Determinants of Danish Firms' choice of R&D-cooperation partners

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Abstract: It is commonly accepted in the literature, that R&D increases productivity and welfare, and that R&D cooperation decreases the cost of R&D, which allows space for additional R&D activities. This paper discusses the rationale for firms' choices of cooperative R&D partners among private firms and public research institutions. Using unique firm specific data information on R&D behaviour and cooperation among Danish R&D firms, the determinants identified for R&D cooperation include R&D competence stocks, absorption capacity and R&D time horizon. The variation in determinants for different cooperation partners allows for a targeted research policy that strengthens R&D cooperation among preferred subgroups of firms and thereby contributes positively to the national welfare.

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1. Introduction

In a knowledge-based economy firms will have to continuously develop and increase their knowledge base to strengthen their market position through innovation in the firms. A part of the innovative behaviour consists of internal research and development, R&D, in the firms. The firm specific internal R&D can alternatively be done in cooperation with other R&D partners. Cooperation may lead to more efficient research processes, which in turn will benefit the participating parts. The aim of this paper is to analyse what factors that determine the choice of R&D cooperation partners among R&D firms. The analyses map a broad range of firm specific factors that determine the choice of partners and partnerships in R&D projects.

From the firm point of view it is not always optimal to possess the necessary R&D competences internally. It can be better; less cost full and more efficient to get access to the necessary R&D related knowledge and competences through cooperation with other R&D performing partners. It may be extraordinary expensive to be experts in all disciplines involved in an R&D project. Likewise the R&D cooperation and the interactions with the R&D partners may ease the access to new markets and make a new market entry more efficient through reduction in entry costs and thereby improve the initial market position the firm. Cooperation may also lower the financial risk regarded to R&D projects by cost splitting; the risk barrier is particular a common barrier for SMEs (small and medium sized enterprises). As such there are numerous economic incentives to cooperate concerning R&D rather than carry out R&D individually.

Other economic incentives concerning R&D cooperation worth mentioning are that cooperation may provide complementary as well as updated R&D competences to the firm such that the firm may cheaper and more efficiently conduct other parts of their own R&D. Furthermore, the benefits and utilisation of external R&D competences may increase such that the firm is better suited for future R&D cooperation. Hence, R&D cooperation may also increase the basic competences concerning the research abilities of the firm. At the same time the firm achieves a better general knowledge base than the market it operates in and thereby strengthens its position in the market. The firm will increase its pay off from its knowledge base since the firm in the future is more capable of understanding, developing and implementing new knowledge.

These positive economic synergies of R&D cooperation, improved transfers of knowledge between firms and between firms and public research centres are some of the main reasons why EU and OECD (as well as) the Danish government choose to put R&D cooperation on top of the research policy agenda.

Naturally, only R&D active firms can participate in R&D cooperation. Thus the firms included in the present analysis are solely R&D active firms. R&D cooperation is defined as an active contribution into R&D projects together with other firms or R&D institutions. This means that all partners gain some kind of commercial benefit such as increased sales or reduced costs from the co-joint project. Firms that only buy R&D is also included in the analysis, as the action of buying R&D is considered to be a complex action, where absorption capacity and R&D knowledge is required.

Initially, it is expected that the firms' choice of R&D cooperation partners is caused by a particular need for R&D in the firms. Therefore the analysis in the present paper will focus on the firm specific R&D profile, R&D competences and absorption capacity as factors that determine the firms' need for and choice of R&D cooperation partners. As assumed above, R&D cooperation needs input from the involved partners. Therefore, it is assumed that the R&D competences and R&D capacity of the firm have a significant influence on the ability to participate in the R&D cooperation. Likewise, the absorption capacity of the firm influence how the firm manage, utilize and implements complex knowledge, i.e. basic research knowledge, in their organisation. Thus relative higher shares of R&D competent and scientifically educated employees will improve the utility and pay off of cooperation with partners that are performing basic research. Public research centres such as universities more often perform basic research.

In section 2 of the paper, the theoretical and empirical literature concerning the motivation for R&D cooperation is shortly scheduled. It is argued that cost minimisation is crucial for the choice to cooperate on R&D. Furthermore, it is argued that the firm specific R&D profile, the R&D absorptions capacity and the R&D competences are significant factors determining the choice of type of R&D cooperation partners. Finally, it is argued that it is expectable in a well-functioning innovation system that a relative higher number of firms cooperate with other firms in stead of public research centres due to the R&D type these partners are involved in, i.e. applied versus basic research.

Section 3 describe the empirical data used in the analysis of the influential factors that determines the Danish firms' choice of R&D cooperation partners, while section 4 provides the results from the empirical modelling. In the model the significance of coefficients of variables in different categories, i.e. R&D profile, R&D competences and R&D absorption capacity are tested. The model shows that the significance of the factors varies with the choice of R&D cooperation partners tested for. The last section summarises the results and schedules some policy implications based on the empirical results.

2 Theoretical motivation for R&D cooperation

It is basically assumed that a profit-maximising firm always optimise its actions. However, R&D is usually time consuming and the final results are unknown when it is initiated. Hence, the optimising behaviour is assumed to be present on average. Thus the R&D active firm will cooperate on R&D whenever it will make it cheaper, more effective and increase the expected utility of the R&D. Cooperation will be an optimal strategy if and only if the synergies are large enough; typically larger for SMEs that often will be relatively more risk averse due to their size, and limited financial strength. Thus R&D cooperation as a way to reduce the initial risk could be a way to increase the R&D activities of SMEs.

The R&D project type and the needs for cost minimising effects initially affect the particular choice of partners but also the firms' own R&D resources matter. Those R&D related factors encounter the type of R&D, the R&D competences and the R&D capacity. Thus those factors explain the variation in choice of partners, as they determine what need the firm have to supplement their own capabilities[1]. Furthermore, if the firm do not posses these particular factors it will be difficult for them to attend R&D cooperation; therefore they would have to do the R&D activities themselves, which is more costly, or ultimately be R&D inactive.

2.1 R&D cooperation incentives

There are both pros and cons[2] for R&D cooperation among firms. From a rational choice point of view one should expect, that the firm would cooperate whenever there are economical advantages either in the short or long run. Hagedoorn and Duysters (1997) state for example that accumulation of knowledge through R&D cooperation may create a long-term positive economic return. Further Vinding (2001) claims that technology and the use of technology is crucial for the competitiveness and economic returns of Danish firms. Similarly, D'Aspremont and Jacquemin (1988) points that the return of R&D cooperation are higher than the return of firm individual based R&D. Likewise Cassiman and Veugelers (1998) state that cooperating firms maximize their common return by cooperation on R&D even in a competitive marked for end or near market products.

As well as R&D cooperation may provide the firm with additional resources to create, build and sustain its competence stock, it may in turn also help the firm to gain new knowledge and competences, as well as it might positively affect the firms technology level. The additional or new knowledge gained from R&D cooperation

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[1] Most firms have R&D activities that are product or process oriented, i.e. oriented to a market. Thus other firms would be an obvious partner and more obvious than basic research oriented public research institutions and universities, c.f. figure 1.

