R&D COOPERATION AND SPILLOVERS: SOME EMPIRICAL EVIDENCE*

by

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Abstract

This paper provides some first empirical evidence on the relationship between R&D spillovers and R&D cooperation. The results suggest disentangling different aspects of know-how flows. Firms which rate incoming spillovers more importantly and who can limit outgoing spillovers by a more effective protection of know-how, are more likely to cooperate in R&D. Our analysis also finds that cooperating firms have higher incoming spillovers and higher protection of know-how, indicating that cooperation may serve as a vehicle to manage information flows. Our results thus suggest that on the one hand the information sharing and coordination aspects of incoming spillovers are crucial in understanding cooperation, while on the other hand, protection against outgoing spillovers is important for firms to engage in stable cooperative agreements by reducing free-rider problems. Distinguishing different types of cooperative partners reveals that while managing outgoing spillovers is less critical in alliances with non-commercial research partners than between vertically related partners, the incoming spillovers seem to be more critical in understanding the former type of R&D cooperation.

JEL: D21, L13, O31, O32.
Keywords: Research and Development; Cooperation; Spillovers

1. Introduction

When devising their innovation strategies, even large and self-contained organizations rely increasingly on cooperative R&D agreements. The advantages of R&D cooperation are compelling, as stressed by the technology management literature (Porter & Fuller (1986), Hagedoorn & Schakenraad (1991), Tyler & Steensma (1995)): it allows to gain access to skills and technologies, realize economies through the exploitation of complementarities, share costs and risks and control competitive forces. Despite these apparent benefits, empirical evidence on the one hand suggests that cooperation carries a disturbingly high risk of failure (Kogut (1988), Harrigan (1988)), while on the other hand many seemingly profitable cooperative partnerships are not consummated. Firms expose, transfer and develop valuable know-how within these cooperative R&D ventures. Such information flows, when uncontrolled, can undermine the long-run technological advantage of firms. When uncontrollable but anticipated, these information flows lead firms to refrain from engaging in seemingly profitable cooperative agreements, while if controllable and managed appropriately, these information flows can result in more profitable and stable cooperative agreements.

The relationship between different know-how flows—spillovers—and cooperation is complex. In a world of imperfect appropriability of know-how, cooperation can be a vehicle to internalize the effect of involuntary transfers—the *outgoing* spillovers—that occur. At the same time cooperating firms will invest more effort in protecting their knowledge, i.e. in managing the *outgoing* spillovers. This increases the stability of R&D cooperation by reducing the incentives for free riding by partners and by firms outside the cooperative agreement. In addition, cooperation can be seen as an instrument to more efficiently manage transfers of know-how among partners and even from outside the cooperation—the *incoming* spillovers. Von Hippel (1988) already stressed the existence of, often very informal, technology trading networks in which partners manage substantial inter-firm flows of information, see also Baumol (1992)). Such information sharing improves the profitability of R&D cooperation.

The relationship between R&D cooperation and R&D spillovers, while relatively well developed in theoretical models, remains largely unexplored in empirical work. The main contribution of this paper is in providing evidence on this relationship, stressing the firm-specificity and endogeneity of spillovers. Our empirical results confirm the recent trends in the literature which emphasize that spillovers are to a large extent firm-specific, with firms actively developing their innovation strategies to maximally benefit from information flows (Katsoulacos & Ulph (1998), Kamien & Zang (1998) as well as Doz & Hamel (1997) for case study evidence). The results further suggest that it is important to distinguish between *incoming* and *outgoing* spillovers. Higher levels of incoming spillovers and lower levels of outgoing spillovers induce a higher probability of cooperation. While the level of spillovers influences the decision of a firm to cooperate in R&D, the decision to cooperate also affects the level of incoming and outgoing spillovers in an important way. A cooperative agreement increases the incoming spillovers. This might be the result of information sharing between partners. In addition, we find evidence that the absorptive capacity of an individual firm increases the importance of these incoming spillovers. Partners in a cooperative agreement also have more effective protection against outgoing spillovers. This suggests that firms that engage in a cooperative agreement invest in protecting the information transferred and created in the cooperative agreement. We thus find evidence that firms actively manage information flows. Furthermore, the effects of incoming and outgoing spillovers depend on the type of research partner. In cooperative agreements with research organizations or universities the level of *incoming* spillovers is an important factor. This is related to the more generic nature of these information flows. When cooperating with suppliers or customers, partners worry more about the *outgoing* spillovers. Information developed and transferred in this type of cooperative agreement is typically more commercially sensitive.

With most of the existing theoretical and empirical research treating spillovers as a technology-driven phenomenon, these results strongly suggest opening new avenues for further research. The next section summarizes some robust findings from a wide range of theoretical models from the industrial organization literature. Section 3 reviews some related empirical literature on the conditions facilitating R&D cooperation and on the measurement of R&D spillovers. The link between R&D cooperation and spillovers is then explored empirically in section 4, using EUROSTAT/CIS survey data from Belgian manufacturing firms. Section 5 concludes.

2. Industrial Organization results on R&D cooperation and spillovers

While the management literature typically analyzes cooperation from a transaction costs' framework (Pisano (1990), Robertson & Gatignon (1998), Oxley (1997))[1] or uses resource-based theories (Tyler & Steensma (1995), Doz & Hamel (1997),[2] the Industrial Organization (I.O.) literature emphasizes competitive motives for engaging in R&D cooperation and concentrates on the knowledge flows and appropriability issue among market participants. When anticipated, voluntary or involuntary transfers of know-how complicate R&D strategies in a non-trivial way. De Bondt (1996) provides an overview of the impact of spillovers on non-cooperative R&D investment levels. A similar focus on the effects of spillovers is omni-present in reviewing the IO literature on R&D cooperation (e.g. Katz (1986), Spence (1984), d'Aspremont & Jacquemin (1988), Beath et al (1988), Kamien et al (1992), Suzumura (1992), and Leahy & Neary (1997)). From this literature, three important issues conditioning the interrelation between the profitability of R&D cooperation and spillovers: coordination, free-riding and information sharing, can be distinguished, although they are very often heavily entwined.

Coordination. A multi-stage, non-tournament, model is typically used where R&D investments have an impact on the output market either through a cost-reducing or demand-enhancing effect.[3] Firms cooperate in the R&D stage, but may continue to compete in the product market. This cooperation is typically industry-wide and takes the

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[1] While arms length technology transactions invoke transaction costs, own development limits these transaction costs, but prevents quick access to external know-how. Collaboration is a hybrid organizational form that allows external access, organizing transfers of technology at lower transaction costs as in an arm's length setting.

[2] Resource based theories suggest that R&D cooperation allows to build new competences more effectively by joining complementary know-how, at least if firms have the capacity for learning from partners.

