# Absorptive Capacity and Innovative Performance: A Human Capital Approach

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**Abstract**

Knowledge received from external partners is important and widespread among firms in the process of innovation but managing the external acquisitions is a difficult task. One of the most comprehensive contributions to this issue is the concept of absorptive capacity where internal capability and external collaboration is viewed as complementary to one another. Besides a theoretical review of the importance of inter-firm relations this study applies a merged database, a survey on firm's organisational and technological change (1993-95) with an integrated database on labour market research (IDA) form the period 1990-97 covering very specific information on each individual employed in each firm. The estimation of an ordered probit model including 1544 firms from the manufacturing and service industry show that the application of HRM practices within the firm combined with development of a closer relationship with both vertical related actors and knowledge institutions promotes not just the ability to innovate, but decreases also the degree of innovative imitation. Thus, an indication of improved ability to deal with complexity. A policy as well as a managerial implication is therefore 1) to broaden the importance of user-producer interaction to also include knowledge institutions. 2) to support the development of human resources by developing the organisational structure, culture and use of techniques, which motivates a qualified labour force where terms like decentralisation of responsibility and influence to the employees in the organisation are essential. According to the estimations should the use of HRM practices on the employees have higher priority than increasing the share of higher educated people. This is only true when sector are included in the models where the variance explained in the share of higher educated employees disappears. Finally does work experience among managers, head of departments and employees at the managerial level not show any effect on the degree of innovative imitation.

## Introduction and Theoretical Review

It is generally recognised that in the current economic context, the technological element is of crucial importance of competitive advantage for the individual firm, nation and the world economy as a whole. Several scholars deal with technological change and even through they are based on different approaches at different levels, they all agree upon the fact that inter-firm relations is of crucial importance in the technological development. Hagedoorn et al. (2000) distinguishes between three broad categories of literature – strategic management theories, industrial organisation and transaction cost economics but also the innovation literature stresses the importance of inter-firm collaboration or in a broader sense the learning economy.

Strategic management theories deal mainly with the firm and its internal organisation of the activities. According to Hagedoorn et al. five such approaches can be viewed under strategic management. First competitive forces (Porter 1980; 1985; Harrigan 1988) is partly based on the structure-conduct-performance approach. Collaboration is viewed as a vehicle of shaping competition by increasing the competitive advantage of the firm. Technological collaboration is thus seen as a mean to react on market needs and to increase the speed of introduction of the new technology to the market. Second, strategic networks which have three rationales for explaining the formation of networks. Networks can increase the efficiency via scale and economies of scope and by reducing the transaction costs. Networks can further establish synergies by exploiting different competencies (Miles and Snow 1984). Finally network formation give the possibility of gaining power for instance by gaining market position and controlling information. Third, the resource-based view of the firm, (Penrose 1959; Rumelt 1984; Wernerfelt 1984; Barney and Link 1991; Mowery, Oxley et al. 1998), which is one of the most influential in strategic management. Competitive advantages are sustained due to the rare, unique resources of the firm, which is difficult to substitute. Collaboration is necessary in the case of gaining access to external complimentary resources (Teece 1986). Fourth, the dynamic capability approach (Teece and Pisano 1994; Teece, Pisano et al. 1997). The main argument here is to accumulate and deploy new skills and capabilities in order to comply with the rapidly changing environment. External collaboration is in this approach used in order to learn for relationships. (Hamel 1991) argues that collaboration primarily is meant as a way on acquiring skills of another firm. Fifth, the strategic option to new technologies (Sanchez 1993). This approach compliments the former by reflecting the resources that is needed in order to operate in uncertain market environments. Collaboration is seen as a way of giving firms possibility to react on new opportunities. A sixth approach is the knowledge-based view of the firm (Grant 1996a; 1996b; 2000) (Kogut and Zander 1992) (Conner and Prahalad 1996). This approach suggests that the key role of the firm is in creating, storing and applying knowledge. According to (Grant 1996b) is collaboration relevant when knowledge cannot be fully integrated in the product. A mismatch between the firm's product domain and its knowledge domain favour collaboration in order to get the right match of knowledge. Finally will uncertainty and the rapid speed of technological change promote inter-firm relations.

Industrial organisation theories focus on the firm and its effects of firm actions on industrial structure, economic efficiency and social welfare. One of the main concerns is the potential failure in the market of scientific and technological knowledge. This is due to the fact that the nature of knowledge is a public good that makes its production relatively more expensive than its transmission (D´Aspremont and Jacquemin 1988). These models show that firms

tend to have incentives to co-operate in R&D due to their individual collusive profits, which are higher than in the non-cooperative case. They further emphasise that economic welfare under R&D collaboration is higher than under competition. R&D collaboration in industrial organisational models thus recognises the advantages over competition in terms of welfare in the sense of higher R&D investment, better diffusion of results, elimination of wasteful duplication of efforts and access to new markets.

