

Firms and Knowledge Institutions – The Innovation Potential in Low-Tech Sectors and Small Firms

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Abstract

Knowledge institutions have been defined as important for the firms' ability to innovate. Much of the knowledge in these institutions is noncodified and dependent where the search and transfer mechanisms are essential in order to capture the knowledge. In this paper, I argue that in order to capture noncodified and dependent knowledge, the strength of ties between firms and knowledge institutions and absorptive capacity of the firm, has an influence on the search and transfer mechanisms. A theoretical model is developed where a high level of absorptive capacity and moving toward strong ties to knowledge institutions promotes the search and transfer mechanisms which then will benefit the innovative performance of the firm, while a low level of absorptive capacity and moving toward weak ties are the least beneficial. The estimation of an ordered probit model including 1544 firms from the Danish manufacturing and service industry supports the hypothesis at the overall level. Estimations for each sector show that the hypothesis is partly supported by the low- and medium-tech sectors, and for the size estimations, that small firms who fulfill the two requirements are in a better position to produce less imitative product innovations compared to large firms. Given the fact that the frequency of interaction with knowledge institutions or universities/technical support institutions is small, and the degree of absorptive capacity is relatively low, for both the low- and medium-tech sectors and small firms, a large innovative potential exists for these types of firms. The results support policies promoting interaction between firms and knowledge institutions in general and especially mobility programs aiming at those firms which have no or few academics employed.

Keywords: Innovation, inter-firm, absorptive capacity, strength of ties, industrial policy

Introduction

The work by Nelson and Winter (1982) was a breakthrough in many ways where one of them was the importance of noncodified knowledge in the process of technological change. Since then, this argument has been strengthened in the sense that concepts like knowledge based economy and the learning economy has gained influence in the economic literature. Such economies are characterized by shorter product cycles, more uncertain and fluctuating markets, more intense use of information technology and more intense competition. These circumstances enhance the demand for firms' ability to change rapidly. In these years we are facing a change towards a more crucial role for the creation, distribution and use of knowledge and information (Lundvall and Johnson 1994). Besides growth in the quantity and complexity of knowledge, processes as learning, forgetting and diffusion of knowledge are of growing importance. Thus, the ability to continuously participate in learning processes and to develop and absorb new knowledge is a crucial element for firms' competitiveness. According to Foray and Lundvall (1996), society is moving towards a networked learning economy where the opportunity and capability to access and join knowledge - and learning-intensive networks determines the relative success of individuals and firms. Inter-organizational interaction in innovation processes are also considered a first-best option, instead of last resort because of firms potentially access to information, resources, markets and technologies. Dodgson (1993) and Schill (1994) point out that external interaction is well established in innovation strategies of the firm. This is due to benefits like increased scale and scope of activities (Gulati, Nohria et al. 2000), shared cost and risks (Teece 1986; Dickson, Coles et al. forthcoming), improved ability to deal with complexity, enhanced learning and welfare effects, flexibility and efficiency and increased speed in the innovation process (OECD 2000).

Despite the large amount of literature on the benefits and the extent of inter-organizational interaction, success can not be taken for granted. The costs associated with realizing product development collaboration are less frequently examined. Nevertheless, as discussed by Leonard-Barton and Sinha (1993), Leverick and Littler (1994), Bruce et al. (1995a), Bruce et al. (1995b) and Littler et al. (1995) they are quite considerable and not always matched by the benefits of the collaboration for the overall outcome of the product development process. Or, as expressed by Day (1994): "Despite recent emphasis on the establishment, maintenance, and enhancement of collaborative relationships, few firms have mastered this capability and made

it a competitive advantage". One reason put forward is that noncodified knowledge is an important component in the process of innovation (Rosenberg 1982; Pavitt 1987; Dosi 1988; Senker 1995).

In this paper I will argue that in order to acquire, transfer and utilize noncodified knowledge a high level of absorptive capacity (Cohen and Levinthal 1990) and development of strong ties (Granovetter 1973) are necessary in the innovation process.

The theoretical framework takes its departure in the model by Hansen (1999) where he uses the search and the transfer mechanism as the two focal points. He argues that within organizations weak ties have an advantage in the search position compared to strong ties when sharing codified and independent knowledge while weak ties experience problems when transferring noncodified and dependent knowledge. But Hansen does not take into account that innovation is a cumulative activity (Dosi 1988; OECD 1992), thus prior knowledge of the firm has to be incorporated. This is especially important when the unit of analysis is changed from intra-firm to inter-firm relations since prior knowledge further determine the ability to assimilate and utilize external knowledge (Cohen and Levinthal 1990). Thus, the concept of absorptive capacity has to be taken into account due to the fact that absorptive capacity has an influence on the innovative performance of the firm (Arora and Gambardella 1990; Rothwell and Dodgson 1991; Gambardella 1992; Vergragt, Groenewegen et al. 1992; Henderson and Cockburn 1996; Tripsas 1997; Veugelers 1997; Vinding 2001). The hypothesis is tested against a data set with 1544 firms covering both the manufacturing and service sector.

The next section presents a theoretical framework and hypothesis. Section three and four explain the data material and model respectively where the results are shown in section five. Finally, conclusions and implications are put forward in section six.

Knowledge complexity and the strength of ties

When firms are in the need for external information, two elements; 1. the information search and 2. information transformation, are crucial in determination of how useful the information will be for the firm. Hansen (1999) deals with these issues in relation to search and transformation within the firm. In his framework the role of weak ties¹ in sharing

¹ Hansen implicit applies Granovetter's (1973) definition of ties where the strength of ties is determined by a "(probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterise the tie. Each of these is somewhat independent of the other, through the set is obviously highly intracorrelated" (Granovetter 1973) p. 1361. In this definition he recognises that ties are positive and symmetric.

knowledge within an organization, where the concepts from the social network theory, the weak and strong ties developed by Granovetter (1973) and the concept of knowledge complexity is applied. Hansen argues that when codified and independent knowledge is transferred, weak ties have an advantage as compared to strong ties while weak ties are insufficient when transferring noncodified and dependent knowledge.²

In the knowledge-based economy where the load of information gets larger and larger the search problem is crucial. Information technology expands the potential information for each individual. Although information technology provides tools in selecting and finding information, society has to deal with a overload of information. Assuming that individuals are bounded rational it is impossible to hold all the relevant information by themselves, thus who knows what and how is important. Here existing relations either weak or strong are crucial because they serve as channels through which both useful knowledge and information about knowledge flow.

In strong ties, information circulates at a high speed within the cluster, where each individual knows what the others know. On the other hand, weak ties are characterized as building on infrequent and distant relationships (Granovetter 1973). Despite this, weak ties have several advantages compared to strong ties. First of all, weak ties promote generation of new ideas and opportunities because through weak ties people in separate clusters are connected. In strong ties the possibility of providing redundant knowledge are more likely. Secondly, weak ties are less expensive to maintain than strong ties. In strong ties one need to spend time cultivating relationships by more frequent visits which are not directly connected to a specific problem. Thus, weak ties make it possible to include a larger number of people and obtaining new ideas and opportunities.