[3] Henderson & Cockburn (1994) provide evidence that R&D competition is less of a racing type, but more of a spilling type. However there also exists a series of tournament models of R&D cooperation (see Beath et al (1995)). In such a tournament model cooperating firms increase their probability of success due to the sharing of complementary know-how (Sinha & Cusumanu (1991)).

form of firms coordinating R&D choices in order to maximize joint profits. Other than a recognition of mutual interests in such R&D cartels and possibly including some sharing of results in research joint ventures (see the Kamien et al (1992) typology), no joint R&D projects are undertaken.[4] Focusing on a world where R&D is imperfectly appropriable and R&D results would leak out involuntarily to rival firms, these models concentrate on horizontal R&D cooperation among rival companies as a mechanism allowing to internalize these spillovers.[5] The presence of spillovers thus conditions the R&D investment of the firms. Spillovers are non-firm specific and symmetric: one firm's outgoing spillover is the other firm's incoming spillover.

A first finding in these models is that investment in R&D when firms cooperate is increasing in the level of the spillover. A second finding across the various models is that when spillovers are high enough, i.e. above a critical level, cooperation in R&D will result in higher R&D investment compared to non-cooperating firms. Cooperation allows to overcome the disincentive effect from the positive externality, which the outgoing spillovers create on rival firms. The nature of product market competition critically shapes this disincentive effect, with the critical spillover level depending on whether firms are marketing substitutes or complements.[6] When goods are substitutes the level of product differentiation and the number of rivals are important parameters that determine the critical spillover level. (see De Bondt et al (1992), Röller et al (1997)).

Given the assumption of coordination through joint profit maximization, while ignoring any explicit costs to R&D cooperation, these models find that cooperation always increases the firms' profitability. But more importantly, spillovers seem to increase the profitability of cooperation in R&D. Furthermore, once spillovers are sufficiently high, i.e.

[4] These theoretical models thus largely ignore one of the most important motives for R&D cooperation, identified in empirical studies such as Mariti & Smiley (1983), Hagedoorn & Schakenraad (1991) and Sakakibara (1997a,b), namely synergies from exploiting asset complementarity. Only part of these synergies can be generated through coordination, allowing firms to better access the existing pool of spillovers. Also explicit sharing of costs and risks is ignored, although costs of R&D will be lowered through avoidance of wasteful duplication. For a model on joint R&D projects, see Veugelers & Kesteloot (1994).

[5] An important implicit assumption of all these models is that R&D investment or effort is contractible or enforceable in some way.

[6] When firms are marketing complementary goods, cooperation always results in higher R&D investment levels than non-cooperation, independent of the level of spillovers.

above the critical spillover level, higher spillovers make R&D cooperation increasingly more attractive as compared to independent R&D (De Bondt & Veugelers (1991)).[7] This means that when spillovers are high enough, firms have an increasing incentive to engage in R&D cooperation. Such cooperation would furthermore enhance welfare.[8]

Free-riding. Most I.O. models focus on the welfare and profitability of R&D cooperation, ignoring the stability of such cooperation. Next to cooperative stability threatened by non-participating companies, the venture has to worry about free-riding by partners who may conceal their technological expertise while trying to absorb as much as possible of the partner's knowledge (e.g. Shapiro & Willig (1990), Baumol (1993)). Kesteloot & Veugelers (1994) find that cooperative agreements that are profitable, and at the same time also stable, require involuntary—outgoing—spillover levels that are not too high.[9] This result can be confronted with the supra reported result that the profits from cooperation are higher, the larger are the outgoing spillovers. Higher spillover levels, although they increase the profits from cooperation through coordination, also and more importantly, increase the profits from cheating by a partner and from free-riding by an outsider to the cooperative agreement.[10] Hence cooperative ventures become more profitable the more able firms are in managing the outgoing spillovers: restricting outgoing spillovers and thus free riding by protecting its information while selectively sharing information with partners. This result emphasizes a potential dual role of spillovers: outgoing spillovers which might jeopardize the cooperative agreement and incoming spillovers which increase the attractiveness of the cooperative agreement. This brings us to this last role of spillovers.

[7] At the critical spillover level, profitability of cooperative and non-cooperative R&D strategies would coincide.
[8] This result is important for the antitrust treatment of R&D cooperation (Ordover & Willig (1985), Jacquemin (1988), Shapiro & Willig (1990)), Cassiman (1998)).
[9] Using repeated game theory methodology, cheating can be prevented by the use of grim-trigger strategies specifying an eternal dissolution of an industry-wide venture. An alternative approach to solve the internal stability problem is through the organizational design of the venture. Perez-Castrillo & Sandonis (1996) for instance characterize incentive compatible and individually rational contracts that lead to disclosure and hence formation of profitable research joint ventures.
[10] Veugelers & Kesteloot (1994) show that when an R&D agreement allows for joint R&D, synergies from complementarities between partners will improve the profitability and stability of R&D cooperation, stifling the incentives to cheat with higher spillovers.

Information Sharing. Some I.O. models take into account that firms can indeed manage spillovers, for instance by voluntarily increasing the spillovers among cooperating partners, as in the research joint venture scenario of Kamien et al (1992). Such information sharing, which increases the *incoming* spillover for partners,[11] is found to further increase the profitability of cooperation in R&D. Furthermore, information sharing not only increases the profitability of R&D cooperation, it also makes such agreements more stable, since it allows to make the punishment of non-sharing harsher (Kesteloot & Veugelers (1994)). Eaton & Eswaran (1997) show that when technology trading cartels are not necessarily industry wide, information sharing is an even stronger stabilizing force. In this case, a much stronger punishment can be specified, namely the ejection of the cheating firm from a technology trading coalition, followed by the continuation of information sharing by the non-cheating members. Similarly, De Bondt & Wu (1997) find that information sharing produces larger coalition sizes that are both internally and externally stable. In a recent paper, Katsoulacos and Ulph (1998) explicitly model the choice of spillovers by cooperating and non-cooperating firms and find that research joint ventures will always share at least as much information as non-cooperating firms because research joint ventures maximize joint profits.

Entwined with the issue on whether spillovers are exogenous or endogenous, is the issue on whether spillovers are symmetric or not. In most I.O. models, firms generate and receive spillovers to the same extent. Assuming symmetrical in- en outgoing spillovers fails to capture the idea that when allowing firms to manage these technology flows, the aim is to minimize the creation of spillovers—the *outgoing* spillovers— while at the same time maximize the *incoming* spillovers. Minimizing outgoing spillovers implies excluding others from sharing through the use of effective legal and strategic protection measures. As already indicated, firms can maximize incoming spillovers by cooperating with other firms in information sharing cartels. Alternatively or at the same time, they can try to increase incoming spillovers by investing in "absorptive capacity" (Cohen & Levintahl (1989)): spillovers are more efficient in reducing own costs when the firm is engaged in

[11] The increased incoming spillover of one partner is the outgoing spillover of the other. This matters directly if your partner is a potential competitor or indirectly if spillovers can move from

own R&D. This model implies that own R&D might directly influence the level of spillovers, particularly the *incoming* spillovers, while also indirectly affecting the profitability of R&D cooperation through coordination. In cases where coordination increases the R&D expenditures of partners, these higher R&D investments, in turn, improve the partners' absorptive capacity. The direct effect of higher absorptive capacity is to increase the incoming spillovers, but indirectly the higher absorptive capacity increases the efficiency of the given level of incoming spillovers, and as a result increases the profitability of R&D cooperation. This notion of absorptive capacity has been recently integrated into the I.O. models on R&D cooperation by Kamien & Zang (1998). They show that firms that cooperatively choose their R&D expenditures, maximize information flows—their *incoming* spillovers—through the choice of very broad research directions for the research joint venture. If the firms cannot coordinate their R&D expenditures, they are more concerned about managing their *outgoing* spillovers by choosing a more narrow research approach. However, given that cooperation implies joint profit maximization, cooperation remains the more profitable option.

