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An Empirical Test

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Abstract
This paper takes an economic approach to investigate the role of geographical proximity for organizing new product development (NPD) activities within inter-firm linkages. Product development theory and the resource-based view is discussed from an inter-firm perspective and contrasted to arguments in the literature on geographical economics. The approach in this paper assumes that geographical proximity is crucial for inter-firm learning, knowledge transfer and creation of capabilities to a higher extent in inter-firm linkages with a high level of interaction, in industries where knowledge is relatively more important as a resource and where collaboration partners are important. Hypotheses are tested by means of a quantitative analysis of a data set containing information about 4842 domestic and international inter-firm linkages of Danish firms in manufacturing industries. The findings in this analysis exhibit low support for the general role of geographical proximity for organizing NPD activities within inter-firm linkages. The result suggests that geographical proximity seems to play a role in inter-firm linkages in few cases. For instance, it is shown that knowledge intensive firms exhibit a propensity for international linkages. It is further suggested closer geographical distance for inter-firm linkages with medium and high level of interaction, suppliers or customers accounting for more than one third of total purchases or sales, and for linkages lasting for at least 10 years.

Key words: capabilities, economics of localization, innovation, inter-firm linkages, knowledge, product development, proximity, resources

JEL-codes: L23, L60, O32

INTRODUCTION*

This paper deals with the importance of geographical proximity for the organization of product development activities in inter-firm linkages. The point of departure is an economic perspective on the economics of the localization of firms in terms of inter-firm learning, knowledge exchange, and the coordination of innovation activities. From a geographical perspective, the approach adopted in this paper contrasts the vast geographic literature on coordination of economic activities in an important way. The latter tend to examine why certain regions - denoted as industrial districts, industrial clusters, regional innovation systems and the alike - are more successful than others or why firms in particular industries tend to agglomerate in particular regions. The approach in this paper explicitly addresses the economics of localization when coordinating innovation activities between firms in a number of different industries and between firms not located in specific regions. Hence, rather than taking the point of departure within the realm of a predefined area of agglomerated firms, this paper seeks to find characteristics of inter-firm linkages in general to explain the role of geographical proximity.

The paper aims to contribute to the economic literature and increase the empirical knowledge about the role of geographical proximity and the coordination of product development activities within inter-firm linkages. In general, it has been shown that in most industries it is difficult to prove the idea of agglomeration of in particular small-scale and unpredictable transactions expected to lead to the effect of cost minimization (Maskell *et al.*, 1998). It is, however, frequently argued that agglomerations of firms facilitate, for instance, sharing of information and knowledge. The issue clearly needs further investigation. The questions arising concern the importance of proximity for coordination of product development activities within inter-firm linkages and the extent to which there are variation of firm characteristics or variation of patterns across industries. The objective of this paper is to investigate, to empirically and quantitatively test, and seek to answer these questions.

The theoretical approach combines product development theory and resource-based theory. It investigates the role of geographical proximity in facilitating and economizing on inter-firm learning, knowledge exchange, and the coordination of innovation activities. The empirical data includes a large number of inter-firm linkages between firms in almost all of the Danish manufacturing industrial sectors. The analysis spans over a wide range of inter-firm linkages

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and industries and is, thus, neither delimited to a specific geographical area nor a narrow selection of industries.

The paper begins with a brief review of the arguments from the literature on economic geography followed by an elaboration on the key issues of product development activities related to the resource-based view. The discussion focuses on inter-firm learning, knowledge exchange, utilization of resources and capabilities, and the coordination of innovation activities. Four hypotheses are deducted from theory. The following part is devoted for testing the hypotheses by using a database of national and international inter-firm linkages in the Danish manufacturing sector. Finally, the findings are analyzed and discussed.

GEOGRAPHY OF INDUSTRIAL ACTIVITY

The distribution of economic activity, as observed by the organizational and geographical dispersion of knowledge and capabilities, is one of the fundamental forces behind general industrial evolutionary processes and economic progress. Firms become more specialized, the overall amount of information and knowledge increases, and as a consequence, the dispersion of information and knowledge increases. Not only among firms and industries per se, but also in geographical terms. In this context, the geographical structure of industries may be related to the functional structure of markets (Stigler, 1951). Stigler refers in particular to the reduction of transaction costs as an incentive to extend markets and argues that spatial localization is one method to increase the size of an industry and, thus, to increase the degree of specialization. Hence, it calls for coordination of economic activities across organizational and geographical boundaries.

