Institut für Halle Institute for Economic Research
Wirtschaftsforschung Halle

Das IWH ist Mitglied der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz WGL

Spillover Effects – an Incentive to Cooperate in R&D?

Anita Wölfl

September 1998 No. 79

Diskussionspapiere
Discussion Papers

Department: Structural Change
Anita Wölfl

Phone: ++49-+345-7753-870
e-mail: awl@iwh.uni-halle.de

INSTITUTE FOR ECONOMIC RESEARCH HALLE (IWH)
Address: Delitzscher Straße 118; D - 06116 Halle/Saale
Postbox: 16 02 07; D - 06038 Halle/Saale

Phone: ++49-+345-7753-60
Fax: ++49-+345-7753-820
Internet: http://www.iwh.uni-halle.de

Spillover Effects – an Incentive to Cooperate in R&D?

Anita Wölfl

September 1998

Abstract

This paper examines empirically the theoretical relationship between spillover effects, in the sense of unintended knowledge transfer, and cooperations in research and development (R&D). According to the results of a logistic regression analysis which has been based on micro-level data, firms tend to form R&D-cooperations to internalise spillover effects. While there is some evidence that this incentive increases with firm-size the results stress the importance of industry characteristics. Taking into account the pressure from existing or potential competition ambiguous effects of spillovers on R&D-cooperations may be expected. Furthermore, the influence of factors which are independent from spillover effects and a comparison of different types of R&D-cooperations point at the relevance of further motivations to co-ordinate R&D-activities in general.

JEL-Classification: O31, O32, O34, L13, L14**.**

1. Introduction

Spillover effects arise whenever know-how or research results of one firm are used by other firms without the latter having to bear any expenses. Research of one firm thus acts as an external effect in favour of other firms. Having in mind these external economies due to research several lines in economic theory see spillover effects as one crucial foundation for economic performance. For example, in Grossman and Helpman (1991) spillovers are one important factor determining growth. Krugman (1992) and Leahy and Neary (1997) ask whether spillovers can be an argument in favour of an activist industrial or trade policy. Together with these theoretical studies, empirical studies, for example Coe and Helpman (1995), examine how spillover effects account for differences in and growth of productivity.

From the viewpoint of the firm however, spillover effects can have a rather opposite implication. There, the property of research as producing external economies reflects the fact that other firms can use research results of one individual firm, without the researching firm being able to influence or control this unintended knowledge transfer. When the researching firm has to fear that its internal research may indirectly spur the competitors' profits, it will retain from investing into R&D. Because of the relevance of R&D for the individual firm as well as for social welfare, theoretical studies have been asking whether cooperations in research and development (R&D-cooperations) can internalise this external effect and thus remove this R&D-hindering incentive. The idea is that firms co-ordinate their research activities and/or exchange research results on the basis of binding contractual agreements, e.g. in the form of common research projects. This would have positive consequences for all. By co-ordinating R&D the problem of the external effect is solved like an internal affair. By exchanging research results know-how is disseminated. However, one crucial prerequisite is that firms actually have an incentive to bind themselves in such contractual arrangements in order to internalise spillover effects.

The microeconometric analysis at hand will review this incentive aspect of spillovers for R&D-cooperations empirically. It starts with a short discusion of the main theoretical arguments in chapter 2. After elaborating on some crucial methodological points in chapter 3, the presentation of the empirical results will follow in chapter 4. At first, the general relationship between spillover effects and R&D-cooperations will be analysed in chapter 4.1. Thereby, special emphasis will be placed on differing cooperational behaviour due to firm-size- and industry-specific spillover effects. Chapter 4.2 will then work out potential reasons for such differences. The focus here will be laid on three aspects: Chapter 4.2.1 will analyse whether the relationship between spillover effects and R&D-cooperations is dependent on firm-size. Chapter 4.2.2 will ask for possible negative effects from the cooperation itself when spillover effects are prevailing. Chapter 4.2.3 then will test the relevance of further motivations for the establishment of R&D cooperations. The paper will close with a final assessment of the incentive aspect of spillovers for R&D cooperations on the ground of the empirical results at hand.

2. Theoretical Background

2.1 Spillover Effects in Theory

The term ‘spillover effects’ has reached a central position within the theoretical and empirical literature on the economics of innovation and technological change. Spillover effects arise whenever firms use the know-how of another firm without the researching firm being able to control or influence the degree of this unintended knowledge transfer.[1] R&D thus produces a positive external effect in favour of other firms. From the viewpoint of social welfare, there is reason enough to promote spillovers, since they spur the dissemination of new knowledge available for the whole society. From the viewpoint of the single firm, however, spillovers may be judged negatively. The individual firm fears that competitors use its internal research results and thus probably increase their profits without having to bear the expenses. Therefore, the researching firm will only have limited incentive to invest into R&D.