[2] The cons concerned R&D cooperation includes problems concerning the tacit nature of R&D along with the risk of losing technological competitiveness by transferring core competences to others.

can be stored and incorporated inside the firm and will in future R&D projects improve the ability to implement and develop complex knowledge in the firm. Thus a considerable incentive for the firms to participate in R&D cooperation is the faster and easier access to new knowledge and technology, cf. Robertson and Gatingnon (1998) and Polt et. al. (2001). The faster and easier access to complex knowledge will minimize the development costs of the firm, and thereby give the firm competitive advantages as it more efficiently can utilize and develop new knowledge into end products or cheaper production processes, cf. Hagedoorn (1993).

2.1.1 Basic competence and absorption capacity

A precondition for firms' participation in R&D cooperation is that they themselves have something to contribute with; either R&D inputs or competences to understand and implement the results from the R&D project. Free riders will usually only participate ones in R&D cooperation, since the abuse of their partners trust will prevent them from future cooperation; in the short run with the project specific group of partners, in the long run with all potential partners, cf. Cassiman and Veugelers (1998). It is therefore of great importance that the participating firms has something to offer the cooperating partners. This in turn means that the firm must posses some basic competences to offer as inputs to the common R&D project to become a participant in R&D cooperation. Here, the basic competences are also of great importance to the firms engaging in cooperation. The basic competences influence the rate of success in the R&D cooperation because they affect the firm capability to discover, embed and appropriate new knowledge that stems from the common R&D project. By participating in successful R&D cooperation and gain further basic competences the firm are better suited for future R&D cooperation projects. A firm that have sufficient competences is better suited to commercialize the new knowledge and the results of the improved knowledge base.

Basic competences are among others the ability to absorb new knowledge, and therefore of great importance for the implementation of R&D cooperation and for the success rate of the projects. So a basic requirement for the firm must be sufficient absorption capacity. Cohen and Levinthal (1990) state that the absorption capacity of the firm positively influences capability to explore the quality and value of new extern knowledge, to understand and employ the knowledge and in the end to commercialize this knowledge to the market.

Empirical findings using data from the Danish Manufacturing industry 1998-2000 states that the openness of the firm towards R&D cooperation positively correlates with the utilization the firm obtain from achieving new knowledge, c.f. Knudsen et. al. (2001). They further state that openness towards R&D cooperation and openness in general are one of the main ways for firms to get access to knowledge, which in turn increases the basic competences and competitiveness of the firm. Only by sequential R&D cooperation the firm can achieve the needed absorption capacity and knowledge that is crucial for the pay off to new knowledge. The utilization of new knowledge depends therefore heavily on the ability of the firm to absorb and use new knowledge. Thus firms with the a large stock of basic competences and a high absorption capacity are expected to participate in R&D cooperation more often than other firms, because of *ceteris paribus* a larger return from such kind of R&D.

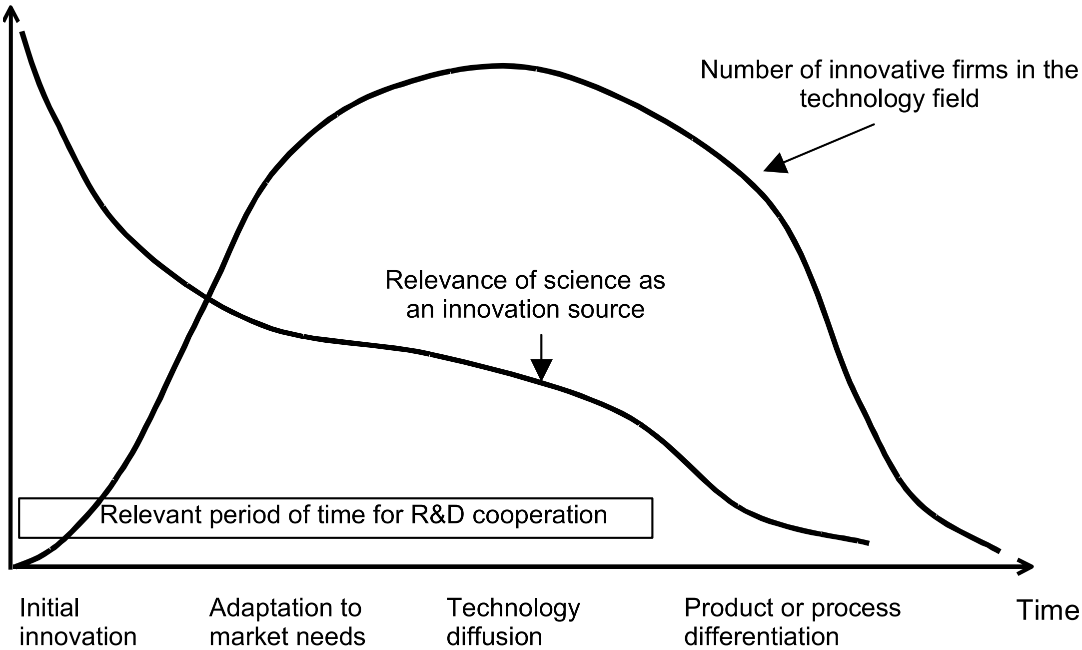
The absorption capacity is not only important for the detection, exploration and formalization of new knowledge. The absorption capacity also influence on the utilization in a longer perspective. It is therefore important that the firm detect and attract the specific partners that are interesting for the firm not only today but also in the future, i.e. have a solid and trustful reputation. The R&D personnel in a firm has their own network of past and present R&D cooperation partners, which often are based on previous R&D cooperation, cf. Polt et. al. (2001). Therefore, the employees' network is important for the firm. The basic competences embedded in the firm are often the key factor for a new cooperation, because the specific employees or competences make the specific firm attractive as partner for R&D cooperation. The absorption capacity in turn is the foundation for the firm to accumulate this new knowledge and participate in new R&D cooperation based on the accumulated new knowledge, cf. Kastelli et. al. (2002), Knudsen et. al. (2001) and Vinding (2002).

The attractiveness of the firm depends on the firm's competence stock and the ways the firm achieve these competences are can be through R&D investments, i.e. invest in their own R&D department, increase their competence network, hiring R&D employees or in a steady and continuously process secure the employees further education. Another way of increase the attractiveness of the firm is to secure that its organizational foundation and culture are geared to participate in R&D cooperation, cf. Simon (1999) and Graversen (2002). Even though desirable it is not enough for the firm to possess the physical framework if the firm do not possess the right organization and culture that motivates, allows and stimulates R&D cooperation. In turn a firm that deliberately increases its initial basic competences and absorption capacity becomes more attractive as R&D cooperation partner, and therefore it have somewhat more degrees of freedom to choose their own "best" partners for R&D cooperation.

2.2 Differences in R&D cooperation with private and public R&D partners

Results from analysis' conducted by Graversen (2002), Polt et. al. (2001), Lundvall (1999) and the results from table 1 in section 3 show that firms more often cooperate on R&D projects with other private firms than with public research centres. Considering an innovation life cycle similar to the product life cycle reveals a straightforward explanation to this fact. The product life cycle theory is useable to understand what we here call the innovation life cycle as shown in figure 1.

