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Empirical Evidence from the EU 4th Framework Programme

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Abstract: The aim of the RTD Framework Programmes within EU is to stimulate European research in new technology. Recognising the argument of a minimum critical mass within a specific research area, the Framework Programmes have been designed to increase European R&D cooperation. Accordingly, the total budget of the 4th Framework Programme was EUR 13.1 billion and the 5th Framework Programme operates with a total budget of EUR 15 billion. Thus, the strengthening of European R&D cooperation seems to have had an increasing priority. The aim of this paper is to present empirical evidence on R&D cooperation for Danish firms. In line with Cassiman & Veugelers (1999), attention is paid to knowledge spillovers. The influence of in- and outgoing spillovers is analysed. Other factors like fear of technological failure and commercial non-success of joint R&D projects are analysed. Furthermore, market conditions such as product market concentration and entry barriers and a number of firm specific factors such as firm size and firm age are included in the model. Based on firm-level data, a logistic model for R&D cooperation under the 4th Framework Programme is estimated under various assumptions.

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1. Introduction

The aim of the RTD Framework Programmes in The European Union (EU) is to stimulate European research in new technology. Recognising that there has to be a certain amount of innovation and R&D (critical mass) within a specific research area in order to ensure an optimal innovation process, the Framework Programmes have been designed to increase European R&D cooperation. The total budget of the 1st Framework Programme in 1984 was EUR 3.8 billion. However, the budget of the 4th Framework Programme, which took place from 1994-1998, was EUR 13.1 billion and the 5th Framework Programme running from 1999 to 2002 has a total budget of EUR 15 billion.

As a first condition to apply for EU funds, firms engaged in research and development must cooperate across European borders. Thus, Danish firms have to find collaborating partners in other EU countries and formulate joint R&D projects in order to apply for funds from the European Commission. Accordingly, as the total budget has grown substantially, the strengthening of European R&D cooperation seems to have had an increasing priority by the Commission and the European Governments. Except for a number of national reports of more descriptive character only poor evidence seems to exist where the motives for firms actually participating in EU-sponsored R&D cooperation are treated in a simultaneous model framework.

The aim of this paper is to give some first, empirical evidence on factors determining Danish firm participation in international research cooperation. In line with Cassiman & Veugelers (1999), attention is paid to knowledge spillovers. Firms with a high rating of incoming knowledge spillovers will most likely participate in research cooperation – compared to other firms. On the other hand, if the firm decides to take part in research cooperation, outgoing spillovers will probably also occur. Thus, firms paying high attention to protection of its own 'know how' are less likely to participate in research activities under e.g. the EU Framework Programme. Other factors are integrated into the model, i.e. fear of technological failure and non-commercial success of the project.
Besides the importance of knowledge spillovers, technical and commercial risks, the importance of product market conditions is introduced, e.g. firms operating in less competitive environments may have incentives to coordinate R&D expenditure and reduce the company' R&D costs. In addition, effective barriers of entry might cause firms to be less induced to participate in any form of R&D cooperation. Finally, a

number of firm-specific factors are discussed, e.g. firm size, -age, -profit and financial solvency.

In the empirical part of the paper, Danish firm cooperation under the 4^{th} EU Framework Programme is analysed. An empirical model for the cooperation is formulated. Based on firm-level data from three data sources: the Danish R&D statistics, an accounting database and a (new) survey including information on attitudes towards cooperation among both participating and non-participating firms, the likelihood of participation in EU research cooperation is estimated using a logit-model framework. Estimations are presented assuming that the explanatory variables are exogenous. However, in order to deal with potential simultaneity an equation system including in- and outgoing spillovers as endogenous variables is estimated with the cooperation using a 2-stage estimation technique. The final section concludes.

2. Theoretical arguments

In this section, some of the key arguments focusing on the relationship between R&D cooperation and spillovers are briefly resumed. Furthermore, the influence of competition, barriers of entry and general market conditions will be discussed as well.

Spillovers and cooperation

Cassiman & Veugelers (1999)[1] discuss the relationship between R&D cooperation as seen from the industrial organisation literature paying attention to three factors affecting the relationship between profitability of R&D cooperation and spillovers. The first issue mentioned is *coordination*. Assuming that firms maximise their joint profit, they may cooperate in the R&D stage. And they may still compete in the product market if spillovers are sufficiently high. In general, firms' profitability will increase with more coordination/cooperation. Furthermore, if spillovers become sufficiently high, R&D cooperation will be relatively attractive compared to independent R&D. As a consequence, higher spillovers are assumed to increase the incentive for participation in R&D cooperation in models of coordination.

Cassiman & Veugelers (1999) discuss the influence of *free riding*. One of the important barriers for engaging in R&D cooperation is the worry about potential free-riding

[1] Cassiman and Veugelers (1999) present a survey focusing on the relationship between spillovers and R&D cooperation. In addition, see Röller et al. (1997), De Bondt (1997), Katz (1986), Kamien et al. (1992). For studies on the influence of R&D cooperation and spillovers on productivity see e.g. Coe & Helpmann (1995).

partners, who try to protect their own knowledge while trying to maximise their absorption of knowledge coming from the partners within the cooperation team. Even though higher spillovers may increase the joint profit, it is obvious that R&D cooperation becomes more profitable if firms are able to protect its own knowledge (restrict outgoing spillovers) while gaining from free information from its partners. Besides gaining from a general high level of spillovers, the incentive to participate in R&D cooperation increases the more the firms are able to limit outgoing spillovers.