Spillover effects may arise in the production as well as in the diffusion phase of the innovation process.[2] According to Geroski (1994:102), the appropriability of a firm, i.e., its capacity to protect its research results, depends on various factors. These are for example the technology itself, the barriers to entry which exist on the market where the technology is used, and the capability of other firms to absorb external knowledge within their internal innovation process. With regard to imitation one example out of Tirole (1993:403-4) can be put forward. Whenever one firm has to fear quick imitation there is only limited incentive for this firm to develop and launch a new product. Instead of investing into R&D it will rather wait for a competitor to develop and launch the product first.

Spillover effects may thus lead to a suboptimal level of R&D investment. However, R&D is essential for the production of innovations itself, both for the internal innovating process of the individual firm as well as for its capacity to absorb external knowledge. Additionally, R&D is essential as a foundation for innovations and thus for the overall performance of an economy. On the one hand, process innovations may be growth-inducing via increased productivity. On the other hand, product innovations may lead to higher consumer welfare via increased product variety. Standard means of preventing market failure due to spillover effects then include R&D-subsidies and a stronger patenting system. However, subsidies have to be financed by taxes and may - according to Katz and Ordover (1990:140) - distort the incentive structure of firms with respect to their R&D investment decision. Strengthening the property rights through patents guarantees (temporary) monopoly power for one firm. This may restrict competition and may - according to Klodt (1995:32-38) -lead to welfare losses. More recent theoretical models focus on the question whether spillover effects can be internalised by the firms through binding contractual arrangements in research and development (R&D-cooperations). Fundamental for the functioning

---

[1] This notion is equivalent to the notion ‘technological spillovers’ in Katz and Ordover (1990). They use this latter notion in order to distinguish these external effects due to lack of appropriability from the pecuniary external effect from research itself, which they call the ‘competitive spillovers’. These two notions will again be relevant in the theoretical considerations about R&D-cooperations.

[2] With regard to this, Katz and Ordover (1990:154) distinguish between ‘intermediate’ and ‘final technological spillovers’.

of such R&D-cooperations as an internalisation device is that firms actually have an incentive to co-ordinate their R&D-activities with other firms when spillover effects arise.

2.2 R&D-Cooperations in Theory

With the help of a simple duopoly-model, d'Aspremont and Jacquemin (1988) made very clear how spillover effects are actually internalised by R&D-cooperations.[3] In their model two individual firms engage in Cournot competition, i.e. they are maximising their profits through the choice of the output level. Since they are using R&D as strategic investment, the firms additionally have to decide how much they want to invest into R&D. In order to separate the maximisation process with respect to these two parameters R&D-input and level of production it can be thought of a two-stage-decision process: On the first stage, the firms decide upon their R&D-investments. On the second stage, they maximise their respective profits through the choice of the production level given a specific level of R&D.

D'Aspremont and Jacquemin concentrate on a model with process innovation. There are three channels through which internal R&D influences a firm's profit: Firstly, R&D directly causes (fixed) investment costs. Secondly, in the case of successful process innovation, R&D reduces production costs. Thus, the direct costs of producing innovations counterweigh the indirect cost reduction in the production of the final good. Thirdly, there is an indirect channel the sign of which depends on the reaction of the competitors. In this context, Katz and Ordover (1990:150) speak of 'competitive spillovers'.[4] With the firms acting independently from each other, each firm has an incentive to invest into R&D. R&D reduces marginal costs and thus increases profits from extended production. In the case of strategic substitutes, i.e., if the other firm reacts with a reduction of its own production, the researching firm can increase its market share and thus its profit. There is no incentive to co-operate. However, with both firms investing into R&D simultaneously, more overall output is produced, leading to lower prices and thus lower profits for each firm. In this case, R&D intensifies competition on the product market.

Whenever spillover effects prevail, there is a fourth channel through which R&D influences the profits of the firms. In models of process innovations, spillover effects occur when additionally to internal R&D some part of external R&D influences the production costs of the individual firm. In that case, the reduction of marginal costs through R&D is already achieved at a lower level of internal R&D. However, this effect works both ways. Internal R&D reduces marginal costs of the competitor, too. Thus it increases the competitor's profits indirectly by influencing its market share. When both firms act independently from each other (R&D competition), each firm can profit from the know-how of the competitor. However, the incentive for investment into R&D diminishes due to the positive external effect of spillovers. In contrast, when the firms are co-ordinating their R&D activities, this problem can be overcome. According to the theoretical model,

---

[3] This analysis will concentrate on the empirical test of the basic relationship between spillover effects and cooperation, as it has been elaborated by existing theoretical models. Therefore, the basic model of the duopoly itself should only illustrate the decision-making process of the individual firms. A direct implementation would have to start from an oligopoly and distinguish between product and process innovations. However, according to Kamien et al. (1992), Suzumura (1992), Morasch (1994) and the model for product-innovations of Motta in Konrad (1997) the central results will not be changed significantly by these extensions.

