Does spatial proximity to customers matter for innovative performance?

Evidence from the Dutch software sector

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Abstract

User-producer interactions are an important source of innovation. Often spatial proximity between organisations is assumed to contribute to such interactive learning processes, because it facilitates face-to-face interactions required to exchange knowledge. However, this assumption has been hardly tested empirically. Using firm-level data, we found that spatial proximity of small Dutch software firms to customers facilitates face-to-face interactions, but it does not affect the firm’s innovative performance, not even indirectly through facilitating interactions. Regular interactions or collaboration with customers does increase the likelihood that software firms bring new products to the market, but those customer contacts do not improve innovation output.

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1 Introduction

Since the 1990s, innovation is regarded as the outcome of an interactive learning process in which interactions between organisations serve as key vehicles of knowledge transfer (Lundvall, 1988). Through their relationships with business partners, firms can gain access to external knowledge. Especially user-producer interactions are often considered to be key sources of innovation (Von Hippel, 1988; Ragatz et al., 1997; Romijn and Albu, 2002). An assumption often found in economic geography is that spatial proximity between organisations facilitates such interactions (Torre and Rallet, 2005). Consequently, co-located organisations would exchange more knowledge and, as a result, have a higher innovative performance.

However, both the importance of inter-organisational relationships with regard to the innovative performance of firms and the stimulating effect of spatial proximity have been criticised in more recent literature. There is an increasing awareness that the importance of external contacts for a firm’s innovative performance tends to be overemphasised, leading to a tendency to overlook the relevance of a firm’s internal ability to develop innovations and to benefit from external knowledge (Oerlemans et al., 1998; Freel, 2003). In addition, hardly any empirical study has tested whether the positive effect of spatial proximity on face-to-face interactions may explain regional differences in innovation. Empirical evidence supporting these assumptions would be useful, since recent studies argue that the relevance of spatial proximity for knowledge exchange has been exaggerated (see Gertler, 2003; Boschma, 2005).

With regards to these criticisms, this paper serves the following purpose. Using firm-level data on the interactions between Dutch software firms and their customers, we
actually test the assumption that spatial proximity facilitates face-to-face interactions between firms. To find out whether this also increases the innovative performance of the software firms, we examine the effect of spatial proximity and face-to-face interactions with customers on the software firm’s innovative performance. Small software firms are an interesting case for this topic, because most innovations made by small software firms follow from the specific needs of customers, as many firms focus on niche markets (Isaksen, 2004). Therefore, user-producer interactions are likely to be an important mechanism for knowledge transfer in this sector.

This paper is structured as follows. Section 2 provides a critical overview of the reasons why inter-organisational relationships and spatial proximity are assumed to be relevant for innovation. Section 3 introduces the empirical case, providing information on the data source. The different sources of innovation in the Dutch software sector are described in section 4, showing the high importance attached to customers as a source of innovation in this sector. Section 5 sets out the variables and research method that are used to test the hypotheses. Section 6 presents the empirical results. The paper ends with some conclusions.

2 Theoretical framework and hypotheses

2.1 Inter-organisational relationships as a source of innovation

Following Nelson and Winter (1982), firms are subject to bounded rationality and, consequently, are unable to gather and interpret all necessary information for optimal decision-making. They rely on routine behaviour to deal with this uncertainty. Broadly speaking, routines are stable patterns of behaviour that characterise organisational reactions to internal and external stimuli. Large parts of these routines consist of tacit
knowledge, because they are semi-automatic responses that have developed from experience. Since the search for new knowledge goes along with a high degree of uncertainty, firms will rely and build on their existing knowledge base. As a result, knowledge accumulates incrementally within the firm, becoming a firm-specific resource.

Inter-organisational relationships are assumed to be important for a firm’s innovation potential, because most innovations occur when various firm-specific competences are combined (Noo teboom, 1999). Since the tacit components of firm-specific routines are hard to copy (Kogut and Zander, 1996), accessing external knowledge would require the establishment of actual relationships between organisations. The basic motivation for a firm to approach other organisations to obtain knowledge is to bring together complementary skills without having to make the high investments that would have been necessary if the firm had developed it internally (Tether, 2002). Business relationships can also function as information-gathering, information-processing or screening devices that help determine promising developments and dead ends early on (Freeman, 1991).

Both in economic geography, but also in innovation studies, it is often assumed that individual firms are rarely capable of innovating independently (Freel, 2003). Nevertheless, in most industries, most of the innovation effort is still made by firms themselves (Nelson, 2000). Even when firms involve external partners in their innovation process, they depend to a considerable degree on their own internal resources (Oerlemans et al., 1998). If a firm is to exchange knowledge successfully, it needs to have a certain level of absorptive capacity: it needs to be able to identify, exploit and integrate the external knowledge into its own knowledge base (Cohen and
Levinthal, 1990). To some extent, the internal and external knowledge should be similar, if a firm is to value the potential relevance of the external knowledge. At the same time, the knowledge should not be too similar, because that would prevent firms from learning from one another (Nooteboom, 1999).

2.2 Spatial proximity, face-to-face interactions and innovation

Spatial proximity between organisations is assumed to facilitate interactive learning processes for two reasons (Gertler, 2003). Firstly, it is assumed that firms that are located near one another are more likely to meet and, therefore, establish a relationship. Co-located firms can more easily arrange the necessary face-to-face interactions and, in this way, allow knowledge to pass from one firm to another. Secondly, people that live or work in the same region are more likely to speak the same language, have common ‘codes’ of communication, shared conventions and norms, and personal knowledge of each other based on a past history of successful collaboration or informal interaction. This enhances the likelihood that they establish a degree of trust that is required to exchange firm-specific knowledge and, in case of complex knowledge, that they are in a position to understand the knowledge that is being offered.