The third issue mentioned by Cassiman and Veugelers (1999) is *information sharing*. If the cooperating firms voluntary increase the spillovers among them, e.g. by explicit managing of information, the profitability of R&D cooperation will increase. Furthermore, explicit information sharing makes punishment of free riders more effective by excluding them and thereafter continuing the cooperation and information sharing between the rest of the firms who are cooperating partners. This potential threat will presumably have a strengthening effect on the stability of R&D cooperation.

Commercial and technical risk factors

Some firms may choose R&D cooperation trying to reduce risk and uncertainty in connection with R&D projects, see Tyler & Steensma (1995). First co-operation on larger R&D projects may reduce the risk of technical failures, i.e. the investment in R&D may not at all lead to any new knowledge. However, by the establishing of cooperating teams including a larger number of researchers, the risk of pure technical failure should be reduced. Accordingly, if the firm already has decided to invest in R&D strong risk aversion should lead to more cooperation.

Risks and uncertainty with respect to the market, i.e. commercial risks are other factors, which could influence the firm decision on R&D cooperation. R&D cooperation may lead to results that are easier to commercialise - thus increasing firm’s incentive to participate in joint R&D projects. On the other, hand joint research projects could be less focused on the needs of the particular firm. In that case, R&D cooperation could lead to results that are more difficult to integrate successfully in the firms’ products or processes. So, risk aversion against commercial failure cooperation could lead to both more and less R&D cooperation.

Competition, barriers of entry and firm size

Lack of competition gives rise to monopoly rents, which may lead to managers slacking and lack of effort among employees as well. In that case, the firm's expenditure on R&D is expected to be affected negatively and as a consequence, the incentive for R&D cooperation may be lower. Alternatively, if a few large firms dominate the market and if there are effective entry barriers preventing newcomers from easy entering to the market, the incumbent firms may have strong incentives for coordination in general. This argument is at work particularly concerning R&D investments. Through collaborative behaviour the firms can save resources that might alternatively have been needed for R&D investments in order to produce differentiated or superior products in more competitive surroundings, see Dilling-Hansen et al. (1998). Thus, firms operating within markets characterised by a high concentration rate may have incentives to cooperate on R&D. On the other hand, if only coordination is present with respect to price competition, the strategic parameters for each firm might be its own performed R&D, e.g. in order to strengthen differentiation of its own products. In that case, R&D cooperation is less likely to take place. The same can be said regarding the isolated influence of operating in markets with high barriers of entry. Most likely, high entry barriers will tend to reduce both R&D and R&D cooperation, as the firm can go on producing without the risk of successful newcomers.

The influence of firm size is discussed in a number of studies; see Cassiman & Veugelers (1999) and Röller et al. (1997). They both argue in favour of a positive relationship between firm size and likelihood of R&D cooperation, noting that the absorptive capacity of the firm, which is a precondition for the exploiting of incoming spillovers, rises with larger firm size.

3. The empirical model

In line with Cassiman & Veugelers (1999), a qualitative response model is used to explain the firm participation in R&D cooperation, i.e. whether they cooperate or not. Important explanatory variables are actual and potential spillovers, i.e. ingoing and outgoing. Explicit attention is paid to risk factors, firm characteristics such as size, profit rate and financial solvency are integrated into the model and finally, a number of variables characterising the market are included into the model.

Assuming a logistic probability function, a logit model is used as the estimation form in the empirical analysis.[2] Thus, the probability of taking part in a EU-funded joint R&D project under the 4th Framework Programme can be written as

$$(1) \qquad L(w) = \frac{e^w}{1+e^w}$$

$$(2) \qquad w = x'b + e$$

x is the matrix of explanatory variables, b is a vector of parameters and finally, e is the error term. The variables and the expected influence on the probability for cooperation are discussed briefly.

Firm size

Firm size is expected to have a positive influence on the cooperation. A lot of effort has to be spent in order to apply for EU funds. Furthermore, the firm must be large enough to have contacts abroad but inside EU because of the rules for fund-application within the European Community. Finally, larger firms probably have a larger absorptive capacity (making the firm able to use ingoing spillovers more effectively). Accordingly, R&D joint ventures for such larger firms, compared to smaller firms, will have a higher probability of success. On the other hand, entrepreneurship may bring some smaller firms (younger firms) to cooperate with other firms on R&D. Thus, cooperation might reduce costs for all cooperating partners meaning that cooperation could be the only solution for smaller firms if they want to gain effectively from R&D investments. Accordingly, a U-shaped functional form between firm size and the probability for R&D cooperation within a EU framework could be possible.

Firm age

The age of the firm is expected to increase cooperation as older firms might have the resources needed for investment in a joint R&D project, which probably will pay off only in the longer run. Having been in business for a longer period the older firms probably have easier access to information on the Framework Programmes and a higher number of contacts abroad.

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[2] See Amemiya (1981).

R&D intensity

It is expected that a high firm R&D intensity will increase the probability of R&D cooperation. Partly because firms already investing substantially in R&D probably are more motivated for further R&D investments/cooperation, and partly because a high R&D intensity can be seen as an indicator of the presence of absorptive capacity.

Minimum efficiency scale

High barriers of entry lower the motive for investment in R&D, see Lunn & Martin (1986) and Dilling-Hansen et al. (1998), because the firm is protected against entrants. If the entry barriers are effective, the firm has no direct incentive for participation in joint R&D projects. On the contrary, cooperation with outgoing spillovers could represent a potential risk for the firm. For that reason, minimum efficiency scale is expected to affect the probability of cooperation negatively.

