the life sciences. Model 4 includes the share of regional contacts as a characteristic for the spatial dimension. No significant effect is found, suggesting that controlling for the total number of contacts the level of regional interaction has no relation with the innovative performance of firms. Model 5 and 6 includes respectively the share of contacts based on a common social background and the share of contacts with research institutes together with the share of regional contacts. Both have a significant and positive effect on innovation suggesting that the higher the share of relations a firm has based on a common background the more innovative it is. Maybe these relations provide a firm with more valuable knowledge due to a higher level of mutual trust as a result of this background. Model 7 includes all three characteristics together. After controlling for the total number of inter-organisational contacts, only a higher share of contacts with research institutes seems to have a positive effect on the innovative performance of firms. These outcomes suggest that in case of life sciences, knowledge flows through inter-organizational contacts have a positive relation with the innovative performance of firms. With regard to the characteristics of these contacts, it seems to matter more with what type of organization you have contact than at what spatial scale.

## Conclusions

Recent empirical and theoretical studies on the role of the region for knowledge spillovers and innovation seem to agree that it is necessary to take a firm level perspective. Different empirical studies (Giuliani 2007, Boschma & Terwal 2007) analyze the role of regional and non-regional networks for the innovative performance of firms. This study builds on this line of research by analyzing the effect of knowledge flows through inter-organisational contacts on the innovative performance of firms in clusters of two different industries. If knowledge spillovers are assumed to take place through networks of inter-organisational contacts, there seems to be no specific reason to assume that the effect of these contacts differ across spatial scales. Therefore, contrary to most previous studies, this study does not focus on the effect of knowledge flows within the cluster, but on having knowledge contacts with other organisations *in general*. The main goal of this study is to analyze the effect of having inter-organisational knowledge contacts on the innovative performance of firms, and to further distinguish which characteristics of those contacts mainly seem to be relevant for knowledge flows among firms. One of those characteristics that is examined in the second step of the analysis is the spatial scale of the knowledge contact. In other words, the spatial scale of a knowledge contact is not the starting point of this analysis but considered as one of the characteristics that may effect innovation, making it possible to compare this effect with that of other potentially relevant characteristics. This is done for firms in three selected clusters in two knowledge intensive and innovative industries that differ in their processes of innovation; the software services industry and the life sciences.

The outcomes of the analysis suggest that there exist large differences between firms in different industries with regard to the effect of knowledge externalities through these contacts. Firms in the software services do not seem to benefit in terms of a better innovative performance from knowledge externalities through inter-organisational contacts, while in case of life sciences inter-organisational networks of knowledge contacts do seem to play an important role as a mechanism for knowledge externalities. In the latter industry, the number of contacts has a positive effect on the innovative performance of firms. This seems to be in line with the general findings on innovation processes in this industry where the innovative performance of firms increasingly depends on the capability to interact and collaborate with other firms and research institutes. In the software services industry, other sources or mechanisms of knowledge externalities may be more important. Weterings (2006) shows for example that inputs from costumers and forums on the internet form important sources to access external knowledge in this industry. These findings seem to imply that the importance and role of specific mechanisms of knowledge externalities are industry specific. If these knowledge externalities are an important driver behind the process of spatial concentration and clustering, the mechanisms of clustering also seem to differ across industries.

The second important finding follows from controlling for the effect of different characteristics of inter-organisational contacts on the innovative performance of life sciences firms. The share of regional contacts in the total number of relations did not have any extra effect on the innovative performance of firms next to the total number of relations, whereas the share of relations with research institutes did. Although on average more than 60 percent of the contacts of life sciences firms take place at the regional level, there is no additional benefit in terms of a better innovative performance in having a higher share of regional contacts. This seems to confirm the more recent view that spatial proximity plays a more indirect role in enabling the establishment and maintenance of inter-organisational knowledge contacts. Possibly, firms outside clusters are confronted with more difficulties and higher costs in finding and maintaining contacts with other organisations. If this is the case, firms in cluster might benefit indeed in terms of knowledge externalities from being located there but 'in a more subtle and indirect way' than often assumed. However, in order to conclude more decisively on this subject, more research is necessary. This study only examines the knowledge contacts of firms within clusters. Future studies should further examine the possible differences between firms inside and outside clusters with regard to the number and effect of knowledge flows through inter-organisational contacts.