In the economic geography literature, the relevance of spatial proximity for the exchange of knowledge is assumed to follow from the distinction between codified and tacit knowledge (Brown and Duguid, 2000). Codified knowledge consists of messages or information that can be written down in articles or software routines and, consequently, can be exchanged over long distances. Tacit knowledge, however, is much more difficult to be expressed in an explicit form, because it cannot be written down, is partly unconscious, and defies easy articulation (Gertler, 2003). Such
knowledge is best acquired through experience, demonstration and practice (learning-by-doing) which requires personal interactions. Therefore, spatial proximity is seen as facilitating the exchange of tacit knowledge.

This view on codified and tacit knowledge has been criticised, because tacit and codified knowledge are not two distinct types of knowledge, but should be viewed as the two end’s of a continuum (Cowan et al., 2000; Lissoni, 2001; Howells, 2002; Gertler, 2003). However, this hardly changes the argument on the relevance of spatial proximity for knowledge exchange. It only implies that the relation between spatial proximity, interactions and knowledge transfer should be viewed as follows: the more tacit the knowledge exchanged, the higher the potential relevance of spatial proximity, because exchanging more tacit knowledge increases the need for personal interactions which are facilitated by short distances.

Although the criticism on the distinction between tacit and codified knowledge has only limited effect on the assumption that spatial proximity facilitates the exchange of knowledge between firms and thus leads to a higher innovative performance, there has been criticism in more recent literature which more severely affects this assumption. There are four reasons to suspect that the relation between spatial proximity, regular face-to-face interactions and the innovative performance of firms is more complicated than is generally assumed.

The first reason is that the need for regular face-to-face contacts for the transfer of tacit knowledge does not automatically mean that individuals have to be located close to one another, but only that they meet frequently (Rallet and Torre, 2000). In many cases, face-to-face contacts can be arranged on a temporary basis, for example through
business travel. In the last decades, people have become more mobile due to developments in transportation and telecommunication. Many firms already use temporary spatial proximity, for instance, through consultant visiting and auditing a firm for several days or employees taking part in conferences or fairs (Gallaud and Torre, 2005). Consequently, one may wonder if spatial proximity between firms is necessary for face-to-face interactions to take place.

The second reason why the relevance of spatial proximity for knowledge transfer should be put into perspective is that the necessity for face-to-face interactions is likely to diminish when the firm grows older. Often it is simply assumed that spatial proximity will invariably be beneficial to the innovative capabilities of a firm. However, the need for regular interactions is likely to diminish during the life cycle of the firm, reducing also the need for spatial proximity. Initially, new firms have to establish a reputation among customers and need to obtain information about the market to ensure that their product matches customer demands. Over time, the need for external contacts with customers is likely to lessen. Since face-to-face interactions involve costs, especially in terms of time, firms will have an incentive to reduce the number of interactions (Illeris, 1996). Moreover, interactions between firms that have worked together on various occasions will become more efficient, which means that fewer contacts will be needed. Firms may also have established trust-based relationships due to positive business experiences, and these are likely to require fewer face-to-face interactions. The latter reason contradicts the notion that trust-based relationships of firms are often characterised by higher numbers of interactions, as argued in the embeddedness literature (Oerlemans et al., 1998). According to this literature, regular personal interactions between exchange partners are needed to establish a certain level of trust.
However, as soon as trust has been developed, people can rely on different channels of communication to exchange information or even knowledge. Face-to-face interactions may still be required at critical moments in the innovation process but, in between, communication through e-mail or telephone is sufficient (Gallaud and Torre, 2005). Consequently, the importance of external relationships is not necessarily related to the number of face-to-face interactions between firms. Furthermore, if the interaction frequency is high, it may even indicate a lack of trust (Freel, 2003).

A third argument why the relation between spatial proximity, face-to-face interactions and innovative performance is likely to be more complicated is that too many interactions between firms and too much spatial proximity may limit the firm’s innovation potential (Boschma, 2005; Torre and Rallet, 2005). When the relationship between firms becomes too close, a firm may suffer from so-called overembeddedness (Uzzi, 1997). This may lead to a reduced awareness of the knowledge and developments outside the inter-organisational relationship. Firms that are involved in this kind of relationship may even feel morally obligated to stay loyal to their partner, and thus end up choosing a less efficient way of production (Uzzi, 1997). In a similar manner, Grabher (1993) has argued that firms that focus too much on local relationships become less aware of technological and market-related developments outside their region. Knowledge creation would require a balance of local and non-local connections, because non-local relationships bring variety and new impulses and ideas into the region (Asheim and Isaksen, 2002; Bathelt et al., 2004; Giuliani and Bell, 2005). Firms that are involved in relationships that are too tight or focus too much on their own region may find it harder to adapt to external changes, which may reduce their innovative capacity (Boschma, 2005).
Finally, recent literature suggests that spatial proximity can only indirectly affect a firm’s innovative performance (Howells, 2002; Torre and Rallet, 2005). Spatial proximity facilitates the face-to-face interactions between firms that are necessary for the exchange of tacit knowledge. Consequently, it is those face-to-face interactions that lead to the higher innovative performance, not spatial proximity per se.