Product market concentration

The influence of product market concentration is ambiguous. If coordination between the firms already exists, R&D cooperation will probably take place too, see above. However, high product marked concentration can also be an indicator of low competition, which would hamper the R&D effort in general, see above.

Spillovers, in- and outgoing

The effect on R&D cooperation from in- and outgoing spillovers has already been discussed in more detail, see above. Increasing ingoing spillovers will increase profits and enlarge the probability of R&D cooperation while the opposite is the result of increasing outgoing spillovers because of the risks of free riding.

Cassiman & Veugelers (1999) argue that spillovers potentially are endogenous in equation (1). For that reason, they use a two-stage least square estimation procedure in order to estimate a system of equations for cooperation, in- and outgoing spillovers. In- and outgoing spillovers are estimated using industry spill-variables as indicators for absorptive capacity and indicators of the 'basicness' of R&D.

In line with Cassiman and Veugelers (1999), the endogeneity problem is analysed. In the empirical section, preliminary 2SLS for in- and outgoing spillovers are discussed and the results of some preliminary estimations are presented.[3]

4. Data

The data used in the analysis are based on three sources. The first data set includes public information on the economic performance of Danish firms. The second data set is The official Danish R&D statistics and the third data set to be used is a survey on the Danish experience from research cooperation within the 4th Framework Programme.

The general information on *economic performance* of firms derives from data from a private data collecting company (*Købmandsstandens Oplysningsbureau LTD).* Firm-specific information has been collected from the public authorities to which *all Danish firms* have a legal obligation to publish the annual report.[4] All firm data on economic performance have been converted to calendar year accounts and all firms have been assigned an industry code corresponding to the NACE-code classification. The sample used in this paper uses various account data from 1993 and 1997. Furthermore, variables characterising the market have been constructed, see below.

The data set including information on R&D was obtained from the official Danish R&D statistics collected every second year by the Danish Institute for Studies in Research and Research Policy.[5] At the empirical level, the concept of R&D comprises *creative work undertaken on a systematic basis in order to increase the stock of knowledge of man and society, and the use of this stock in order to devise new applications*; see the Frascati-manual p. 29.

The basic reporting unit of the R&D survey is the legal firm unit, which can be identified in the account statistics just mentioned. In the 1997 R&D survey, the number of respondents was 4,076. The final data set includes 3,689 firms, which gives a 'response rate' of 91%.[6] Of these, 1,099 firms are recorded to have positive R&D expenditure.

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[3] This version of the paper presents only preliminary estimations, i.e. 2SLS estimation. In a later version, the equation system will be estimated in a FIML framework.

[4] For a description of the account database, see Dilling-Hansen et al. (1997).

[5] Until the 1995 issue, The Danish Ministry of Education and The Danish Ministry of Research were responsible for providing the data and for publishing the statistics.

[6] The true response rate was slightly lower, 85%, because the R&D expenditure for a number of non-responding firms was estimated from the 1995 survey.

The third data set used in the analysis comes from a survey on the Danish experience with R&D cooperation within The EU Framework Programmes. CORDIS were used to identify the population of Danish firms engaged in R&D cooperation under the 4^{th} Framework Programme, and questionnaires were sent to the CEO managers and to the persons in charge of the particular framework research programme of the firm. The former group amounted to 383 of which 31% returned a fulfilled questionnaire, which resulted in 116 usable records. The latter group consisting of the people actually in charge of the specific R&D project within the firm, included 882 persons, and 39% of the questionnaires were returned.[7]

In addition, the survey includes answers from CEO managers from firms not participating in R&D projects funded by the EU 4^{th} Framework Programme. Using the firm register of the official Danish R&D statistics, a stratified sample (with respect to size and industry) of non-participants was collected. 317 firms were included in this sub-population. The response rate was 29%. Accordingly, the sample includes 92 firms.

Finally, the data is merged by its identification number, which is a compulsory unique 8-digit registration number for each single firm in Denmark. Table 1 gives summary statistics for the main variables used in the analysis. First, the table illustrates the problems with missing observations. In addition, some firms included in the CORDIS database could not be identified by its firm number resulting in loss of observations, when merging the survey on cooperation with the accounting data and the R&D statistics. Thus, the total sample size is 174 firms of which 89 are part of a EU-funded R&D project (COOP=1).

The number of employees measures firm size (SIZE). The average size is 779 with some suggesting that the larger firms are over-represented in the analysis. As can be seen from standard error, some very large firms are included in the sample.

In line with other studies, see Lunn & Martin (1986) and Dilling-Hansen et al. (1998), the minimum efficiency scale (MES93) is approximated by log of the first quartile sales in each industry at the 4-digit NACE classification level. As the 4^{th} Framework Programme relates to 1994-1998, 1993 values of MES have been used in the analysis.

[7] Note that one firm can colaborate on several projects.

Product market concentration (HERF93) is measured by the Hirch-Herfindahl concentration index stressing the importance of larger firms. As is the case for the minimum efficiency scale, the 1993-concentration index has been used partly in order to minimise potential simultaneity problems but more importantly because the decision to participate must depend on the market situation before or close to the start of the framework programme in 1994. The values of the standard error suggest that there is a considerably variation present in the concentration measure across industries.

The firm age (AGE) is measured by years since establishment. The average age is 22 years, again with some rather old firms giving the large standard error. R&D_INT is a dummy variable controlling for very R&D-intensive firms (equal to 1, if R&D relative to firm sales is larger than 20%). 18.5% of the firms are considered to be R&D-intensive, i.e. they have a high absorptive capacity.