Figure 1 R&D as a source for innovation in the Innovation Life Cycle, ILC



Source: Based on Polt et. al. (2001)

Usually one firm or a consortium of firms carry out the fundamental break through of a crucial or initial innovation, typically building on or being basic research. The common basic factor is a large input of basic knowledge. This in turn affects the possibility for cooperation with a public research institution versus a private firm. Public research institutes are strong on basic research while the average private R&D performing firm is strong on development and implementation. Hence, initial innovation cooperation involves equally often public research institutions as private firms. Over time the initial innovation spreads through the networks and publications of employees who have worked with it and those who sees the potential of the innovation in terms of market interests. Eventually, more and more firms will work with the innovation trying to make it fit the demands of the market, or alternatively commercialize it believing that it will create a change in consumer behaviour. Thus, many firms are at this point working with the innovation where further development still requires some research dependent input, although not basic research, coming from public and other research institutions. At this stage the input from public research institutions will typically come from non-profit independent research and technology providers. Simultaneous there are an increasing need for complementary knowledge from other private firms, i.e. access to markets, production capacity, etc.

The knowledge included in the innovation continues to spread out through the educational system, through labour mobility or network and ends up being common knowledge in a scientific sense. At this point of the innovation cycle the number of firms contributing to further development of the innovation is at it's highest. The knowledge of the innovation is now possessed by a relative large number of firms that are capable of implementing and using the innovation. The innovation has now reached a point, where its main users, the firms, are mainly product and process oriented. They try to gain additional benefit from improvements of the innovation, which in turn will outdo earlier versions of the product, an action that can be compared to Schumpeter's term "creative destruction". At this stage it is still possible to make minor changes and improve the initial innovation. At the end of the cycle the potential for further development of the product will vanish and the only way to make any profit is to product differentiate or price dumping. At this stage there are no use for research-based knowledge as well as no base for R&D cooperation.

If we compare the incentives for R&D cooperation under the assumption of rational firms, then the firms will be expected to choose the R&D cooperation partners needed in the particular situation. This in turn mean that the kind of conducted R&D in the firm, its R&D competences and absorptions capacity, as well as the need for complementary knowledge, the intensity of research as well as business sector specific characteristics, will determine the choice R&D cooperation partners.

3 Data on R&D cooperation among R&D active firms

The Danish Centre for Studies in Research and Research Policy collects data concerning R&D activities in Danish firms. In this present analysis the available data for 2001 is used, c.f. The Danish Centre for Studies in Research and Research Policy (2003). The research statistic database includes R&D data for 2465 firms and the database covers all private firms with more than 10 employees through an advanced weighting of each firm. From the sample of 2465 firms 592 firms had R&D activities. This includes those who responded that they only bought R&D. When the figures are weighted to population representativity 2641 firms had R&D activities out of a total population of 18381 firms, i.e. a ratio on 14 percent. The 2641 R&D active firms are the representative population of the present analysis, and it is the data sample that will be used in the empirical analysis in section 4.

The survey answers from the R&D active firms is used to determine whether the firms had any kind of R&D cooperation with partners from either Denmark or abroad and whether the partner were from the public or private sector. 63 percent of the R&D active firms confirm that they had some sort of R&D cooperation. Table 1 summarize the average rate of R&D cooperation with different types of R&D partners.

Table 1 Share of Danish R&D active firms that cooperates in 2001, percent

Type of R&D cooperation partners	Cooperating share of firms
R&D cooperation partners in Denmark	54
R&D cooperation partners outside of Denmark	28
R&D cooperation partners within public research centres	28
R&D cooperation partners within the private sector	54
At least one of the cooperation partners	63

3.1 Improvement of data quality

Some of the explanatory variables in the survey database suffer from missing values. The missing values are updated and improved with multiple imputation techniques. The method treats and corrects variables with missing values and is an efficient way to improve the information in data sets with missing values from a statistical and an econometric point of view. The multiple imputation method uses different methods for applying new valid values. In this paper the propensity score method is used, which is a non-parametric draw of valid observations from a particular well-defined group of observations. From this group of observations values are applied to the observations with missing values. The method is very effective in this case where only minor fractions of the single variables are missing, although all the used variables have a larger fraction where one or more observations are missing. Multiple imputations are a relatively new method for economic statisticians or econometricians to update and improve data, which contains missing values although mathematicians and physicians have used the method for years.[3]

3.2 Descriptive statistics of the R&D active firms

The average, minimum and maximum values for the variables used in the analysis are printed in table 2 split into four groups due to the discussion earlier, i.e. firm characteristics, R&D profile, R&D competence and absorption capacity and business sector characteristics.

The statistics for the firms shortly state the demographic profile of the firm. The R&D profile concerns the different competences the firm posses and vis-à-vis the complementary competences and therefore the R&D cooperation partners that the

[3] Depending on the pattern of the missing values the method covers the regression method, the Markov chain Monte Carlo method and the propensity score method. In this paper the propensity score method is used, since it was the most suitable method given the actual data with many discrete variables. The method is the conditional probability of assignment to a particular treatment given a vector of observed covariates. In the method a propensity score is generated for each variable with missing values to indicate the probability of that particular observation to be missing. The observations are then grouped based on these propensity scores, and an approximate Bayesian bootstrap imputation is applied to each group.

firm needs to gain the needed competences. More specifically the variables measures whether the firm is geographically situated in the same or next to a municipality with a knowledge centre[4], i.e. a measure for whether firms with intensive R&D also are situated next to these knowledge centres. Further variables measures whether the firm is product, process or knowledge oriented in their R&D activities, which illustrates how the type of R&D activity affects the needs for and the choice of R&D cooperation partner. The part of operating R&D-expenditures used on either basic research, common research or development show how each firms own R&D specialisation in each area of research is affecting the choice of R&D cooperation partners, c.f. Figure 1 and the discussion there.

As indicators for R&D capacity and absorption capacity, the analysis includes a range of variables that describe the competence stock in the firm. The variables includes whether the firm has its own R&D department, whether it employs researchers or foreign researchers and the ratio of R&D employees to the total number of employees. The variable female part of total R&D employees is a measure of the differences in typically male dominated research areas compared to those who are not male dominated and how it affects the choice of R&D cooperation partners as well as the level of R&D cooperation. According to table 2 there is a low ratio of females among the R&D personnel in the firms, i.e. the private sector.

Both the researcher intensity and R&D intensity are continuous variables that in turn have a maximum value of one. The researcher intensity reveals how much time the R&D personnel actually use to do research, i.e. full time equivalences. If the firm employs a high number of full time researchers it indicates that the firm has high researcher intensity. The R&D intensity is the economic equivalent to researcher intensity. It determines how dominating R&D is to the firm and in particular to other activities in the firm and thereby how important R&D is for the firm. The capital intensity is also a continuous variable, which measures R&D expenses per full time equivalent R&D employee. The variable reveals whether the firm R&D is technology oriented (capital intensive) or manpower demanding (human capital intensive).