Further, strong ties require processing the incoming information in a more careful way. Reciprocity is often demanded in the sense that in strong ties high levels of help to others is expected to be provided in return. Weak ties which is similar to the notion of loose coupling (Weick 1976) further implies that if organizational entities are less tightly linked to other units the entities are more likely to be adaptive in the sense that it is easier to escape from penalties and to leave a network. Finally, strong ties can to a larger extent result in inertia. A unit belonging to a strongly tied network is more likely to stay with its existing network relations due to the fact that they are familiar and close where the team can easily turn. Hence, units

² In a taxonomic dimension of knowledge, Winter (1987) distinguish between the complexity/simplicity dimension of knowledge. For instance a pocket calculator can stand alone and can be transferred and used

connected by strong ties are less likely to search for knowledge outside their existing contacts and look for new ties.

The second element the transformation of information is also crucial since the cost of transferring knowledge can be considerable (Arrow 1969; Teece 1977). Moreover, the characteristics in the knowledge-based economy mentioned earlier make the transformation process even more important.

In product innovation there are two explanations for a transfer problem (Hansen 1999). There is the problem of willingness and the ability to share knowledge. Hansen leaves out the discussion of willingness and concentrates on the ability problem. In order to deal with the problem, he takes the complexity of knowledge into account where one dimension is the codification vs. noncodification of knowledge (Winter 1987) while the second dimension is the level of knowledge independence ((Teece 1986; Winter 1987). The argument is that the transfer of codified and independent knowledge is unproblematic for both strong and weak ties, i.e. the knowledge can be sent by email. However, when the knowledge is mainly noncodified and dependent the transfer between strong ties is most likely to be beneficial. Strong ties are more likely to spend time in articulating complex knowledge and Granovetter (1982:209) argues that “strong ties have greater motivation to be of assistance and are typically more easily available”. Further strong ties favour mutual interaction and feedback loops between the sender and the recipient (Leonard-Barton 1993), which is especially important in the process of innovation (Kline and Rosenberg 1986; Rothwell 1992).³ Further, the actors connected by strong ties have often established a specific heuristic, which promotes the understanding among themselves.

On the other hand, it is problematic to transfer complex knowledge with weak ties. The infrequency of the interaction between the source unit and the recipient implies that the recipient has to spend a proportionate amount of time in interpreting and modifying the noncodified and dependent knowledge. The source will often be absent for further explanations and if questions arise the source might not be available at all and if they are, the specific heuristic which favour an effective communication will be missing.

Table 1 shows the search and transfer effects associated with four combinations of knowledge complexity and tie strength. When codified and independent knowledge is being transferred, weak ties have an advantage in the search position compared to strong ties due to

without any problem. On the other hand is a module to a microcomputer an element of a system which may be difficult to understand unless the whole system is understood.

the fact that more people can be reached. Further, weak ties do not experience transfer problems since the transferred knowledge is not complex. Thus, in these cases weak ties are preferable. On the other hand, there are problems with weak ties when transferring noncodified and dependent knowledge. Weak ties may still have an advantage in the search process but in the transfer process severe problems remain because of a poor interaction with the source unit. Thus, strong ties seem to be favorable when dealing with noncodified and dependent knowledge.

Table 1. Search and transfer effects associated with four combinations of knowledge complexity and tie strength

Knowledge	Tie strength	
	Strong	Weak
Noncodified, dependent	Low search benefits, Moderate transfer prob.	Search benefits, Severe transfer problems
Codified, independent	Low search benefits, Few transfer problems	Search benefits, Few transfer problems

Source: Hansen (1999), p. 89

Absorptive capacity

The framework developed by Hansen (1999) is based on examination of the role of weak ties in sharing knowledge within an organization. In his framework the kind of knowledge and the strength between the parties is known. But Hansen does not take into account that innovation is a cumulative activity (Dosi 1988; OECD 1992), thus prior knowledge of the firm has to be incorporated. This is especially important when the unit of analysis is changed from intra-firm to inter-firm relations, since prior knowledge further determines the ability to assimilate and utilize external knowledge (Cohen and Levinthal 1990). Thus, the concept of absorptive capacity has to be taken into account due to the fact that absorptive capacity has an influence on the innovative performance of the firm (Arora and Gambardella 1990; Rothwell

³ Polanyi (1966) recognises that the recipient most likely does not capture the whole piece of knowledge completely during the first interaction but needs several opportunities to assimilate it.

and Dodgson 1991; Gambardella 1992; Vergragt, Groenewegen et al. 1992; Henderson and Cockburn 1996; Tripsas 1997; Veugelers 1997; Vinding 2001).

By including absorptive capacity in the framework both the search and the transfer mechanisms will be affected and thus the implications of the analysis presented by Hansen. I will argue that absorptive capacity has an impact on the transfer mechanism but also the search mechanism will be affected as well. Further, I point out that noncodified and dependent knowledge are more sensitive to absorptive capacity compared to codified and independent knowledge.

In the conceptualization of absorptive capacity Cohen and Levinthal argued that, doing one's own R&D produces not only new knowledge in the sense of innovations, but contributes also to the firm's absorptive capacity by increasing its stock of knowledge. A stronger knowledge base will create opportunities to exploit new technical developments by increasing the ability to assimilate and utilize external knowledge. This explains why some firms may invest in basic research, even though the findings will spill over to the public (Cohen and Levinthal 1990). Absorptive capacity may be seen as cumulative in nature – previously accumulated knowledge makes it easier to assimilate new knowledge. Moreover, the existence of a certain level of knowledge in a particular field will make it easier to read signals and to predict and import new technological opportunities, which is especially important in uncertain environments.

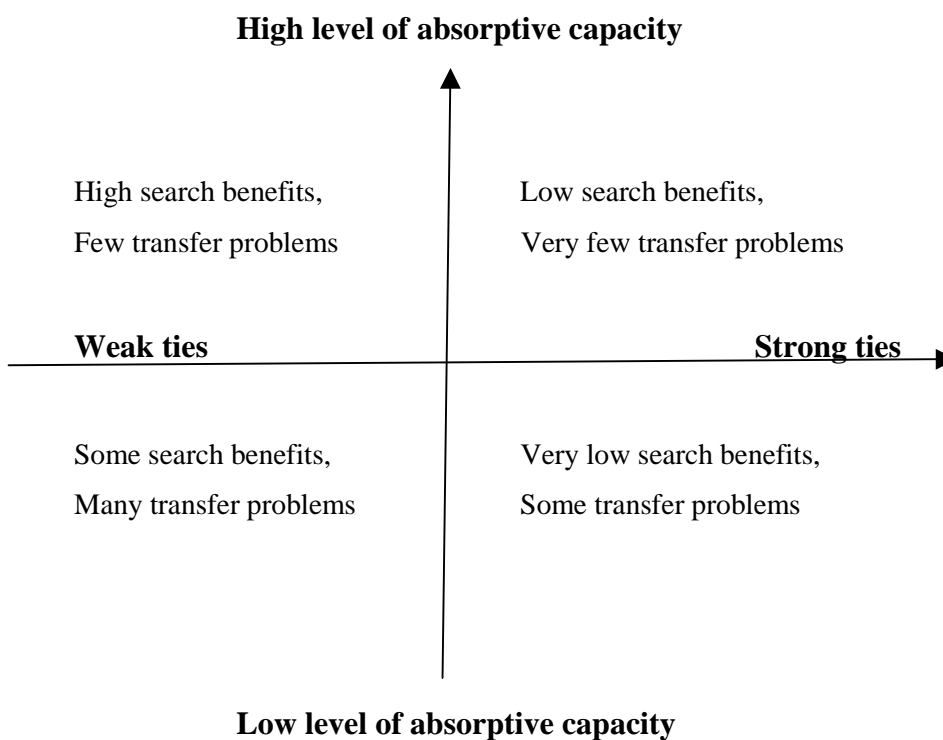
The complementarity between internal capability and external collaboration has been documented in a number of studies by, for example, using traditional science indicators such as R&D or patents. Other studies have moved away from the traditional indicators and instead focused on the human capital involved in the processes. Cohen and Levinthal were aware of the fact that absorptive capacity is dependent on individuals working in the organization. They argue that absorptive capacity may be developed “directly by sending employees to monitor and read the technical literature in their areas of expertise” (Cohen and Levinthal 1994 p.227). This is especially the case for people located at the interface of either the firm or its environment or at the interface between subunits within the firm. These “gatekeepers” are essential; Tushman and Katz (1980) also emphasize that “gatekeepers” are able to reduce the mismatch in language and cognitive orientation between two systems, which is especially important in development projects. Inside the firm, an important task for the “gatekeeper” is to transmit the information to the rest of the organization, and if the other members of the organization have high levels of expertise, the transmission process will become easier. This