Table 1. Summary statistics for variables used in the empirical analysis.

	Number of observations	Mean	Std
EU programme participation (COOP)	174	0.517	0.501
Firm size - number of employees (SIZE)	171	779	2,936
Minimum efficiency scale (MES93)	160	7.641	0.922
Herfindahl concentration index (HERF93)	163	0.264	0.247
Firm age (AGE)	164	22.372	23.969
Dummy for R&D intensity (R&D_INT)	146	0.185	0.390
Ingoing spillover, technological (INSP_TEC)	174	0.650	0.263
Outgoing spillover (OUTSPILL)	161	0.200	0.233
Ingoing spillover, economic (INSP_ECO)	168	0.429	0.231
Risk, technological (RISK_TEC)	138	0.420	0.345
Market risk (risk_mar)	137	0.382	0.332

Looking at ingoing spillovers, a distinction is made between the importance of economic spillovers INSP_ECO and technical spillovers INSP_TEC. On a Likert scale from 1 to 5, firms were asked to rate the importance of several topics as motives for participating in R&D projects under the 4th Framework Programme (firms with

COOP=1) and analogue questions were asked to non-participants (COOP=0) as a potential motive for potential participation in the future. INSP_TEC is measured as the average score on questions focussing on access to technology (process and product related), equipment and R&D-network.[8] INSP_ECO measures the importance of access to financial sources and the increasing market contact qua participation in the EU-R&D-project.[9]

Outgoing spillovers OUTSPILL have been constructed using averages of questions on the importance of risk factors such as protection of core competence and intellectual property rights output from the R&D projects for participating firms. The survey did not include a similar question for non-participants. Values for the OUTSPILL variable were approximated using the answers on questions concerning potential risks in joint R&D projects and whether joint R&D projects is in accordance with the firms R&D strategy. Comparing the mean scores in Table 1, it is easily seen that the average score of the OUTSPILL variable is much lower than that of e.g. INSP_TEC. Looking at the standard errors, there are only minor differences between the inspill- and outspill variables.

Finally, RISK_TEC and RISK_MAR give the average score on the questions explicitly focusing on the reductions of risks. RISK_TEC is the score on the importance of reducing technological risk from participation in the EU-sponsored joint R&D project. And a similar question has been asked on the importance of reducing market risks and uncertainty as a separate motive for actual or potential participation in joint R&D projects. The average rating is on level with the inspill/outspill variables but in both cases the variations in answers are larger. Cumulative distributions for the spillover and risk variables are shown in the appendix.

5. Results

The empirical results from the estimation of equation (1) are shown in Table 2. The model in the first column focuses on the influence of firm size and barriers of entry. The simple estimation form suggests that the influence of size has a U-like form with a maximum close to a firm size of 24 employees. This means that for nearly the entire range of firm sizes there is a positive relationship with size! The influence of entry barriers is negative and clearly significant as suggested in the theoretical discussion

[8] In line with Cassiman and Veugelers (1999), the Likert-scores have been rescaled as score=(score-1)/4. Thus inspill, outspill and risk variables vary between 0 and 1 making the scores more appropriate for the analysis.
[9] This variable has not been used in the estimations presented in Tables 2 and 3.

above. Using the model for prediction of whether the firm cooperates or not, the prediction will be correct in 67.3% of the cases.

In column 2, the influence of product market concentration as an indicator of competition is added to the model. The parameter is positively signed giving support to the collusive behaviour argument. However, the parameter is only slightly significant.

The third column includes the influence of the age of the firm and in addition, control is made for firms having a very large R&D intensity. In accordance with the discussion in Section 2, both parameters are positively signed and highly significant. On the other hand, the influence of size becomes insignificant, indicating that multicollinarity problems are present.[10] In appendix B, partial Pearsons Correlation Coefficients between the variables are given. There is a significant indication of correlation between size and a number of variables, especially age, R&D intensity and minimum efficiency scale.

Finally, spillover variables are included in the fourth column. Both variables have fairly large parameters. Ingoing spillovers have a positive influence on the likelihood of R&D cooperation, which is in accordance with the theoretical arguments. But outgoing spillovers have the wrong sign and are positively significant.[11] The influence of the other variables included in the model is rather stable and the overall model fit has increased to nearly 84%, i.e. the model predicts correctly in 84% of the cases.[12]

One of the major questions concerning the estimation presented in the last column of Table 2 is whether the in- and outspill variables are really exogenous; see Cassiman & Veugelers (1999) who argue that the decision to cooperate should interact with the effects of spillovers on innovation incentives. If firms manage spillovers, the decision on R&D cooperation is taken simultaneously with decisions on the spill-levels. Next, focusing at the answers from the questionnaires sent to the each firm, the participation in the EU-sponsored R&D projects might in fact influence the answers on the importance of potential spillovers in itself. Thus, firms being part of successful R&D

[10] Except for becoming insignificant, the influence of size is rather stable, i.e. maximum probability close to 28 employees.

[11] Except for the situation where the firm voluntarily and in a perfect arrangement of managing knowledge sharing with its partners increases outgoing spillovers in order to enjoy ingoing spillovers, the sign of OUTSPILL is excepted to be negative.

joint projects would probably not rate the (hampering) importance of outgoing spillovers very high and the way the firm values ingoing spillovers would surely also be influenced.

Table 2. Logistic probability models for EU-funded R&D cooperation.