Agglomeration of firms

In the literature on economic geography several theoretical concepts appear based on empirical observations of firms closely located within certain geographical places, e.g. industrial districts (Marshall, 1890), economic space (Perroux, 1950), new industrial spaces (Scott, 1988), industrial clusters (Porter, 1990), and local milieux (Crevoisier & Maillat, 1991). These concepts differ somewhat in terms of the factors, such as its historically and geographically specificity, explaining the emergence of agglomeration and its effects for the firms. Common for a wide range of approaches is that they are founded on the conceptual tradition of Marshall (1890), which outlines the framework for research on geographical clusters of today. The framework has though been further developed by e.g. Brusco (1982), Becattini (1990), Dei Ottati (1994), and Markusen (1996), all emphasizing the role of geographical proximity for the coordination of economic activity.

Innovation systems

The systems of innovation literature encompasses national (Lundvall, 1992), sectoral (Malerba, 2002) and regional (Cooke, 1998) levels. There are different explanations to which level where interaction is most important for innovation activities and firm performance. However, the literature rests upon two assumptions that (a) interactions occur among a given population of actors and (b) that the level of innovation is affected by these interactions (Edquist and McKelvey, 2000). Innovations materialize from a collective process of information sharing and knowledge development (Foray, 1997).

Internationalization

Increasing internationalization of economic activities is in some respects the opposite to and in other respects complementary to agglomeration of firms. Innovation and technological development activities have in general been increasingly internationalized during the recent decades (Bartlett & Ghoshal, 1989; Dunning, 1993; Cantwell, 1995). Multinational corporations, for instance, internationalize their technological activities by drawing on local resources, knowledge, and capabilities possessed by firms in various locations (e.g. Dunning & Wymbs, 1999; Kuemmerle, 1998, 1999; Pearce, 1998, 1999; Zander, 1998, 1999). Through adopting an internationalizing strategy, multinational corporations may develop and diversify their technological capabilities (Cantwell & Piscitello, 1999, 2000; Zander, 1997). In this context, Kuemmerle (1999) argues that firms may need to enhance their competitive advantage by locating parts of their innovative activities in agglomerations in their own industry, domestically or internationally, to take advantage of other location-specific assets.

Economics of localization

Factors triggering the emergence of agglomerations may be found in the local context or as a consequence of purely random effects (Malmberg, 1998). The random order of the emergence of agglomerations is due to two mechanisms, Malmberg (*ibid*.) argues. First, a successful local established firm is likely to be followed by other similar firms or firms in complementary industries. Second, firms tend to show low propensity to move to other places once they are established. The effects of being in an industrial district can be summarized in four advantages (*ibid*.). Firms may reduce their costs in terms of shared infrastructure, lower transaction costs (due to the spatial proximity of related firms), shared skilled labor force, and a dynamic environment stimulating learning and innovation.

As theories seek to explain why firms tend to locate at the same place, a common characteristic is the discrepancy between theory and empirical studies. Mechanisms derived by the theoretical discussions have still not been successfully proved by empirical evidence (Malmberg, 1998). Case studies prevail and the empirical studies do not provide an unambiguous affirmation of the theoretical hypotheses. Sourcing business opportunities, learning opportunities, and collaboration partners locally or across geographical borders for inter-firm linkages aiming at technology transfer and innovation may, however, say something about the importance of geographical proximity in various industrial contexts. In the following, the importance of geographical proximity for product development in inter-firm linkages will be explored from the perspectives of product development theory and resources-based theory. Hypotheses derived from the theoretical elaboration will be tested by a quantitative analysis of a large number of inter-firm linkages in the Danish manufacturing sector.

THE NATURE OF NEW PRODUCT DEVELOPMENT

In this paper it is referred to new product development (NPD) embracing innovations new-to-the-firm, new-to-the-world, and incremental changes of existing product or production process technologies. The former two refer to radical innovation while the latter refers to incremental innovations. A radical innovation is here viewed as a change of a technological paradigm, while incremental innovations are continuously taking place within an existing paradigm. Changes occur, for instance, in the function or the appearance of products and production processes or in their range of application. The study presented in this paper is not concerned about R&D activities in a narrow sense but the entire development process leading to new or improved products and production processes.

Increasing rates of technological obsolescence (Norton & Bass, 1992) and shorter product life cycles (Bayus, 1994; von Braun, 1990) require firms to adopt a strategy of continuous development of capabilities and knowledge creation to be able to sustain a competitive advantage. New, innovative, and more advanced products are more likely to show superior performance in comparison with competitive products and substitutes. At the same time, they may yield sustainable rents for a longer time (Griffin & Page, 1996). Hence, to achieve a continuous flow of NPD and thereby advancing the competitive advantage, the importance of formalized NPD activities has gained increasing attention (Jürgens, 2000).