is in line with Mangematin and Nesta (1999). They argue that highly educated employees in particular, through their daily tasks, will increase the stock of knowledge of the organization. They will further encourage relationships with other individuals with similar competencies outside the firm, thus facilitating access to external networks of knowledge, especially in the case of utilizing scientific knowledge (Rothwell and Dodgson 1991). Carter (1989) argues that employees with higher education are the main contributors to know-how trading due to the high levels of knowledge embodied in these people. The high level of knowledge implies that they will be in a better position to recognize and value new external knowledge.

Noncodified and dependent knowledge, tie strength and absorptive capacity

Incorporating absorptive capacity in the framework of knowledge complexity and tie strength changes the pattern. As shown in figure 1 and 2 absorptive capacity is most influential firstly, when dealing with noncodified and dependent knowledge and secondly, when dealing with transformation of knowledge. Vice versa absorptive capacity is less influential on codified and independent knowledge and search benefits.

Figure 1. Search and transfer effects associated with four combinations of absorptive capacity and tie strength in the case of noncodified and dependent knowledge.



In figure 1 it is assumed that the search benefits concerning noncodified and dependent knowledge are basically driven by the strength of the ties. As in Hansen, weak ties favour search benefits compared to strong ties because it covers a larger span of opportunities. When the other dimension is taken into account, a high level of absorptive capacity favours the search benefit compared to low level of absorptive capacity. Organizations with a high level of prior knowledge know where to search. Moreover, since highly educated people are the main carriers of noncodified and dependent knowledge, and since these persons are more likely to encourage relations with other individuals with similar competencies outside the firm (Carter 1989; Burt 1992; Mangematin and Nesta 1999), firms with a high level of absorptive capacity will be better off in terms of their search mechanism.

In the transfer of noncodified and dependent knowledge absorptive capacity plays a central role since absorptive capacity is the ability to assimilate and utilize external knowledge which is very much in line with the transformation process. Organizations with a high level of absorptive capacity will hence be in a better position to absorb noncodified and dependent knowledge. This is especially the case if strong ties have been established where reciprocity, larger engagement from the source and establishment of specific heuristic has taken place. The second best solution in the transformation process is weak ties combined with high absorptive capacity. The argument is that even though weak ties are characterized as being infrequent, distant, without reciprocity and specific heuristic, a high level of absorptive capacity may compensate for the disadvantages. Organizations with a high degree of highly educated employees do not need the same degree of help in assimilating and interpreting and utilize the knowledge being transferred compared to a low degree of absorptive capacity. This is line with Carter (1989), Senker (1995) and Guellec (1996) who argue that educated people are aware of the tacit ability to acquire and use knowledge. Finally, a low degree of absorptive capacity presents the most severe transformation problems.⁴ This is especially the case when dealing with weak ties where the disadvantages mentioned earlier can not be compensated by the absorptive capacity. The disadvantages become less significant with a low degree of absorptive capacity and strong ties because strong ties are characterized by reciprocity, larger engagement from the source and establishment of specific heuristic, which will be helpful for an organization with a low level of absorptive capacity.

⁴ The argument can actually be traced back to Harary *et al.* (1965). They point out that it is only within a certain distance (length of path) that communication will be feasible. If the distance is too long the cost of transmission will be too high.

Summing up, absorptive capacity is most influential on the transformation issue while tie strength is the most powerful in the search issue when operating with noncodified and dependent knowledge. However, since transformation of noncodified and dependent knowledge can be difficult I will argue that the elements in absorptive capacity in this case are the most important concept.

In recent years knowledge institutions have achieved much attention due to the large and unused knowledgebases in these institutions. However, knowledge institutions cover a large number of actors which play different roles in the innovation system. One way is to distinguish between basic and applied research where universities mainly carry out basic research. One of their main purposes is to produce codified knowledge in terms of theories and models which explains and predict the reality. On the other hand, is the aim of applied research to develop and produce useable artefacts which demands complex knowledge accumulated through trial and error. Sector research institutes, consultancy firms and technological institutes mainly carry out applied research. However, academic research is often used as background knowledge in the sense that the published papers are used to screen and identify new developments or identify researchers with specific expertise. The limitations of the codified knowledge is then followed up by personal contact to the author(s) in order to acquaint oneself with the techniques used or interpretation of the material contained in the literature - hence knowledge of tacit and noncodified nature (Senker 1995; Pavitt 1998).⁵

In addition, as argued in Grandstrand *et al.* (1997), product innovations are increasingly based upon a number of scientific disciplines e.g. computing, materials and biotechnology. According to Grandstrand the motives for the firms are three-folded; “opportunities to introduce new technologies into products and systems for improved performance and new functionalities, the continuing relevance of old technologies, and the co-ordination of innovation and change in core products with complementary changes in the production system and supply chain” (Grandstrand, Patel *et al.* 1997 p. 9). All three increase the inter-relatedness and the dependency of knowledge.

Following these arguments knowledge institutions are important contributors of noncodified and dependent knowledge and since noncodified knowledge is an important component of innovation (Rosenberg 1982; Pavitt 1987; Dosi 1988; Senker 1995) and thus, for the performance of the firm (Barney and Link 1991; Barney 1995; Spender 1996), I put forward a hypothesis arguing that:

***Hypothesis 1:** High level of absorptive capacity and moving toward strong ties favour acquirement and transformation of noncodified and dependent knowledge from knowledge institutions, thus promoting the innovative performance of the firms.*

It is a well-known fact that the dependency on noncodified and dependent knowledge is primary related to high-tech industries (Pavitt 1984; Mansfield 1995; Cockburn and Henderson 1997) while low- and medium-tech industries has been less frequently examined although the benefits can be considerable as well. This leads to the hypotheses:

***Hypothesis 2:** The importance of a high level of absorptive capacity and moving toward strong ties differs among industries.*

Moreover, it is also a well-known fact that small firms are more dependent on external resources e.g. lack of technological and related resources which limit the potential in finding synergies across technologies. This leads to the third hypothesis:

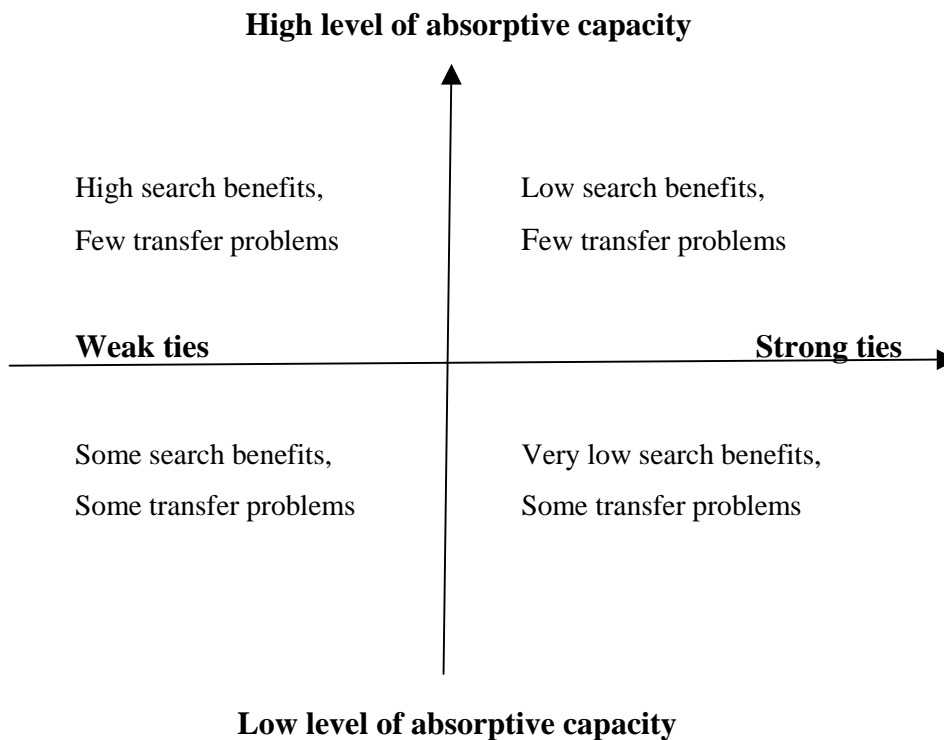
***Hypothesis 3:** The importance of a high level of absorptive capacity and moving toward strong ties are more important among small firms.*

Codified and independent knowledge, tie strength and absorptive capacity

Compared to the noncodified and dependent knowledge the absorptive capacity is less important, but its main influence is again headed towards the process of transformation. The search benefits are the same because the benefits of the search procedure are unrelated to the complexity of knowledge. This means that the highest benefits best can be achieved with weak ties since it covers a larger span of opportunities. As with noncodified and dependent knowledge the same argument goes for the absorptive capacity where a higher degree of absorptive capacity favours the search conditions. According to Carter (1989), highly educated employees are the main contributors of know-how trading due to high level of knowledge embodied in these people which can be interpreted as these kind of employees know where to search.

⁵ Based on three technological fields, Senker (1995) found that in biotechnology, literature was more important

Figure 2. Search and transfer effects associated with four combinations of absorptive capacity and tie strength in the case of codified and independent knowledge.



Dealing with codified and independent knowledge reduces the degree of transfer problems. The strength of the tie is independent of the piece of knowledge that is being transferred since codified knowledge like blueprints etc. can be sent i.e. by email. On the other hand a high degree of absorptive capacity reduces the transfer problems compared to a low degree. Although codified and independent knowledge is easy to transfer some codified knowledge might be hard to understand i.e. math formulas or other technical knowledge. In these cases one might assume that a high degree of absorptive capacity will increase the interpretation and utilization of that kind of knowledge compared to a low degree.

To sum up, the dispersion of the search and transfer effects seems to be lower for codified and independent knowledge compared with noncodified and dependent knowledge. This is mainly due to the absorptive capacity, which plays a minor role for the former type of knowledge complexity.

Data

Two databases have been combined in order to carry out the analysis. One is a survey on organizational and technological change (1993-95). The survey was carried out in 1996 at Aalborg University and was submitted to almost 4000 firms from the manufacturing and service sectors, where firms with 10 employees or more were selected. All firms with at least 100 employees were selected due to the fact that large firms are most likely to carry out organizational change. The overall response rate was 48% (1900 firms), and in the manufacturing and service sectors the response rates were 52% and 45% respectively.⁶ The second database is the integrated database on the labor market (IDA), which includes register data on each individual in Denmark for the period 1980-97. The two databases were merged, and along with survey data for the period 1993-95, IDA data for 1990-97 were included. The merged database is constructed in such a way that each firm has to be represented in all years, which reduces the number of firms from 1900 to 1544.

Model

On the basis of the theoretical and empirical discussion, a model is estimated in which a firm's ability to innovate is used as a dependent variable, and the combination of tie strength and nature of knowledge as shown in figure 1 and traditional control variables as independent variables. The basic structure of the model may be specified as follows:

$$a = f(\beta_1 z + \beta_2 q) \quad (1)$$

a represents the innovative activity of the firm, $\beta_1 z$ and $\beta_2 q$ are vectors concerning tie strength/nature of knowledge and other standardized variables used in the literature explaining the innovative activity of the firms. See appendix 1 for descriptive statistics.

a expresses the innovativeness of the firm on an ordered scale from 0-3. 0 is equal to a non-innovator firm (761), 1 indicates that the firm has introduced a product/service in the period of 1993-95 that is new to the firm (584), 2 indicates that the firm has introduced an innovation that is new in the Danish context (110), and, finally, 3 indicates that the firm has introduced an innovation that is new to the world (89). Thus the dependent variable measures both innovativeness and the degree of non-imitative innovation.

⁶ For information about descriptive statistics and questionnaire, see Lund and Gjerding (1996).

β_{Iz} can be decomposed into one variable representing a measure combining tie strength and absorptive capacity as shown in figure 1. As argued earlier one can assume that knowledge institutions (ACAknow), defined as consultants, technical support institutions, or universities, are important contributors of noncodified and dependent knowledge. Universities might be misplaced in this respect since the aim of universities is to codify knowledge. As argued earlier, the knowledge produced by the universities is complex and context dependent which lead firms to develop closer interaction i.e. personal contacts, in order to acquire the tacit skills and experiences that underlie published articles. Moreover, as can be seen from appendix 1 are Danish firms reluctant to interact with universities and technical support institutions. Only 17% have developed a closer relationship and we know from another survey carried out in the same period which distinguish between interaction with technical support institutions and universities that only 28% of the firms have collaborated with universities. Hence, universities play a minor role in the estimations.

In order to test the first hypothesis a high level of absorptive capacity is measured as having at least one employee with an academic degree while having no such employees is equally to a low level. Having at least one employee with an academic degree is basically enough, a threshold, for a firm to be in a better position to assimilate and utilize information from knowledge institutions.

In order to measure, tie strength the question concerning to what degree firms have developed a closer relationship with knowledge institutions is applied. Moving toward strong ties is approximated as having developed a closer relationship, while firms that have not established a closer relationship with knowledge institutions are categorized as being weak. Thus, the variable reflects the four quadrants in figure 1.

For policy purposes it is also interesting to examine those knowledge institutions which are more or less governed by the government. This is the case for universities and technical support institutions. Separate estimations are made for these institutions (ACAUNI), in order to examine how public financed institutions effect the innovative ability of the firms.