Following from these arguments, we can formulate four hypotheses on the relation between spatial proximity and face-to-face interactions between software firms and their customers, and how these affect the innovative performance of software firms:

1. spatial proximity between software firms and their customers is positively related to the number of face-to-face interactions between those firms;
2. the age of the software firm is negatively related to the number of face-to-face interactions between these firms and their customers, and this reduces the need for spatial proximity;
3. the effects of spatial proximity and the number of face-to-face interactions between software firms and customers on the innovative performance of software firms are positive, but only up to a certain threshold;
4. the positive effect of face-to-face interactions on the innovative performance of firms is strengthened by spatial proximity between the organisations.

These hypothesis will be tested in the remaining part of this paper.

3 Data and measuring innovation

To test these four hypotheses, we gathered cross-sectional data by a survey among 265 software firms located in the Netherlands. The data were drawn from two consecutive telephone surveys. The first survey was conducted in October and November 2002,
while the second extended survey was held in June and July 2003. The first survey was used to identify the research population. We randomly selected half of all firms with two or more full-time employees that are registered at the Dutch Chamber of Commerce at NACE codes 72101, 72102, 7220 and 7230. One-man businesses have been excluded from our study. Previous empirical studies showed that these firms are often not eligible, because these firms are often part-time activities of persons who also work at other firms, or they never became economically active (see Bleichrodt et al., 1992). The selected 4,144 firms have all been approached by telephone. A large number of these firms were not eligible, because firms had quitted their activities, or they appeared not to be specialised in ICT. The first questionnaire resulted in the reactions of 1,608 ICT firms. As we wanted to avoid the results to be affected by differences in activities and types of firms, the firms had to meet two other criteria. Firstly, firms had to develop their own software with the aim to sell the product directly on the market to ensure that their main activities are similar. Secondly, the firms had to be independent. Out of all firms, 617 interviewed firms met these criteria. These firms were approached again for a more extended telephone survey. All respondents were interviewed about their innovative performance, the sources of innovation that they used and the various characteristics of the relationship they had with their customers. The response rate was 43%, resulting in 265 firms in the dataset. A difference of means Z test and the Z test for proportions showed that this sample is representative for the total research population with respect to size, registration at NACE codes and location of the firms in the Netherlands.
The software sector is part of business services. Innovation in services is regularly assumed to have specific characteristics: there is close interaction between user and producer that leads to continuous adaptations to customer requirements, services have a high information content which makes them intangible, and services are often a combination of hard products like software and soft parts of human skills or practices (Gallouj, 2002; Hollenstein, 2003). Due to these characteristics, innovation in services is difficult to measure (Djellal and Gallouj, 2000). Most solutions are tailor-made, which makes it difficult to distinguish a small change to a product from a real innovation, and most innovations focus on quality improvement rather than higher productivity (Steiner et al., 2001).

We measured the innovative performance of software firms through a survey using similar questions as the Community Innovation Survey (CIS). In order to distinguish innovative firms from non-innovators in our survey, respondents were asked if they brought any new products or services to the market between 2000 and 2003. If so, the respondent were asked to estimate the percentage of current turnover due to the sales of those new products or services, as an indicator of the firm’s innovation output. With these questions, it is possible to obtain insights in the innovative behaviour of firms that hardly patent their products or do not have R&D departments, such as software firms (Chabchoub and Niosi, 2005). Furthermore, these indicators take the success of the new product on the market into account, contrary to more traditional indicators like R&D investments and patents which only provide information on the inputs (Kleinknecht et al., 2000).

A disadvantage of measuring innovation with a survey is that respondents can only give ‘rough estimates’ of the percentages used to measure innovation output. Therefore, the
answers can be affected by subjectivity (Tether, 2003). However, this is especially a problem when a comparison is made of the innovative performance among firms active in different sectors. In this study, we only compare the innovative performance of firms in the same industry and, therefore, our results are less likely to be affected by this.

We excluded 46 firms that were younger than 3 years from our dataset to avoid a bias to the indicators of innovation. This is because the new product of these firms is often their first product and, consequently, their innovation input and output will often be 100%.

Of the 219 remaining firms, 42 firms did not introduce any new products to the market in the period 2000-2003 and 12 firms did not yet gain any turnover from the sales of the new products that they developed. These firms are considered to be non-innovators. In total 165 entrepreneurs confirmed that their firm had brought new products to the market. Therefore, about 75% of the firms could be said to be innovative. This percentage is relatively high, probably because the business cycle of software products is relatively short and small software firms specialise in sector-specific products aimed at small niche markets (Weterings, 2006).

4 Sources of innovation in the Dutch software sector

Before testing the hypotheses formulated in section 2, we first provide an overview of the main sources of innovation in the Dutch software sector. This overview shows the overriding importance of relationships with customers as a source of innovation in this sector.

Firms were asked to list 13 sources of innovation and to indicate whether or not a particular source had inspired the firm during the innovation process. These questions were addressed to firms that had brought new products or services to the market
between 2000 and 2003 (165 firms) and to firms that had been working on new products or services but had not yet brought them to the market (20 firms). Using a scale of 0-10, they also had to indicate how important each of the sources had been and to describe what their contribution to that process had been. Figure 1a and 1b present the results. Four sources were only mentioned by a very small number of respondents and, therefore, these are not shown in the figures.

Figure 1a –

Figure 1b -

As figure 1a and 1b clearly show, customers are the main source of innovation in the Dutch software sector. Most of the respondents mentioned customers as a source of innovation (95%), and they also gave them the highest average score (8). The description that respondents gave on how the source of innovation has contributed to their innovation process showed that about 22% of the software firms collaborated with their customers to develop new products or services, but in most cases customers were involved in discussions on product design (41%). Regular contacts with customers help software firms understand what their customers want, which inspires them to develop new products or services (see Isaksen, 2004).