[4] The definition of a knowledge centre is either a university, a public research centre or something alike.

Table 2 Descriptive statistics for Danish R&D active firms in 2001

Explanatory variables		Average	Minimum	Maximum
Firm characteristics				
Age (Years)		16	1	145
Size (Employees)		132	1	10091
Part of a concern		60 %	0	100
Situated in the region of Copenhagen		41 %	0	100
R&D profile				
Placed in the same municipality as a knowledge centre		0.30	0	1
Placed next to a municipality with a knowledge centre		0.28	0	1
Conducting product oriented R&D		0.95	0	1
Conducting process oriented R&D		0.66	0	1
Conducting common oriented R&D		0.64	0	1
Conducting customer oriented R&D		0.79	0	1
Basic research part of operating R&D expenditure		5 %	0	100
Applied research part of operating R&D expenditure		13 %	0	100
Improvement expenditures part of operating R&D expenditure		82 %	0	100
Self finance part of total R&D expenditure		0.88	0	1
R&D competence and absorption capacity				
Own R&D department		0.41	0	1
R&D employees relatively to employees		0.25	0	1
Female part of total R&D employees		0.18	0	1
Research educated employed		0.13	0	1
Foreign researchers employed		0.02	0	1
Research intensity (R&D man year/R&D employees)		0.63	0.04	1
R&D intensity (Operating R&D costs/turnover)		0.11	0	1.97
Capital intensity (R&D costs/R&D man year)		0.70	0.06	9.01
Business sector characteristics				
Minimum efficiency scale (log 1. quartile expenditure at business sector level)		1.92	0.63	8.63
Market concentration index		1.55	0.04	104
Capital requirement (log business sector avg. of the sum of assets)		0.46	0.01	431
Profitability (business sector avg. of ordinary return relatively to net turnover)		0.04	-10.96	13.71
Business sector	IT	19 %	0	100
	Machinery	8 %	0	100
	Agro-foodstuffs industry	8 %	0	100
	Knowledge service	20 %	0	100
	Environmental industry	7 %	0	100
	Medico & health care	5 %	0	100
	Other manufacturing industry	32 %	0	100
Number of observations: 592 (Not weighted), 2641 weighted				

To emphasize specific business sector characteristics four meso variables are used. The variables are defined on a two digit NACE classification level. The minimum efficiency index is defined as the log to the first quartile of the turnover for the firms in the specific business sector. It defines the size of the firms of the business sector and in turn how difficult it is for smaller firms to enter a market defined from its business sector constraints. Market concentration is another meso variable that is defined at business sector level as the sum of the turnover in firm *ij* as part of the sum of the turn over in business sector *j* where firm *ij* is firm *i* in business sector *j*.[5] The market concentration index tells how monopolistic the specific business sector is. The closer the index is to one the more monopolistic the business sector is, as fewer actors tend to be in the business sector. In a business sector with few firms, i.e. monopolistic, there is a possibility for over normal earnings. The demand for capital illustrates how big firms in the business sectors is and in turn it shows the barriers for new entrants in the business sectors. Profitability measures the average of the firm earnings to the firm turnover in the specific business sector. The profitability thereby shows how competitive the specific business sector is, and it can be used as a mark up on the average economic settings of the market.

Further a general business sector graduation is used. This business sector graduation is constructed from a range of firm specific characteristics, i.e. R&D activities, production and other activities. The graduation is therefore not right away equal to the NACE classification.[6]

4. Determinants of R&D cooperation among Danish firms

Danish R&D firms have various R&D cooperation partners; from the public as well as the private sector and national as well as foreign firms. This distinguishing between types of R&D cooperation partners makes it possible to analyze what particular factors that are determining the choice of specific R&D cooperation partners. The average share of cooperating firms that cooperate with four main types of cooperating partners was given in table 1. In this section, the probability for cooperation among the R&D firms is estimated by logistic regressions on the various kinds of cooperation partners. Table 3 shows the results from regressions concerning whether the firm cooperates with at least one partner, with a partner from Denmark (national), from foreign countries, from a private firm and from a public research institutions. A further differentiation is summarized in the appendix tables A1 and A2.[7] The results indicates that some explanatory factors affects the

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[5] Market concentration index in business sector *j* = Σs^2_{ij}, where $s^2_{ij} = \frac{\text{tunr over}_{ij}}{\text{turn over}_{j}}$,and where i is firm i.

[6] Firms without R&D cannot be placed in this particular business sector graduation

[7] Table A1 summarize the results for cooperation partners from the group of private firms. They are divided further into whether they have group relations or not; nationally and internationally. Table A2

probability for all types of R&D cooperation partners while others show either no effect or affects the firms' choice of R&D cooperation partners in opposite ways.

The general model in table 3 column one shows the overall factors that are determining whether to cooperate or not on R&D projects. The results from a differentiation in type of R&D cooperation partner shows that there is partner specific explanations to the choice of different types of cooperation partners as illustrated in figure 1. A first division between national and international cooperating partners provides a more detailed picture of factors that determine the choice of these types of R&D cooperation partners. Going further in division provides an even more detailed picture and reveals further insight to be useable in research policy formulation. However, while the detailed specification on cooperation partner types show differences in determining factors, the picture becomes on the other hand blurred with few common factors explaining the choice of the specific R&D partner in the most detailed version.

The general to specific development in the analysis shows some contingencies and differences in the determining factors for R&D firms' choice of cooperation partners, c.f. tables 3, A1 and A2. At the same time the results confirm some of the suggested contingencies stated in section 2. The results in table A.1 and A.2 also explain in more details the general results found in table 3. Some determining factors, though, have become more diffused and much harder to elaborate on. Table 3 shows the estimation results that will be used as the main source for the further analyses of the results. The results from the more specific graduation of the model will be used in the analysis when they significantly contribute to the understanding of which factors that determine Danish firms' choice of R&D cooperation partners.

Elder firm is expected to have a more developed network than a younger firm so the age of a firm is expected to be a positive contributor to the probability of R&D cooperation. The general result is thus, that age does not play a significant determinant of cooperation although it is found that older firms have a somewhat higher probability for cooperation with foreign partners' from the private sector. These results match the findings of Smith et al. (2001). They found that Danish firms that participated in or gained founds from the 4th Framework Programme, also increased their engagements in cooperation as their age increased.[8]

The size of the firm is also expected to be a positive factor for cooperation since larger firms is expected to have larger network, more R&D personnel and more R&D projects. However, this factor only matters for R&D cooperation with a Danish

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summarize the results for cooperation partners from public research institutions. They are further divided into universities or public research centres again both nationally and internationally.

[8] Danish firms in the 4th Framework Programme would be expected to have cooperation with partners abroad due to the specifications of the Programme and how the founds were dispended.

partner from the private or the public sector. If the partner is foreign the size of the firm does not matter, the factor is insignificant. This may be caused by a significant group of small R&D intensive firms that are very international in their choice of R&D partners. However, a broad range of other articles draws equivalent conclusions regarding firm size. Cassiman and Veugelers (1998) focusing on Belgium firms, Bayona et al. (2001) on Spanish firms and Smith et al. (2001) on Danish firms have all shown that the size of the firms positively affects the probability of R&D cooperation. Also firms who are a part of a group tend to have a higher probability of R&D cooperating with Danish firms.