β_{2q} represents four standard control variables in the model. First, sectoral affiliation (*SECTOR*) where Pavitt's taxonomy, with four sectors representing the manufacturing sector while five sectors represent the service firms, is applied.⁷ One Schumpeterian hypothesis concerns innovation and *SIZE*. The late Schumpeter argued that innovative activity was positively correlated with firm size due to the existence of R&D departments. Although there

have been contradictory results concerning this issue over the decades, the results seem to be in favor of a positive relationship (Acs and Audretsch 1988; Brouwer and Kleinknecht 1996).⁸ The third control variable, competition (*COMP*), was also touched upon by Schumpeter. Several measures have been applied, mostly the level of competition in terms of different ratios concerning concentration, and, over the last decades, contradictory results have been obtained. Schumpeter was in favor of concentrated industries being more innovative. Others have found that competition doesn't matter (Arvanitis S. and Hollenstein 1996), while still others have found that increased competition favors innovation (Geroski 1990). *COMP* is measured in a slightly different way since the firms are asked to rate the change in the level of competitive pressure within the period; thus, this study deals with growth in competition instead of level of competition. Finally, the study controls for whether or not the firm is a subsidiary of a larger firm – *SUBSID*. Again, contradictory results exist, although the most recent studies tend to show that a positive relationship exists due to the fact that subsidiary firms have access to the parent firm's larger resource base and thus benefit in terms of innovative activity.

Results

All firms

As mentioned previously, the dependent variable takes four discrete ordered values. Hence, an ordered probit model is applied and maximum likelihood is the method used as the means of estimation.

In table 2 the estimations of equation 1 are reported where the first two columns concern knowledge institutions and the last two columns universities and technical support institutions.⁹ For both types of institutions the first hypothesis is supported. High level of absorptive capacity and moving toward strong ties seem to benefit acquirement and transformation of noncodified and dependent knowledge from both knowledge institutions and universities/technical support institutions in the sense that these firms besides promoting

⁷ The categorization of the service firms is taken from Laursen (2000). For further details on the categorization, see appendix 2 and 3.

⁸ See Cohen (1995) for an empirical review.

⁹ When size and sector are included in the same model, size becomes insignificant. As argued in Laursen (2000a), the additional variance explained by size is removed when sector is included. Thus, the size of firms between the nine sectors differs, but the effect of the variance in size is not that important within each sector. Further, size is also one of the criteria behind the taxonomy of classification into the nine sectors. One could therefore argue that the size variable should be omitted from the estimations.

the ability to innovate also reduces the degree of imitation. Moreover, due to the larger potential of getting access to complimentary research activities and results, the dispersion of estimates for universities and technical support institutions are not larger as one could expect.¹⁰ However, an interesting result emerges. For all models in table 2 the combination of low absorptive capacity and moving toward strong ties have higher estimates than high absorptive capacity and low ties. Thus, moving toward strong ties seems to be more beneficial for the firms' ability to produce less imitative innovation than having at least one academic person employed in the firm.

The degree of increased competition (COMP) shows the right sign and is significant for both models. Firms exposed to increased competition are, *ceteris paribus*, more likely to innovate, which is in line with Geroski (1990).

Firms belonging to a subsidiary firm (SUBSID) show significant results for all models. Subsidiary firms are hence more likely to increase innovative performance due to access to the larger resource base of the parent firm.

The size variable is significant, although the estimates are not as clear-cut as expected. Firms with fewer than 20 employees are not as likely to produce fewer imitative innovations compared to firms with more than 50 employees. The argument is well known since larger firms can more easily devote resources to the innovation process.

Finally, the sector variable shows that *crafts*, *specialized services* and *scale intensive services* innovate significantly less than the benchmark category *ICT intensive services*. The service industry seems to be much more fragmented in innovation compared to the manufacturing industry. The sector variable also reflects that development of innovations is more important in the earlier stages of the value chain where *ICT intensive services* and manufacturing firms are located. Further down the value chain, where the rest of the service firms are placed, other elements such as personal contacts with customers may be more important for survival than development of innovations. Instead, these firms rely on and receive innovations/knowledge from manufacturing and knowledge intensive service firms, as argued in Drejer (1998).

¹⁰ See Cohen et al. (1997) for a review which highlights the importance of interaction with universities in the sense that interaction enhances firms' sales, R&D and patenting productivity.

TABLE 2 Probit Model of Innovative Performance, Absorptive Capacity and Strength of Ties with Know. Inst. and Universities/Technical. Sup. Inst.

Variable	Knowledge Institutions				Universities and Technical Support Institutions			
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	-1.627**	0.104	-1.363**	0.161	-1.469**	0.097	-1.236**	0.156
Absorptive capacity and strength of ties:								
- High absorptive capacity and strong ties	0.745**	0.092	0.574**	0.093	0.757**	0.107	0.547**	0.109
- High absorptive capacity and weak ties	0.379**	0.090	0.120*	0.094	0.344**	0.076	0.188*	0.077
- Low absorptive capacity and strong ties	0.478**	0.088	0.464**	0.091	0.512**	0.132	0.435**	0.135
- Low absorptive capacity and weak ties	bench.	-	bench.	-	bench.	-	bench.	-
SUBSID – Belonging to a sub. firm, binary								
- Yes	0.233**	0.066	0.179*	0.068	0.240**	0.066	0.197**	0.067
COMP – Experienced increased comp. binary								
- Yes	0.319**	0.062	0.313**	0.063	0.327**	0.062	0.323**	0.063
SIZE – Size of the firm								
- < 20	-0.224*	0.086			-0.264**	0.087		
- 20 - 50	-0.125	0.080			-0.152	0.079		
- > 50	bench.	-			bench.	-		
SECTOR								
- Supplier dominated firms			-0.247	0.147			-0.256	0.146
- Scale intensive firms			-0.177	0.144			-0.126	0.141
- Specialised suppliers			0.122	0.158			0.149	0.156
- Science-based firms			-0.097	0.192			-0.032	0.188
- Crafts			-0.964**	0.159			-0.930**	0.157
- Wholesale trade			-0.212	0.141			-0.223	0.140
- Specialised services			-0.732**	0.150			-0.715**	0.148
- Scale intensive services			-0.805**	0.206			-0.733**	0.204
- ICT intensive services			bench.	-			bench.	-
Number of observations	1544		1544		1544		1544	

Notes: ** significance at 1% level; * significance at 5% level.

Sectoral estimations

Table 3 and appendix 4 show the estimations of equation 1 for each of the nine sectors in relation to knowledge institutions and universities/technical support institutions. In the sector estimations, the dependent variable takes a binary value yes/no to the innovation question since some of the sectors have a limited number of observations. Another problem with the estimations concerning university/technical support institutions is that ACAUNI is biased. As can be seen from appendix 1, only 17% of the firms have developed a closer relationship with universities and technical support institutions versus 42% for knowledge institutions. Hence, Danish firms seem to be reluctant to interaction with universities and technical support institutions, despite the large potential of gaining access to research results and studies showing that interaction with universities will pay off as this paper and others have shown (David 1994; Rosenberg 1994; Narin 1997; Baldwin and Link 1998).¹¹ These facts are the reason for insignificant estimates for universities and technical support institutions and for that reason the comments will be based on knowledge institutions alone.