Besides customers, software firms value external contacts as a source of innovation lower than internal contacts or public sources such as literature and conferences. The development of new products or services clearly requires much internal contacts. Many respondents also indicated that they obtain ideas and inspiration for the development of new products or services simply by observing the products or services introduced by
other software firms. This is also the main reason why a high share of firms mentions competitors as a source of innovation. They do not cooperate with competitors, but mainly learn by observing their developments. In other words, they learn from other software firms without any interactions taking place (compare Malmberg and Maskell, 2002).

External inputs on technological knowledge for the development of new products or services are valued quite low. The few firms that mention universities as a source of innovation above all see them as suppliers of highly-educated employees. The main suppliers concern foreign developers of software platforms. The reason why not much knowledge exchange takes place with these suppliers is the very strong market position of these multinationals. In general, technological knowledge is relatively easily accessible in this sector. The knowledge needed to programme software is highly codified. Most software developers can find additional technological information and solutions to practical problems in journals or on the Internet.

In sum, customers are clearly the most important source of innovation in the Dutch software sector, followed by internal contacts. It appears that a combination of both contacts with customers and internal contacts is necessary for a software firm to innovate. In the following section, we further examine the relation between spatial proximity and face-to-face interactions of software firms with their customers, and to what extent this contributes to the innovative performance of software firms.

5 Variables and statistical method

The hypotheses formulated in section 2 are tested with several regression analyses using various dependent variables. The first two hypotheses predict that spatial proximity
facilitates regular face-to-face interactions and that age reduces the need for regular interactions and, consequently, the need for spatial proximity. To test this, we estimated two models. In the first one, the number of face-to-face interactions with customers was the dependent variable while spatial proximity is included as an explanatory variable. In the second model, this was turn around.

The two other hypotheses predict the effect of the different characteristics of relationships with customers on the innovative performance of software firms. We selected two indicators for the innovative performance of software firms: (1) a dummy 0-1 coded variable that indicates whether a firm has brought new products or services to the market between 2000 and 2003 or not, and (2) the percentage of turnover due to the sales of those new products or services (innovation output). Both indicators for innovation are similar to the ones used by empirical studies on innovation based on data gathered by the Community Innovation Survey (CIS) (compare Kleinknecht et al., 2000).

The model with the dummy variable for innovation has been estimated with a probit model. Since the other three dependent variables (i.e. number of face-to-face interactions, spatial proximity to customers and innovation output) cannot take a value below zero, an Ordinary Least Squares (OLS) regression model is not appropriate. An OLS regression assumes that dependent variables can take on any value and may hence result in inconsistent estimators and predictive values below the limit of zero (McDonald and Moffit, 1980). Therefore, we have used a tobit model as an alternative. This model can handle dependent variables above (or below) some limit value. All models presented below have been estimated with maximum likelihood estimation in Stata, version 9. Since tobit models do not include a $R^2$, we have used a modified
version of the McKelvey-Zaviona\textsuperscript{ii} statistic to calculate a pseudo $R^2$, as recommended by Veall and Zimmerman (1994).

All variables necessary to test the hypotheses formulated in section 2 have been composed using data drawn from the interviews with entrepreneurs in the second survey. The variable \textit{spatial proximity} of the software firm to customers indicates the percentage of customers located within a 50 kilometre range. Previous empirical studies showed that most of the entrepreneur’s daily activity takes place within this region and this area also covers most of a firm’s labour market (Stam, 2003). Besides the percentage of customers within that region, respondents were asked to make a similar regional division of customers based on the percentage of sales that is generated by customers. However, these two divisions of customers were highly correlated and therefore we decided to use only one indicator.

The variable \textit{number of face-to-face interactions} with customers measures the average number of face-to-face interactions per month between the software firm and its customers. A few firms mentioned a very high frequency of contacts with their customers. To ensure that the variable is normally distributed, we excluded 10 firms that indicated meeting their customers 15 or more times per month.

Besides spatial proximity and face-to-face interactions between software firms and customers, we composed another indicator of the relationship between the software firm and its customers: \textit{collaboration with customers}. This variable is based on the question in the survey whether respondents cooperate with their customers when they develop new products or services or not. Firms that collaborate with their customers are more likely to have regular face-to-face interactions and, therefore, it is necessary to control
for this characteristic of the relationship in the models that test hypotheses 1 and 2. Furthermore, we included this variable also in the models that estimate the innovative performance of software firms to control for the possibility that, instead of the number of interactions or spatial proximity (hypothesis 3), the innovative performance of firms is mainly affected by the strength of the relationship with customers. Having regular face-to-face contacts does not necessarily imply that firms also exchange more relevant information. In case of collaboration, it is more likely that the involved firms can learn from one another and, therefore, collaboration may be a better indicator for the strength of a relationship than regular interactions.

To test hypothesis 2, we included age of the firm in the models that estimate the relation between spatial proximity and face-to-face interactions. The number of years that the firms were active in the software sector is used as a proxy for age. Also the variable customisation of products, which measures the percentage of customised products in the total turnover of the firm, is included in those models. Firms that develop more standardised products are expected to have fewer face-to-face interactions with customers.

In the models that estimate the effect of spatial proximity and the intensity of interactions on the innovative performance of firms, we controlled for differences between firms by including their age and size. Size is measured by the number of fulltime employment.

In the model that estimates the innovation output of the firm, we have included another control variable: innovation input. Innovation input indicates the percentage of fulltime employment in the firm that was actively involved in developing the new products or
services between 2000 and 2003. Input is an indicator of the firm’s R&D intensity which is found to be positively related to the innovation output (Brouwer and Kleinknecht, 1999) Including this variable in the model makes it possible to check whether it has the expected sign and suggests that our results are to some extent similar to previous studies.