A geographical position of the firm in the capital region of Denmark is furthermore believed to give a higher potential for the firm to cooperate on R&D with local partners because this region perform the majority of the national R&D, c.f. section 2 and The Danish Centre for Studies in Research and Research Policy (2003). It is in general found that R&D firms placed in the capital region have a higher probability for R&D cooperation. More specific, the result only matters for firms that have partners from abroad and partners from the private sector. Hence it seems that the firms in the capital region are more international in their choice of R&D partners.

4.1 The firm specific R&D profile

Firms placed near public research centres are expected to have more intensive R&D cooperation because of the expected engagement in R&D intensive clusters situated around public research centres in Denmark. The results in table 3 show a negative overall result for the probability of engaging in R&D cooperation though most coefficients for the more detailed cooperation partners are insignificant. An explanation to the findings could be that firms cooperating with other private firms need other complementary R&D competences than firms cooperating with public research centres. There is thus no clear evidence for this explanation.

The type of R&D activity of the firm seems to affect their probability of cooperation as well as their choice of R&D partner type. At the general level the firms conducting product oriented R&D tends to have a higher probability to cooperate on R&D. National belongings do not change the result although the influence on a foreign partner from the public sector is insignificant. Focusing on firms conducting process oriented R&D activities also have a higher probability of engaging in R&D cooperation, particularly with partners from Denmark and indeed partners from the public sector in Denmark. Firms conducting process oriented R&D activities also have a lower probability of engaging in R&D cooperation with foreign private firms. Customer oriented research do not increase the probability of R&D cooperation except for foreign public research institution partners, i.e. a very low share on eight percent of the R&D firms have this kind of partners.

These results indicate that higher intensity levels of R&D activities affect the probability of engaging in R&D cooperation and it might be an indication of the specialization in product innovation, where the need of complementary resources and competences growths and therefore the need of R&D cooperation also growth. The lack of cooperation concerning the other determinants of R&D activities could be caused by the fact that process oriented R&D activities; R&D activities developing the common knowledge or/and customer oriented R&D activities are either vertically integrated in the firm or gained through the market. The difference in the probability of cooperation could thus be the result of a more complex product innovation, where the market for achieving the needed resources or competences simply are not existing, c.f. Teece (2003) or that vertically integrating partners is not economically efficient when focusing on product innovations due to opportunism, contract costs, frequency or uncertainty in the transactions, c.f. Williamson (1975, 1985).

Another indicator that more knowledge intensive, i.e. basic, activities affect the probability for R&D cooperation positively is the significant coefficients regarding the part of R&D expenditure used on basic research in the firms. This shows that a higher ratio of R&D expenditure in basic research means a greater probability to engage in R&D cooperation. The effect is most significant when the cooperation partner is from the public sector, but still there is a clear general effect. This is an indicator of the importance of basic competences and absorption capacity within the firms and support the view in figure 1. On the contrary the ratio of applied research compared to the overall R&D expenditure is an insignificant factor. Again this is an indicator of the more complex the R&D is the more appropriate cooperation seems to be.

The self-financed part of total firms specific R&D expenditure would be expected to have negative influence concerning the probability for firms to cooperate. This is so because the higher amount of self-finance reduces the dependence of external sources. Another reason to expect the self-finance part of the total R&D to be negative is that a broad range of external finance programs, i.e. EUREKA-programme or the RTD Framework Programme in EU, demand interaction and cooperation with private firms or public research centres. In the analysis the result is generally insignificant. Actually, a positive effect from is found for the national private sector partner type. Thus, this is interesting because it shows that the choice of R&D cooperation as well as partner type is somewhat insensitive to external funding.

Table 3 Logistic modelling concerning Danish R&D conducting firm and their cooperation partners; total, by nationality; by main sector and by both

Explanatory variables	R&D cooperation with at least one partner from								
				Private sector			Public sector		
	Total	Denmark	Abroad	Total	Denmark	Abroad	Total	Denmark	Abroad
Intercept	-7.82	-7.78	-7.18	-6.47	-5.69	-7.32	-11.95	-11.89	-10.29
Firm Characteristics									
Age (Years)	0.01	0.01	0.01	0.00	-0.00	**0.02**	0.01	0.01	-0.01
Size (Log number of employees)	**3.98**	**4.28**	0.68	**2.43**	**2.43**	0.97	**6.51**	**6.33**	0.63
Size squared	**-0.99**	**-1.18**	-0.02	**-0.58**	**-0.63**	-0.11	**-1.56**	**-1.49**	0.05
Size tripled	**0.08**	**0.10**	0.00	**0.05**	**0.05**	0.01	**0.12**	**0.11**	-0.00
Part of a concern	**0.59**	**0.46**	0.19	**0.51**	0.26	0.08	0.02	-0.02	-0.21
Situated in the region of Copenhagen	**0.50**	0.23	**0.40**	**0.51**	0.21	0.41	-0.21	-0.20	-0.15
Firm R&D profile									
Placed in the same municipality as a knowledge centre	-0.20	-0.29	-0.44	-0.25	-0.29	-0.30	0.12	0.23	-0.06
Placed next to a municipality with a knowledge centre	**-0.52**	-0.32	**-0.61**	-0.23	-0.23	-0.42	-0.34	-0.21	-0.58
Product oriented R&D	**1.75**	**1.42**	**2.33**	**1.31**	**0.76**	**2.52**	**1.83**	**1.74**	1.16
Process oriented R&D	**0.44**	**0.44**	**-0.60**	0.19	0.24	**-0.66**	**0.45**	**0.44**	0.68
Customer oriented R&D	-0.11	-0.34	-0.33	-0.22	-0.01	-0.43	0.33	0.18	**1.05**
Basic research part of operating R&D expenditure	**0.03**	**0.02**	**0.03**	**0.02**	0.00	0.01	**0.03**	**0.03**	**0.04**
Applied research part of operating R&D expenditure	0.01	**0.01**	-0.00	-0.00	0.00	-0.01	**0.01**	0.01	**0.04**
Self finance part of total R&D expenditure	-0.05	0.29	0.62	**0.74**	**0.74**	0.49	-0.58	-0.43	0.30

Table 3 continues on the following page.

Table 3 continued....