The transaction cost economics, (Williamson 1975; 1985) which to some extent can be viewed as a mixture between the two, seeks to explain why firms organise internally, while at the same time addressing market or industry forces. The main argument is the relative costs of carrying out transaction under different organisational regimes – market, hierarchy or a mixture in between a hybrid form (Williamson 1996). The relative cost is determined by production cost and transaction costs. The former is dependent upon the knowledgebase of the firm, the ability to learn and economies of scale and scope. The latter which varies form each transaction, is dependent on those costs that is necessary to carry out an transaction – for instance writing, observance and control of contracts. Intangible assets like knowledge might cause possibility of incomplete contracts due to the fact that knowledge is subject to positive externalities, its production is uncertain and its dissemination can induce opportunistic behaviour. Collaboration or the hybrid form can facilitate these activities by minimising the cost of transactions involved with intangible assets and by reducing the opportunistic behaviour.

Influenced from the evolutionary economics is the innovation theory. In its early contribution innovation was seen as a linear process where interaction with external partners was neglected. This process were later modified by Kline & Rosenberg (1986) who viewed the innovation process as chain-linked model. Technological change is highly emphasised as a result of feedback loops between knowledge-producing and knowledge-using agents where a varying degree of interaction within and among firms takes place. DeBresson (1999) points out that co-ordination of innovation almost always require a network of collaboration partners with different competencies. Especially partners like users has been emphasised (Lundvall 1985; Lundvall 1992) and in some cases leading edge customers (Rothwell and Dodgson 1991) but also the interaction with both users and suppliers has been touched upon (Von Hippel 1976; 1988) (Harabi 1999) and (Kristensen and Vinding forthcoming).

A systematic and more broad approach to interaction elements in the process of innovation is the concept of national innovation systems (Freeman 1987), (Lundvall 1992), (Nelson 1993), (Edquist 1997) and the concept "learning economy" (Lundvall and Johnson 1994). The learning economy is characterised by shorter product cycles, more uncertain and fluctuating markets, more intense use of information technology and increased 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.[1] Besides growth in the quantity and complexity of knowledge, processes as learning, forgetting and diffusion of knowledge become of growing importance. Thus, the ability to continuously participate in learning processes and to develop and absorb new knowledge becomes a crucial element for firms' competitiveness.

In the learning economy where information becomes more complex and abundant, know-how (skills in selecting and using information) and know-who (who knows what and who

[1] Gibbons et al. (1994) goes as far as arguing that the economy is entering a new mode of producing knowledge named mode 2.

knows what to do, thus the capability to co-operate) is becoming of great importance. According to Foray and Lundvall (1996) the 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. Collaboration in innovation processes is also often considered as a first-best option, instead of last resort because of firms potentially access to information, resources, markets and technologies. Dodgson (1993) and Schill (1994) points out that collaboration is well established in innovation strategies of the firm. This is due to the fact of 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).

Empirically the benefits of external collaboration for a firm's innovation was already pointed out in the 1972 SAPPHO studies (Rothwell, Freeman et al. 1974). Later studies like CIS I (1993) and II (1997) (Community Innovation Surveys), PACE (1995) (Policies, Appropriability and Competitiveness for European Enterprises) as well as the DISKO survey (Danish Innovation System a Compartive Analysis) emphasis quantitatively the importance of collaboration.

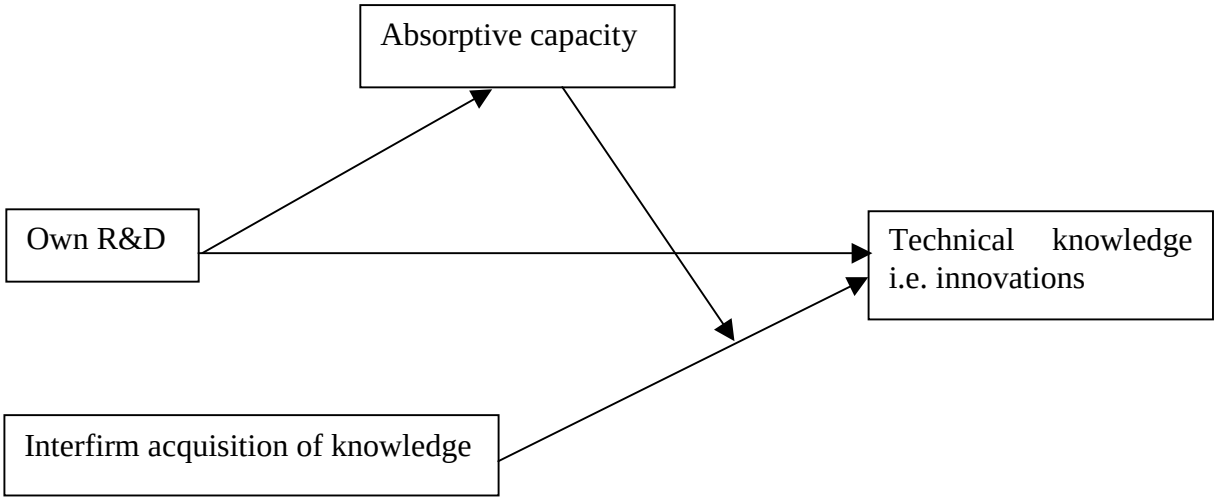
Other studies have dealt with formal versus informal networks in the process of innovation. Håkansson (1987; 1989) and Freeman (1991) argue the significance of both informal and formal networks. Harabi (1999) finds that informal networks of R&D co-operation seem to be more important for firms innovative behaviour than formal ones. Behind every formal networks, usually various informal networks are to be found (Freeman 1991). Informal networks are by Von Hippel (1989) identified to exchange information between firms. Networks of staff in research and development is found to be useful in order to gain access to new knowledge (Rabba and Debackere 1992).