For each of the four models, we tested the correlation of the independent variables. None of the variables had a correlation higher than 0.5 and, therefore, no multicollinearity problems occurred in the models.

6 Results
This section describes the results of testing the hypotheses formulated in section 2. In the first part, we examine to what extent the spatial proximity affects the number of face-to-face interactions between a software firm and its customers. Section 6.2 tests the effect of the characteristics of a firm’s relationships with customers on the innovative performance.

6.1 Spatial proximity and face-to-face interactions
Table 1 presents the descriptive statistics for all the variables we used to further disentangle the relation between spatial proximity to customers and the number of face-to-face interactions with customers. As expected, most software firms have quite intensive contacts with their customers, considering the characteristics of that relationship (see table 1). The average percentage of customers within a 50 kilometre range surrounding the software firm is 36% and, on average, software firms meet their customers 1.6 times per month. Somewhat over 20% of all software firms characterise
their relationship with their customers as a collaboration on the development of new products or services. However, the differences between firms are considerable, as indicated by the high standard deviation of these variables. Using Tobit regression analyses, we further examine the links between these three characteristics of the user-producer relationships in the Dutch software sector.

- Table 1 -

Hypothesis 1 predicts that spatial proximity between firms has a positive impact on the number of regular face-to-face interactions. Model 1 in table 2 presents the results of the tobit regression analysis to test this relation. Confirming the hypothesis, the percentage of customers within a 50 kilometre range has a positive and statistically significant effect on the number of face-to-face contacts, although the effect is quite weak. Furthermore, this model also shows that the age of the firm negatively affects the number of face-to-face interactions with other firms. As expected, older firms meet their customers face-to-face less often than younger firms do.

As stated in hypothesis 2, we expect that the negative effect of age of the firm on face-to-face interactions will also reduce the need for spatial proximity to customers. To test this hypothesis, we conducted a regression analysis with spatial proximity to customers as the dependent variable and included an interaction variable between the age of a firm and the number of face-to-face interactions. The results are shown in model 2. Confirming the hypothesis, the interaction term is statistically significant and has a negative value. As a firm grows older, the frequency of interactions with customers drops and, consequently, so does the percentage of customers located in the same
region. The variable age itself is not statistically significant in model 2, not even when the interaction effect is left out of the model. This suggests that age does not affect the share of customers located near the software firm, but that only the reduced need for interactions lowers the need for spatial proximity.

- Table 2 -

Model 1 shows that collaboration with customers indeed has a positive and statistically significant effect on the number of face-to-face interactions between firms. However, as model 2 demonstrates, this variable has no statistically significant effect on the spatial proximity to customers. In other words, firms that work together with their customers do not have a significant higher number of customers located in the same region, despite the higher number of interactions. Spatial proximity is not necessary to arrange the more intensive interactions that characterise user-producer collaboration.

Product customisation has a statistically significant and positive effect in both models. In other words, firms that develop a larger share of customised products meet their customers face-to-face more often and have a higher percentage of customers that are located in the same region. We also expected that older software firms are more likely to have standardised their products. However, the interaction term between customisation of products and age of the firm was not statistically significant. This suggests that older firms do meet their customers face-to-face less often, but that is not related to a further standardisation of products.

6.2 The effect of inter-organisational relationships on innovative performance
In this section, we examine the effect of spatial proximity and face-to-face interactions between software firms and their customers on the innovative performance of software firms. Table 3a and 3b provide the descriptive statistics for the independent variables used to examine the effects of spatial proximity and face-to-face interactions on respectively the likelihood that firms are innovative (table 3a) and the innovation output of software firms (table 3b). As we mentioned earlier, we excluded ten firms that met with their customers 15 or more times per month. Due to three missing cases for the variable spatial proximity, 194 cases are valid for the model that estimates the likelihood that firms are innovative. Information regarding innovation input and output was only available for 141 firms, and some independent variables had missing cases. Therefore, 139 cases were valid in the model for innovation output.

- Table 3a -

- Table 3b -

Table 4 presents the estimation results of the probit and tobit regression model for innovative performance. For both types of models, we did two estimations. The first estimation includes both the squared terms of spatial proximity to customers and face-to-face interactions with customers and an interaction term between these two variables. The squared terms are necessary to test hypothesis 3 that predicts that the number of face-to-face interactions with customers and the spatial proximity to customers has a positive effect on a firm’s innovative performance, but only up to a certain threshold. To
test such a relation, the variables number of face-to-face interactions with customers and spatial proximity to customers, as well as the squared terms of these variables should be included (see Aiken and West, 1991). The fourth hypothesis predicts that spatial proximity to customers only has an indirect impact on the firm’s innovative performance because it facilitates face-to-face interactions with customers. In other words, we expect a statistically significant and positive interaction effect between spatial proximity and the number of face-to-face interactions on the innovative capabilities of software firms. Therefore, we also included the interaction term between spatial proximity and face-to-face interactions in the first models presented in table 4. As not all squared terms and the interaction term had a significant effect, we excluded the non-significant effects in a second step and present those results in the second models shown in table 4.