Formalizing the NPD process appears to have an impact on the commercial success of the output of NPD processes (Cooper, 1990). Also, several studies have shown that cross-functional NPD teams, in addition, seem to have a positive impact on the NPD performance (e.g. Cooper & Kleinschmidt, 1994; Gupta & Wilemon, 1990; Hayes, Wheelwright & Clark, 1988; Henke, Krachenberg & Lyons, 1993; Page, 1993; Takeuchi & Nonaka, 1986).

Multiple factors are, however, crucial for a successful NPD. Identifying fourteen success factors, Cooper (1990) was not able to find a single crucial factor. In fact, it is not only the integrative strategy of NPD processes among technological fields (e.g. Paashuis, 1998; Bullinger & Warschat, 1996) that seems vital, but also the integration of multiple factors leading to successful NPD processes (Cooper & Kleinschmidt, 1990).

Innovation in general may be described as a process being highly uncertain, complex, cumulative, relying on contemporary research, and where learning-by-doing is an important feature (Dosi *et al.*, 1988). These attributes have implications for the location of firms. Some firms may benefit from being closely located to research organizations, such as universities, to source information and knowledge for the innovation process (Feldman, 1993). In addition, innovation and geographical location seem to positively correlate (Feldman, 1994). Hence, the cumulative aspect of innovation suggests that firms may locate in areas where front-edge knowledge has been developed and may more easily be acquired.

The first hypothesis relates to the level of importance of knowledge compared to other resources in a given industry. It is assumed that the more important knowledge becomes compared to other resources, the closer the geographical proximity in inter-firm linkages undertaking product development activities.

> *Hypothesis 1:*
> *The higher the level of relative importance of knowledge compared to other resources in a given industry, the closer the geographical location between firms undertaking product development in inter-firm linkages.*

KNOWLEDGE, LEARNING, AND CAPABILITIES IN INTER-FIRM LINKAGES

Many products, such as automotives and electronics, entail an increasing number of different technologies making it more difficult to undertake all activities in-house (Iansiti, 1998). As firms deploy cross-functional teams in NPD processes, they may need to coordinate activities requiring information, knowledge and capabilities possessed by two or more firms.

Information, knowledge, and capabilities

The interaction between innovators and producers, and between producers and users is characterized by a process where exchange of information and knowledge. This process involves several iterations and constitutes a feedback loop, which may result in new process and product developments (Rosenberg, 1982; von Hippel, 1994). The locus of innovation changes as a result in changes of costs of acquiring the information needed for the problem solving. The incremental cost required to transfer the information, often referred to as the "stickiness" of information, depends on the amount of information transferred, the nature of the information itself, and the choices made by firms providing and searching for information. It is further argued that even when small amounts of information are required, firms may sometimes have to acquire related information and knowledge to be able to utilize it successfully (von Hippel, 1994).

Moreover, the definitions of resources and capabilities have been extensively discussed within the resource-based view (Wernerfelt, 1984; Dierickx & Cool, 1989; Barney, 1991; Amit & Schoemaker, 1993; Peteraf, 1993). According to this research tradition, *resources* and *capabilities* possessed by firms may under certain conditions and with certain characteristics, endow a given firm with competitive advantage. Resources may be seen as a "stock of available factors that are owned or controlled by the firm […] and are converted into final products or services by using a wide range of other assets" (Amit & Schoemaker, 1993, p. 35). Resources may be, for instance, know-how, financial assets, physical assets, and human capital. Hence, resources per se are most likely dubious sources of competitive advantage (Barney, 1986; Dierickx & Cool, 1989), mainly because they may be trade-able on the market. Capabilities, on the other hand, "refer to a firm's capacity to deploy resources, usually in combination, using organizational processes, to effect a desired end" (Amit & Schoemaker, 1993, p. 35). They may, in comparison to resources, become complex, unique, rare and unimitable (Barney, 1986) allowing the firm to earn rents. Knowledge is sometimes viewed as the most important resource for the firm (Conner & Prahalad, 1996). It is also argued that *dynamic capabilities* are crucial to develop for firms to achieve and sustain competitive advantages (Pisano *et al.*, 1997; Wheelwright & Clark, 1992; Dosi & Marengo, 1994).