## Absorptive Capacity and Innovation

Although knowledge received from external partners seem to be important and widespread among firms, managing external acquisitions is a difficult task. Besides the problem of finding the right person/partner - know-who, difficulties in assimilating and exploiting the information might be the next problem. One of the most comprehensive contributions to this issue is Cohen and Levinthal (1989; 1990) concerning absorptive capacity where internal capability and external collaboration is viewed as complementary to one another.[2] See figure 1.

[2] This is very much in line with Rosenberg (1982) who argues that fundamental research inside the firm is complimentary with external R&D from either public or the private sector.

Figure 1. Model of absorptive capacity and R&D incentives.




Source: Cohen and Levinthal (1990), p.141

They argue that own R&D produces not only new knowledge in the sense of innovations but contributes also to the absorptive capacity of the firm by increasing the skills of the employees who have been involved in the R&D process. These stocks of skills or of prior knowledge determine the ability to assimilate and utilise external knowledge. In cases where the absorptive capacity is important for the development of new knowledge, the absorptive capacity will have an influence on both the direction and intensity of R&D of the firm. This could be in cases where knowledge that has to be accumulated is complex and highly sophisticated i.e. in high-tech industries. Absorptive capacity is cumulative in its nature and accumulation will permit a more efficient accumulation in the next period because of already accumulated some knowledge in that field thus easier to assimilate new knowledge. Second the existence of a certain level of knowledge in that particular path will thus provide better signals to predict and import new technological opportunities, which is especially important in uncertain environments. The firm further increases the attractiveness to partners and thus increase the firm's collaboration opportunities (Ahuja 2000). Mangematin et. al. (1999) argues that a high degree of absorptive capacity extends the assimilation to all kinds of applied, fundamental form of knowledge and through all modes of vehicles like PhD students, scientific staff, technical devices etc.. Summing up firms with a high level of absorptive capacity will be in a better position to assimilate and utilise external knowledge thus increase the pay-off in the process of interaction and in the innovation process increase the innovative performance.

The verification of the hypothesis is mostly based on specific sectors especially in the biotech sector. Gambardella (1992) found evidence from 14 case studies of large US drug manufactures using patent data as the output indicator. Firms who are in a position of better in-house scientific capabilities (measured as scientific publications) are able not only to make more efficient use of internal knowledge but also to exploit more effectively external knowledge. This is in line with Henderson and Cuckburn (1996), who found similar results of

large firms in pharmaceuticals and Arora & Gambardella (1990) in biotechnology. Tripsas (1997) finds in the typesetting industry that a combination of internal investment in absorptive capacity of the firm and an external communication infrastructure to facilitate the transmission of external knowledge, enables firms successfully to integrate knowledge outside its boundaries. Rothwell and Dodgson (1991) emphasise the importance of SME´s in having highly qualified technical specialists, scientist and engineers in order to access external knowledge. Veuglers (1997) finds in the Flemish manufacturing industry that R&D cooperation and to a certain extent R&D contracted out have a positive effect on the internal R&D, but only if the absorptive capacity takes the form of full-time staffed R&D department. Vergragt (1992) argues that creation of internal networks extended with external relations will improve the possibility of technological development. Simulation analysis also suggests that building up absorptive capacity tends to be a superior strategy in technological heterogeneous environments (Cantner 1998).

In the work of Cohen and Levinthal R&D budgets determines the absorptive capacity by increasing the firm's stock of knowledge. But they are also aware of the fact that absorptive capacity is dependent on individuals working in the organisation. Especially people located at the interface of either the firm or its environment or at the interface between subunits within the firm. These "gatekeepers" is essential and Tushman and Katz (1980) also emphasise that "gatekeepers" is able to reduce the mismatch in language and cognitive orientation among two systems and 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 organisation and if the other members of the organisation is in a position of a high level of expertise the transmission process will become easier. This is in line with Mangematin *et al.* (1999). He argues that especially high-educated employees naturally by their daily task will increase the stock of knowledge in the organisation. They will further encourage relations with other individuals with similar competencies outside the firm, thus facilitate access to external networks of knowledge, especially in the case of utilising scientific knowledge (Rothwell and Dodgson 1991). Carter (1989) argues that higher educated employees are the main contributors of know-how trading due to high level of knowledge embodied in these people. This statement in further supported by Guellec (1996) who emphasise skilled labour to be in a better position to generate new knowledge because they master the state of the art and thus is better to manage new technology. Canto et al. (1999) finds that intangible resource - dived into human and commercial issues is the main determinant of carrying out R&D compared to financial and physical resources.[3]