	(1)	(2)	(3)	(4)
Intercept	4.1306 ** (1.6812)	4.0634 ** (1.6798)	3.5294 (2.2697)	1.7216 (2.6253)
SIZE (log)	-0.5389 ** (0.2707)	-0.5356 ** (0.2714)	-0.3684 (0.3261)	-0.4085 (0.3635)
SIZE squared	0.0853 * (0.0312)	0.0822 * (0.0312)	0.0594 (0.0378)	0.0543 (0.0410)
MES93 (minimum efficient scale)	-0.4927 ** (0.2251)	-0.5270 ** (0.2257)	-0.6580 ** (0.3111)	-0.6200 *** (0.3477)
HERF (concentration index)		1.5812 *** (0.8347)	1.0093 (0.9908)	
AGE			0.0595 * (0.0207)	0.0539 ** (0.0214)
R&D_INT (1: R&D intensity>20%, else 0)			1.2502 ** (0.0241)	1.0304 *** (0.6251)
INSP_TEC (ingoing technical spillovers)				2.4900 ** (0.9796)
OUTSPILL (outgoing spillover)				3.1182 * (1.1059)
Number of observations	157	157	131	124
-2 Log Likelihood	201.0	197.1	141.7	121.4
Concordant (percent)	67.3	70.0	79.6	83.6

Notes: Numbers in brackets are standard errors of the estimated parameters. An asterisk * indicates that the estimated parameter is significantly different from zero at the 1% level of significance, ** at the 5% level, and *** at the 10% level of significance.

[12] Note that the number of observations has decreased to 124. Despite of still fewer observations going from column 1 to column 4, the general level of significance is quite stable while the overall model fit increases.

The endogeneity problem demands modelling of a simultaneous equation system. As a starting point a 2-stage estimation procedure can be used in order to estimate equations for INSP_TEC and OUTSPILL. Table 3 includes OLS, 2SLS and 2-stage TOBIT estimations for INSP_TEC and OUTSPILL using the third column estimations as first step for the latter type estimation. In accordance with Cassiman & Veugelers (1999), industry averages are used as explanatory variables for the spillover variables, in order to *'capture the technological conditions of the industry influencing the ease of flows of know how'* (IND_INSPILL) and in order to *'capture technological conditions shaping strategic protection possibilities'* (IND_OUTSPILL).

Looking at the estimation results for OUTSPILL, the estimations give a rather unsatisfactorily overall fit with R^2 close to 0.15 in the OLS-based models. Comparing OLS estimates with the result of the TOBIT equation, only minor differences are seen. In all estimation forms, the only variable being significant is the industry level outgoing spillover variable.

Moreover, the variable for cooperation is insignificant, suggesting that the endogeneity problem might be of minor importance. The equations for ingoing spillovers give nearly the same results except for the fact that more variables are significant and the cooperation variable is significant at the 5% level in the Tobit regression, suggesting some endogeneity of the INSPILL variable in equation 1. Still, none of the equations performs very well.

The main conclusion to be drawn from Table 3 is that significant endogeneity of outgoing spillovers with respect to the decision to cooperate or not could not be verified. In the OLS estimation forms, the result is the same for ingoing spillover, however using the Tobit specification cooperation seems to influence ingoing spillovers. Thus, the evidence on endogeneity is mixed, which could be due to the fact that the number of observations used for the estimations in Table 3 is rather limited. This could also be a major explanation for the rather poor model fit in general. Furthermore, use of full information estimation methods might increase the estimation, calling for future empirical work.

Table 3. Results of OLS and Second stage 2SLS estimation of INSP_TEC and OUTSPILL.

	OUTSPILL OLS	INSP_TEC OLS	OUTSPILL 2SLS	INSP_TEC 2SLS	OUTSPILL TOBIT	INSP_TEC TOBIT
COOP[1)]	0.1319 (0.1014)	0.1976* (0.0591)	0.0136 (0.1200)	0.2127*** (0.1287)	0.0171 (0.1843)	0.2823** (0.1467)
Other strategic R&D alliances (YES=1)	0.1195 (0.0936)		-0.0456 (0.0622)		0.2773* (0.0982)	
HERF93	-0.1437 (0.1098)	-0.0290 (0.1253)	-0.1234 (0.1113)	0.0162 (0.1321)	-0.0835 (0.1701)	-0.0188 (0.1515)
IND_OUTSPILL (industry-level outgoing spillover)	0.1643 (0.3672)		0.3138 (0.3536)		1.0902** (0.6164)	
RISK_TEC (importance of reducing techn. risk)	0.0276 (0.0743)		0.0346 (0.0766)		0.0299 (0.1178)	
FS financial solvency	-0.0002 (0.0088)		-0.0014 (0.0089)		-0.0040 (0.0125)	
Other R&D co-operations (YES=1)	-0.0679 (0.0612)		0.2076* (0.3165)		-0.0613 (0.0957)	
IND_INSPILL (industry-level techn. ingoing.spill)		0.7342** (0.2866)		0.9033* (0.0301)		1.0073* (0.3333)
SIZE		0.0069 (0.0140)		0.0018 (0.0156)		0.0030 (0.0173)
RISK_MAR (importance of reducing market risk)		0.2346* (0.0834)		0.2177** (0.0882)		0.2790* (0.0983)
Number of observations	72	72	72	72	72	72
R^2 (F-value)	0.15 (2.8)**	0.29 (6.8)*	0.12 (2.4)**	0.20 (4.7)*		
Log Likelihood					-28.8450	-14.4309

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

(1) 2SLS and Tobit estimations use COOP as predicted from the Logistic Probability Model (3) in Table 3.