Knowledge transfer and learning

External knowledge-flows may be regarded as a mean of utilizing other firms' knowledge resources and to develop capabilities. Existing accumulated knowledge is crucial for the ability to recognize and assess the value of new information, to make use of knowledge possessed by other firms and, hence, important for the competitive advantage (Cohen &

Levinthal, 1990). Successful innovation and technological advantage will enhance the possibilities to sustain technological advantage of tomorrow (Nelson & Winter, 1982) and knowledge spillovers seem to have a significant impact on innovative activities in industries (Audretsch, 1998; Grupp, 1996).

According to Takeuchi and Nonaka (1986), it is not possible to fully learn or to acquire knowledge, unless the receiver possesses some ex ante required tacit knowledge. Tacit knowledge is a key issue in the context of learning as a process of 'learning-by-using' (Rosenberg, 1982) and 'learning-by-interaction' (Lundvall, 1988) leading to small incremental changes but with a significant cumulative effect (Rosenberg, 1982). Takeuchi & Nonaka (1986) argues that a shared tacit knowledge exists in all knowledge sharing processes. In particular spatial proximity is increasingly important when the degree of tacit knowledge created and transferred in inter-firm relations increases (Maskell *et al*, 1998) and geographical proximity promotes face-to-face contacts in inter-firm linkages (Casson, 2000). Hence, we may pose a second hypothesis expecting closer geographical proximity to facilitate interaction and iterative learning processes in inter-firm linkages the higher the intensity of interaction related to product development activities.

> *Hypothesis 2:*
> *The higher the level of interaction in inter-firm linkages related to product development activities, the closer the geographical location between firms.*

PRODUCT DEVELOPMENT AND THE ROLE OF INTER-FIRM LINKAGES

NPD activities have been more formalized in the sense they have become crucial components in firm strategies to survive in competitive markets. As managers have become increasingly concerned about the importance of NPD, such activities have also become increasingly integrative and cross-functional to reap the fruit from complementary but dispersed sources of knowledge and capabilities. Apart from cross-functionality in internal production and development teams, cross-functionality also entails people from different firms, such as suppliers and customers. Hence, integrating different sources of knowledge and capabilities is believed to enhance NPD processes in many industries. Consequently, inter-firm linkages tend to become increasingly important as the technological complexity and the stock of knowledge increases. Increasing stock of knowledge and product complexity necessitates coordination of competencies and capabilities possessed across firm boundaries. In conjunction with acquisition of complementary knowledge and resources (Gemunden *et al.*, 1992) the time for development processes and costs may be reduced (Bonaccorsi & Lipparini, 1994).

The structure of a firm's inter-firm linkages may be viewed as a mirror of the information and knowledge management strategy of that specific firm. Duysters *et al.* (1999), among others, argue that inter-firm linkages are a core element in technological development and they embrace a spectrum of different forms of coordination (Dicken, 1998). Firms of all sizes have increased their exploitation of inter-firm linkages during the latest decades (Hagedorn, 1996) and it has become an increasingly important strategic issue for firms (Madhavan, Koka & Prescott, 1998). Customers and suppliers have become crucial partners in innovation processes (Afuah, 2000) and close inter-firm linkages entailing commitment and investments make available complementary knowledge and new product ideas (Biemans, 1992; Li and Calantone, 1998). Such linkages, thus, become potential sources of innovation (von Hippel, 1988). In addition, firms may face problems to mobilize and develop internal knowledge and capabilities to be able to response rapidly to changing market conditions and, hence, to reduce time from problem identification to market introduction (Dierickx & Cool, 1989). Also, as the locus of innovation-related rents may differ (von Hippel, 1988), that has often resulted in separation between the innovator and the user firm (Lundvall, 1985).

Empirical evidence shows that knowledge spillovers are locally bounded (Jaffe, Trajtenberg & Henderson, 1993). In an industrial district, for instance, frequent interaction is an important factor in creating new knowledge by unplanned interaction with others. From this perspective, importance of close interaction between technology users and producers in the innovation process has been emphasized by e.g. Lundvall (1988) and von Hippel (1988). In particular, 'in-bound' transfer of technology that is significantly different from the existing technology in a given firm has to be transferred through extensive interaction (Lundvall, 1988).

In accordance with the discussion so far, we may pose a third hypothesis on the role of geographical proximity for inter-firm relationships based on the assumption that the more important particular customers or suppliers become for a given firm, the closer the spatial proximity.