To conclude, the I.O. models on R&D cooperation show that imperfect appropriation and hence involuntary *outgoing* spillovers of know-how make R&D cooperation more attractive because of coordination but increase the instability of cooperative agreements through free-riding. Information sharing, which increases the *incoming* spillovers, improves the profitability of R&D cooperation, while at the same time increasing internal stability. Recent extensions of these models, taking into account that firms may manage these spillover levels actively, clarify that firms will choose spillover levels carefully to maximally capitalize on the benefits from R&D cooperation, increasing incoming spillovers, not only through information sharing, but also by investing in absorptive capacity while limiting the outgoing spillovers to non-partners.

3. Empirical research on R&D cooperation and spillovers

In contrast to the large number of theoretical I.O. papers on the relation between spillovers and R&D cooperation, the topic has not yet been subjected to thorough empirical analysis.

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your partner to your competitors through your suppliers, customers or research partners and

Brandstetter and Sakakibara (1998) find some indirect evidence of R&D cooperation on research productivity and attribute this to the increased incoming spillovers between partners. Related, Henderson & Cockburn (1996) find that incoming spillovers between research groups in related therapeutical classes within and across pharmaceutical companies, are an important determinant of research productivity. Incoming spillovers thus impact the pharmaceutical's innovation strategy and the boundaries of its organization. There is however a growing empirical literature on the determinants of R&D cooperation and investment, as well as an equally growing empirical literature on assessing the importance of spillovers. This section will review both these strands of the literature as a pre-cursor to our attempt to study the relationship between spillovers and R&D cooperation, reported in section 4.

3.1. R&D cooperation

With methodological problems assessing the profitability of R&D cooperation, most studies indirectly use the frequency of occurrence of R&D cooperation to assess which characteristics are more beneficial to R&D cooperation (Röller et al (1997), Kleinknecht & van Reijnen (1992), Colombo & Gerrone (1996)).[12] These studies provide strong evidence for the size and R&D orientation of firms to be beneficial to R&D cooperation.[13] This is reminiscent of the absorptive capacity idea which stresses the need to have in-house (technological) power to optimally benefit from R&D cooperation. Size symmetry and product complementarity among partners are also found to positively affect the likelihood of R&D cooperation (Röller et al (1997)). Sakakibara (1997a,b) finds that access to complementary knowledge is one of the most important objectives of establishing government sponsored research corporations in Japan Next to compatibility between partners, Tyler & Steensma (1995) provide evidence for the importance of cost and risk sharing for the success of R&D cooperation.

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brings us back to the free-riding issues.

[12] The discussion focuses around the use of subjective (e.g. through questionnaires) versus objective measures (such as financial measures or stock market responses). Traditional financial measures may be difficult to find separately for R&D cooperation.

[13] The relationship between R&D intensity and R&D cooperation should be treated as a two-way relationship : firms with own R&D are more cooperation prone, while cooperation may also stimulate own in-house R&D.

3.2. Spillovers

While public policy makers have recognized the public good character of (technological) know how and shifted attention to strengthening the distributive power of innovative systems, empirical studies on trying to assess a latent variable such as spillovers have grown accordingly. For a review, see Geroski (1996) or Griliches (1992). This literature can be classified into those studies trying to measure spillovers and those assessing the impact of spillovers. The approach used to measure spillovers are based on surveys (e.g. Levin et al ((1987), Levin (1988)). These try to identify which information transmission mechanisms are used and assess from that the existence of spillovers. Typical spillover channels identified are movement of personnel, informal communication networks, meetings, input suppliers and customers, patent applications and reverse engineering (Mansfield (1985)). The results from these studies indicate that independent R&D is one of the most efficient channels to absorb external know-how. This confirms that the management of these knowledge flows through investing in absorptive capacity is important to capitalize on external learning (Levin & Reiss (1988), Cohen & Levinthal (1989)).

A second approach is to infer the existence of spillovers from looking at how know-how stocks of one agent (typically an industry) affect productivity growth in others (Bernstein & Nadiri (1988)). In order to assess which agents benefit more, a measure of "distance" between receiver and generator is included. Several approaches are used here: input-output flows (Terleckyj (1974)), technology flows obtained from patent information,[14] import or FDI flows for international channels (Coe & Helpman (1988)). This last approach mingles causes and effects, where an effect of foreign R&D is taken to be evidence of spillovers. In general it is difficult to disentangle spillovers from other factors such as increasing returns or rent spillovers, due to measurement error, as Geroski (1996) argues.

Most of the studies trying to measure spillovers seem to suggest that spillovers are likely to be substantial. But even if they are imperfectly measured to be large, do they affect the innovative performance of agents? Do they stimulate or undermine the incentives to innovate? The empirical studies inferring the impact of spillovers are not conclusive on the direction of their effect. Bernstein & Nadiri (1989) find evidence that foreign R&D indeed seems to substitute for own R&D, but studies by Jaffe (1986), Cohen & Levinthal (1989) and Geroski et al. (1993) seem to suggest the opposite, namely that spillovers stimulate own R&D. Only firms with a strong own innovative capacity benefited from spillovers from rivals' innovations. Overall, the existing empirical literature finds evidence that spillovers impact the incentives to innovate in important ways (Griliches (1992)).

Given the favorable evidence for spillovers, the decision to cooperate should thus interact with the effect of spillovers on innovation incentives. Information complementarities are an important driver of cooperative agreements resulting in increased information flows—the *incoming* spillovers—between partners. Given this motivation for engaging in cooperative agreements, firms will be more concerned about protecting their knowledge and the knowledge produced within the partnership while extracting as much information as possible. This increases the need for protection, i.e. the management of the *outgoing* spillovers. The fact that firms might manage spillovers—incoming as well as outgoing—within and through cooperative R&D agreements, has not yet been addressed empirically.

4. R&D cooperation and spillovers

The relationship between spillovers and the innovative strategies of companies in terms of whether or not to cooperate in R&D has not yet been explored in empirical work. This section provides some first empirical evidence on this relationship. Building further on the results from the theoretical and empirical literature as reviewed in the previous sections, it is clear that in order to understand this relationship better, spillovers need to be disentangled into *incoming* and *outgoing* spillovers. Also the distinction between involuntary and voluntary spillovers through managing information flows is important.