An important element, which Cohen and Liventhal put less emphasis in, is the organisational settings the employees operate in. They point out that cross-function interfaces i.e. among R&D, design, manufacturing and marketing increases the absorptive capacity. Also practices like rotating of R&D personnel through other units within the firm is of importance. In general terms these restructuring of employment relation in the form of human resource practices (HRM)[4] has shown positive linkages to innovative performance (Gjerding 1997;

[3] Florida (1995) generalised the importance of the issue by arguing that we are entering into a new age of knowledge creation and continuous learning where the main source of value and economic growth is the human mind instead of the firm. According to Florida the competitiveness of the firm is determined by a unique combination of individual competencies as a result of acquired skills, education, qualification and training.

[4] HRM has within the last 10 years become of great importance. The basic idea is to promote the development of human resources by developing the organisational structure, culture and use of techniques, which motivates a qualified labour force. Terms like decentralisation of responsibility and influence to the employees in the organisation.

Mendelson 1999; Michie 1999). Laursen and Foss (2000) goes one step further and finds that complementarities between HRM practices has a positive influence on innovative performance.

Another element which Nelson and Winter (1982) put forward is the tacit dimension of knowledge in the development process which they find crucial. This kind of firm specific knowledge i.e. in the form of learning by doing can be measured by work experience of the employees. Albaladejo (2000) finds that work experience obtained in either multinational or large domestic firms in UK by founder/manager(s) has an influence on firms innovative capabilities. But also prior work experience in public R&D institutions as well as having a degree in science and engineering has an impact.

## Hypothesis

According to the above discussion both general knowledge in terms of formal education, firm specific knowledge in terms of work experience and finally the organisational set-up matters for the determination of absorptive capacity, thus a refinement of the concept. In the literature all three elements is expected to be positive associated with innovative performance due to the ability to be in a better position to absorb external information form collaboration partners. But the literature has so fare mainly taken one of the indicators into account. What happens if all three indicators are included in a model, as shown in figure 2? Do the three indicators compliment each other, as one would expect and which of the indicators is of greatest importance?

Figure 2. Modified model of absorptive capacity and R&D incentives.