R&D competence and absorption capacity									
Own R&D department	**1.04**	**0.81**	**1.71**	**0.82**	**0.39**	**1.59**	**1.05**	**0.98**	1.37
R&D employees relatively to employees	**1.04**	**1.26**	**1.77**	**1.79**	**1.66**	**1.51**	0.28	0.09	1.38
Female part of total R&D employees	0.06	0.65	**-1.93**	0.01	**0.78**	**-2.00**	**1.43**	**1.51**	0.33
Research educated employed	**1.77**	**0.94**	**0.81**	**1.35**	0.47	**0.61**	**1.72**	**1.63**	**0.98**
Foreign researchers employed	-1.24	-0.78	**1.44**	-0.42	-0.40	**1.69**	-0.55	-0.30	**1.65**
Scientist intensity (R&D man year/R&D employees)	0.55	**0.73**	0.41	0.48	**0.52**	0.42	-0.66	-0.38	**-1.28**
R&D intensity (Operating R&D costs/turnover)	-0.61	-0.65	0.10	-0.38	-0.47	0.41	0.10	-0.19	**1.80**
Capital intensity (R&D costs/R&D man year)	**0.48**	0.32	0.15	-0.03	-0.09	0.17	**0.57**	**0.57**	-0.09
Business sector characteristics									
Minimum efficiency scale (log 1. quartile expenditure at business sector level)	**-0.17**	-0.07	-0.02	-0.09	-0.02	-0.01	-0.02	-0.00	0.36
Market concentration index	-0.01	-0.01	-0.00	-0.01	-0.01	-0.00	-0.02	-0.01	-0.01
Capital requirement (log business sector avg. of the sum of assets)	-0.01	-0.01	-0.13	-0.07	-0.02	-0.14	-0.01	-0.01	-0.04
Profitability (business sector avg. of ordinary return relatively to net turnover)	-0.05	-0.01	-0.17	-0.08	-0.02	**-0.18**	-0.02	-0.01	-0.09
Business sector: IT	0.39	0.27	-0.23	**0.51**	0.55	-0.10	-0.49	-0.46	-0.58
Business sector: Machinery	0.02	-0.13	-0.60	0.43	0.29	-0.39	**-0.95**	**-0.87**	-2.18
Business sector: Agro-foodstuffs industry	-0.22	-0.17	0.21	0.35	0.03	0.19	**-0.93**	**-0.94**	0.48
Business sector: Knowledge service	0.30	-0.03	**0.62**	**0.50**	0.24	0.30	**-0.76**	**-1.12**	0.94
Business sector: Environmental industry	**1.89**	**1.02**	**1.22**	**1.38**	0.41	**1.41**	**1.87**	**1.94**	0.01
Business sector: Medico & health care	0.50	0.10	0.77	**0.87**	0.31	**0.94**	-0.42	-0.38	-1.43
Weighted number of observations	2641	2641	2641	2641	2641	2641	2641	2641	2641
-2 Log Likelihood	783	816	696	817	816	668	707	689	322
Concordant (percent)	79	78	82	76	70	81	84	83	89
Part which is cooperating (percent)	63	54	28	54	45	25	28	27	8

Note: Significant parameter estimates are in bold. The business sector reference is other manufacturing industry.

4.2 R&D competence and absorption capacity

This subsection concerns the competences the firm posses. The competences, and derived from that, their absorption capacity, make the firm more capable to identify, collect and utilize new knowledge along with an increased attractiveness as a potential R&D partner for other firms. Thus, the assumption of a large importance of absorption capacity is verified by the analysis. A permanent R&D department within the firm increases the probability for R&D cooperation and likewise does the employment of research-educated employees. Bayona et. al. (2001) and Cassiman and Veugelers (1998) also find that a permanent R&D department within the firm affects the probability of engaging in R&D cooperation. Cassiman and Veugelers (1998) further more point out a positive linkage between a permanent R&D preparedness within the firm and R&D cooperation.

A high ratio of R&D employees relatively to the number of employees seem to affect the probability of R&D cooperation positively in general but particular in the private sector. The effect is insignificant for public sector R&D institutions. The effect of having a foreign scientist employed seems only to affect the probability when the partner type is foreign. Thus, the employment of foreign scientist indicates strong international focus from the firm.

Generally a larger female part of the total R&D employees will decrease the probability of R&D cooperation with foreign partners especially a foreign partner from the private sector. However a larger female part of R&D employees increase the probability of cooperate with a public research institute, especially if the institute is situated in Denmark, and with Danish private firms.

The scientist intensity only affect the probability of R&D cooperation with partners from private firms and foreign public research institutes, respectively positive and negative. The R&D intensity on the contrary only positively affects the probability of having R&D cooperation with foreign public research institutes. In general, the R&D intensity is an insignificant factor, a result opposite to the result found in Smith et. al. (2001) and Graversen and Mark (2003). Finally the capital intensity of the R&D activities also tend to affect the probability of R&D cooperation at a general level or when the partner is from the public sector in Denmark, otherwise the coefficients are insignificant. This indicates that R&D cooperation with public sector R&D institutions demand expensive facilities and thus is more capital expensive.

4.3 Business sector characteristics

To test whether business sector characteristics or differences influence the R&D cooperation among Danish firms four indirect measures is used. The four measures encounter minimum efficiency scale, market concentration index, required capital and profitability. The minimum efficiency scale seems not to have any effect, although negative and significant in general the effect is insignificant for all subgroups. A positive effect would have shown that the bigger the smaller firms in the business sector are, the more the participants of this business sector should cooperate. The effect from the market concentration index shows that the business sector with a few dominant players only rarely cooperates. Thus one should not put too much emphasis in this statement while all of the coefficients are highly insignificant. Further the measure for required capital shows that when the business sector has high requirements to the capital strength of the firms the probability for cooperating lessens. Again one should not put much emphasis in the results while the coefficients are insignificant. Finally the measure for profitability shows that when firms are a player in a market, that is profitable, i.e. with little competition, the probability for cooperating with other partners is declining. This is in particular true, when focusing on foreign private sector partners. The interpretation of this result is that when the market is profitable the firm does not what to share the profits. Likewise it does not want to share the risk, but when the market is profitable enough this seem as a plausible strategy.

A general division of the firms into different business sectors depending on their main research area was made to investigate whether business sectors matter. It does not affect the probability for cooperation in the machinery industry or in the agro-foodstuffs industry, except from a significant negative influence from agro-foodstuff industry when the partner is from the national public sector. When the firm is from the IT industry, there is very little evidence in this analysis. Contrary to an earlier study by Graversen and Mark (2003b) using older data, there are only weak support for IT business sector cooperation although the weak indications concern the private sector as also found in Graversen and Mark. Thus if the partner origins from the private sector in Denmark, the probability of engaging in cooperation is positive, otherwise it is insignificant. The explanation to this change compared to Graversen and Mark, may be found in the burst of the IT bubble in the year 2000.

The probability that firms from the knowledge service sector engages in R&D cooperation is only larger if the from the private sector (and less significant a foreign partner). Firms from the knowledge service sector engage less often in R&D cooperation with national public R&D institutions. The results in table 3 also show that firms from the environmental industry have a higher probability of R&D cooperation. This conclusion holds whether the partner is from Denmark or abroad but more specifically if the partner is foreign and from abroad or national and public R&D institution. On the contrary the medical and health care industry seem only to cooperate over average with foreign partners from the private sector. The reference business sector is other manufacturing industry.