[4] Sometimes, the terminus 'business-stealing effect' is used in this respect. [Konrad (1997), König et al. (1994)]

there is an incentive to co-operate whenever high spillover effects prevail.[5] In this case, the positive internalisation effect from cooperation more than outweighs the negative competitive spillover effect from research.[6]

R&D-cooperation in general can take two forms. First, the firms form an R&D-cartel on the first stage of the decision process. Thereby, they co-ordinate the amount of R&D they want to invest in order to maximise the common profit. Second, they form an R&D joint venture on the second stage by exchanging their research results without any agreement on the actual R&D-investment. According to Kamien et al. (1992), the optimal form of cooperation is the RJV-cartel. There, the firms co-operate with respect to both, the amount of R&D to be invested as well as the exchange of knowledge. On the one hand, exchanging the research results enables both firms to make use of all knowledge. On the other hand, while R&D still influences the profit of the competitor, this external effect is internalised by maximisation of the common profit. Both firms therefore have again an incentive to invest into R&D. Thus, internalising the spillover effects through an RJV-cartel counteracts exactly the two channels through which suboptimal R&D would result in the case of competitive research: the co-ordination of the R&D-inputs encourages R&D and thus innovation. The exchange of research results provides the dissemination of knowledge throughout the whole economy.[7]

3. An Empirical Analysis

While there already exists a wide range of theoretical models, there are only few studies which analyse the relationship between spillover effects and R&D-cooperations empirically. As can be seen from the theoretical considerations above, the empirical analysis at hand will focus on the general question whether firms actually have the incentive to co-operate in R&D, when they fear spillover effects. Before the empirical results will be presented, some general considerations have to be added, about how to measure spillover effects and R&D-cooperations empirically and how to adequately assess the empirical relationship between them.

3.1 Data Source and Definition of the Variables

Led by the theoretical models, the empirical relevance of spillover effects for R&D-cooperations is examined with the help of a cross-sectional analysis. It is based on information from German firms about their innovative behaviour. Most relevant questions have been on the one hand how effective they judged various appropriation facilities. On the other hand, relevant questions have been whether firms have been engaged within R&D-cooperations and with what

---

[5] In d'Aspremont and Jacquemin (1998) the critical value is some 0,5. This means that half of the research results of one firm can be used by the other firm. Empirical simulations by Morasch (1994) support this result. With respect to the oligopoly models, Morasch (1994) shows that the incentive for R&D cooperations increases with increasing spillover effects. The incentive is even higher when the spillovers between members are higher than spillovers to non-members.

[6] In this case, additional effects preventing cooperation like asymmetric information and coordination problems are counteracted. For a survey of theoretical models that handle these topics, see Bihn (1997).

[7] Additionally, Morasch (1994:52) points at positive 'indirect efficiency effects'. These arise for example when synergies between the research projects are exploited and double research is prevented. Furthermore, the binding agreements on both stages reduce the incentive for free-rider-behaviour. See here Kamien et al. (1992:1302)

type of cooperation partner. These data have been collected within the ‘Mannheimer Innovationspanel 1993’ (MIP 1993)[8]. However, data with respect to the here relevant variables are only collected in irregular time intervals. In the set of 1993 all relevant data have been available simultaneously.[9]

With regard to the definition of R&D-cooperations, an empirical test of the theoretical relationship between spillover effects and R&D-cooperations has to focus on R&D-cooperations between (potential) competitors.[10] This may be the case within both spheres, the vertical and the horizontal inter-firm relations. Therefore, in accordance to Scherer (1997:27), the analysis at hand includes direct competitors as well as suppliers and customers as R&D-cooperation partners. For a matter of comparison, additionally so-called general R&D-cooperations are analysed. They include universities, research institutions and consultancies together with firms as possible cooperation partners.