> *Hypothesis 3:*
> *The higher the importance of specific customers/suppliers, the closer the geographical location between firms undertaking product development in inter-firm linkages.*

The literature on inter-firm linkages tends, however, to emphasize the benefits and positive impact of customer or supplier participation on innovation and development activities in general (e.g. Biemans, 1992; Gmunden *et al.*, 1992; Ford, 1997) and in NPD activities in particular (e.g. Parkinson, 1982; Cooper & Kleinschmidt, 1994). First, the performance of new products developed in inter-firm partnerships is not necessarily superior to in-house developments (Bidault & Cummings, 1994). Second, a number of studies on the role of geographical proximity found that geographical location was of minor importance. For instance, Narula and Hagedoorn (1999) found that firms primarily tend to choose partners in relation to their ability to provide good opportunities for learning. Gertler (1993, 1995) acknowledges that proximity plays an important role in technology transfer interactions but argues that mutual and bi-directional technology transfer is most efficient when producer and user are geographically, organizationally, *and* culturally proximate. We conclude the discussion by posing a fourth hypothesis based on the assumption that the role of geographical proximity is of minor importance.

> *Hypothesis 4:*
> *Inter-firm linkages undertaking product development activities show no pattern of geographical location compared to other inter-firm linkages.*

EMPIRICAL ANALYSIS

Data and method

The data used for testing the hypotheses are obtained from a survey of inter-firm linkages carried out in 1995. The database contains information about inter-firm linkages in the Danish manufacturing sectors. The questionnaire was distributed to a total of 4072 Danish firms. Selection of firms was delimited to the population of manufacturing firms according to the NACE industrial classification system (NACE ver. 1, categories 15 to 36, see also table 1). The population was further delimited to firms with at least 10 employees according to annual reports from 1994. In total, 1278 firms responded, resulting in a response rate of 31,4 percent. Although the response rate varied in different sectors, the response analysis indicated a variation matching the total population of manufacturing firms in Denmark. Each firm was asked to submit information about the four most important suppliers and customers respectively, but who accounted for at least 10 percent of purchases or sales. For each linkage, firms had to answer 19 questions, each based on dichotomous answers. The ensuing database contains a total of 4842 inter-firm linkages distributed on the sectors as shown in table 1.

Table 1 Distribution of relationships on NACE sectors

NACE (Rev. 1)	Branch	No. of relation-ships	Share of relation-ships (%)	Sector[1]
15-16	Manufacture of food products, beverages and tobacco	320	6,6	SDOM
17-18	Manufacture of textiles and textile products	381	7,9	SDOM
19	Manufacture of leather and leather products	18	0,4	SDOM
20	Manufacture of wood and wood products	235	4,9	SDOM
21-22	Manufacture of pulp, paper and paper products; publishing and printing	452	9,3	SDOM
23	Manufacture of coke, refined petroleum products and nuclear fuel	0	0	SDOM
24	Manufacture of chemicals, chemical products and man-made fibres	127	2,6	SCIB
25	Manufacture of rubber and plastic products	343	7,1	SCAI
26	Manufacture of other non-metallic mineral products	156	3,2	SCAI
27-28	Manufacture of basic metals and fabricated metal products	799	16,5	SCAI
29	Manufacture of machinery and equipment n.e.c	818	16,9	SPEC
30-33	Manufacture of electrical and optical equipment	651	13,4	SCIB[2]
34-35	Manufacture of transport equipment	165	3,4	SCAI
36	Manufacturing n.e.c.	377	7,8	SDOM
	Total	**4842**	**100**	

[1] SDOM = supplier-dominated; SCIB = science-based; SCAI = scale-intensive; SPEC = specialized suppliers
Classification according to Pavitt (1984) modified by Laursen & Meliciani (2000)
[2] NACE code 31, Electrical machinery, is categorized as SPEC

Geographical distance

The dependent variable, geographical distance between firms in each dyadic linkage, has been estimated by calculating the distance between the geographical centers of the communities in which each firm is located. Table 2 shows the six categories of distances used in the analysis ranging from local to international linkages. The variable is discrete and ordered and each distance category is assigned a value ranging from zero to five. As showed, the category of international linkages has been given the highest value (5).

Table 2 Categorization of geographical distances in inter-firm linkages

0	Supplier and customer are located in the same community
1	Supplier or customer is located within 25 km
2	Supplier or customer is located within 50 km
3	Supplier or customer is located within 100 km
4	Supplier or customer is located further away than 100 km
5	Supplier or customer is located in another country

The distance is calculated as the distance following a straight line between the geographical centers of the communities where firms in each dyadic linkage are located respectively.