[14] Various approaches are pursued here: patent information on principal users in the Yale studies, supplementary technology codes in EPO (Verspagen (1995)), clustering techniques (Jaffe (1986)), citations (Jaffe, Henderson & Trajtenberg (1993)).

Cooperation is not only influenced by exogenous spillovers but at the same time may be used as a vehicle to improve knowledge transfers, leading to a simultaneous relationship between cooperation and spillovers.

4.1. The data and the spillover measures

The data used for this research are innovation data on the Belgian manufacturing industry that were collected as part of the Community Innovation Survey (CIS) conducted by Eurostat in the different member countries in 1993. The survey intended to develop insights into the problems of technological innovation in the manufacturing industry and was the first of its kind organized in many of the participating countries. It contained questions characterizing the R&D strategies of firms : whether they innovate or not, how they acquire knowledge and technology, as well as whether they cooperate or not.[15] In addition, the data allow to identify motives of and obstacles to innovation, sources of technological information, mechanisms used to absorb know-how, as well as mechanisms used to protect the results of innovation. A representative sample of 1335 Belgian manufacturing firms was selected and a 13-page questionnaire sent out to them. The response rate was higher than 50% (748). The researchers in charge of collecting the data for the CIS also performed a limited non-response analysis and concluded that no systematic bias could be detected (Debackere & Fleurent, 1995).

The sample used in this study is restricted to the firms that innovate.[16] These firms are distinguished from those who do not innovate based on their answer on the question whether they innovated in the last two years, by introducing new or improved products or processes, and specified a positive amount spent on innovation: 60% (439) of the firms in the sample claim to innovate, while only 40% do not. This number is in line with the survey results from other EC countries (Source: Eurostat, Statistics in Focus, 1996-2).

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[15] An analysis of the R&D strategies chosen by the sample firms, is reported in Veugelers & Cassiman (1998).

[16] Only the innovating firms needed to fill out all questions in the survey. This might lead to sample selection if we believed that cooperation is an important way to innovate for firms that would otherwise not be innovative active. In the data set all firms that cooperate do have some other innovation strategies, such as own R&D or some form of knowledge acquisition (see Veugelers and Cassiman (1998)).

The cooperation variable: the dependent variable, whether firms cooperate or not, **cp**, is constructed from the questionnaire where firms responded whether or not they cooperate with either competitors, suppliers, customers or research institutes. Cooperation means an active participation of the partners in a joint R&D project.[17] Due to missing values, we are left with 411 firms that innovate of which 185 have some type of cooperative agreement. The data allow to disentangle different types of cooperative partners: competitors (33), vertical partners (135) and research institutes (135). It is already interesting to note that most of the cooperative agreements are vertical or with research institutes. This contrasts with the bulk of the theoretical literature, which analyzes cooperative agreements between competitors.

In order to capture the many aspects of spillovers, several measures are constructed. First, in- and outgoing spillovers are disentangled at the firm level. Second we construct industry-level spillover variables for each type of firm-specific spillover variable to capture the exogenous nature of spillovers, determined by technology or market characteristics.[18]

Incoming spillovers: in the questionnaire, firms rated the <u>importance</u> for their innovation process of publicly available information such as patent information, specialist conferences, journals and gatherings, and expositions or fairs on a 5-point Likert scale (from unimportant (1) to crucial (5)).[19] In order to manage the answers to these questions, we aggregated the answers by summing up the scores on these variables and re-scaled the total score to a number between 0 and 1 to generate a measure of incoming spillovers: **INSPILL**.[20] This measure is firm-specific. The variable **indINSPILL** is the average

[17] The questionnaire only contains information on whether firms cooperate or not. No information on extent and nature of the cooperative agreement or on the number of cooperative agreements within one category was available.
[18] The data do not allow to identify spillover flows to and from partners versus non-partners in cooperation.
[19] Other information sources included suppliers and customers, research institutes and competitors. These were not included to avoid tautology with the cooperation variable, but including these sources in the spillover variables did not alter the reported results.
[20] The rescaling of a variable with a the Likert scores between 1 and 5 to a variable between 0 and 1 is done for each Likert score used in the analysis: rescaled score = (score - 1)/4. This makes

industry score for the firms responding in the sample.[21] The questionnaire thus provides a direct measure of the importance of incoming spillovers for the innovation process. Indirect measures typically assume that a given proxy for spillovers, such as R&D performed by a related industry, works uniformly across industries and firms.

Outgoing spillovers: the questionnaire allows to construct proxies on the effectiveness of protection measures for the innovation process, which can be used as a reciprocal for outgoing spillovers. We distinguish two types of protection: *legal* protection through patents, brand names, copy right, and *strategic* protection through secrecy, complexity or lead time of the product. Again we aggregated answers by summing up the scores of the answers to these questions and generate a measure of legal and strategic protection against outgoing spillovers: **PROTleg** and **PROTstrat** respectively. Next to these firm-specific variables, industry averages are constructed: **indPROTleg** and **indPROTstrat.**

In Figures 1 to 3 we plot the cumulative distribution of the importance of incoming spillovers (**INSPILL**) and the effectiveness of protection against outgoing spillovers (**PROTleg** and **PROTstrat**) for cooperating and non-cooperating firms. These figures provide some first indication of the correlation between higher *incoming* spillovers and lower *outgoing* spillovers and the propensity of firms to cooperate. The cumulative distribution of cooperating firms always lies below the cumulative distribution of the non-cooperating firms, indicating a higher rating of cooperating firms of the importance of incoming spillovers as well as a higher rating on the effectiveness of protection of know-how, with legal as well as strategic means.

4.2 The empirical model

The decision of the firm on whether to cooperate or not is based on comparing the profitability of both options. We estimate a Probit model of this decision. The latent variable in our model is the difference in the profitability of the cooperation option with the profitability of not cooperating, cp*:

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comparisons of coefficients feasible. The questionnaire did not provide a weight of the relative importance for each of the questions.

[21] The industry is defined at the nace 2 digit sector level.

$$cp^* = \Pi^c(X) - \Pi^{nc}(X) = \beta' X + \varepsilon,$$

where Π^c are profits when cooperating, Π^{nc} are profits of non-cooperation and X is a vector of firm and industry characteristics. We assume that ε has a normal distribution with zero mean and variance one.[22] We are interested in estimating β and more specifically the effect of a change in the independent variables on the marginal probability of cooperation. Our observation, the decision to cooperate or not, **cp**, depends on the value of this latent variable:

$$\mathbf{cp} = 1 \quad \text{if } cp^* > 0,$$
$$\mathbf{cp} = 0 \quad \text{if } cp^* \leq 0.$$

As pointed out before there seems to be a strong correlation between the decision to cooperate and our spillover measures, with a possible endogeneity problem. The level of spillovers might affect the profitability and hence the decision to cooperate, but the decision to cooperate could also influence the actual level of spillovers, when firms use cooperative agreements as a vehicle to manage information flows. Cooperating firms may try to maximize *incoming* spillovers through information sharing, which will enhance the profitability as well as stability of cooperation. In response to free-riding, firms will want to limit *outgoing* spillovers to non-partners. Although outgoing technology flows to partners are essential in information sharing agreements in search of synergies, carefully managing this exposure of own know-how within the alliance is necessary in view of the threat of opportunistic partners. We expect that firms that are better at restricting outgoing spillovers in general, will be more successful at controlling information sharing with their partners.