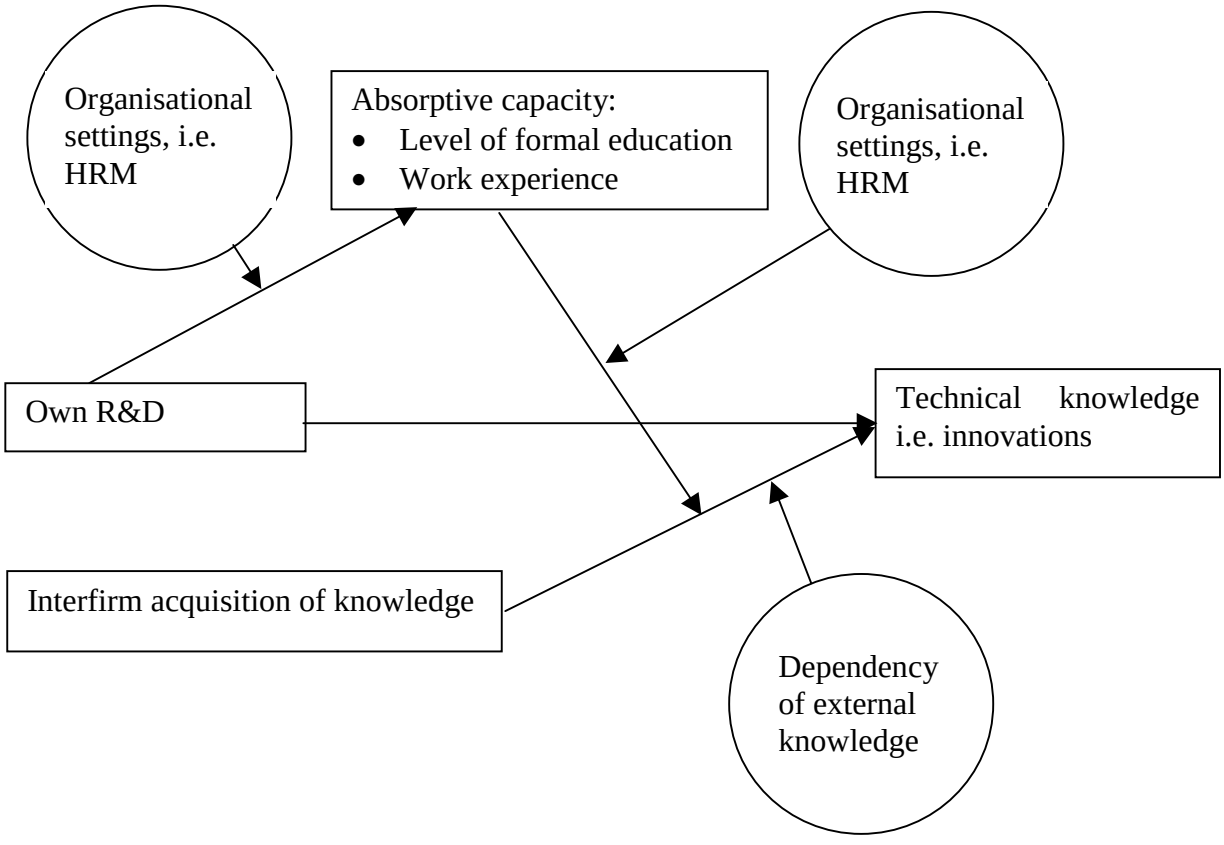


Figure 2 also shows a fourth indicator, the dependency of external knowledge. The literature has so far been concentrating on arguing that absorptive capacity is important in order to utilise and assimilate external knowledge. Research has not taken into account that the importance of absorptive capacity varies between firms. For instance Pavitt taxonomy and other taxonomies on industry characteristics in the process of innovation show that some firms are more dependent on knowledge institutions, others on customers and so on. Hence, absorptive capacity will play a minimal role in cases where firms hardly use external knowledge in their process of innovation. On the other hand, firms that in their process of innovation develops a closer relationship to its external partners the element determining the absorptive capacity will play a significant role and thus be important in the innovative outcome.

Besides incorporating a three-fold approximation of absorptive capacity this study goes further. Instead of intermediary outcome like citations or patents this study applies the innovativeness of the firm which according to Acs and Audretch (1988) is the most direct measure of innovative activity. Finally is the whole economy analysed and thus gives possibility to check for sectoral differences.

## The model

The theoretical discussion of interaction effects gives possibility of estimating a model where a firm's ability to innovate is used as a dependent variable and absorptive capacity and traditional control variables as independent variables (ordered probit model). The model can be specified as follows:

$$a = f(\beta_1 z + \beta_2 q + \beta_3 x) \tag{1}$$

Where $a$ represents the innovative activity of the firm, $\beta_1 z$ and $\beta_2 q$ vectors concerning the absorptive capacity and dependency of external knowledge. $\beta_3 x$ express other standardised variables used in the literature explaining the innovative activity of the firms. More specific the model can be decomposed to include the following:

$$A_i = \beta_1 HIEDU_i + \beta_2 EXPE_i + \beta_3 HRM_i + \beta_3 EXTERN_i + \beta_4 SECT_i + \beta_5 SIZE_i + \beta_6 COMP_i + \beta_7 SUBSID_i + \varepsilon_i, \tag{2}$$

$A_i$ expresses the innvoativeness of the firm on an ordered scale form 0-3.[5] 0 is equal to a non-innovator firm (761), 1 if the firm has introduced a product/service in the period of 1993-95 which is new to the firm (584), 2 if the firm has introduced an innovation which is new in the Danish context (110) and finally 3, if the firm has introduced an innovation which is new to the world (89). Thus the dependent variable measures the degree of innovative imitation.

*HIEDU*, *EXPE* and *HRM* represent the variables which is needed in the organisation in order to assimilate and utilise external knowledge while EXTERN measures the importance of absorptive capacity for the individual firm.

*HIEDU* measures the share of employees with an academic degree and is expected to be positive associated with innovative performance (Acs and Audretsch 1988) (Rothwell and Dodgson 1991; Albaladejo 2000). EXPE measures the work experience of the employees. In

[5] A similar scale is used in Albaladejo et al.(2000).

order to grasp those employees in the organisation which are the most influential in the development process, managers, head of departments as well as workers at the managerial level is taken into account. An *HRM* index developed in Gjerding (1997) is applied. This includes *HRM* practices like (i) interdisciplinary workgroups, (ii) quality circles, (iii) systems for collection of employee proposals, (iv) planned job rotation, (v) delegation of responsibility, (vi) integration of functions and (vii) performance related pay. Firms using 0-2 practices are considered as having a level of low development, 3-4 practices as medium and 5-7 high level of HRM practices.

*EXTERN* takes three values and indicates at the first place firms that have not developed a closer relationship with its external actors. The second value represents firms which have developed a closer relationship with either customers/suppliers as pointed out by (Lundvall 1988; Von Hippel 1988) or knowledge institutions. Knowledge institutions express whether the firm had developed a closer relationship with institutions like technical support institutions, consultants or universities. Information from these partners requires higher absorptive capacity due to the higher level of sophistication. This indicates that in order to understand and fully absorb knowledge from these institutions firms have to invest in-house (Mowery and Rosernberg 1989) and it can be expected that capacities to absorb external knowledge are especially important for high-tech firms. Even through much of the universities research is basic research, the industry seems to pay off from these results (Rosenberg 1994) (David 1994) (Narin 1997). Further Brouwer and Kleinknecht (1996) stresses that firms collaboration with innovation centres increases the propensity to innovate and (Albaladejo 2000) points out the same conclusion when it comes to interaction with R&D and training institutions present for small UK. companies in software, electronics and clothing. Finally, are those firms which have developed a closer relationship with both types of actors and thus have developed a closer relationship with a network of actors which according to Foray and Lundvall (1996) is expected to be crucial for survival in the networked learning economy.