5. Conclusive remarks

The present paper analyses what factors that are determining Danish firms choice of R&D cooperation partner. R&D cooperation is commonly accepted to reduce the expenses to R&D activities. Thereby the firms gain a better market position through both cheaper, faster and easier access and better understanding of technological progress, innovation and development. Further cooperation concerning R&D will lower the expenses to specific R&D projects and thereby minimize the economic risks or economic barriers that the firms are facing, when they are engaging in R&D projects.

The analysis uses representative firm specific R&D data for 2001 from The Danish Institute for Studies in Research and Research Policy (2003). The analysis on R&D cooperation was performed on the R&D active firms, solely, where 63 percent had R&D cooperation with at least one type of R&D partner. Those partners could be from their own group, other private firms, universities or other public research centres; either placed in or outside of Denmark.

The basic characteristics of the firms do seem to affect the probability for R&D cooperation. This is so when looking at cooperation partners from the private sector. The effect lessons when the cooperation partners are from the public sector. Similarly, the R&D profile of the firm seem to affect the probability of engaging in R&D cooperation with all types of partners. One exemption is clustering around national knowledge centres. Lastly, if the firm is doing product orientated R&D or has a high ratio of basic science it affects the probability of R&D cooperation positively.

The ability of the firm to identify, collect and commercialese new knowledge through R&D cooperation and thereby the probability of actually having an R&D cooperation depends heavily on the ability of the firm to utilize the gains from the R&D cooperation. Firms who posses permanent R&D competences i.e. have a permanent R&D department or research educated employees have the competences to utilize the gains from R&D cooperation, and therefore have a higher probability of engaging in R&D cooperation. This is confirmed in the analysis. Other R&D specific economic and resource measures such as R&D intensity have no affect on the probability of participating in R&D cooperation. On the contrary scientist intensity seem to affect the probability in general.

Different business sector characteristics show only minor additional evidence. Though almost all coefficients are insignificant they all tend to be negative, which are by no means surprisingly, because the firms would not share their surplus through cooperation.

Different business sector dummies relations seem only to have little variation in effect on the probability of engaging in R&D cooperation. While the reference business sector is other manufacturing industry, it is only firms from the environmental industry that is more likely to engage in R&D cooperation. Further examination shows that the IT and medico sectors more often cooperate with the private sector. The public sector is not a used partner relative to the reference business sector. An exception is the environmental industry.

5.1 Research policy implications

As it was pointed out in section 2, R&D cooperation provide the R&D-active firm with the possibility to reduce their costs and as such maximize their profits. What kind of partners the firms choose to cooperate with depends on it's own R&D activities. This was illustrated in figure 1 and empirical evidence was presented in section 4. One would expect that firms always would cooperate in R&D projects whenever there is an economic rationale or benefit, i.e. if cooperation provides a larger benefit than what you otherwise would expect. However, some firms still prefer to perform the R&D themselves and to prevent others to copy their inventions. This behaviour may from a firm point of view be fully rational but it may also be possible for them to increase their benefit from the R&D by improvements of the National Innovation System. Hence, there is room for policy actions if there are firms who are either not R&D active or not yet fully R&D cooperating. To strengthen these gaps there are a broad range of research and business policy actions that can be undertaken to reveal the necessary complementary competences, i.e. increase the potential number of R&D cooperation partners[9].

The political instruments that can be used to increase R&D cooperation will initially have to fit the current political priorities. Thus, the actions taken and the used instruments will vary depending on the current political agenda. A general focus on having more firms carrying out R&D will naturally lead to a higher number of potential partners and thereby more cooperation.

Graversen (2002) or Graversen and Mark (2003a) provides a listing of various political instruments that can be used to increase the direct incentives, which in turn will lead to increased R&D cooperation. Those instruments will also depend on priorities of the political agenda. An overall effort to increase the number of R&D active firms will naturally increase the number of potential cooperation partners and as such increase the number of R&D cooperation partners. This could be obtained through tax deduction obtained from R&D expenses or more directly as R&D subsidies.[10] On the other hand another policy could be to aim at more research competent employees in none R&D firms or an increase in the initial knowledge base at each individual firm by educating the current workforce. This in turn will increase the R&D competences and absorptions capacity as well. This will increase the gains from R&D cooperation and as such increase the incentives to engage in R&D cooperation. The political instruments could also include tax deduction from supplementary education and economic rewards to those who have increased their knowledgebase to a certain level. Subsides to hire highly educated employees as well as research competent Danes, immigrants or foreigners will also lead to an increase in the R&D competences and absorptions capacity and thus R&D

[9] The rationale for public support to increase the potential number of R&D partners is the positive difference between social and firm specific return from R&D activities in the economy, where increased R&D is desirable for the society due to the higher payoff, see Sørensen et.al. (2003).

[10] High intensive R&D firms with no surplus in the short run cannot use tax deductions as long as they do not pay taxes.

cooperation. Moreover tax deduction concerning R&D expenses linked directly to expenses stemming from R&D cooperation will reduce the costs the individual firm faces when it cooperates with a university. This will make the access to institutional knowledge more easy to obtain and in turn this will increase the knowledge circulation and knowledge transfer, which in turn could increase the mobility as the two worlds become more familiar with each other. This will lower these barriers linked to R&D cooperation. Another way to reduce the barriers is to build and support knowledge service centres, competence centres, business campus, and different networks and venture capital foundations. These organizations can help matching private firms and public institutions and thereby reduce otherwise significant search costs. This will help firms to locate the "right" partner for R&D cooperation.

The analysis in the present paper indicates a room for changes in both research and business policy that will increase the range of R&D cooperation between Danish R&D active firms. By increasing the range and the intensity of R&D cooperation among Danish firms the gains from the invested R&D funds will increase. An increase in R&D cooperation among Danish firms will lead to positive synergies, which will increase the social welfare in the society.

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Appendix: Further estimation results

See next page......

Table A.1. The probability of R&D firms' R&D cooperation with different types of partners, logistic model