To address this possible endogeneity problem, we will model a system of simultaneous equations of **cp**, **INSPILL** and **PROTstrat** and estimate it by using a two-stage-least-squares estimation procedure. The variable **PROTleg** measuring the effectiveness of patent protection, although firm-specific, is not assumed to depend on the cooperation.

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[22] The results for the Logit model are very similar.

cp = f(INSPILL, PROTleg, PROTstrat, indINSPILL, indPROTleg, indPROTstrat, Xcp)

with Xcp=(SIZE, SIZEsq, COST, RISK, TECH) (1.1)

INSPILL = g(cp, Xinspill)

with Xinspill=(indINSPILL, INFOint, BasicRD) (1.2)

PROTstrat = h(cp, Xprotstrat)

with Xprotstrat=(indPROTstrat, INFOint, EXPint, TIME) (1.3)

A sufficient number of other independent variables affecting cooperation, Xcp, but also spillovers, Xinspill and Xprotstrat, need to be identified. Xcp reflects the other independent variables affecting cooperation, besides the endogenous and exogenous spillover variables. This includes **SIZE**, as measured by firm sales, a variable most often found in other studies explaining cooperation (see supra). To check for any non-linearity in the size relationship, a quadratic size term is included as well, **SIZEsq**. As work by Mariti & Smiley (1983) a.o. has indicated, other motives such as cost and risk sharing as well as getting access to new technologies are important drivers for cooperation. The survey information allows to proxy for these motives. The firms rated the importance of different obstacles to innovation on a scale of 1 (unimportant) to 5 (crucial). When costs are an important obstacle to innovation, we expect to observe more cooperative agreements with the purpose of cost sharing. We construct an aggregate measure of the responses to questions as lack of suitable financing, high costs of innovation, long pay-back period or difficult to control cost of innovation: **COST**. Similarly **RISK** is the response to importance of high risks as barrier to innovation. **TECH** is the importance of lack of technological information as barrier to innovation. Although a lack of internal technology may drive firms to cooperate to access missing technologies externally, it simultaneously reduces the scope for complementarities to exploit through cooperation. A lack of externally available technologies reduces the scope of relevant partners.

For *incoming* spillovers, **INSPILL**, the literature seems to suggest that especially absorptive capacity through internal technological capabilities is important to optimally benefit from external information. The survey asked for the importance of internal sources of information to innovation on the Likert scale from 1 to 5, which we use to proxy for absorptive capacity, **INFOint.** We should note the strong correlation between this variable and whether or not the firm does internal R&D. Given that generic research is more difficult to appropriate, firms that use more basicR&D, relative to applied R&D or development are more likely to benefit from incoming spillovers and hence are expected to have a higher score on **INSPILL** (see Vonortas (1994) for a model on different levels of spillovers in the research versus development stage). The variable **BasicRD** measures the importance for the innovation process of information from research institutes and universities relative to the importance of suppliers and customers as an information source, which we use to proxy for the basicness of R&D performed by the firm. The industry variable **indINSPILL** is included as well to capture the technological conditions of the industry influencing the ease of flows of know-how.

The strategic protection variable **PROTstrat** will be influenced specifically by variables characterizing the competitive environment of the firm. The more competitive the environment, the more a firm is expected to invest in protecting any technological competence. Included here are the variables **EXPint**, the share of exports in total firm sales, as well as the pervasiveness of time-to-market based competition, **TIME**, measured through the importance of uncertainty on the timing of market introduction of the new innovation as barrier to innovation. More export intensive firms typically face a more competitive environment, while strategic protection is more likely to be effective in industries where there is more uncertainty regarding the timing of new market introductions. Given that firms might invest in improving strategic protection, we include **INFOint** as an explanatory variable. Firms with a higher internal technological capacity might not only be better at absorbing incoming spillovers, but also be better at protecting their knowledge through secrecy, complexity or lead time. The variable **indPROTstrat** is included to capture technological conditions shaping strategic protection possibilities.

4.3 The results and discussion

We estimate a Probit model of whether the firms decide to cooperate or not. Section 4.3.1 reports the results both without and with taking the potential endogeneity problem into account with similar results (model (1) and model (2) respectively in Table 2). The two-stage procedure allows to discuss what determines the level of in- and outgoing spillovers. Table 3 shows the estimated **INSPILL** and **PROTstrat** variables from the second stage of the 2SLS regression, whose results are discussed in section 4.3.2. We also jointly estimate the models for vertical cooperation and cooperation with research institutes in a bivariate Probit model.[23] These results are discussed in section 4.3.3.

4.3.1 Results on cooperation

The coefficients in Table 2 present the marginal effect of the explanatory variables on the probability of cooperating, while keeping everything else constant. We first discuss the non-spillover determinants of cooperation. All the coefficients of these variables remain fairly robust across the different regressions on the spillovers, correcting for the endogeneity of spillovers or not. The effect of firm size is very significant. Larger firms are thus more likely to cooperate. But size affects cooperation at a decreasing rate, suggesting a significant non-linearity in the size relationship. This important size effect is consistent with earlier work on the decision to cooperate (Colombo and Gerone (1996)). When costs are an important obstacle to innovation, innovating firms are more likely to engage in cooperative agreements (**COST**), confirming Tyler & Steensma (1995). While cost-sharing seems to be an important driver for cooperation, risk-sharing is not. Firms for which risk is an important barrier to innovate are less likely to cooperate (**RISK**). This is not so surprising considering that it will be more difficult to manage cooperative contracts minimizing opportunistic partner behavior when the technology is characterized by a large amount of uncertainty. Contrary to most of what the literature assumes, it seems important to distinguish between costs and risks when analyzing the cooperation decision. With an explanatory variable that combines cost and risk factors, insignificant results are obtained. The more important the lack of technological know-how, the lower the probability of cooperation (**TECH**). A lack of technology indeed reduces the scope for complementarities to exploit through cooperation. Sakakibara (1997a,b) also finds that

[23] 46% of cooperating firms have cooperative agreements of both types. All the firms that cooperate with competitors also have a cooperative agreement with suppliers/customers or research institutes.

expected complementaries are one of the most important motives for forming government sponsored research consortia in Japan.[24]

For the spillover variables, the correction for the endogeneity does not influence the signs of the spillover effects, but significantly increases their coefficients, see Table 2. *Incoming* spillovers have a positive and significant effect on the probability of firms cooperating (**INSPILL**). When correcting for simultaneity, the coefficient on *incoming* spillovers remains positive and very significant, but becomes much larger. This positive coefficient is consistent with a coordination theory of cooperation, where the existing base of know-how is better tapped by cooperating firms because of the improved technological competence of the partners. This increases the expected profitability and hence probability of cooperation.