Relative level of knowledge as an important resource

The first independent variable is related to the first hypothesis expecting closer geographical location the higher the level of relative importance of knowledge compared to other resources. The taxonomy of industrial sectors developed by Pavitt (1984) is used as a proxy for the relative importance of knowledge. Using the innovating firm as the basic unit of analysis, Pavitt categorizes industries in three different technological trajectories based on firms' principal activities. These trajectories are depending on sectoral differences in a) sources of technology, b) users' needs and c) mean of appropriating benefits. Four sectors are identified; supplier-dominated (SDOM), science-based (SCIB), scale-intensive (SCAI), and specialized suppliers (SPEC). See categorization of industries in table 1.

SDOM-firms are generally small firms with weak capabilities for in-house NPD and engineering. NPD is mainly initiated and performed by suppliers of equipment and materials. Production intensive firms are divided into two sub-categories; scale-intensive and specialized suppliers. SCAI-firms are basically firms producing standard materials and producers of durable consumer goods and vehicles. The competitive advantage of SCAI-firms is mainly embedded in the design and integration of large-scale processes rather than in particular innovations. SPEC-firms are often small suppliers of equipment and instruments. In this sector, the capabilities of continuous NPD and understanding of customers' needs are crucial. Finally, SCIB-firms are found in the chemical and eletronic/electrical sectors. Their main source of technological development is in-house R&D. Rapid NPD based on basic research is crucial for firms in this sector. In this paper, SCIB-firms are considered to exhibit the highest relative importance of knowledge compared to other resources in the industries followed by SPEC-firms. SDOM-firms are considered to exhibit the lowest relative importance of knowledge.

Level of interaction

The second independent variable is the level of interaction in each dyadic linkage. This variable is related to the second hypothesis expecting closer geographical location, the higher the level of interaction in inter-firm linkages. The linkages have been divided in different categories based on the answers given by the firms to six selected questions. The questions are used as a proxy for measuring the level of interaction and include a) to what extent they are involved in NPD activities, b) whether they resell products manufactured by the other firm, c) whether they have coordinated product system numbers, d) whether they have agreed to manufacture shared systems of products, and e) whether the firms occasionally make tools, buildings, or expertise available to each other. Each question can be answered by a "yes" or a "no". A "yes" is given the value of "1", and a "no" is given the value of "0". The total value for each linkage between the respondent firms and their suppliers or customers, is reached by the sum of the answers given to the questions. Consequently, a linkages can be given the minimum value of "0" and the maximum value of "6", thus, resulting in a set of seven categories ranging from "0" to "6". The number of linkages obtaining the value of 4, 5, and 6 have been grouped in category "3" to make four equally sized groups for the analysis. An inter-firm linkage with a total value of "0" is considered as an inter-firm linkage with low level of interaction, while an inter-firm linkage with a total value of "3" is considered an inter-firm linkage with high level of interaction.

Importance of customers/suppliers

The third independent variable is the importance of customers or suppliers. The level of importance is here measured as the relative size of total sales or purchases. This variable is related to hypothesis 3, expecting closer geographical location between firms, the higher the importance of specific customers/suppliers. The relative size of total sales or purchases is divided into four categories; “0-9%”, “10-19%”, “20-32%”, and “32-%“.

Model

The level of geographical proximity (DISTANCE) is treated dependent variable. As independent variables, we use the sector (SECTOR), the level of interaction (INTERACTION), and the size of total sales or purchases (SIZE). We also control for the duration of each inter-firm linkage in terms of the number of years (YEAR). Since the dependent variable is discrete and ordered we use an ordered Probit model to estimate the probabilities of the dependent variable. The basic model for testing the hypotheses may be stated as follows:

$$P = f\,(\beta_1 x_1,\ \beta_2 x_2,\ \ldots\ \beta_n x_n)$$

This model measures the probability *P* of the function of a set of determinants x with parameter vectors β. The operational form of the model based on the variables presented above may be specified as follows:

$$Prob\ (DISTANCE{=}0..j) = \alpha SECTOR_f + \beta SIZE_f + \gamma INTERACTION_f + \delta YEAR_f + \varepsilon_f$$

The expression *Prob* ($DISTANCE_i$=0..*j*) denotes the probability of a given level of geographical distance in an inter-firm linkage *f*. Model (i) calculates estimates for all linkages without taking into account whether the linkages involve NPD activities or not. Model (ii) allows variable SECTOR and SIZE to differ if inter-firm linkages comprise NPD activities or not. In the latter model, linkages without NPD activities are the benchmark. This is to check if estimates of geographical distance in inter-firm linkages involved in NPD activities are different compared to estimates of inter-firm linkages in general.