As can be seen from the estimations in table 3, the second hypothesis is not supported. High levels of absorptive capacity and moving toward strong ties are not more conducive to innovation for high-tech firms than for low- and medium-tech firms. On the contrary, absorptive capacity and tie strength does more or less have an influence on the *scale intensive*, *specialized suppliers*, *craft*, *wholesale trade* and *specialized services*. A hypothesis might be that the capacity of receiving knowledge is optimized for knowledge intensive firms. An improvement will only be marginal. Instead, these firms experience other problems in terms of finding the right and qualified person for fulfilling the task of the firm. On the other hand, the result show evidence to suggest that low- and medium-tech firms are cable of achieving innovative benefits if they have academics employed while at the same time have established closer relationship with knowledge institutions. Moreover, since the frequency of firms fulfilling these terms is small, a large potential exists.

Again, low absorptive capacity and moving toward stronger ties are important for the first three sectors.

¹¹ In a Danish context the result is not surprising and has been supported in a number of studies, i.e. Christensen et al. (forthcoming) for the latest.

TABLE 3 Probit Model of the Ability to Innovative yes/no, Absorptive Capacity and Strength of Ties with Knowledge Institutions

Variable	Supplier dominated		Scale intensive		Specialised suppliers		Science-based	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	0.547*	0.244	-0.325	0.282	-0.203	1.001	1.011	1.684
ACAknow – Absorptive capacity and strength of ties with knowledge institutions								
- High absorptive capacity and strong ties	0.389	0.280	1.146**	0.286	1.050*	0.414	0.110	0.951
- High absorptive capacity and weak ties	-0.030	0.268	0.342	0.300	0.766	0.401	-0.428	0.977
- Low absorptive capacity and strong ties	0.331	0.296	0.825*	0.326	1.710**	0.470	-0.033	1.171
- Low absorptive capacity and weak ties	bench.	-	bench.	-	bench.	-	bench.	-
SUBSID – Belonging to a sub. firm, binary								
- Yes	0.200	0.208	0.340	0.202	0.223	0.295	-0.273	0.409
COMP – Experienced increa. comp. binary								
- Yes	0.821**	0.198	0.204	0.187	-0.214	0.278	0.723	0.384
SIZE – Size of the firm								
- < 20	-7.124	16.157	1.014	0.789	6.059	17.386	5.159	28.490
- 20 - 50	-0.348	0.230	0.415	0.242	-0.438	0.304	-0.620	0.555
- > 50	bench.	-	bench.	-	bench.	-	bench.	-
Number of observations		195		225		120		59

Notes: ** significance at 1% level; * significance at 5% level.

TABLE 3 Probit Model of the Ability to Innovative yes/no, Absorptive Capacity and Strength of Ties with Knowledge Institutions (cont.)

Variables	Craft		Wholesale trade		Specialised serv.		Scale int. serv.		ICT int. serv.	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	-0.210	0.503	0.685*	0.479	-0.185	0.363	-0.047	0.899	1.266	1.325
ACAKNOW – Absorptive capacity and strength of ties with knowledge institutions:										
- High absorptive capacity and strong ties	0.984*	0.423	0.519*	0.244	0.951**	0.355	-0.500	0.652	0.766	0.618
- High absorptive capacity and weak ties	-0.003	0.427	0.164	0.208	0.406	0.290	-0.163	0.509	-0.117	0.589
- Low absorptive capacity and strong ties	0.662**	0.214	0.415	0.240	0.349	0.203	0.280	0.420	0.434	0.772
- Low absorptive capacity and weak ties	bench.	-	bench.	-	bench.	-	bench.	-	bench.	-
SUBSID – Belonging to a sub. firm, binary										
- Yes	0.226	0.250	0.698**	0.162	-0.040	0.209	0.187	0.369	0.406	0.366
COMP – Experienced increa. comp. binary										
- Yes	0.638**	0.210	0.494**	0.163	0.471**	0.171	0.027	0.331	0.912**	0.327
SIZE – size of the firm										
- < 20	-0.056	0.351	0.036	0.242	-0.212	0.311	-0.223	0.486	-0.150	0.464
- 20 – 50	-0.342	0.349	0.038	0.241	-0.294	0.306	-0.288	0.463	-0.019	0.476
- > 50	bench.	-	bench.	-	bench.	-	bench.	-	bench.	-
Number of observations	231		284		271		62		97	

Notes: ** significance at 1% level; * significance at 5% level.

Also, increased competition (COMP) seems to be more conducive to innovation in the service sector than in the manufacturing sector. An explanation might be that the questionnaire reflects the change in the competitive pressure instead of the level of competition. A hypothesis could be that service sectors that start with a lower intensity of competition may be more sensitive to an increase.

Finally, firms belonging to a subsidiary firm, only show significant results in the *wholesale trade industry*, and, surprisingly, it is not possible to detect significant results in the size variable.

Size estimations

Table 4 shows the estimations for two size categories, less than and more than 50 employees. It is a well-known fact that small firms are less likely to have an academic employed and have developed closer relationship with knowledge institutions or universities and technical support institutions in particular. But, those who do, an interesting result emerge. The estimates for firms with less than 50 employees are larger for universities and technical support institutions thus indicating that small firms who are capable in fulfilling these requirements are in a better position not just to innovate, but to produce less imitative product innovations. This is not the case for estimations on knowledge institutions although the same result turns up when the sector variable is excluded. These results support the argument that academic research to some extent is a public good, it is easy to transmit, but it is not a free good. Firms have to invest in-house, both in human resources and in closer relationships, in order to acquire and transform research of this kind. However, since only few of the firms are capable of fulfilling these terms, a large potential exists.

Small firms who belong to a subsidy firm (SUBSID) and have experienced increased competition (COMP) show the expected estimates. These firms are more likely to innovate irrespective of estimations from knowledge institutions or universities and technical support institutions. Finally, are the estimates for the nine sectors (SECTOR) more dispersed for small firms, thus indicating a fluctuating propensity to innovate among these firms.

TABLE 4 Probit Model of Innovative Performance, Absorptive Capacity and Strength of Ties with Know. Inst. and Uni. and Tech. Sup. Inst.

Variable	Knowledge Institutions				Universities and Technical Support Institutions			
	< 50 employees		> 50 employees		< 50 employees		> 50 employees	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	-1.255**	0.203	-1.456**	0.323	-1.148**	0.187	-1.229**	0.305
Absorptive capacity and strength of ties:								
- High absorptive capacity and strong ties	0.577**	0.146	0.600**	0.171	0.564**	0.188	0.482**	0.161
- High absorptive capacity and weak ties	0.123	0.127	0.249	0.178	0.142	0.103	0.131	0.136
- Low absorptive capacity and strong ties	0.421**	0.107	0.558**	0.208	0.514**	0.158	0.237	0.253
- Low absorptive capacity and weak ties	bench.	-	bench.	-	bench.	-	bench.	-
SUBSID – Belonging to a sub. firm, binary								
- Yes	0.240*	0.093	0.070	0.112	0.249**	0.087	0.089	0.109
COMP – Experienced increased comp. binary								
- Yes	0.385**	0.087	0.223*	0.100	0.408**	0.081	0.204*	0.098
SECTOR								
- Supplier dominated firms	-0.373	0.209	-0.211	0.286	-0.409*	0.196	-0.225	0.280
- Scale intensive firms	0.024	0.222	-0.256	0.279	0.042	0.208	-0.212	0.274
- Specialised suppliers	0.042	0.239	0.116	0.293	0.069	0.226	-0.121	0.288
- Science-based firms	-0.149	0.399	-0.113	0.312	0.018	0.374	-0.083	0.306
- Crafts	-1.001**	0.188	-0.808*	0.374	-0.967**	0.177	-0.874*	0.367
- Wholesale trade	-0.248	0.167	-0.187	0.307	-0.259	0.158	-0.201	0.302
- Specialised services	-0.798**	0.179	-0.470	0.346	-0.794**	0.168	-0.378	0.339
- Scale intensive services	-0.834**	0.256	-0.839*	0.397	-0.766**	0.241	-0.794*	0.390
- ICT intensive services	bench.	-	bench.	-	bench.	-	bench.	-
Number of observations	966		578		966		578	

Notes: ** significance at 1% level; * significance at 5% level.