Four standard control variables are included in the model. As discussed above *(SECT)* sectoral affiliation is expected which according to Mohnen *et al.* (2000) reflects the technological opportunity of the industry. In the model Pavitts taxonomy is applied with four sectors representing the manufacturing sector while five sectors represents the service firms.[6]

One of the Schumpeterian hypotheses concerns innovation and *SIZE*. Schumpeter argued that innovative activity was positive correlated with firm size due to the existence of R&D departments. Although there has been contradictory results concerning this issue over the decades the results seem to be in favour of a positive relationship (Acs and Audretsch 1988; Brouwer 1996) (OECD 1996) (Laursen 2000).[7]

The third control variable competion – *COMP*, was also touched upon by Schumpter. Several measures has been applied mostly the level of competition in terms of different ratios concerning concentration and over the last decades contradictory results has arisen. Schumpeter was in favour of concentrated industries in affiliating innovative activity. Others have shown that competition doesn't matter (Arvanitis S. 1996) (Crepon 1996), while others have shown that increased competition favours innovation (Geroski 1990; Gjerding 1997). *COMP* is measured in a slightly different way since the firms are asked to rate the

[6] The categorisation of the service firms is taken from Laursen (2000). For further details on the categorisation, see appendix 1 and 2.

[7] See Cohen (1995) and OECD (1996) for an empirical review.

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 exists although the most recent studies argues the existence of a positive relation due to the fact that subsidiary firms have access to a larger resource base by the parent firm and thus will benefit on innovative activity.[8]

## Data

Two databases are used in order to carry out the analysis. The DISKO survey on organisational and technological change (1993-95). The survey was carried out in 1996 at Aalborg University and was submitted to almost 4000 firms to the manufacturing and service sector. Firms with 20 employees or more were selected while firms with 10 employees or more were selected form the service industry. In return, all firms with at least 100 employees were selected due to the fact that especially large firms carry out organisational change. The overall response rate was 48% (1900 firms), and in the manufacturing and service sector the responds rates were 52% and 45% respectively.[9] The second database is the integrated database on labour market research, (IDA) and includes data on each individual person in Denmark form the period 1980-97. The two databases are merged and besides covering the survey form the period of 1993-95, IDA data form 1990-97 is included as well. 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. The data is unique because it links data on organisation and technical change with information on each employee employed in these firms within the period. Thus the richness and very detailed information on each firm and its employees makes it possible to enrich the discussion, in this case on absorptive capacity and innovative performance.

## Results

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

[8] See Laursen (2000) for a short empirical review.
[9] For descriptive statistics see Gjerding (1997) and the questionnaire can be viewed in Lund (1996).

**Table 1: Ordered probit estimation of innovative performance and absorptive capacity**

| | Model I | | Model II | | Model III | | Model IV | |
|---|---|---|---|---|---|---|---|---|
| **Variables** | Estimates | p-value | Estimates | p-value | Estimates | p-value | Estimates | p-value |
| Intercept | **-1.048** | **0.000** | **-1.197** | **0.000** | **-0.821** | **0.001** | **-0.810** | **0.001** |
| **HIEDU**, average 90-95 | **1.741** | **0.001** | | | 0.757 | 0.218 | | |
| **HIEDU** | | | | | | | | |
| - upgrading 93-95 | | | **0.262** | **0.003** | | | 0.093 | 0.293 |
| - degrading 93-95 | | | **0.310** | **0.001** | | | 0.135 | 0.153 |
| - unchanged 93-95 | | | Benchmark | | | | Benchmark | |
| **EXPE** | 0.001 | 0.691 | 0.001 | 0.792 | 0.000 | 0.969 | 0.000 | 0.964 |
| **HRM** | | | | | | | | |
| - low | **-0.569** | **0.000** | **-0.520** | **0.000** | **-0.444** | **0.000** | **-0.430** | **0.000** |
| - medium | **-0.180** | **0.000** | -0.154 | 0.065 | -0.153 | 0.054 | -0.146 | 0.069 |
| - high | Benchmark | | Benchmark | | Benchmark | | Benchmark | |
| **EXTERN** | | | | | | | | |
| - none | **-1.073** | **0.000** | **-1.014** | **0.000** | **-1.001** | **0.000** | **-0.989** | **0.000** |
| - either vertical/know.inst. | **-0.273** | **0.000** | **-0.251** | **0.001** | **-0.237** | **0.001** | **0.232** | **0.002** |
| - both | Benchmark | | Benchmark | | Benchmark | | Benchmark | |
| **SUBSID** | **-0.249** | **0.000** | **-0.189** | **0.010** | **-0.159** | **0.025** | **-0.143** | **0.049** |
| **COMP** | **-0.224** | **0.001** | **-0.213** | **0.003** | **-0.220** | **0.001** | **-0.216** | **0.002** |
| **SECTORS** | | | | | | | | |
| - Scale intensive | | | | | -0.227 | 0.209 | **-0.309** | **0.047** |
| - Supplier dominated | | | | | -0.149 | 0.399 | -0.241 | 0.112 |
| - Science based | | | | | 0.105 | 0.576 | 0.019 | 0.911 |
| - Specialised suppliers | | | | | -0.113 | 0.591 | -0.195 | 0.327 |
| - Crafts | | | | | **0.823** | **0.000** | **-0.878** | **0.000** |
| - Wholesale trade | | | | | 0.206 | 0.230 | -0.268 | 0.076 |
| - Specialised services | | | | | **-0.660** | **0.000** | **-0.719** | **0.000** |
| - Scale intensive services | | | | | **-0.763** | **0.002** | **-0.828** | **0.000** |
| - ICT intensive services | | | | | Benchmark | | Benchmark | |