Outgoing spillovers have a negative effect on the probability of firms cooperating. The higher is the strategic protection, the lower the outflow of information, and the higher the probability of cooperation (**PROTstrat**). Higher protection reduces the potential for free riding within and beyond the cooperative agreement and improves the stability of these agreements. This coefficient remains significant but increases after correction for endogeneity. Also better legal protection improves the probability of observing cooperation by the firm, but this coefficient looses significance after the correction for endogeneity (**PROTleg**).

It is interesting to observe that once firm-level spillovers are included, the industry level variables of the spillovers, **indINSPILL** and **indPROTstrat**, always fail to influence significantly the decision to cooperate, whether correcting for endogeneity or not. This strongly suggests that in- en outgoing spillovers mainly matter at the firm level. Only legal protection seems to be industry specific. Firms operating in industries where legal protection is important, have a higher probability of cooperation (**indPROTleg**).[25]

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[24] Where Sakakibara (1997a, b) explicitly analyzed the motives for cooperation in R&D, the CIS questionnaire analyzed innovative behavior in general. The questions from which we derive our explanatory variables were never directly related to the decision of the firm to cooperate or not. As a result we expect our results to be less driven by what managers answering the questionnaire thought was the “correct” answer with respect to the cooperation decision.

[25] This is consistent with our assumption that PROTleg is not endogenously determined.

The overall predictive power of the estimated cooperation model is good, with for instance for the exogenous model, model (1), more than 70% of all cases predicted correctly.[26] There is however a tendency to underpredict the number of cooperative cases: only 62% of all cooperations were predicted correctly.[27]

In conclusion, the results on the relationship between spillovers and cooperation seem to suggest that indeed *incoming* and *outgoing* spillovers have an important and separately identifiable effect: higher incoming spillovers and lower outgoing spillovers or stronger protection increase the probability of cooperation. The correction for the endogeneity of spillovers is important for evaluating the effect of spillovers on the decision to cooperate. The results also favor firm-specific rather than industry-specific spillover variables, with the exception of legal protection mechanisms which, if they matter, seem to matter more at the industry level.

4.3.2 Results on spillovers

In Table 3 we present the results of the second-stage regressions of **INSPILL** and **PROTstrat** respectively. That there is evidence for simultaneity is suggested by the significantly positive coefficient of the **cp** variable in the second stage estimations reported in Table 3[28]. Firms that are cooperating will have a higher rating of importance of *incoming* spillovers. This positive coefficient is consistent with an information sharing explanation of cooperation where cooperating firms increase the *incoming* spillovers. Likewise for *outgoing* spillovers, the second stage estimations suggest simultaneity. Firms that are cooperating rate the effectiveness of strategic protection higher. This might imply that firms that engage in a cooperative agreement invest more in protection in order to limit the outgoing spillovers and protect themselves from opportunistic partners and non-partners.

For *incoming* spillovers, as expected, the importance of internal information for the innovation process is significant in explaining the importance the firm attaches to

[26] The naïve model would classify 55% correctly.
[27] The percentages for model (2) are comparable: 72% and 64% respectively.

incoming spillovers (**INFOint**). We interpret this as evidence for the effect of absorptive capacity of the firm. If firms generate a lot of information for innovation internally, it must mean that they are better able at generating useful information for innovation from the environment. Another determinant of the incoming spillovers is the relative importance for the innovation process of information from research institutes and universities, which is more generic, relative to the importance of suppliers and customers as a source of information, which relates more to specific developmental know-how (**BasicRD**). Firms operating in industries characterized by easier external technology appropriation are more likely to rate incoming spillovers as important (**IndINSPILL**).

Internal information sources for the innovation process are positive instruments for protection of know-how, but their effect fails to show up significantly (**INFOint**). However, firms facing tougher competitive environments, such as exporting firms (**EXPint**) and firms for which lead times are important (**TIME**) will more effectively protect their know-how strategically. Again technology or market characteristics favoring strategic protection will help firms to manage outgoing flows of information (**IndPROTstrat**).

In summary, the correction for endogeneity of spillovers, although not affecting the direction of the effects of incoming and outgoing spillovers on cooperation, suggests that the average cooperating firm increases the importance of incoming spillovers, while also the effectiveness rating of strategic protection increases. Our results therefore provide strong support for the information sharing aspects of *incoming* spillovers in understanding cooperation, while at the same time, the management of protection against *outgoing* spillovers is important for firms to engage in internally and externally stable cooperative agreements.

4.3.3 Cooperation with different types of partners

Distinguishing between cooperation along the vertical chain, i.e. with suppliers or customers, and cooperation with research institutes, allows to test the importance of the

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[28] The Hausman test for endogeneity rejects the null hypothesis for no endogeneity of INSPILL and PROTstrat at the 1% level of significance. The reduced form equations of the first stage estimation of the two-stage least squares procedure can be found in Table A1 in the Appendix.

type of partner on the relationship between spillovers and R&D cooperation. A third type, cooperation with competitors, could not be included separately because of too little observations. This fact is in itself interesting because it suggests spending more effort on theoretical models specifying vertical rather than horizontal R&D alliances.[29] The results of the bivariate probit model, corrected for endogeneity through a 2SLS estimation, are presented in Table 2 in column (3) and (4) for vertical cooperation and cooperation with research institutes respectively.

Starting with the non-spillover determinants of cooperation, it is interesting to observe that high costs (**COST**) and high risks (**RISK**) are only relevant in affecting cooperation with research institutes, while this is not important in explaining cooperation within the vertical chain. This result can be related to the more basic nature of joint R&D with research institutes, entailing higher costs and thus scope for cost sharing and higher risks with increased room for opportunism by partners. The search for external know-how and complementarities, however, seems to be more important for vertical cooperations (**TECH**). For both types of cooperative agreements, firm size is an important determinant, with again evidence for a non-linear relation.