## References

- Acs Z, Anselin L and Varga A. (2002) Patents and innovation counts as measures of regional production of new knowledge. *Research Policy* 31 (7): 1069-1085
- Agrawal, A., Cockburn, I., McHale, J. (2006) Gone but not forgotten: knowledge flows, labor mobility, and enduring social relationships. *Journal of Economic Geography*, 6: 571–591.
- Anselin L, Varga A and Acs Z (2000) Geographic and sectoral characteristics of academic knowledge externalities. *Papers in Regional Science* 79: 435-445
- Audretsch DB, Feldman MP (1996) R&D spillovers and the geography of innovation and production. *American Economic Review* 86(3): 630-640
- Bathelt H., Malmberg A. & Maskell P. (2004) Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography* 28 (1): 31-56.
- Beugelsdijk S. (2007) The regional environment and a firm's innovative performance; a plea for a multilevel interactionist approach. *Economic Geography* vol. 83.2, p. 181-199
- Boschma R.A. (2005a), Proximity and innovation. A critical assessment, *Regional Studies* 39 (1): 61-74.
- Boschma, R.A. & A.L.J. ter Wal (2007), Knowledge networks and innovative performance in an industrial district: the case of a footwear district in the South of Italy. *Industry and Innovation* 14 (2), pp. 177-199
- Boschma, R.A. & K. Frenken (2006), Why is economic geography not an evolutionary science? *Journal of Economic Geography* 6 (3), pp. 273-302
- Breschi, S. and Lissoni, F. (2003) Mobility and Social Networks: Localised Knowledge Spillovers Revisited. *CESPRI Working Paper* 142.
- Breschi, S. and Lissoni, F. (2001) Localised knowledge spillovers vs. innovative milieux: Knowledge "tacitness" reconsidered. *Papers in Regional Science* 80 (3): 255-273
- Cantner, U. & H. Graf (2006) The Network of Innovators in Jena: An Application of Social Network Analysis. *Research Policy* 35 (4): 463-480.
- Cohen, W.M., R.R. Nelson and J. Walsh. 2002. Links and Impacts: The Influence of Public Research on Industrial R&D. *Management Science* 48: 1-23.
- Cooke P. (2001) Regional innovation systems, clusters, and the knowledge economy, *Industrial and Corporate Change* 10 (4): 945-74.
- Dahl MS, CØR Pedersen (2004) Knowledge flows through informal contacts in industrial clusters: myth or reality? *Research Policy* 33 (10): 1673-1686

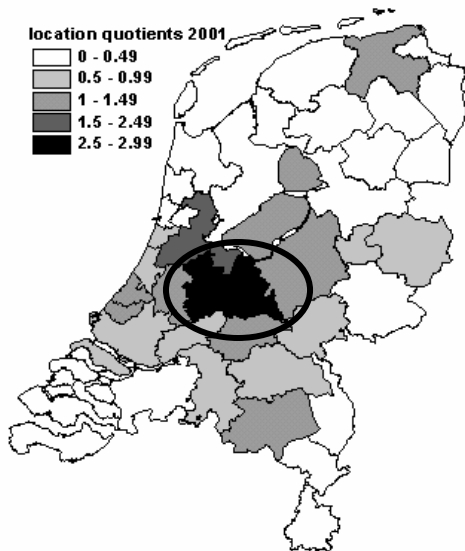
- Del Barrio-Castro and Garcia-Quevedo (2005) Effects of University research on the Geography of Innovation. *Regional Studies* 39(9):1217-1229
- Dicken P. and A. Malmberg (2001) Firms in Territories: A Relational Perspective. *Economic Geography*, 77 (4): 345-363
- Doring T. & J. Schnellenbach (2006) What do we know about geographical knowledge spillovers and regional growth?: A survey of the literature. *Regional Studies* 40 (3) 375-395
- Freel M.S. (2003) Sectoral patterns of small firm innovation, networking and proximity. *Research Policy* 32 (5), 751-770
- Freeman C. (1991) Networks of innovators: a synthesis of research issues. *Research Policy* 20 499-514.
- Frenken, K. & R.A. Boschma (2007), A theoretical framework for economic geography: industrial dynamics and urban growth as a branching process. *Journal of Economic Geography* 7 (5), pp. 635-649
- Fritsch M and Slavtchev V (2007) Universities and innovation in space. *Industry and innovation* 14(2): 201-218
- Fritsch M. & G. Franke (2004) Innovation, regional knowledge spillovers and R&D cooperation *Research Policy* 33 (2): 245
- Giuliani E. & Bell M. (2005) The micro-determinants of meso-level learning and innovation. Evidence from a Chilean wine cluster, *Research Policy* 34: 47-68.
- Griliches Z.(1990) Patent Statistics as Economic Indicators: A Survey. *Journal of Economic Literature* 28 (4): 1661-1707
- Guiliani E. (2007) The selective nature of knowledge networks in clusters: evidence from the wine industry. *Journal of Economic Geography* 2007 7(2):139-168
- Howels JRL (2002) Tacit knowledge, innovation and economic geography. *Urban Studies* 39 (5): 871-884
- Jaffe, AB (1989) Real effects of academic research. *American Economic Review* 79 (5): 957-970
- Kaufman & Tödting (2001) Science-Industry Interaction in the Process of Innovation: The Importance of Boundary-Crossing between Systems. *Research Policy* 30 (5), 791-804
- Kleinknecht (2002) The Non-Trivial Choice between Innovation Indicators. *Economics of Innovation and New Technology* 11 (2): 109-121
- Klepper S. (2002) The Evolution of the US Automobile Industry and Detroit as its Capital. Paper presented at the 9th Congress of the International Schumpeter Society in Gainesville.