RESULTS

Table 3 exhibits the results from the Probit regression for model (i) and table 4 for model (ii). Table 5 and 6 in Appendix contain the marginal effects corresponding to the coefficients in table 3 and 4.

Table 3 Regression results explaining geographical proximity in inter-firm linkages (N=4842)

	Model (i)		
Independent variables	**Estimate**	***p*-value**	
Constant	1,494	0,000	***
SDOM	Benchmark		
SCIB	0,294	0,000	***
SCAI	-0,089	0,022	**
SPEC	0,006	0,891	
Sales/purchase 0-9%	Benchmark		
Sales/purchase 10-19%	-0,030	0,443	
Sales/purchase 20-32%	-0,060	0,212	
Sales/purchase 33- %	-0,188	0,001	***
No interaction	Benchmark		
Low interaction	-0,022	0,623	
Medium interaction	-0,006	0,989	
High interaction	-0,020	0,627	
0-3 years	Benchmark		
4-9 years	-0,014	0,743	
10-19 years	-0,086	0,040	**
20- years	-0,138	0,003	***
Log likelihood	-7569,427		
Restricted log likelihood	-7605,805		
Likelihood ratio test (*p*-value)	0,000		***

**** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level*

Hypothesis 1 (*The higher the level of relative importance of knowledge compared to other resources in a given industry, the closer the geographical location between firms undertaking product development in inter-firm linkages.*) seems to be rejected since the coefficients in both models are positive and significant for SCIB. That is, positive coefficients means that the geographical distance increases in SCIB industries compared to SDOM industries. In fact, model (ii) exhibits higher coefficient for SCIB taking into account NPD activities. Hence, the distance increases when inter-firm linkages are involved in NPD activities. The evidence of increasing distance for SCIB-firms is strong since the marginal effects exhibits positive coefficients only for international linkages. SCAI shows closer geographical proximity for inter-firm linkages in general since the coefficient is negative and significant at the 5%-level, as shown in model (i). The coefficient is also higher (and negative) and more significant in model (ii) suggesting that the geographical distance is closer for SCAI-firms in inter-firm linkages not undertaking NPD activities.

The second hypothesis (*The higher the level of interaction in inter-firm linkages related to product development activities, the closer the geographical location between firms.*) is not confirmed in model (i) since no coefficient is significant. The estimates in model (ii), however, suggest that medium and high level of interaction have an impact on the geographical distance, taking into account NPD activities in inter-firm linkages. The estimates are significant at the 5% level and, thus, confirm the hypothesis.

Table 4 Regression results explaining geographical proximity in inter-firm linkages (N=4842)

	Model (ii)		
Independent variables	**Estimate**	***p*-value**	
Constant	1,564	0,000	***
SDOM	Benchmark		
SCIB – NPD	0,312	0,000	***
SCIB – no NPD	0,299	0,000	***
SCAI – NPD	0,053	0,339	
SCAI – no NPD	-0,185	0,000	***
SPEC – NPD	0,060	0,286	
SPEC – no NPD	-0,026	0,654	
Sales/purchase 0-9%	Benchmark		
Sales/purchase 10-19% - NPD	0,025	0,630	
Sales/purchase 10-19% - no NPD	-0,066	0,168	
Sales/purchase 20-32% - NPD	0,041	0,523	
Sales/purchase 20-32% - no NPD	-0,135	0,036	**
Sales/purchase 33- % - NPD	-0,196	0,004	***
Sales/purchase 33- % - no NPD	-0,152	0,060	*
No interaction	Benchmark		
Low interaction	-0,068	0,135	
Medium interaction	-0,109	0,040	**
High interaction	-0,136	0,019	**
0-3 years	Benchmark		
4-9 years	-0,013	0,762	
10-19 years	-0,093	0,027	**
20- years	-0,145	0,002	***
Log likelihood	-7555,992		
Restricted log likelihood	-7605,805		
Likelihood ratio test (*p*-value)		0,000	***

**** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level*

The third hypothesis (*The higher the importance of specific customers/suppliers, the closer the geographical location between firms undertaking product development in inter-firm linkages.*) is partly confirmed. Customers or suppliers accounting for more than a third of the total sales or purchases seem to be closer located than customers and suppliers in general. The coefficient is negative, indicating closer geographical proximity, and significant at the 1% level in model (i) and at the 5% level in model (ii). The latter suggest that there is a weaker relationship for inter-firm linkages involved in NPD activities than for linkages in general. Also the coefficient is slightly lower in model (ii), -0,147 compared to –0,188.