Explanatory variables		R&D cooperation with at least one partner from					
		Another firm	Another firm in Denmark	Another firm abroad	Own group	Own group in Denmark	Own group abroad
Intercept		-4.92	-4.55	-6.54	-6.09	-6.24	-11.02
Firm characteristics							
Age (Years)		-0.01	**-0.01**	-0.00	0.01	0.01	**0.02**
Size (Log number of employees)		**1.47**	**1.34**	1.06	-0.02	0.73	-0.03
Size squared		-0.29	-0.28	-0.12	-0.02	-0.24	0.14
Size third		0.02	0.02	0.01	0.01	0.03	-0.01
Part of a concern		-0.03	-0.02	-0.45	**1.37**	**1.19**	**2.62**
Placed in the capital region		**0.54**	**0.38**	0.24	0.35	0.34	0.55
R&D profile							
Placed in the same municipality as a knowledge centre		**-0.44**	**-0.38**	**-0.72**	0.08	0.07	0.11
Placed next to a municipality with a knowledge centre		**-0.51**	**-0.40**	**-0.80**	0.09	0.05	0.18
Conducting product oriented R&D		0.64	0.67	**2.02**	**1.76**	0.57	**2.57**
Conducting process oriented R&D		**0.40**	**0.34**	-0.32	0.00	0.25	-0.61
Conducting customer oriented R&D		0.07	-0.05	-0.14	0.09	0.45	-0.11
Basic research part of operating R&D expenditure		-0.00	0.01	-0.01	**0.03**	0.02	**0.03**
Applied research part of operating R&D expenditure		-0.00	-0.00	-0.01	-0.00	0.01	-0.01
Self finance part of total R&D expenditure		0.66	0.45	0.62	**0.97**	**2.06**	0.31
R&D competence and absorption capacity							
Own R&D department		**0.43**	0.27	**1.34**	**0.62**	0.05	**1.53**
R&D employees relatively to employees		**1.64**	1.41	**1.11**	**2.08**	**3.01**	1.35
Female part of total R&D employees		-0.07	0.48	**-1.48**	**-0.82**	-0.76	-0.68
Research educated employed		**0.87**	0.42	**0.73**	0.03	0.14	-0.15
Foreign researchers employed		-0.12	0.31	**0.96**	0.69	-1.27	**1.71**
Research intensity (R&D man year/R&D employees)		0.18	0.49	-0.07	0.37	-0.03	0.88
R&D intensity (Operating R&D costs/turnover)		0.19	-0.11	0.89	-0.65	-1.04	0.51
Capital intensity (R&D costs/R&D man year)		0.09	0.08	0.04	-0.34	**-1.20**	0.16
Business sector characteristics							
Minimum efficiency scale (log 1. quartile expenditure at business sector level)		-0.02	0.04	0.03	-0.03	-0.10	0.07
Market concentration index		-0.01	-0.01	0.00	-0.01	-0.00	-0.01
Capital requirement (log business sector avg. of the sum of assets)		-0.06	-0.04	-0.07	-0.05	-0.00	-0.12
Profitability (business sector avg. of ordinary return relatively to net turnover)		-0.10	-0.06	**-0.16**	0.01	0.04	-0.04
Business sector	IT	**0.76**	**0.79**	0.06	-0.40	**-0.64**	0.08
	Machinery	**0.62**	0.55	-0.42	0.33	0.59	0.23
	Agro-foodstuffs industry	0.44	0.31	-0.12	0.89	**0.95**	0.48
	Knowledge service	**0.56**	0.44	0.28	-0.46	**-1.04**	0.17
	Environmental industry	**1.23**	**0.74**	**0.95**	0.13	-0.59	**1.21**
	Medico & health care	**0.86**	0.54	0.72	0.16	0.35	0.41
Weighted number of observations		2641	2641	2641	2641	2641	2641
-2 Log Likelihood		815	797	561	624	502	434
Concordant (percent)		69	67	76	77	72	85
Part which is cooperating (percent)		45	40	18	22	15	12

Note: Significant parameter estimates are in bold. The business sector reference is other manufacturing industry.

Table A.2. The probability of R&D firms' R&D cooperation with different types of partners, logistic model

Explanatory variables	R&D cooperation with at least one partner from					
	Universities	Universities in Denmark	Universities abroad	Research centres	Research centres in Denmark	Research centres abroad
Intercept	-9.99	-9.91	-7.99	-8.85	-9.11	-9.99
Firm characteristics						
Age (Years)	0.01	0.01	-0.00	0.01	0.00	-0.02
Size (Log number of employees)	**4.72**	**4.97**	0.16	**2.49**	**2.63**	**3.23**
Size squared	**1.09**	**-1.15**	0.14	**-0.48**	**-0.52**	**-0.49**
Size third	**0.08**	**0.08**	-0.01	0.03	**0.04**	**0.03**
Part of a concern	-0.48	-0.48	-0.75	0.40	0.54	-0.06
Placed in the capital region	0.08	0.12	0.01	-0.00	-0.03	**0.81**
R&D profile						
Placed in the same municipality as a knowledge centre	0.31	**0.55**	-0.17	-0.11	-0.16	**1.13**
Placed next to a municipality with a knowledge centre	0.29	-0.12	-0.97	-0.40	-0.28	**1.40**
Conducting product oriented R&D	**3.19**	**2.87**	0.95	0.43	0.55	**1.59**
Conducting process oriented R&D	**0.78**	**0.81**	0.78	**-0.57**	**-0.51**	**-0.77**
Conducting customer oriented R&D	-0.10	-0.37	0.68	0.58	0.54	**1.46**
Basic research part of operating R&D expenditure	**0.04**	**0.04**	0.03	0.00	0.01	0.01
Applied research part of operating R&D expenditure	**0.01**	**0.01**	0.03	**0.02**	**0.02**	**0.04**
Self finance part of total R&D expenditure	-0.62	-0.57	-0.12	0.63	0.68	0.03
R&D competence and absorption capacity						
Own R&D department	0.43	0.24	**1.40**	**1.34**	**1.46**	0.07
R&D employees relatively to employees	0.13	-0.18	**1.44**	**1.61**	**1.77**	**0.78**
Female part of total R&D employees	0.58	0.60	-0.36	0.63	0.87	0.71
Research educated employed	1.84	**1.86**	0.90	**1.02**	**0.92**	**0.97**
Foreign researchers employed	-0.34	-0.12	**1.73**	0.39	0.46	0.43
Research intensity (R&D man year/R&D employees)	0.51	**0.85**	-0.77	-0.70	-0.61	-0.86
R&D intensity (Operating R&D costs/turnover)	-0.26	-0.60	**1.96**	0.53	-0.39	1.05
Capital intensity (R&D costs/R&D man year)	-0.06	-0.02	0.30	0.25	0.20	0.27
Business sector characteristics						
Minimum efficiency scale (log 1. quartile expenditure at business sector level)	-0.12	-0.11	-0.20	**0.27**	**0.24**	**0.40**
Market concentration index	0.02	-0.01	-0.05	0.00	0.00	0.00
Capital requirement (log business sector avg. of the sum of assets)	-0.01	-0.01	-0.01	-0.03	-0.02	-0.11
Profitability (business sector avg. of ordinary return relatively to net turnover)	-0.03	-0.03	-0.11	0.04	0.07	0.06
Business sector						
IT	-0.30	-0.26	-0.84	**-0.95**	**-0.97**	0.31
Machinery	**-1.02**	-0.85	**-1.73**	-0.95	**-0.92**	0.35
Agro-foodstuffs industry	-0.67	-0.72	-0.13	-0.63	-0.72	**1.71**
Knowledge service	-0.24	**-0.79**	0.44	**-0.74**	**-1.12**	**1.82**
Environmental industry	0.63	0.53	-0.06	**1.63**	**1.73**	0.38
Medico & health care	-0.34	-0.36	-1.62	-0.78	-0.61	-0.58
Weighted number of observations	2641	2641	2641	2641	2641	2641
-2 Log Likelihood	598	564	276	521	506	192
Concordant (percent)	83	83	90	82	82	86
Part which is cooperating (percent)	20	18	6	16	15	4

Note: Significant parameter estimates are in bold. The business sector reference is other manufacturing industry.