A more severe problem is how to measure spillover effects empirically. As mentioned above, spillovers arise whenever a firm is not able to fully appropriate his research results. Since spillovers cannot be observed directly, the analysis at hand constructs an indicator from firm data with regard to the effectiveness of various appropriation facilities. In contrast to the statistical procedure in König et al. (1994), however, the indicator here has been chosen on the ground of theoretical considerations. König et al. (1994) base their interpretation of spillover effects on the results of a factor-analysis. In their view therefore, spillovers arise whenever firms judge ‘firm-specific appropriation facilities’[11] as effective in protecting internal research results. Examples for these firm-specific appropriation facilities are secrecy, complex product design, fast implementation and long-term employment of qualified personnel. This indicator has one advantage: the fact that firms judge these appropriation mechanisms as effective directly reflects their reaction to an - in their view - ineffective patenting system. However, there are possible caveats to this indicator: One is that there may be doubts whether firms co-operate at all when they judge ‘secrecy’ as very effective. The other is that firms are actually capable to protect their knowledge when they state some means of protection as effective. This indicator therefore contradicts the theoretical notion of spillover effects. Accordingly, this indicator does not represent these firms that are not able to protect their knowledge through any protection mechanism. Therefore, the empirical analysis at hand will be based on a more extensive indicator for spillover effects. It will take into account all appropriation facilities. It thus, will also include firms that judge protection mechanism as ineffective that are not captured within the official patenting system. Within the data set at hand, the effectiveness of the various appropriation facilities has been measured on a scale ranging from 1 to 5 points. Therefore, with the interpretation used in this

---

[8] See ZEW (1998).

[9] The argument of a lack of up-to-date data can be opposed by the fact that there are no big changes to be expected within short run with regard to the general attitudes of firms towards spillover effects and R&D cooperation.

[10] The indicator ‘cooperation variety’ in the analysis of König et al. (1994) measures only the extend to which spillovers influence the degree of variety in cooperation partners. It also includes cooperations with universities and research institutes, and thus cannot directly indicate whether spillover effects can be internalised through the market mechanism itself.

[11] The terminology was chosen in accordance to Harhoff (1997:348).

analysis spillovers arise whenever firms assigned 1 to 3 points to the various appropriation facilities, representing no, low or medium effectiveness.

The form of spillovers and their influence on R&D-cooperations may differ with firm- size and industry. With regard to appropriation conditions, and thus with respect to the relevance of spillover effects in general, there is no unanimous result in the theoretical and empirical literature. On the one hand, Symeonides (1996:52) refers to an empirical study, according to which small firms may not be able to fully appropriate their knowledge since they do not have easy access to 'firm-specific' appropriation facilities. On the other hand, Symeonides (1996:53) and Geroski (1995:102) point out that there is more empirical relevance for inter-industry rather than for firm-size-related differences of appropriability. For example, according to a study of Mansfield from 1986 patenting was found to be relevant for pharmaceuticals, chemicals and mineral-oil processing, while patents had only limited relevance in sectors like office machinery.

With regard to the role of firm-size for the influence of spillovers on R&D-cooperations, theoretical reasoning has to be built upon existing theoretical studies analysing the relationship between innovation, firm-size and market structure. Firms invest into R&D in order to create market share and higher profits by launching new products or by reducing production costs though process innovations. According to Tirole (1993), the amount of R&D that the individual firm wants to invest (with this the incentive to co-operate) depends on the market structure. A firm which has already achieved a high market share, in the extreme case monopoly power, will invest less into R&D than a firm which faces full competition. Tirole (1995:392) points to the so-called 'replacement effect': The market leader only takes into account the additional profit which would result from the realisation of the innovation. However, with increasing spillover effects there is also the threat of potential competition. A firm facing potential competition will invest heavily into R&D due to the so-called 'efficiency-effect' [Tirole (1995:393]: Now, the market leader has to worry about the loss of his market power, in the extreme case his monopoly power. [12] On the ground of these arguments, big firms with high market share may have a high incentive to internalise spillover effects within R&D-cooperations, when they are not able to fully appropriate their research results. However, there are some doubts whether firms, that have been successful in building up high market power actually have to fear potential competition when spillover effects arise. The reason is that high market power reflects the good performance of this firm. This again may result from a more efficient production, maybe due to better technology. Thus, this firm is not easily affected. Even if this firm has an incentive to invest into R&D it will not take spillover effects seriously. An incentive to cooperate in R&D in order to internalise spillover effects does not exist.

In contrast, firms have a high interest to use R&D investments as an instrument to strategically influence the market when they constantly have to fear the loss of their market shares. According

---

[12] According to Mazzucato (1998) and Symeonides (1996:55) increasing concentration will not occur because of diminishing returns, even without spillover effects. Mazzucato (1998:66) calls it the problem of dynamic diseconomies of scale. The potential for further cost reduction due to innovations may shrink with increasing market share. In this case, there may be leapfrogging through small firms with drastic innovations. According to Mazzucato, spillover effects increase the probability for this leapfrogging. This scenario is additionally reinforced if small firms are able to exploit economies of scale- and scope by networking and clustering. All these points weaken the argument that innovations would be basically produced in big firms.

to Tirole (1993:ch.10.2), this scenario is most likely in situations with a patent race, i.e. in situations where the firms face severe competition in the research stage.[13] There only one firm can succeed in implementing and launching its innovations, while the others have to suffer losses due to the R&D-investment expenditures. This case is relevant in R&D-intensive industries. Firms fear that by passing on their internal research results via co-ordination they may even increase the probability of their competitors winning the race. In these cases, spillovers may even hinder firms from co-operating in R&D.