In table 1 the estimations of equation 2 is reported. As can been seen from the first two models are the average share of higher educated employees and firms upgrading the competencies significant positive, but also firms which have been degrading the competencies have estimates significant positive form the benchmark category, firms with unchanged competence level. The reasons are three folded. First, firms in the unchanged category are primary small service firms, which have a low innovative propensity, especially when it comes to less imitated innovations. Second, firms in the degrading category could be benefiting form earlier innovations and thus hire more workers in order to keep up the growing demand. Third, we know that organisational change and restructuring of the firms and thus firing of employees can be conducive to innovation.

On the other hand is the average work experience among top management not significant as one could expect due to the learning by doing effect. This is true for all four models. The specific knowledge embodied in these people does not have an impact on the degree on innovative imitation. One explanation could be that younger people are educated with the latest knowledge about technology and management practices where as elderly people are less updated, i.e. not aware of the latest advantages in information technology.

When the models are controlled for sector and size (not shown in table 1) (model III and IV) the share of higher educated employees becomes insignificant although the estimates

have the right sign.[10] Including sectors remove the variance explained in the share of higher educated employees. Hence, the share of higher educated employees between each sector differs substantially, but the effect of the variance in the share of higher educated employees is not particularly important within each sector category.

The sector variable shows that *crafts, specialised services* and *scale intensive services* innovates significantly less than the benchmark category *ICT intensive services* in model III. Additionally are *scale intensive* firms less innovative in model IV. 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. Later on in the value chain where the rest of the service firms are placed, other elements like personal contacts to customers is 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).

For all four models the use of HRM practices is significant. Firms who applies a high degree HRM practices are in a better position to innovate, thus verifying the ideas of Cohen and Levinthal. The result is also in line with Laursen and Foss (2000), (Laursen 2000a; 2000b) who finds that the application of HRM practices are more effective in influencing the innovative performance when these practices are applied together rather than alone. Hence, HRM practices are complementary to one another.

Development of a closer relationship to external relations of the firm is also significant for all four models. This is especially true for firms, which have developed a closer relationship to vertical related actors like customers and suppliers but also to knowledge institutions like universities and consultants. They do significantly better on innovative performance compared to firms who have only developed a closer relationship to one of the actors and much better compared to firms who have not developed a closer relationships to its external actors. There seem to be evidence to suggest that the user-producer interaction put forward by Lundvall (1988) and von Hippel (1988) has to be broadened to include actors which are not located in the value chain of the product/service. Instead it is the whole network of external actors which matters. This is in line with Foray and Lundvall (1996) who argues that we are moving towards a networked learning economy where networks determines the relatively success of the firms. Also the rationale put forward by DeBresson (1999) that firms who interact with a multitude rather than with a few external actors seem to beneficial.

The last two variables the degree of competition and belonging to a subsidiary firm both show the right sign and are significant for all four models. Firms exposed for an increased competition are more likely to innovate which is in line with Geroski (1990) and Gjerding (1997). Subsidiary firms are also more likely to increase the innovative performance due to access to a larger resource base by the parent firm.

[10] Size was included in the model at the first place, but became insignificant when the sector variable entered. 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 is different form one another, 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.

## Conclusion

The use of external knowledge in the innovation process has in the last decades become of growing importance. In order to assimilate and utilise this knowledge in an effective way research have shown that increasing the internal capability of the firm is one way to absorb knowledge form the outside.

The estimation of an ordered probit model show that the application of HRM practices within the firm combined with development of a closer relationship with both vertical related actors and knowledge institutions improves a firm's ability, not just to innovate, but decreases also the level of imitation in the development of innovation thus, an indication of improved ability to deal with complexity (OECD 2000).