Conclusions

In the knowledge-based economy knowledge is recognized as being the most important resource for the competitiveness of the firm. Some of the most important carriers of knowledge are the consultants, universities and technical support institutions. Much of the knowledge in these institutions is noncodified and dependent which are emphasized as being a crucial contributor in the development of product innovations and in order to capture this kind of knowledge the search and transfer mechanisms are essential for the firm. In this paper, I have argued that absorptive capacity and strength of ties have an influence on the search and transfer mechanisms. A theoretical model was developed where a high level of absorptive capacity and moving toward strong ties to knowledge institutions promote the search and transfer mechanisms which then will benefit the innovative performance of the firm, while a low level of absorptive capacity and moving toward weak ties were expected to be the least beneficial.

The estimation of an ordered probit model including 1544 firms from the Danish manufacturing and service industry supports the hypothesis. Thus, moving towards strong ties to knowledge institutions and a high level of absorptive capacity seem to benefit acquirement and transformation of noncodified and dependent knowledge from both knowledge institutions and universities and technical support institutions. Firms, who fulfill the two requirements, increase not just the ability to innovate but reduces also the degree of innovative imitation. Moreover, sectoral estimations do not support the hypothesis that high-tech firms are more dependent on noncodified and dependent knowledge compared to low- and medium-tech firms. On the contrary, absorptive capacity and the strength of ties seem more or less to have an influence on the *scale intensive*, *specialized suppliers*, *craft*, *wholesale trade* and *specialized services*. Given the fact that the frequency of interaction with knowledge institutions and the degree of absorptive capacity is relatively low for the low- and medium- tech sectors, one could put forward the hypothesis that there is a large potential to be gained for those firms who invest in absorptive capacity and develop stronger ties to knowledge institutions, in the sense that they will be capable of producing less imitative product innovations.

As for low- and medium-tech sectors, the same argument is present for small firms.¹² It is a well-known fact that small firms rarely have academic employed and have developed closer

¹² As mentioned earlier, the sectoral classification applied in this paper, are among other elements, based on size, so a coincidence will be natural.

relationships with knowledge institutions or universities and technical support institutions in particular. But, those who are capable in fulfilling these requirements are in a better position not just to innovate, but to produce less imitative product innovations.

Thus, the results bear evidence to support policies in promoting interaction between firms and knowledge institutions in general. To be more specific, policies supporting interaction like center contracts, innovation incubators and science parks and at the individual level mobility programs, where the latter seem to be particularly interesting. Given the results in this paper for small and low- and medium-tech sectors, public subsidies to those firms, who for the first time hire an academic should be taken up for further discussion (isbryderordningen). Employing academics will besides upgrading the skills of the firm, and thus increase the absorptive capacity, also increase the likelihood that the firm will establish a closer relationship towards strong ties which might benefit the firm in the long run. In this case universities contribute to the process of product innovations in two ways. Firstly, by conducting research which might lead to new techniques, instruments or knowledge which might be applied in the industry. Secondly, and properly even more important to educate candidates and promote social interaction by establishing personal networks between the candidates which might increase the interaction between the industry and research institutions as shown in this paper, but also between firms as the agglomeration economics argue.

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APPENDIX 1: Variable definition and descriptive statistics

Variable	N	Percent
Innovative performance	1544	100%
- Non-innovator	761	49%
- Product/service innovation new to the firm	584	38%
- Product/service innovation new in the Danish context	110	7%
- Product/service innovation new to the world	89	6%
ACAknow – Absorptive capacity and strength of ties with knowledge institutions:	1544	100%
- High absorptive capacity and moving toward strong ties	377	24%
- High absorptive capacity and moving toward weak ties	314	20%
- Low absorptive capacity and moving toward strong ties	284	18%
- Low absorptive capacity and weak ties	569	37%
ACAuni – Absorptive capacity and strength of ties with universities and technical support institutions only:	1544	100%
- High absorptive capacity and moving toward strong ties	166	11%
- High absorptive capacity and moving toward weak ties	525	34%
- Low absorptive capacity and moving toward strong ties	85	6%
- Low absorptive capacity and moving toward weak ties	768	50%
SUBSID – Belonging to a subsidiary firm, binary	1544	100%
- Yes	673	44%
COMP – Experienced increased competition, binary	1544	100%
- Yes	602	39%
SIZE – Size of the firm	1544	100%
- < 20	475	31%
- 20 - 50	491	32%
- > 50	578	37%
SECTOR – See appendix for classification	1544	100%
- Supplier dominated firms	195	13%
- Scale intensive firms	225	15%
- Specialised suppliers	120	8%
- Science-based firms	59	4%
- Crafts	231	15%
- Wholesale trade	284	18%
- Specialised services	271	18%
- Scale intensive services	62	4%
- ICT intensive services	97	6%

APPENDIX 2: Sectoral classification

Making use of the SPRU database, Pavitt (1984) developed a taxonomy of sectoral patterns of innovation based primarily on information about main knowledge inputs into the innovation processes, requirements of users and means of appropriation. These characteristics and variations are classified according to four sectors: *Supplier dominated*, two kinds of production intensive (*scale-intensive* and *specialized suppliers*) and *science-based*. Firms in the *supplier dominated* sector are traditionally characterized as manufacturing firms that are small in size and have a low technology orientation. Technological progress is therefore dependent on external actors such as suppliers of equipment and materials and, in some cases, large customers and government-financed research and extension services. Firms in the *scale-intensive* sector are low-technology oriented as well, but they do have some in-house development capability. Besides being large in size, those firms interact primarily with firms in the second part of the production-intensive sector - *specialized suppliers* - where the level of technology is higher and the firm size is smaller. For specialized suppliers, the pattern of interaction is more based on the user-producer relationship. In the *science-based* sector, the main sources of technology (which is quite high) are in-house development together with the underlying science developed in universities.

Since the empirical material covers the whole economy, Pavitt's taxonomy has to be extended. For this propose, the categorization in Laursen and Foss (2000) is applied. In their categorization, five additional sectors were added to Pavitt's taxonomy – ICT- (Information and Communication Technology) intensive services, wholesale trade, scale intensive services, specialized services and crafts. See appendix 3 for a detailed assignment of all industries into the nine sectors.