- Klevorick, A .K., R.C. Levin, R.R. Nelson. & S.G. Winter (1995). On the sources and significance of interindustry differences in technological opportunities. *Research Policy*, 24(2),185-205.
- Malerba (2002) Sectoral systems of innovation and production. *Research Policy* 31: 247–264
- Markusen A. (1996) Sticky Places in Slippery Space: A Typology of Industrial Districts. *Economic Geography* 72 (3): 293-313
- Markusen, A. (2003) Fuzzy Concepts, Scanty Evidence, Policy Distance: The Case for Rigour and Policy Relevance in Critical Regional Studies. *Regional Studies* 37(6&7): 701–717
- Martin R. & P. Sunley (2003) Deconstructing clusters: chaotic concept or policy panacea? *Journal of Economic Geography*, 3 (1): 5-35
- Maskell P. (2001) The Firm in Economic Geography. *Economic Geography*, 77 (4): 329-344
- Morgan, K (1997) The Learning Region: Institutions, Innovation and Regional Renewal. *Regional Studies* 31 (5) 491-503
- Pavitt K (1984) Sectoral patterns of technical change: towards a taxonomy and a theory. *Research Policy* 13: 343-373
- Powell WW, Koput K, Smith-Doerr L (1996) Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology. *Administrative Science Quarterly* 41: 116-145
- Raspe & Van Oort 2007 What When Space Matters Little For Firm Productivity? A multilevel analysis of localised knowledge externalities. PEEG working paper 0706. Utrecht University, Section of Economic Geography.
- Saxenian, (1994) *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Harvard University Press, Cambridge, MA (1994).
- Shan W., G. Walker, B. Kogut (1994) Interfirm Cooperation and Startup Innovation in the Biotechnology Industry. *Strategic Management Journal*, 15( 5): 387-394
- Storper M. (1997) The Resurgence of Regional Economies, Ten Years Later. The Region as a Nexus of Untraded Interdependencies. *European Urban and Regional Studies*, 2 (3): 191-221
- Tether B.S. (2002) Who co-operates for innovation, and why. An empirical analysis. *Research Policy* 31 (6), 947-967.
- Wasserman S. & Faust K. (1994) *Social network analysis. Methods and applications*. Cambridge University Press, Cambridge Massachusetts
- Wernerfelt, B (1984) A Resource-Based View of the Firm. *Strategic Management Journal*, 5 (2): 171-180

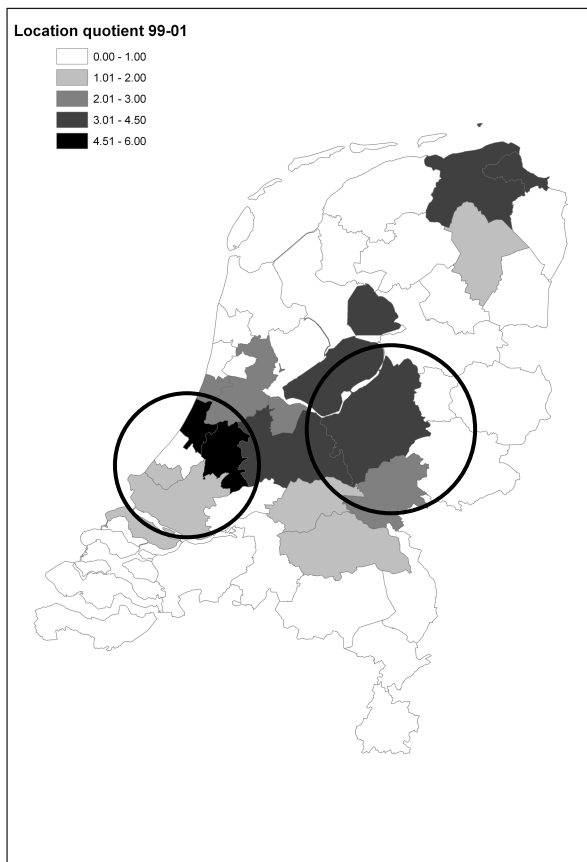
Weterings (2006) Do firms benefit from spatial proximity?: testing the relation between spatial proximity and the performance of small software firms in the Netherlands. PhD thesis. NGS 336.