6. Conclusion

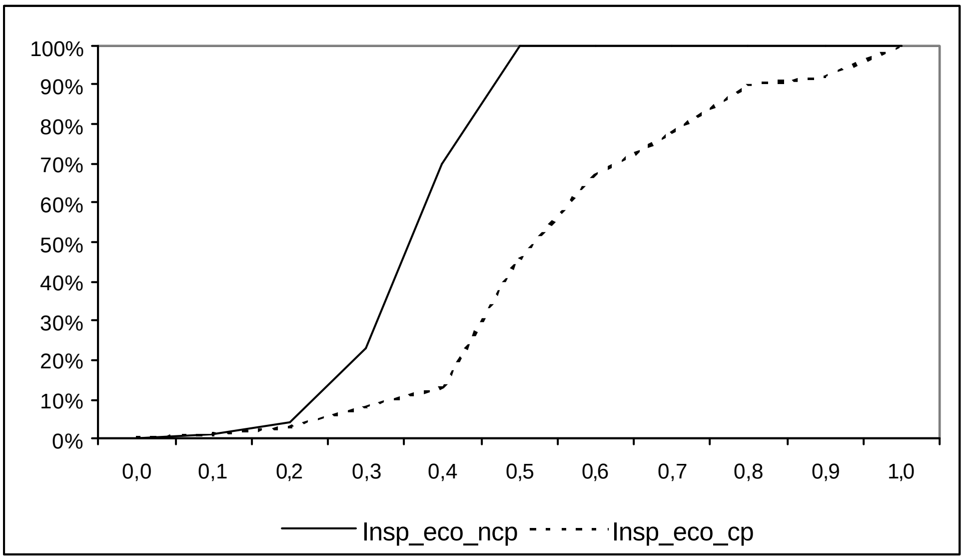
The aim of this paper is to present empirical evidence on R&D cooperation for Danish firms. Using information from a survey on Danish firms' participation in R&D cooperation under the EU 4th Framework Programme, a model based on firm-level data explicitly paying attention to market factors, in- and outgoing spillovers are estimated.

The analysis finds that except for very small firms, size of firm increases the probability of R&D cooperation. The situation is the same with respect to firm age, i.e. older firms are relatively more engaged in R&D cooperation. High entry barriers are found to affect R&D cooperation negatively, whereas being an R&D- intensive firm will increase the probability of participation in EU-funded R&D joint venture. However, the influence of market concentration is ambiguous.

In- and outgoing spillovers from R&D cooperation are both found to affect R&D cooperation positively. For the former, it is in accordance with the expectations a priori. In line with other studies, the problem of potential endogeniety between the decision to cooperate and the spillover variables is discussed, and a system of simultaneous equations is needed. As a starting point, some very first estimations for in- and outgoing spillovers within a 2-stage estimation framework are presented. The estimations do not give evidence in favour of the endogeneity hypothesis for outgoing spillovers, whereas there is some evidence for the ingoing spillovers. Still, more empirical work using other estimation techniques is needed in order to be conclusive on this point.

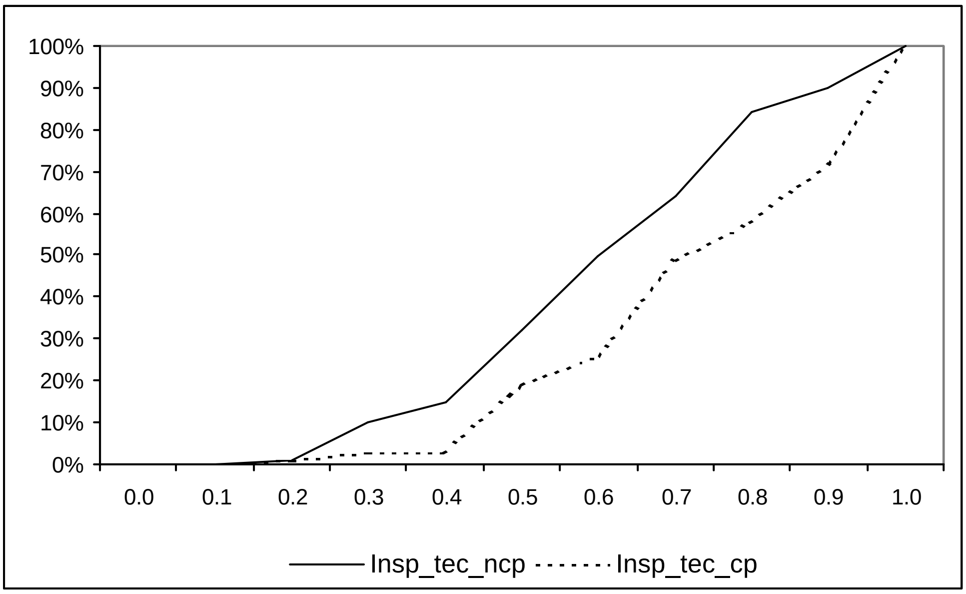
Appendix A.

Figure 1. Cumulative distribution of economic ingoing spillovers in connection with R&D cooperation.