The control variable of the number of years suggests in both models that the longer the relationship, the closer the geographical distance. The estimates for linkages lasting 10-19 years are significant at the 5% level, while estimates for linkages lasting for more than 20 years are significant at the 1% level.

FINAL REMARKS

The findings in this analysis exhibit low support for a general role of geographical proximity for organizing NPD activities within inter-firm linkages. The result suggests, however, that geographical proximity seem to play a role in inter-firm linkages in some specific cases.

SCIB-firms exhibit a propensity for international linkages rather than more local or regional linkages. One reason might be the importance of international markets for knowledge, partnering, production, and marketing, such as in the biotech industry. The size of the domestic market and the number of potential domestic partners in terms of knowledge and financing might be too limited. Instead firms are required to go international. On the other hand, estimates for SCAI-firms suggest closer geographical distances. Strongest evidence is shown in particular for linkages not involved in NPD activities.

Taking into account whether inter-firm linkages involves NPD activities or not, the findings suggest closer geographical distance for inter-firm linkages with medium and high level of interaction. Long lasting relationships in which firms undertake NPD activities, also seem to be closer located than what is the case for inter-firm linkages in general. Further, suppliers or customers accounting for more than one third of total purchases or sales show higher propensity to be closely located to their collaboration partners. The same accounts for linkages lasting for at least 10 years. For the purpose of this paper, it is important to note that the evidence become stronger in all cases but one when taking into account whether NPC activities are undertaken within the linkages.

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APPENDIX

Table 5 Marginal effects of model (i)

Variable	DIST=0	DIST=1	DIST=2	DIST=3	DIST=4	DIST=5
Constant	-0,223	-0,197	-0,067	-0,072	-0,015	0,574
SCIB	-0,044	-0,039	-0,013	-0,014	-0,003	0,113
SCAI	0,013	0,012	0,004	0,004	0,001	-0,034
SPEC	-0,001	-0,001	-0,000	-0,000	-0,000	0,002
Sales/purchase 10-19%	0,004	0,004	0,001	0,001	0,000	-0,011
Sales/purchase 20-32%	0,009	0,008	0,003	0,003	0,001	-0,023
Sales/purchase 33- %	0,028	0,025	0,008	0,009	0,002	-0,072
Low Interaction	0,003	0,003	0,001	0,001	0,000	-0,008
Medium interaction	0,000	0,000	0,000	0,000	0,000	-0,000
High interaction	-0,003	-0,003	-0,001	-0,001	-0,000	0,008
4-9 years	0,002	0,002	0,001	0,001	0,000	-0,005
10-19 years	0,013	0,011	0,004	0,004	0,001	-0,033
20- years	0,021	0,018	0,006	0,007	0,001	-0,053

Table 6 Marginal effects of model (ii)

Variable	DIST=0	DIST=1	DIST=2	DIST=3	DIST=4	DIST=5
Constant	-0,232	-0,207	-0,070	-0,075	-0,016	0,601
SCIB – NPD	-0,046	-0,041	-0,014	-0,015	-0,003	0,120
SCIB – no NPD	-0,044	-0,040	-0,013	-0,014	-0,003	0,115
SCAI – NPD	-0,008	-0,007	-0,002	-0,003	-0,001	0,021
SCAI – no NPD	0,028	0,025	0,008	0,009	0,002	-0,071
SPEC – NPD	-0,009	-0,008	-0,003	-0,003	-0,001	0,023
SPEC – no NPD	0,004	0,003	0,001	0,001	0,000	-0,010
Sales/purchase 10-19% - NPD	-0,004	-0,003	-0,001	-0,001	-0,000	0,010
Sales/purchase 10-19% - no NPD	0,010	0,009	0,003	0,003	0,001	-0,025
Sales/purchase 20-32% - NPD	-0,006	-0,006	-0,002	-0,002	-0,000	0,016
Sales/purchase 20-32% - no NPD	0,020	0,018	0,006	0,007	0,001	-0,052
Sales/purchase 33- % - NPD	0,029	0,026	0,009	0,010	0,002	-0,075
Sales/purchase 33- % - no NPD	0,026	0,020	0,007	0,007	0,002	-0,059
Low interaction	0,010	0,009	0,003	0,003	0,001	-0,026
Medium interaction	0,016	0,014	0,005	0,005	0,001	-0,042
High interaction	0,020	0,018	0,006	0,007	0,001	-0,052
4-9 years	0,002	0,002	0,001	0,001	0,000	-0,005
10-19 years	0,014	0,012	0,004	0,005	0,001	-0,036
20- years	0,022	0,019	0,007	0,007	0,002	-0,056

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