To summarise, there is evidence for presuming that the relevance of spillover effects for R&D cooperations is not solely dependent on firm-size. Rather, differences in the effects of spillovers can be expected if the interdependence of firm-size and industry, especially the degree of competition, is taken into account. To work out such differences, the incentive of industry- and firm-size-specific spillovers as well as possible interactions between them are analysed below.

3.2 Some Methodological Remarks

In order to work out the internalisation aspect of R&D-cooperations the logistic regression model has been used as one special case of regressions with qualitative dependent variables.[14] In general, this type of model was necessary since the available data set does not contain information about the actual number of R&D-cooperations, but only whether firms have been engaged in R&D-cooperations at all.

With respect to the accurate specification, the choice of the independent variable is led by the theoretical considerations concerning possible differences in the incentives from spillovers with industry and firm-size. Thus, spillover effects are always regarded as firm-size or industry-specific spillover effects.[15] One methodological problem occurred insofar as partly high correlations between industries and groups of firm-size had to be expected. Therefore, the problem of near multicollinearity could not be excluded.[16] While the coefficients can be estimated, the estimators are not efficient and cannot be interpreted unambiguously. To leave out the variables producing multicollinearity may have led to a loss of information, since these variables were interesting from the theoretical point of view. Additionally, transforming the 'collinear' variables would have produced interpretation problems afterwards.[17] Because of this trade-off between pure

---

[13] See also Katz and Ordover (1990:152).

[14] The choice between the Logit- and the Probit-specification in general is based on the assumption about the distribution of the endogenous variable [Fahrmeir et al. (1996, p. 244-250)]. In the case at hand, the specification starts from the assumption of a binomial distribution of the endogenous variable - therefore the Logit-model. The choice between Logit or Probit-model should not be taken too seriously. Fahrmeir et al. (1996, diagram 1.1, p.249) have shown that - except for the lower and higher ends of the distribution - the estimations on the ground of either Logit or Probit-analysis are almost identical.

[15] This has been modelled by multiplying the spillover variable with the firm-size or industry-dummy-variable respectively.

[16] The presumption that some variables may to some degree be represented through a linear-combination of another variable has been supported by estimations where both the firm-size- and industry-specific spillover effects were included simultaneously. The estimated variance-covariance-matrix showed some estimates ranging between 0.4 and 0.8.

[17] For an extensive survey of the various remedies for multicollinearity, see Gujarati (1994). Another way is to select the significant parameters stepwise. With high correlations between some variables the best solution is to apply both the

methodological and pure theoretical thinking, a stepwise procedure has been chosen. The three steps will be reflected below in the interpretation of the results.

The first step was to analyse the impact, the sign and the level of significance of the various firm-size and industry-specific spillovers. In order to do this, the influence of the firm-size and industry specific spillovers were tested separately from each other, acknowledging that there may be additional effects represented by the estimated coefficients.[18] Again as a consequence of the trade-off between theory and methodology all categories of a variable have been considered at the cost of leaving out the constant. With the decision to consider one category for reference, this category can no longer be directly tested for its significance. With respect to industry-specific spillover effects, it would not have created severe interpretation problems to choose one category as the reference-category. However, in the case of firm-size specific spillover effects, the choice which group to take as the reference-category was difficult from the theoretical point of view.

The second step was to work out the interdependence between industry-specific spillovers and firm-size influencing R&D-cooperations. Since the coefficients of a Logit-model can not be interpreted directly it was useful to apply the sensitivity analysis.[19] There, the impact of one specific spillover effect on R&D cooperations is assessed by comparing the probability for R&D-cooperations due to spillover effects with some reference probability. In the analysis at hand, this latter reference probability has been calculated on the basis of the (unweighted) spillover-means. It therefore has to be read as the probability for R&D-cooperations when spillover effects arise on average, i.e., when all spillover effects are balanced.[20] In order to calculate the probability for R&D cooperations due to one specific spillover effect, this spillover-mean has been substituted by the mean of the endogenous variable, the R&D-cooperations. Thereby, the influence of the other exogenous variables have been left unchanged. The difference between the resulting probability and the reference probability then represents the incentive effect of this specific spillover for the establishment of R&D-cooperations.

To analyse the interaction between industry-specific spillover effects and firm-size the whole sample has been split into subsamples according to the group of firm-size. Within each of these subsamples the influences of industry-specific spillovers on R&D-cooperations have been examined separately. By comparing the results of the sensitivity analysis for each subsample to the ones for the overall sample then, it is possible to examine whether the influence of spillovers on the formation of R&D-cooperations can be traced back to firm-size factors.