With respect to the likelihood that software firms have brought new products or services to the market, we can only partly confirm hypothesis 3. As shown in model 1 in table 4, the effect of the variable spatial proximity to customers and its squared term is not statistically significant. By contrast, the squared term of face-to-face interactions with customers is statistically significant and has a negative value, while the variable itself has a positive effect on the likelihood of being innovative. This indicates that firms which more regularly meet their customers face-to-face are more likely to be innovative, but only up to a certain threshold. The negative and statistically significant sign of the squared term shows that the firms with the highest number of face-to-face interactions per month are less likely to be innovative. In other words, the relation between the number of interactions with customers and the likelihood of bringing new
products or services to the market tends to have an inversed U-shape. Although these results should be interpreted with some care as we cannot control for the effect of other potentially relevant factors, the results do seem to confirm our hypothesis that user-producer interactions have a beneficial effect on the innovative performance of firms. However, the number of face-to-face interactions and its squared have no statistically significant effect on the innovation output of Dutch software firms, as model 1 of the Tobit regression in table 4 shows. In other words, regular interactions with customers to some extent contribute to the likelihood that software firms decide to bring new products or services to the market, but those customer contacts do not appear to contribute to success of the market introduction. Spatial proximity to customers has no statistically significant effect on both indicators for the innovative performance of software firms.

- Table 4 -

The fourth hypothesis predicts that spatial proximity to customers only has an indirect impact on the firm’s innovative performance because it facilitates face-to-face interactions with customers. To test this assumption, we included an interaction term between these two aspects of the relationship with customers in both the probit and tobit model. If hypothesis 4 is correct, we would find a statistically significant and positive interaction effect between spatial proximity and the number of face-to-face interactions on the innovative capabilities of software firms. As table 4 shows, however, we have to reject this hypothesis for both indicators of the innovative performance of software
firms. In both cases, the interaction term between spatial proximity and face-to-face interactions is not statistically significant.

Besides the effect of spatial proximity and face-to-face interactions between software firms and their customers, we also examined the effect of collaboration with customers on both indicators for innovative performance. As explained in section 5, collaboration with customers may be a better indicator for the strength of inter-organisational relationships than the number of face-to-face interactions. Indeed we find a positive and statistically significant effect of the collaboration with customers on the likelihood that software firms have brought new products or services to the market. It seems that firms which collaborate with their customers are more likely to innovate, although the effect is not highly significant. Furthermore, collaboration with customers has no statistically significant effect on the innovation output of software firms (see table 4, Tobit model 1). This result suggests that the importance of collaboration with customers for innovation should not be exaggerated. Collaboration with customers may inspire firms to bring new products or services to the market to fulfil the specific needs of those customers. Nevertheless, the firms who organise their innovation process in such a manner do not generate a significantly higher percentage of turnover due to the sales of those products.

In the probit model estimating the likelihood that software firms bring new products to the market, we included age and size of the firm as control variables. Both variables are not statistically significant in these models. Size and age of software firms appears to be unrelated to the likelihood that a software firm brings new products or services to the
market. In the model on innovation output, the three control variables age, size and innovation input all have a statistically significant effect. As expected, innovation input positively affects the innovation output. Firms that have a higher percentage of employees working on the development of new products or services also generate a higher percentage of turnover due to the sales of those new products or services.

The age of the firm has a negative effect on innovation output, i.e. younger firms have a higher innovation output, while the effect of the size of the firm has a slightly positive effect. Similar results were found in another empirical study on innovation in computer services (Tether, 2003). As we suggested in section 3, the negative effect of age may be related to the way we measure innovation output and therefore we excluded firms younger than three years from the analysis. However, the effect of age still is significant for the group of firms of three years and older.

To summarize, the empirical results show that spatial proximity to customers does not affect a software firm’s innovative performance, while the number of face-to-face interactions appears to do so. The likelihood that a software firm brings a new product or service to the market increases when the firm has more intensive face-to-face contacts with its customers, but only up to a certain threshold. Firms which meet their customers face-to-face most frequently are less likely to be innovative. Firms also seem to benefit from the collaboration with customers with respect to the market introduction of new products or services. Despite these positive effects of face-to-face interactions and collaboration with users on the likelihood of being innovative, however, the more intensive contacts with customers do not appear to improve the success of the market introduction. None of the characteristics of the relationship between software firms and
their customers included in our analysis have a statistically significant effect on the innovation output of these firms.

7 Conclusions

The purpose of this paper was to actually test the effect of spatial proximity between software firms and their customers on the number of face-to-face interactions, and whether this indeed contributes to the innovative performance of Dutch software sector. In this way, we examined both the often assumed relevance of user-producer interactions for the innovation process and the facilitating role of spatial proximity between organisations for such interactive learning processes.

Using the results of a telephone survey among small software firms in the Netherlands, we found that the customers are indeed the main source of innovation in this sector, followed by intra-firm learning processes. Our results confirmed that firms with a higher percentage of customers located in the same region meet their customers face-to-face more often. In other words, spatial proximity indeed seems to facilitate interactions between firms. However, this relation is more dynamic than often assumed. Our analyses demonstrated that the relation between spatial proximity and face-to-face interactions was negatively affected by the age of the firm. Older firms seem to have less need to meet with their customers, perhaps because they have managed to standardise their inter-organisational relationships.

We also found that firms that collaborate with their customers on the development of new products or services meet them more often face-to-face per month, but this relation does not appear to be affected by spatial proximity. In other words, collaboration
requires more interactions, but this does not imply that the firms involved should be located in each other’s vicinity.

Further testing showed that spatial proximity to customers also does not affect the innovative performance of software firms, not even indirectly through facilitating regular face-to-face interactions. More intensive user-producer relationships, however, do seem to contribute to the innovation process in the Dutch software sector. Firms that collaborate with their customers or that meet them more often face-to-face per month are more likely to bring new products or services to the market, at least up to a certain threshold. Nevertheless, neither spatial proximity to customers nor regular face-to-face interactions with customers seem to contribute to the success of the market introduction of new products or services.