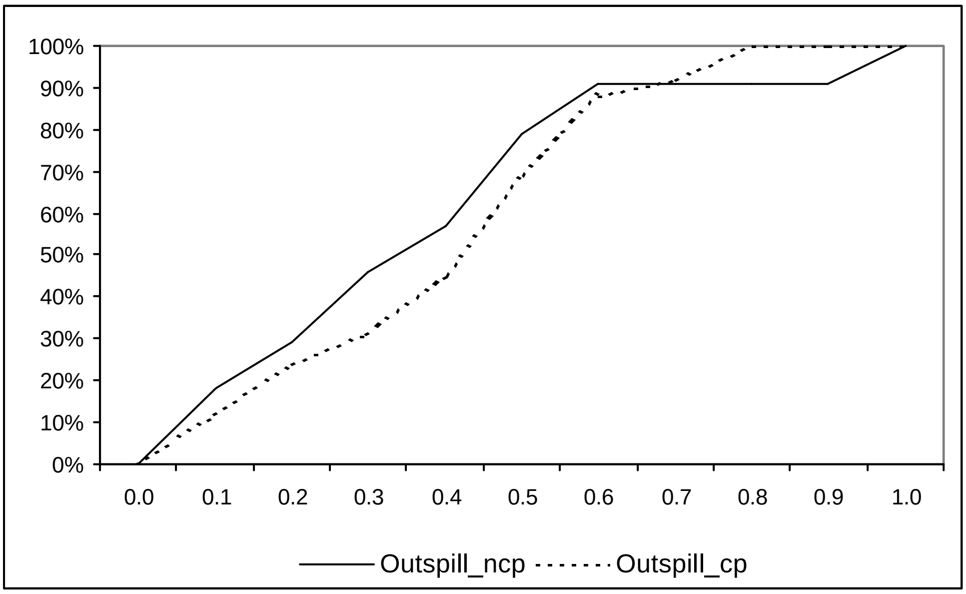
1. Axis: Likert values; 2. Axis: Cumulative number of firms (%).
_cp: cooperation; _ncp: non-cooperation

Figure 2. Cumulative distribution on firm rating of technological ingoing spillovers in connection with R&D cooperation.



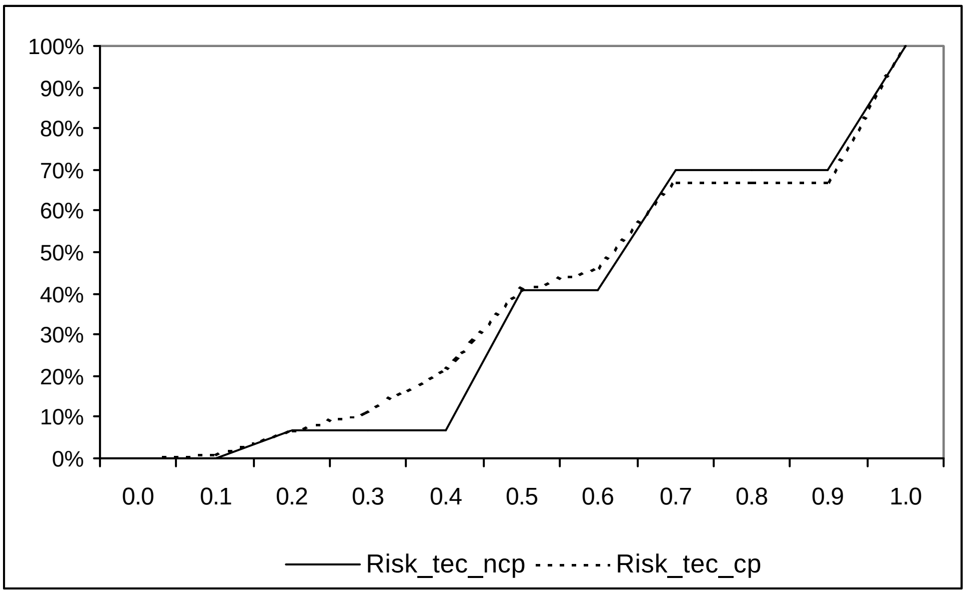
1. axis: Likert values; 2. axis Cummulative number of firms (%).
_cp: cooperation; _ncp: non-cooperation

Figure 3. Cumulative distribution on firm rating of outgoing spillovers in connection with R&D cooperation.



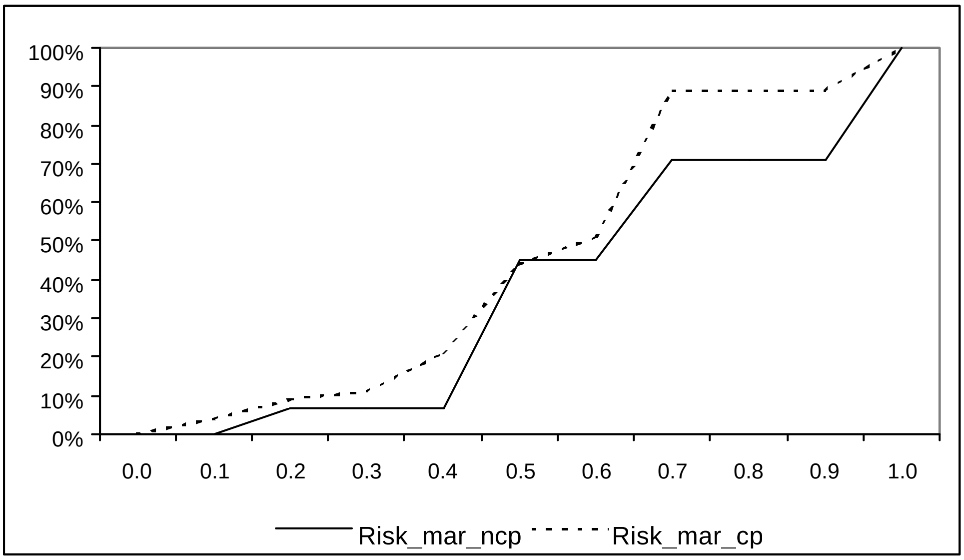
1. axis: Likert values; 2. axis Cumulative number of firms (%).
_cp: cooperation; _ncp: non-cooperation

Figure 4. Cumulative distribution market risks and uncertainty in connection with R&D cooperation.