The third step finally was to analyse whether it is the spillover effect which is relevant for R&D-cooperations. Therefore, factors had to be filtered out that are characteristic for the specific industry or firm-size and that are encouraging R&D-cooperations, independent of spillovers.

---

backward- and forward-selection method simultaneously. However, this option was not included in the statistic computer program at hand.

[18] For further considerations see the methodological appendix.

[19] In contrast to classical regression analysis, the coefficients of a Logit-model measure the influence of the exogenous variables (spillovers) on the logit and not on the actual probability of R&D cooperations. For an extensive survey of the methodology and possible applications of the logistic regression see Krafft (1997).

[20] Therefore, the objective of the reference-probability is accomplished: it serves as a neutral scenario to which the influence of one specific spillover can be compared. For further considerations see the methodological appendix.

Hence, the influence of spillovers has been separated from potential influences through firm-size or industries in general.[21]

4. Empirical Results

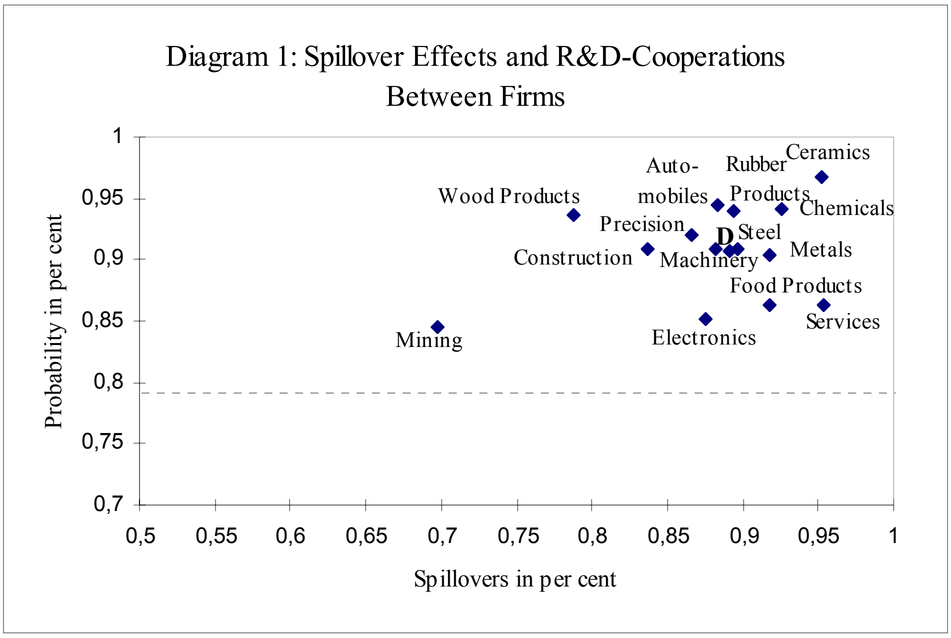
The theoretical and empirical considerations above allow the presumption that under specific conditions firms have the incentive to co-operate in R&D in order to internalise spillover effects. However, these considerations also show that the incentive for R&D-cooperations due to spillover effects may depend on the market structure, most of all on the pressure from existing or potential competition. Therefore, the first part of the presentation of the empirical results will focus on possible differences in the influence of spillovers on R&D-cooperations, depending on the specific group of firm-size and the specific industry considered. In the second part then it will be asked how such differences can be explained. Special emphasis will be placed on the interdependence between industry-specific spillover effects and firm-size, on possible cooperation-preventing factors, and on the relevance for additional motivations for firms to cooperate in R&D. In all these steps the object of investigation are R&D-cooperations between firms. For matter of comparison however, also R&D-cooperations in general are taken into account. They include universities, research institutions and consultants in addition to firms.

4.1 The Internalising Effect of R&D-Cooperations in General

From diagram 1 one can conclude that there is some relevance for the general incentive effect of spillovers for R&D-cooperations, as it was derived from theory. In diagram 1, the means of the industry-specific spillovers are drawn on the horizontal axis in order to represent the height of spillovers. In order to compare the influences of the various spillovers weighted means have been calculated by using the number of observations in the respective industry as weights. Both, means and weights are given explicitly in table 1a. These means show the frequency with which firms of the specific industry are not able to fully appropriate their research results. On the vertical axis, the estimated probabilities for R&D-cooperations are drawn. These represent the incentive for the firms of the various industries to take part in an R&D-cooperation with another firm, when spillover effects arise in this industry. In order to compare the influences of various spillovers with each other, the reference-probability is given as the punctuated line. It represents the probability that R&D-cooperations are formed when there are no specific spillover effects arising. According to this diagram now, firms have an incentive to co-ordinate their R&D-activities with other firms when they face spillover effects. The mean-cooperation-combinations are always above the reference probability.