Our results tend to contradict the general ideas in the literature on the co-location of firms and innovative performance of firms. The results do confirm the often assumed positive relation between spatial proximity and the number of interactions with customers, but also show that spatial proximity to customers does not improve the innovative performance of software firms, not even indirectly by facilitating the required face-to-face interactions. These results seem to confirm the recent critical arguments that spatial proximity is not only not sufficient for interactive learning processes to take place, but that it is also not a necessary condition (Boschma, 2005). As we already explained in section 2, spatial proximity is not sufficient because firms cannot learn from one another simply by being located in the same region. Co-location can only indirectly contribute to interactive learning processes through facilitating the interactions between organisations that are necessary for such learning processes.
(Howells, 2002). However, our results suggest that spatial proximity is not even necessary for the arrangement of those interactions. The innovation process of Dutch software firms is positively affected by the collaboration with customers and to some extent of having regular face-to-face interactions with customers, but is not affected by a higher percentage of customers located in the surrounding 50 kilometre range. Furthermore, the lack of any indirect effect of spatial proximity on the intensity of a relationship with customers suggests that the interactions with customers can also be arranged over longer distances. Other types of proximity such as organisational or social proximity can help to provide the necessary trust to exchange knowledge without the need of spatial proximity (see e.g. Breschi and Lissoni 2003).

In contrast to the literature, our empirical study showed that the effect of user-producer interactions on the innovation process is quite limited. The innovation process of software firms does seem to benefit from regular interactions with customers, but regular face-to-face interactions with customers are not positively related to the innovation output of a firm. Even the collaboration with customers on new products or services does not appear to help software firms generate a higher turnover from the sales of those newly developed products or services. These results seem to indicate that, at least as far as the Dutch software sector is concerned, having face-to-face contacts or collaboration with customers only partly improves the innovative performance of software firms. Perhaps software firms do not need to have a strong relationship with their customers to be able to develop successfully new products or services. In section 4, we found that customers are considered to be an important source of innovation by the entrepreneurs of software firms. However, also more general business relationships can serve as a source of innovation. Firms may get all the information they need with
regards to customer demands and technological requirements through market transactions, so no formal collaboration is required (Belderbos et al., 2004). A more in-depth study of customers as a source of innovation showed that customer involvement is useful in the early stages, in terms of idea generation, but that it is less relevant during the development process (Conway, 1995). Therefore, the relevance of user-producer interactions for the innovation process should not be exaggerated. Our results tend to suggest this is the case in the Dutch software sector.

Both the relevance of spatial proximity and user-producer interactions for interactive learning processes and innovation deserve further attention in future empirical studies. Such studies should examine these processes in other industries and for other types of inter-organisational relationships to obtain further understanding of learning between organisations and the underlying reasons for the tendency of innovation processes to concentrate in space.
References


Bleichrodt, H., Louter, P.J., Sleegers, W.F., 1992. Young economic activities in the Netherlands: an economic geography perspective. EGI-research publication No. 02, Economic Geographic Institute, Erasmus University, Rotterdam. (in Dutch)


Tether, B.S., 2003. The sources and aims of innovation in services: variety between and within sectors. Economics of Innovation and New Technology 12, 481-505.


Figure 1a The importance of sources of innovation, measured as the percentage of innovative software firms that mention a source of innovation (n = 185)

Figure 1b Importance that innovative software firms attach to the source of innovation on a scale of 1 to 10*

*only by the firms that mentioned to have used the specific source
Table 1 Descriptive statistics of the variables used to estimate the relation between spatial proximity and face-to-face interactions

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial proximity to customers</td>
<td>36.4</td>
<td>30.05</td>
<td>0</td>
<td>100</td>
<td>233</td>
</tr>
<tr>
<td>Number of face-to-face contacts customers</td>
<td>1.63</td>
<td>2.14</td>
<td>0</td>
<td>12</td>
<td>237</td>
</tr>
<tr>
<td>Collaboration with customers</td>
<td>0.21</td>
<td>0.41</td>
<td>0</td>
<td>1</td>
<td>236</td>
</tr>
<tr>
<td>Age of the firm</td>
<td>9.72</td>
<td>6.08</td>
<td>1</td>
<td>28</td>
<td>235</td>
</tr>
<tr>
<td>Customisation of products</td>
<td>41.92</td>
<td>39.46</td>
<td>0</td>
<td>100</td>
<td>234</td>
</tr>
</tbody>
</table>

Table 2 Estimation results of the number of face-to-face contacts with customers per month (model 1) and the percentage of customers within a 50 kilometre range (model 2)

<table>
<thead>
<tr>
<th></th>
<th>Model 1: Log (face-to-face interactions)</th>
<th></th>
<th>Model 2: Spatial proximity to customers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>S.E.</td>
<td>B</td>
</tr>
<tr>
<td>Constant</td>
<td>0.277***</td>
<td>0.045</td>
<td>16.117**</td>
</tr>
<tr>
<td>% customers within 50 km</td>
<td>0.001*</td>
<td>0.001</td>
<td>--</td>
</tr>
<tr>
<td>Log (n of face-to-face contacts)</td>
<td>--</td>
<td>--</td>
<td>36.176**</td>
</tr>
<tr>
<td>Age of the firm</td>
<td>-0.007**</td>
<td>0.003</td>
<td>0.663</td>
</tr>
<tr>
<td>Number of face-to-face contacts * age of the firm</td>
<td>--</td>
<td>--</td>
<td>-2.546*</td>
</tr>
<tr>
<td>Collaboration with customers</td>
<td>0.102**</td>
<td>0.042</td>
<td>-4.142</td>
</tr>
<tr>
<td>Customisation of products</td>
<td>0.001**</td>
<td>0.000</td>
<td>0.247***</td>
</tr>
<tr>
<td>N</td>
<td>227</td>
<td></td>
<td>227</td>
</tr>
<tr>
<td>-2 log likelihood</td>
<td>43.30</td>
<td></td>
<td>2071.18</td>
</tr>
<tr>
<td>Sigma</td>
<td>0.26***</td>
<td></td>
<td>29.78***</td>
</tr>
<tr>
<td>Pseudo R^2</td>
<td>0.093</td>
<td></td>
<td>0.102</td>
</tr>
</tbody>
</table>