APPENDIX 3: The assignment of industries into nine sectoral categories

No. Industry	Sector	No. Industry	Sector
1 Production etc. of meat and meat products	SCAI	43 Sale of motor vehicles, motorcycles etc.	SSER
2 Manufacture of dairy products	SCAI	44 Maintenance and repair of motor vehicles	CRAF
3 Manufacture of other food products	SCAI	45 Service stations	SSER
4 Manufacture of beverages	SCAI	46 Ws. of agricul. raw materials, live animals	WTRA
5 Manufacture of tobacco products	SCAI	47 Ws. of food, beverages and tobacco	WTRA
6 Manufacture of textiles and textile products	SDOM	48 Ws. of household goods	WTRA
7 Mfr. of wearing apparel; dressing etc. of fur	SDOM	49 Ws. of wood and construction materials	WTRA
8 Mfr. of leather and leather products	SDOM	50 Ws. of other raw mat. and semimanufactures	WTRA
9 Mfr. of wood and wood products	SDOM	51 Ws. of machinery, equipment and supplies	WTRA
10 Mfr. of pulp, paper and paper products	SDOM	52 Commission trade and other wholesale trade	WTRA
11 Publishing of newspapers	SDOM	53 Re. sale of food in non-specialised stores	SCIS
12 Publishing activities, excl. newspapers	SDOM	54 Re. sale of food in specialised stores	SSER
13 Printing activities etc.	SDOM	55 Department stores	SCIS
14 Mfr. of refined petroleum products etc.	SCAI	56 Retail sale of phar. goods, cosmetic art. etc.	SSER
15 Mfr. of chemical raw materials	SCIB	57 Re. sale of clothing, footwear etc.	SSER
16 Mfr. of paints, soap, cosmetics, etc.	SCAI	58 Re. sale of furniture, household appliances	SSER
17 Mfr. of pharmaceuticals etc.	SCIB	59 Re. sale in other specialised stores	SSER
18 Mfr. of plastics and synthetic rubber	SCAI	60 Repair of personal and household goods	SSER
19 Mfr. of glass and ceramic goods etc.	SDOM	61 Hotels etc.	SSER
20 Mfr. of cement, bricks, concrete ind. etc.	SCAI	62 Restaurants etc.	SSER
21 Mfr. of basic metals	SCAI	63 Transport via railways and buses	SCIS
22 Mfr. construction materials of metal etc.	SCAI	64 Taxi operation and coach services	SSER
23 Mfr. of hand tools, metal packaging etc.	SDOM	65 Freight transport by road and via pipelines	SSER
24 Mfr. of marine engines, compressors etc.	SPEC	66 Water transport	SCIS
25 Mfr. of other general purpose machinery	SPEC	67 Air transport	SCIS
26 Mfr. of agricultural and forestry machinery	SPEC	68 Cargo handling, harbours etc.; travel agencies	SCIS
27 Mfr. of machinery for industries etc.	SPEC	69 Monetary intermediation	ITIS
28 Mfr. of domestic appliances n.e.c.	SCAI	70 Other financial intermediation	ITIS
29 Mfr. of office machinery and computers	SCIB	71 Insurance and pension funding	ITIS
30 Mfr. of radio and communication equipment etc.	SCIB	72 Activities auxiliary to financial intermediates	ITIS
31 Mfr. of medical and optical instruments etc.	SPEC	73 Letting of own property	SSER
32 Building and repairing of ships and boats	SCAI	74 Real estate agents etc.	SSER
33 Mfr. of transport equipment excl. ships, etc.	SCAI	75 Renting of machinery and equipment etc.	SSER
34 Mfr. of furniture	SDOM	76 Computer and related activity	ITIS
35 Mfr. of toys, gold and silver articles etc.	SDOM	77 Research and development	ITIS
36 General contractors	CRAF	78 Legal activities	ITIS
37 Bricklaying	CRAF	79 Accounting, book-keeping and auditing activities	ITIS
38 Install. of electrical wiring and fittings	CRAF	80 Consulting engineers, architects etc.	ITIS
39 Plumbing	CRAF	81 Advertising	ITIS
40 Joinery installation	CRAF	82 Building-cleaning activities	SCIS
41 Painting and glazing	CRAF	83 Other business services	ITIS
42 Other construction works	CRAF		

SCAI = Scale intensive firms; SDOM = Supplier dominated firms; SCIB = Science based firms; SPEC = Specialised suppliers; CRAF = Crafts; WTRA = Whole sale trade; SSER = Specialised services; SCIS = Scale intensive services; ITIS = ICT intensive services.

Source: Laursen and Foss (2000, p. 16)

APPENDIX 4 Probit Model of the Ability to Innovative yes/no, Absorptive Capacity and Strength of Ties with Uni. and Tech. Sup. Inst.

Variable	Supplier dominated		Scale intensive		Specialised suppliers		Science-based	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	0.658**	0.244	0.037	0.282	0.366	0.390	0.689	0.862
ACAUNI – Absorptive capacity and strength of ties with universities and tech. sup. inst.:								
- High absorptive capacity and strong ties	0.260	0.280	1.406**	0.286	0.383	0.406	0.952	0.932
- High absorptive capacity and weak ties	-0.008	0.268	0.226	0.300	0.431	0.329	0.056	0.788
- Low absorptive capacity and strong ties	0.080	0.296	0.361	0.326	6.708	14.676	5.864	28.494
- Low absorptive capacity and weak ties	bench.	-	bench.	-	bench.	-	bench.	-
SUBSID – Belonging to a sub. firm, binary								
- Yes	-0.178	0.208	0.379	0.202	0.074	0.292	0.306	0.430
COMP – Experienced increased comp. binary								
- Yes	0.768**	0.198	0.114	0.187	0.032	0.270	0.774*	0.403
SIZE – Size of the firm								
- < 20	-7.210	16.157	0.662	0.789	5.982	4.676	5.50	28.494
- 20 - 50	-0.398	0.230	0.306	0.242	-0.443	0.297	-0.401	0.575
- > 50	bench.	-	bench.	-	bench.	-	bench.	-
Number of observations	195		225		120		59	

Notes: ** significance at 1% level; * significance at 5% level.

Appendix 4 Probit Model of the Ability to Innovative yes/no, Absorptive Capacity and Strength of Ties with Uni. and Tech. Sup. Inst. (cont.)

Variables	Craft		Wholesale trade		Specialised serv.		Scale int. Serv.		ICT int. serv.	
	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	0.058	0.376	0.806**	0.262	0.046	0.327	0.026	0.527	1.443*	0.618
ACAUNI – Absorptive capacity and strength of ties with universities and tech. sup. inst.:										
- High absorptive capacity and strong ties	0.370	0.687	0.468	0.333	0.826	0.818	-6.430	17.386	0.469	0.537
- High absorptive capacity and weak ties	0.287	0.312	0.195	0.184	0.478	0.247	-0.347	0.442	-0.063	0.448
- Low absorptive capacity and strong ties	0.757*	0.348	0.540	0.379	0.257	0.347	-	-	6.017	17.386
- Low absorptive capacity and weak ties	bench.	-	bench.	-	bench.	-	bench.	-	bench.	-
SUBSID – Belonging to a sub. firm, binary										
- Yes	0.274	0.247	0.723**	0.161	0.018	0.204	0.137	0.356	0.446	0.360
COMP – Experienced increased comp. binary										
- Yes	0.721**	0.208	0.531**	0.163	0.505*	0.169	0.007	0.333	0.791*	0.320
SIZE – size of the firm										
- < 20	-0.040	0.348	0.016	0.240	-0.335	0.304	-0.257	0.479	-0.272	0.461
- 20 – 50	-0.336	0.347	0.005	0.238	-0.384	0.299	-0.293	0.457	-0.003	0.469
- > 50	bench.	-	bench.	-	bench.	-	bench.	-	bench.	-
Number of observations	231		284		271		62		97	

Notes: ** significance at 1% level; * significance at 5% level.