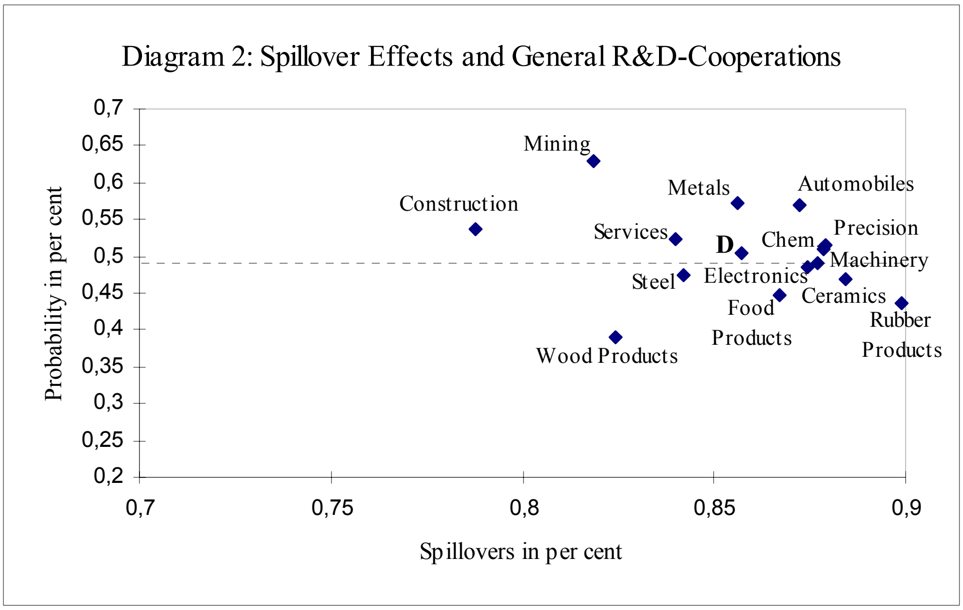
---

[21] With this however, solely the approximate amount and the sign of the coefficients can be interpreted unambigously. A test for significance has to be left out due to possible interdependencies among the exogenous variables.



Source: MIP 1993, own calculations.

Comparing diagram 1 with diagram 2 makes clear that it is the R&D-cooperation with other firms which serves to internalise spillover effects. In diagram 2 - analogously to diagram 1 - the combinations of the weighted spillover means and the estimated probabilities are drawn for the various industries. However, diagram 2 takes a view at the probability for R&D-cooperations in general. These include also cooperation partners like universities. The noticeable difference to the relationship before is that now there are only some industries where spillovers positively influence R&D cooperations. This can be seen by looking at the average combination of spillover and probability (D), which lies only slightly above the punctuated reference-probability.



Source: MIP 1993, own calculations.

From table 1a and 1b more precise statements with regard to the various firm-size and industry-specific spillover effects can be given.

With respect to firm-size-specific spillover effects no unambiguous relationship between spillover effects, firm-size and R&D-cooperations can be observed. At a first view at table 1 the incentive to form an R&D-cooperation due to spillovers increases with firm-size. This can be seen from the coefficients in the first column of table 1a. The highly significant, positive coefficient of spillover effects within large firms point at the relevance of spillover effects for the potential loss of market shares of firms with high market power. However, a closer look at the results in table 1a makes clear that this clear-cut relationship between spillover effects, firm-size and R&D-cooperations can not be maintained. The high spillovers as represented by the values for the weighted means in the fifths column of table 1a reflect the presumption of Symeonides (1996) that small firms fear spillover effects. According to the highly significant and positive coefficients of spillover effects in small and medium-sized firms, R&D-cooperations may be seen as one way to alleviate this burden. To put it the other way round: The results provide some evidence for the presumption that small and medium-sized firms see investments into R&D as one fundamental prerequisite for entering new markets. Then, the theoretical incentive for co-operating in R&D in order to internalise the spillover effects can be expected. The internalisation of the technological spillovers through R&D-cooperation more than outweighs the competitive spillover effect from research. Furthermore, there is a much higher degree of variability with regard to industry-specific spillover effects than with regard to firm-size-specific spillover effects. This, together with the observations just mentioned, support the presumption from existing empirical results that it is rather the interaction with industry factors, instead of pure firm-size specific spillover-effects which matters.