## Figures and tables

**Figure 1.** Relative spatial distribution of employment in software services in 2001



**Figure 2.** Relative spatial distribution of patents in life sciences between 1999 and 2001



**Table 1.** Definition and descriptive statistics of the variables for the computing services sector

Variable	Definition	Obs	Mean	Std.	Min	Max
Innovation	Share of new products and services in total turnover	110	53.06	32.34	0	100
Input	Share of employees in fte involved in development of new products or services	110	46.40	31.20	0	100
Size	Number of employees in fte	110	33.10	108.55	0.8	1100
Age	Number of years between starting year and 2006	110	8.95	6.25	0	34
Quality workforce	Share of employees that have a university or PhD degree	110	31.11	30.45	0	100
Number of contacts	Total number of contacts	110	2.86	2.80	0	12
Share regional	Share of regional contacts	110	50.22	41.50	0	100
Share social	Share of contacts based on a common social background – former colleagues or classmates	110	15.31	29.57	0	100
Share research	Share of contacts with research institutes	110	7.64	21.28	0	100
Share firms	Share of contacts with firms	110	48.59	42.75	0	100

**Table 2.** Definition and descriptive statistics of the variables for the life sciences

Variable	Definition	Obs	Mean	Std.	Min	Max
Region	Dummy variable taking value 1 if a firm is located in Gelderland and 0 if located in South-Holland	44	0.43	0.50	0	1
Innovation	Number of patents	44	2.09	3.61	0	18
Input	Share of employees that are actively involved in R&D activities	44	63.84	31.51	10	100
Size	Number of employees in fte	44	14.82	20.43	1	80
Age	Number of years between starting year and 2006	44	5.66	4.74	0	17
Quality workforce	Share of employees that have a university or PhD degree	44	59.05	29.80	9.1	100
Number of contacts	Total number of contacts	44	6.05	4.47	0	24
Share regional	Share of regional contacts	44	62.80	35.40	0	100
Share social	Share of regional contacts based on a common social background	44	23.09	28.18	0	100
Share research	Share of contacts with research institutes	44	38.32	34.00	0	100
Share firms	Share of contacts with firms	44	46.59	36.57	0	100

**Table 3.** Correlation matrix computing services

	Innovation	Input	Size	Age	Quality workforce	Number of contacts	Share regional	Share social regional	Share research	Share firms
Innovation	1.00									
Input	0.46*	1.00								
Size (log)	-0.53*	-0.18	1.00							
Age (log)	-0.46*	-0.32*	0.60*	1.00						
Quality workforce	0.10	0.32*	0.03	-0.01	1.00					
Number of contacts (log)	-0.09	-0.04	0.24*	0.04	0.15	1.00				
Share regional	-0.02	-0.06	0.18	0.11	0.10	0.52*	1.00			
Share social regional	0.05	0.06	0.05	0.00	0.03	0.07	0.05	1.00		
Share research	0.13	0.19*	-0.09	-0.18	0.21*	0.08	0.20*	-0.14	1.00	
Share firms	-0.08	-0.13	0.20*	0.05	0.06	0.55*	0.33*	0.36*	-0.27*	1.00