A policy as well as a managerial implication is therefore to support the development of human resources by developing the organisational structure, culture and use of techniques, which motivates a qualified labour force where terms like decentralisation of responsibility and influence to the employees in the organisation are essential. According to the estimations should the use of HRM practices on the employees have higher priority than increasing the share of higher educated people. This is only true when the sector variable is included in the models where the variance explained in the share of higher educated employees disappears. The share of higher educated employees between each sector differs substantially, but the effect of the variance in the share of higher educated employees is not particularly important within each sector category.

Including a network of external actors support the hypothesis that the importance of user-producer interaction has to be broaden to include knowledge institutions. A development of a closer relationship with a network of actors will be beneficial in several ways. The uncertainty in the technological development as well as opportunism will be reduced (DeBresson and Amese 1991). The learning economy will further increase the need for more efficient and trustworthy information. According to Powell (1990) can this be achieved through networks since information which passes through networks are "thicker" than information obtained in the market due to the fact that participants know each other. The information will further be more "freer" than communicated in a hierarchy which is characterised as being more formalised.

For knowledge institutions it can be argued that firms, which are able to utilise and assimilate this kind of sophisticated knowledge, will be in a better position to adjust more rapidly to the changing environment. The problem with knowledge institutions compared to other types of external actors is that firms do not know the value of the information they buy. In the case of choosing a supplier the firm know what it actually gets. Thus, an important task is to increase the transparency of the market for knowledge intensive services (Christensen forthcoming).

The work experience of managers, head of departments as well as workers at the managerial level does not show a significant effect on the degree of imitative innovation. Thus the learning be doing effect does not seem to have the same importance as the theory expects. One explanation could be that younger people are educated with the latest knowledge about technology and management practices where as elderly people are less updated, i.e. not aware of the latest advantages in information technology. Still if the variable is specified in more detail, for instance managers/employees with work experience in R&D departments the effect might show up.

Finally, sectoral differences especially between firms in the service industry appear where *ICT intensive services* are the most conducive to innovation while *craft* is less conducive.

One could put forward a hypothesis that industries in the beginning of the value chain of the product are more dependent on innovative activity. Industries at the end of the value chain, like most of the service industry, are less dependent on innovation but more on other factors like personal contact to customers and so forth. Another and well-documented argument is the relatively small level of competition in the service industry. Incentives to increase the level of competition in the service industry can be put forward. An implication could then be that the competitive pressure would spread to the rest of the economy through the backward linkages from the service industry.

This paper has shown that some variables seem to be more important than others in determining the absorptive capacity of the firm. Further research is necessary in order to specify in more detail, how the absorptive capacity of the firm affects the outcome in terms of innovative performance. For instance are certain types of education more conducive to innovations than others? Are some types of work experiences more important than others, i.e. work experience achieved in the same sector compared to experience achieved from other sectors? These kinds of learning by doing practices could be more influential in some industries like the craft industry. Finally a log-linear approach could be applied in order to determine the most effective combination of absorptive capacity.

# Appendix 1
# The Sectoral Classification Applied in this Paper

(Pavitt 1984), identifies differences in the importance of different sources of innovation according to which broad sector the individual firm belongs. The taxonomy of firms, according to principal activity, emerged out of a statistical analysis of more than 2000 post-war innovations in Britain and was explained by the sources of technology; the nature of users needs; and means of appropriation. Four types of firms were identified accordingly, namely supplier dominated firms, scale-intensive firms, specialised suppliers and science-based firms. *Supplier dominated* firms are typically small. Most technology comes from suppliers of equipment and material. *Scale intensive* firms are found in bulk materials and assembly. Their internal sources of technology are production engineering and R&D departments. External sources of technology include mainly interactive learning with specialised suppliers, but also inputs from science-based firms are of some importance. *Specialised suppliers* are small firms, which are producers of production equipment and control instrumentation. Their main internal sources are primarily design and development. External sources are users (science-based and scale-intensive firms). *Science based firms* are found in the chemical and electronic sectors. Their main internal sources of technology are internal R&D and production engineering. Important external sources of technology include universities, but also specialised suppliers.

Since the Pavitt taxonomy was created mainly with the manufacturing sector in mind (although our *crafts* sector [see below] could be included in the *supplier dominated* sector, if one were to follow the original Pavitt taxonomy), and since we are conducting an analysis of firms in both manufacturing as well as in services, we have added five additional service sectors. *ICT (Information and Communication Technology) intensive services* are firms providing business services and financial services. *Wholesale trade* consists of firms selling bulk materials or machines. *Scale intensive services* consists of typically large firms in the transport industries, cleaning service as well as of supermarkets and warehouses. *Specialised services* is made up of smaller firms including miscellaneous shops, hotels and restaurants, taxi companies etc. *Crafts* consists of firms in construction industries, as well as of automobile repair shops.

For a detailed assignment of all industries into our nine sectors, see Appendix 2 to this paper.

Source: Laursen and Foss (2000)

# Appendix 2:
# 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 services.

Source: Laursen and Foss (2000)

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