Regarding the effects of spillovers, some interesting differences emerge between research and vertical cooperations. *Incoming* spillovers have a significantly positive effect on cooperation with research institutes.[30] Firms cooperating with research institutes seem to attach a higher importance to incoming spillovers, while incoming spillovers do not seem to affect the likelihood of vertical cooperation. A different pattern emerges for *outgoing* spillovers. Outgoing spillovers are not important in deciding to cooperate with research institutes. For vertical cooperations however, limited outgoing spillovers are important to induce cooperation, either firm-specific through strategic mechanisms or industry-specific through patent-protection. All this seems to suggest that outgoing spillovers to non-industrial partners are less critical than spillovers between industrial partners. This is

[29] One of the few significant and distinguished effects that came out of the horizontal cooperation regressions is that legal protection at the firm level is important (together with incoming spillovers and size), while strategic protection failed to show up significantly.
[30] The coefficient of INSPILL also increases significantly, but note that the coefficient of indINSPILL increases as well and acts as a correction on the firm-specific incoming spillover effect.

reminiscent of the idea that competitors learn about their rivals through common suppliers or customers. Similarly firms want to avoid backward integration by customers or forward integration by suppliers because of what they learn through cooperative agreements. These results also indicate that our measure of incoming spillovers proxies for more generic information, which is generated and disseminated through R&D cooperation with research organizations but which is not as commercially sensitive as the more practical information that is generated and disseminated in cooperative agreements along the vertical chain. Our results show that the explanatory variables for the pooled case nicely fall into two categories: variables affecting cooperation along the vertical chain on the one hand and variables affecting cooperation with research institutes on the other.[31]

5. Conclusions

The empirical results presented on the relationship between R&D cooperation and spillovers strongly suggest disentangling different aspects of know-how flows. Firms which rate *incoming* spillovers more importantly and who can limit *outgoing* spillovers by a more effective protection of know-how, are more likely to cooperate in R&D. In addition, our analysis finds that cooperating firms have higher incoming spillovers and higher effectiveness of protection of know-how, indicating that cooperation may serve as a vehicle to better manage information flows. We thus find support for the theoretical models that stress *information sharing* and *coordination,* related to incoming spillovers, and *free riding,* related to outgoing spillovers as important elements for understanding R&D cooperation. Given that most of the cooperative agreements are between partners along the vertical chain, suppliers or customers, or, with research institutes or universities, it is not surprising that we find little support for the theoretical models on coordination effects of R&D cooperation related to the outgoing spillovers. Any effects of R&D cooperation in these models results from the joint profit maximization by competing firms.

Two important conclusions that we can draw from our results are that spillovers are firm-specific and that it is the firm-specific rather than industry-specific spillover

[31] A LR test for equality of coefficients for the full model as well as for the coefficients of INSPILL and PROTstrat, is rejected at the 1% level of significance.

variables that are important in explaining R&D cooperation. Firms actively manage incoming and outgoing knowledge flows. Investing in absorptive capacity on the one hand, and forming cooperative agreements on the other, seem to be important in the management of these firm specific incoming spillovers. Furthermore, firms in more competitive environments and firms that cooperate in R&D seem to invest more in strategic protection, increasing its effectiveness and limiting outgoing spillovers. With the exception of legal protection mechanisms, which seem to matter more at the industry level, these firm-specific spillovers strongly impact the decision to cooperate in R&D. In recent years policy makers have become convinced of the importance of spillovers in increasing the impact of innovation through the diffusion of technology. Our results then suggest that policy makers should concentrate their efforts less at the industry-level, targeting "strategic" sectors rather at the firm-level by identifying and stimulating spillover generating firms, improving the absorptive capacity of individual firms as well as encouraging spillover enhancing cooperative agreements.

Besides spillovers, firm size and the traditional cost and risk motives as well as search for complementary technological know-how are found to significantly drive R&D cooperation. While cost sharing is an important motivation favoring R&D cooperation, riskiness of R&D projects, making it harder to devise stable R&D alliances, is associated negatively with R&D cooperation. Distinguishing different types of cooperative partners revealed that outgoing spillovers to non-commercial research partners are less critical than spillovers between vertically related partners. The level of incoming spillovers, however, is more important in understanding the former type of cooperation. Cooperation with research institutes is induced by cost sharing, while avoiding risk. Lack of technological information is an important barrier to cooperative agreements with suppliers and/or customers.

Given the lack of previous empirical work on this topic, the first results generated by this paper provide some interesting suggestions for further theoretical work which distinguishes between different information flows or different partners and treats the level of these information flows as strategic variables. At the same time, more empirical work needs to be done to check robustness of the results. The EUROSTAT/CIS data proves to be a rich set of information, allowing to replicate this exercise on other European countries. However, the qualitative nature of most of the information limits the analysis, in terms of quantifying R&D cooperation, R&D spillovers and their relation.

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Table 1: Description of Variables

CP	CP=1, if firms cooperate with suppliers, customers, research institutes or competitors.
SIZE	Firm Sales in 10^{10} BEF.
SIZEsq	Firm Sales in 10^{10} BEF squared.
EXPint	Export share in total Firm Sales
INSPILL	Aggregate measure of importance of patent information, specialized conferences, meetings, publications, trade conferences, seminars.
PROTleg	Aggregate measure of importance of patents, registration of brands, copyright as protection measure of innovation.
PROTstrat	Aggregate measure of importance of secrecy, complexity of process design as a protection measure of innovation.
IndINSPILL	Inspill at industry level.
IndPROTleg	Importance of legal protection at industry level.
IndPROTstrat	Importance of strategic protection at industry level.
INFOint	Importance of internal information sources for the innovation process.
COST	Aggregate measure of importance of no suitable financing available, high costs of innovation, pay-back period too long, innovation cost hard to control as an obstacle to innovation.
RISK	Measure of importance of high risks as an obstacle to innovation.
TECH	Measure of importance of lack of technological information as an obstacle to innovation.
BasicRD	Ratio of measure of importance of universities, public and technical research institutes as source of information for the innovation process and measure of importance of suppliers and customers as information source for innovation process.
TIME	Measure of importance of uncertainty about timing of market introduction of new innovation as an obstacle to innovation.

Table 2: Results of Probit Regression for Cooperation

	All types of Cooperation		Bivariate Probit Model	
	model (1)	model (2) (2SLS)	Vertical Cooperation (3)	Cooperation with research institutes (4)
CONSTANT	-0.899** (0.39)	-0.79** (0.38)	-0.87** (0.39)	-1.217** (0.57)
SIZE	0.18*** (0.048)	0.166*** (0.047)	0.134** (0.061)	0.148*** (0.038)
SIZEsq	-0.0074*** (0.0025)	-0.0072*** (0.0025)	-0.00433 (0.0078)	-0.00731*** (0.0022)
INSPILL	0.499*** (0.15)	1.585*** (0.55)	-0.0107 (0.596)	2.795*** (0.598)
PROTleg	0.369* (0.19)	0.245 (0.30)	0.02 (0.32)	-0.299 (0.32)
PROTstrat	0.217* (0.12)	0.966** (0.47)	1.227** (0.49)	0.394 (0.53)
IndINSPILL	-0.075 (0.74)	-0.865 (0.85)	0.63 (0.92)	-1.596 (1.02)
IndPROTleg	3.77*** (1.34)	4.31*** (1.33)	2.447* (1.39)	2.73* (1.53)
IndPROTstrat	-0.488 (0.64)	-1.279* (0.78)	-1.213 (0.82)	-0.144 (0.95)
COST	0.83*** (0.21)	0.493** (0.23)	0.286 (0.26)	0.554** (0.25)
RISK	-0.338** (0.14)	-0.408*** (0.16)	0.0158 (0.16)	-0.551*** (0.17)
TECH	-0.368** (0.17)	-0.447*** (0.18)	-0.576*** (0.19)	-0.293 (0.19)
	$\chi^2 = 106.33^{***}$ LL=-229.67	$\chi^2 = 108.41^{***}$ LL=-228.63	correlation = 0.583^{***} LL = -403.68 (LLlvert=-222.66, LLlres=-204.23)	

*** significant at 1%, ** significant at 5%, * significant at 10%, standard errors between brackets.

Table 3: Results of Second stage Estimation INSPILL and PROTstrat

	INSPILL	PROTstrat
CP	0.0443** (0.019)	0.0755*** (0.025)
INFOint	0.113** (0.049)	0.0844 (0.0599)
BasicRD	0.191*** (0.042)	
EXPint		0.115*** (0.035)
TIME		0.188*** (0.043)
IndINSPILL	0.534*** (0.088)	
IndPROTstrat		0.584*** (0.0902)
	R^2=0.156 F=25.15***	R^2=0.194 F=24.37***
*** significant at 1%, ** significant at 5%, * significant at 10%, standard errors between brackets.		