* p < 0.10 ; ** p < 0.05 ; *** p < 0.01
Table 3a Mean, standard deviation, minimum and maximum value for each independent variable included in the model estimating the likelihood to be innovative

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial proximity to customers</td>
<td>36.48</td>
<td>30.01</td>
<td>0</td>
<td>100</td>
<td>194</td>
</tr>
<tr>
<td>Number of face-to-face interactions</td>
<td>1.57</td>
<td>2.07</td>
<td>0</td>
<td>10</td>
<td>197</td>
</tr>
<tr>
<td>Collaboration with customers</td>
<td>0.21</td>
<td>0.41</td>
<td>0</td>
<td>1</td>
<td>197</td>
</tr>
<tr>
<td>Age</td>
<td>11.13</td>
<td>5.64</td>
<td>4</td>
<td>28</td>
<td>197</td>
</tr>
<tr>
<td>Size</td>
<td>14.68</td>
<td>21.75</td>
<td>1.5</td>
<td>202</td>
<td>197</td>
</tr>
</tbody>
</table>

Table 3b Mean, standard deviation, minimum and maximum value for each independent variable included in the model on innovation output

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial proximity to customers</td>
<td>36.82</td>
<td>29.48</td>
<td>0</td>
<td>100</td>
<td>140</td>
</tr>
<tr>
<td>Number of face-to-face interactions</td>
<td>1.55</td>
<td>1.72</td>
<td>0</td>
<td>8</td>
<td>141</td>
</tr>
<tr>
<td>Collaboration with customers</td>
<td>0.26</td>
<td>0.44</td>
<td>0</td>
<td>1</td>
<td>141</td>
</tr>
<tr>
<td>Age</td>
<td>11.04</td>
<td>5.89</td>
<td>4</td>
<td>28</td>
<td>141</td>
</tr>
<tr>
<td>Size</td>
<td>15.00</td>
<td>18.58</td>
<td>2</td>
<td>100</td>
<td>141</td>
</tr>
<tr>
<td>Innovation input</td>
<td>50.57</td>
<td>28.74</td>
<td>0.1</td>
<td>100</td>
<td>140</td>
</tr>
</tbody>
</table>
Table 4 Estimation results of the Probit regression model (estimating the likelihood that Dutch software firms brought new products or services to the market, 2000-2003) and the Tobit regression model (estimating the innovation output of software firms)

<table>
<thead>
<tr>
<th></th>
<th>Probit: innovative or not</th>
<th>Tobit: innovation output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>S.E.</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.248</td>
<td>0.423</td>
</tr>
<tr>
<td>Spatial proximity to customers</td>
<td>0.010</td>
<td>0.000</td>
</tr>
<tr>
<td>Spatial proximity to customers squared</td>
<td>-0.0001</td>
<td>0.000</td>
</tr>
<tr>
<td>Log (number of face-to-face contacts with customers)</td>
<td>2.416**</td>
<td>1.208</td>
</tr>
<tr>
<td>Log (number of face-to-face interactions) squared</td>
<td>-2.693**</td>
<td>1.307</td>
</tr>
<tr>
<td>Spatial proximity * number of face-to-face interactions</td>
<td>0.005</td>
<td>0.013</td>
</tr>
<tr>
<td>Collaboration with customers</td>
<td>0.473*</td>
<td>0.269</td>
</tr>
<tr>
<td>Age of the firm</td>
<td>-0.005</td>
<td>0.019</td>
</tr>
<tr>
<td>Log (size of the firm)</td>
<td>0.337</td>
<td>0.270</td>
</tr>
<tr>
<td>Innovation input</td>
<td>0.680***</td>
<td>0.084</td>
</tr>
<tr>
<td>N</td>
<td>194</td>
<td>194</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-107.90</td>
<td>-108.35</td>
</tr>
<tr>
<td>LR Chi Square</td>
<td>13.65*</td>
<td>12.75**</td>
</tr>
<tr>
<td>Pseudo R square</td>
<td>0.060</td>
<td>0.056</td>
</tr>
</tbody>
</table>

* p < 0.10 ; ** p < 0.05 ; *** p < 0.01

1 NACE code 72101 are system developers, 72102 consultants concerning automation, 7220 consultancy activities for software and software development, and 7230 data-processing activities.

\[ R^2 = \frac{\sum_{i=1}^{N} (\hat{y}_i - \hat{y}^*)^2}{\sum_{i=1}^{N} (\hat{y}_i - \hat{y}^*)^2 + N\hat{\sigma}^2} \]

ii
Where $\hat{y}_i = \hat{\beta} \chi_i$ is the predicted value of the latent variable for the individuals with characteristics $\chi_i$. $\hat{\beta}$ is the coefficient of determination, and $\hat{\chi}_i$ is the mean of $\hat{\chi}_i$ for the individual $i$. The numerator of the McKelvey-Zavoina $R^2$ is a measure of the explained variance, and the second term in the denominator is an indicator of unexplained variance.