**Table 4.** Correlation matrix life sciences

	Region	Innovation	Input	Size	Age	Quality workforce	Number of contacts	Share regional	Share social regional	Share research	Share firms
Region	1.00										
Innovation	0.29	1.00									
Input	0.17	0.31*	1.00								
Size	0.16	0.49*	0.08	1.00							
Age	-0.11	-0.05	-0.33*	0.32*	1.00						
Quality workforce	-0.42*	-0.12	0.03	-0.45*	-0.25	1.00					
Number of contacts	0.06	0.36*	0.07	0.10	0.06	-0.08	1.00				
Share regional	0.31*	0.11	0.17	-0.06	-0.17	-0.17	0.04	1.00			
Share social regional	0.02	0.07	0.10	0.03	0.11	-0.22	-0.01	0.05	1.00		
Share research	0.08	0.11	0.24	-0.21	-0.15	0.19	0.08	-0.05	0.44*	1.00	
Share firms	0.16	-0.01	-0.18	0.10	0.01	-0.21	0.07	0.04	-0.30*	-0.77*	1.00

**Table 5.** Regression results for computing service sector

	1	2	3	4	5	6	7
Input	0.457** (0.109)	0.457** (0.109)	0.456** (0.109)	0.462** (0.109)	0.459** (0.109)	0.459** (0.108)	0.454** (0.109)
Quality workforce	0.324** (0.096)	0.336** (0.097)	0.336** (0.097)	0.336** (0.096)	0.336** (0.096)	0.317** (0.097)	0.315** (0.097)
Size (log)	12.497* (7.182)	14.062* (7.407)	14.154* (7.471)	14.178* (7.398)	13.940* (7.416)	14.297* (7.373)	13.938* (7.386)
Age (log)	-35.141** (13.043)	-36.441** (13.092)	-36.606** (13.138)	-35.726** (13.137)	-35.629** (13.131)	-33.689** (13.211)	-33.370** (13.207)
Number of regional contacts (log)			-5.662 (10.149)				
Number of non-regional contacts (log)			-6.130 (11.947)				
Number of contacts (log)		-7.789 (9.286)		-5.234 (10.692)	-5.354 (10.690)	-4.811 (10.661)	-4.955 (10.653)
Share regional				-0.039 (0.082)	-0.040 (0.082)	-0.059 (0.083)	-0.061 (0.083)
Share social					0.038 (0.097)		0.058 (0.098)
Share research						0.186 (0.153)	0.200 (0.154)
Constant	31.792** (14.665)	34.560** (14.975)	34.302** (14.978)	34.264** (14.959)	34.137** (14.957)	32.478** (14.959)	32.137** (14.957)
N	110	110	110	110	110	110	110
Number of left-censored observations	5	5	5	5	5	5	5
Number of right-censored observations	13	13	13	13	13	13	13
McKelvey and Zavoina's R2	0.34	0.34	0.34	0.35	0.35	0.36	0.36

**Table 6.** Regression results for life sciences

	1	2	3	4	5	6	7
Input	0.013** (0.007)	0.017** (0.006)	0.017** (0.007)	0.017** (0.007)	0.020** (0.008)	0.020** (0.008)	0.020** (0.008)
Quality workforce	0.006 (0.011)	0.004 (0.011)	0.006 (0.008)	0.004 (0.010)	0.008 (0.009)	0.004 (0.007)	0.005 (0.008)
Size (log)	1.765** (0.342)	1.690** (0.307)	1.867** (0.289)	1.726** (0.294)	1.786** (0.330)	2.072** (0.355)	2.060** (0.358)
Age (log)	-0.508 (0.746)	-0.563 (0.592)	-0.883 (0.548)	-0.602 (0.588)	-0.366 (0.546)	-0.538 (0.356)	-0.495 (0.396)
Number of regional contacts (log)			0.776** (0.353)				
Number of non-regional contacts (log)			1.063** (0.462)				
Number of contacts (log)		1.443** (0.502)		1.467** (0.504)	1.543** (0.517)	1.415** (0.492)	1.433** (0.495)
Share regional				-0.003 (0.007)	-0.004 (0.007)	0.000 (0.004)	0.000 (0.004)
Share social					0.011* (0.006)		0.002 (0.006)
Share research						0.012** (0.005)	0.012** (0.005)
Region	0.469 (0.450)	0.099 (0.352)	0.191 (0.377)	0.156 (0.384)	0.190 (0.373)	-0.040 (0.384)	-0.014 (0.382)
Constant	-2.451* (1.283)	-3.501** (1.287)	-3.400** (0.916)	-3.428** (1.258)	-4.418** (1.369)	-4.660** (1.233)	-4.759** (1.245)
N	44	44	44	44	44	44	44
Loglikelihood	-82.930	-75.120	-73.192	-74.802	-72.647	-69.342	-69.274
McFadden's Adj R2	0.31	0.36	0.36	0.36	0.36	0.39	0.38