Table A1: Reduced form (First Stage) estimations for Cooperation and Spillovers

	CP	INSPILL	PROTstrat
CONSTANT	-1.179*** (0.39)	-0.205* (0.12)	-0.0778 (0.15)
SIZE	0.00153*** (0.00048)	0.297E-04 (0.00013)	-0.151E-03 (0.00016)
SIZEsq	-0.64E-06*** (0.25E-6)	0.569E-08 (0.63E-07)	-0.56E-07 (0.78E-07)
PROTleg	0.395** (0.19)	0.123** (0.0606)	0.466*** (0.076)
IndINSPILL	-0.0109 (0.705)	0.803*** (0.21)	-0.424 (0.26)
IndPROTleg	3.376*** (1.32)	-0.325 (0.397)	-0.47 (0.50)
IndPROTstrat	-0.412 (0.63)	-0.0303 (0.19)	0.969*** (0.24)
COST	0.927*** (0.21)	0.139** (0.066)	0.20** (0.083)
RISK	-0.312** (0.14)	0.114*** (0.044)	-0.091* (0.055)
TECH	-0.449** (0.19)	-0.0221 (0.057)	-0.0173 (0.071)
INFOint	0.329** (0.16)	0.138*** (0.05)	0.142** (0.062)
BasicRD	0.342*** (0.13)	0.205*** (0.041)	0.00986 (0.052)
EXPint	0.21** (0.085)	0.0288 (0.027)	0.149*** (0.034)
TIME	0.0638 (0.14)	-0.0263 (0.046)	0.147*** (0.057)
	χ^2=108.57*** LL=228.55	R^2=0.226 F=8.90***	R^2=0.281 F=11.96***

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

Figure 1: cumulative distribution of importance of incoming spillovers for cooperating and non-cooperating firms

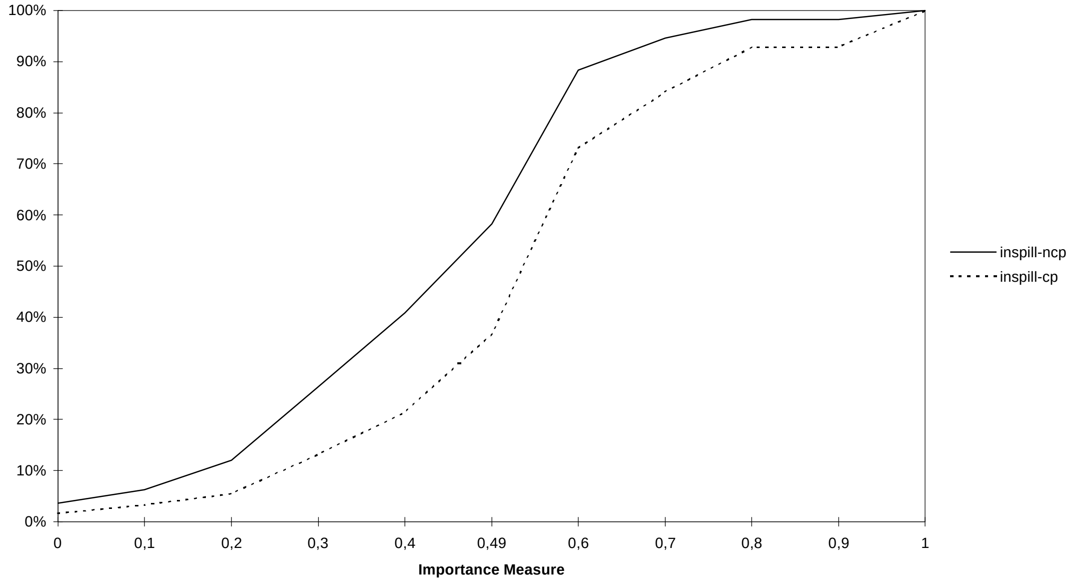

Figure 2: cumulative distribution of effectiveness of legal protection for cooperating and non-cooperating firms

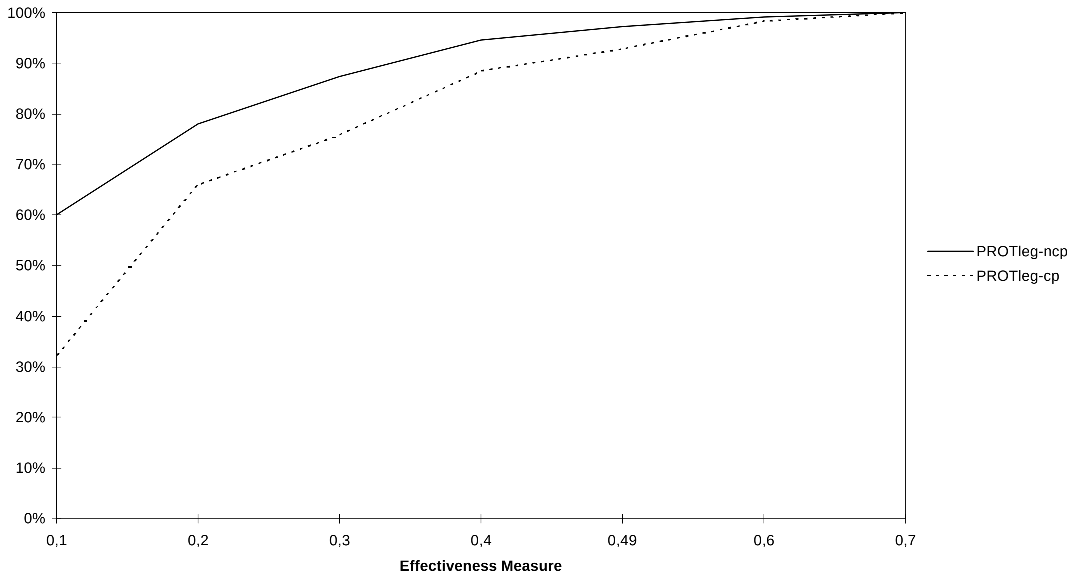

Figure 3: cumulative distribution of effectiveness of strategic protection for cooperating and non-cooperating firms