1. axis: Likert values; 2. axis Cummulative number of firms (%).
_cp: cooperation; _ncp: non-cooperation

Figure 5. Cumulative distribution of technological risks in connection with R&D cooperation.



1. axis: Likert values; 2. axis Cumulative number of firms (%).
_cp: cooperation; _ncp: non-cooperation

Appendix B.

Correlation Analysis

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0
/ Number of Observations

	SIZE	SIZE_SQ	MES93	HERF93	AGE	FOUINT
SIZE	1.00000	0.95160	0.34847	0.12688	0.45058	-0.33562
SIZE	0.0	0.0001	0.0001	0.1099	0.0001	0.0001
	171	171	157	160	161	144
SIZE_SQ	0.95160	1.00000	0.33697	0.15519	0.51231	-0.27855
SIZE_SQ	0.0001	0.0	0.0001	0.0501	0.0001	0.0007
	171	171	157	160	161	144
MES93	0.34847	0.33697	1.00000	0.13915	0.24203	-0.19726
MES93	0.0001	0.0001	0.0	0.0793	0.0023	0.0218
	157	157	160	160	157	135
HERF93	0.12688	0.15519	0.13915	1.00000	0.11052	0.12139
HERFH93	0.1099	0.0501	0.0793	0.0	0.1641	0.1577
	160	160	160	163	160	137
AGE	0.45058	0.51231	0.24203	0.11052	1.00000	-0.16563
	0.0001	0.0001	0.0023	0.1641	0.0	0.0522
	161	161	157	160	164	138
FOUINT	-0.33562	-0.27855	-0.19726	0.12139	-0.16563	1.00000
FOUINT	0.0001	0.0007	0.0218	0.1577	0.0522	0.0
	144	144	135	137	138	146
INSP_TEC	0.19028	0.17594	-0.02487	0.11004	0.09494	0.10500
INSP_TEC	0.0127	0.0213	0.7549	0.1620	0.2265	0.2072
	171	171	160	163	164	146
INSP_ECO	0.09318	0.10664	-0.10489	0.03251	0.12999	0.03239
INSP_ECO	0.2339	0.1728	0.1911	0.6841	0.1024	0.6999
	165	165	157	159	159	144
OUTSPILL	-0.01216	-0.00269	0.02113	0.08786	0.04016	0.12864
OUTSPILL	0.8791	0.9732	0.7988	0.2834	0.6233	0.1356
	159	159	148	151	152	136
RISK_TEC	0.09887	0.06410	-0.08614	-0.03800	-0.06322	0.07630
RISK_TEC	0.2539	0.4602	0.3242	0.6617	0.4630	0.4115
	135	135	133	135	137	118
RISK_MAR	-0.03795	-0.06905	-0.15383	-0.17778	-0.16427	0.03496
RISK_MAR	0.6633	0.4279	0.0782	0.0399	0.0560	0.7083
	134	134	132	134	136	117

Correlation Analysis (cont.]

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

	INSP_TEC	INSP_ECO	OUTSPILL	RISK_TEC	RISK_MAR
SIZE	0.19028	0.09318	-0.01216	0.09887	-0.03795
SIZE	0.0127	0.2339	0.8791	0.2539	0.6633
	171	165	159	135	134
SIZE_SQ	0.17594	0.10664	-0.00269	0.06410	-0.06905
SIZE_SQ	0.0213	0.1728	0.9732	0.4602	0.4279
	171	165	159	135	134
MES93	-0.02487	-0.10489	0.02113	-0.08614	-0.15383
MES93	0.7549	0.1911	0.7988	0.3242	0.0782
	160	157	148	133	132
HERF93	0.11004	0.03251	0.08786	-0.03800	-0.17778
HERF93	0.1620	0.6841	0.2834	0.6617	0.0399
	163	159	151	135	134
AGE	0.09494	0.12999	0.04016	-0.06322	-0.16427
	0.2265	0.1024	0.6233	0.4630	0.0560
	164	159	152	137	136
FOUINT	0.10500	0.03239	0.12864	0.07630	0.03496
FOUINT	0.2072	0.6999	0.1356	0.4115	0.7083
	146	144	136	118	117
INSP_TEC	1.00000	0.65749	0.19764	0.45894	0.32948
INSP_TEC	0.0	0.0001	0.0120	0.0001	0.0001
	174	168	161	138	137
INSP_ECO	0.65749	1.00000	0.22023	0.28269	0.28481
INSP_ECO	0.0001	0.0	0.0056	0.0009	0.0008
	168	168	157	136	135
OUTSPILL	0.19764	0.22023	1.00000	0.19136	0.16262
OUTSPILL	0.0120	0.0056	0.0	0.0286	0.0645
	161	157	161	131	130
RISK_TEC	0.45894	0.28269	0.19136	1.00000	0.68553
RISK_TEC	0.0001	0.0009	0.0286	0.0	0.0001
	138	136	131	138	137
RISK_MAR	0.32948	0.28481	0.16262	0.68553	1.00000
RISK_MAR	0.0001	0.0008	0.0645	0.0001	0.0
	137	135	130	137	137

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