With respect to industry-specific spillover effects, one presumption from the considerations above can be seen to be reflected in the results at hand: Different influences may result from different degrees of competitive pressure on either stage of the decision process. R&D-cooperations are strongly encouraged by spillover effects in the chemical industry, in automobiles and aircraft, in ceramics, wood processing and rubber products.[22] In table 1a, the values of these coefficients range from 1,47 to 2,71. Noticeably highly significant coefficients prevail in industries where high competition may be expected, most of all automobiles and aircraft, chemicals and precision and optical instruments. However, this is not the case for electronics. Here, in contrast, the relatively low coefficient of some 0,58 may be due to effects that prevent the formation of R&D-cooperations. This then supports the hypothesis that in industries which are characterised by high competition in the research stage, the co-ordination of research results is rather seen as a danger of the own market share. Giving the competitors access to internal knowledge through cooperation may enhance the competitors' innovation process and thus their market power. In the case of the electronics industry this presumption may be relevant since this industry includes to a high degree R&D-intensive subsections like office machinery and computer electronics.

---

[22] The classification of the industries is given in the appendix.

Table 1a:
Spillover Effects and R&D-Cooperations between Firms

	Results from the Logit-estimation			Descriptive	
Number of observations[a] -2Loglikelihood[b] Correct Classification (in per cent)[c]	540 559,993 78,70	 Llcorr[ba]:	 0,521		
Influencing variables	Coefficient	P-value[d]	Probability[e]	Mean[f]	Observations
Firm-size specific spillovers					
Small firms	1,1787	0,0393	0,8982	0,899	18
medium-sized firms	1,1558	0,000	0,8965	0,870	159
Large firms	1,4035	0,000	0,9131	0,914	390
Reference probability[g]			0,7787		
Number of observations -2Loglikelihood Correct Classification (in per cent)	540 541,426 78,70	 Llcorr :	 0,517		
Influencing variables	Coefficient	P-value	Probability	Mean	Observations
Industry-specific spillovers					
Mining	0,5108	0,4843	0,8446	0,697	11
Construction	1,2993	0,0461	0,9095	0,837	16
Chemicals	1,9095	0,000	0,9418	0,926	64
Services	0,6931	0,4235	0,8623	0,954	6
Automobiles/aircraft	1,9694	0,000	0,9443	0,883	53
Precision/optical goods	1,4663	0,001	0,9197	0,866	53
Ceramics	2,7076	0,0087	0,9679	0,952	16
Machinery	1,2993	0,000	0,9095	0,882	153
Metal products	1,204	0,0097	0,9032	0,918	27
Food/textiles	0,6931	0,0895	0,8623	0,918	28
Steel processing	1,2809	0,0003	0,9083	0,897	49
Electronics	0,5819	0,0422	0,8517	0,875	58
Wood products	1,7918	0,0190	0,9365	0,788	17
Rubber products	1,8718	0,0137	0,9401	0,894	16
Average	-	-	0,9073	0,892	-
Reference probability			0,7848		

[a] Represents the number of firms for which information has been available, dependent on the type of R&D-cooperations. – [b and ba] represent the goodness of fit statistics. –2 Loglikelihood is equivalent to the difference between the probability which has been estimated on the ground of the exogenous variables and the maximum probability achievable. In the case of independent influencing variables the loglikelihhod function is equivalent to the sum of the logs of the likelihood functions. It therefore increases with the number of observations. In order to make the different estimations comparable this statistic has been roughly corrected through the degrees of freedom (ba). [See here Fahrmeir et al. (1996:ch.2).] – [c] States the number of cases that have been correctly classified through the estimations. – [d] A p-value smaller than 0,05 is equivalent to a level of significance of 95%. According to tests for heteroscedasticity, the regressors show no significant influence on the squared residuals of the original estimations. This has been tested by using a linear specification analoguously to the test of White (see here Gujarati (1995:379). An alternative way is to regress the residuals on an exponential function of the regressors. This method was originally proposed for Logit- or Probit-models by Harvey (see here Greene (1997:889). However, it cannot be applied for the specification at hand. – [e] Represents the probability resulting from the Logit-estimations. – [f] Mean of spillover effects which is weighted by the number of observations in the respective firm-size group or industry. – [g] Represents the probability with which firms form an R&D-cooperation when no specific spillover effect arises. Differences in reference probabilities for firm-size or industry-specific spillovers are due to rounding.

Source: MIP 1993, own calculations

Comparing the results for R&D-cooperations between firms (table 1a) with those for general R&D cooperations (table 1b) it may be concluded that general R&D-cooperations are motivated by other reasons than the internalisation of spillover effects.

Table 1b:
Spillover Effects and R&D-Cooperations in General

	Results from the Logit-estimation			Descriptive	
Number of observations[a]	1432				
-2Loglikelihood	1929,729	Llcorr:	0,6752		
Correct Classification (in per cent)	59,85				
Influencing variables	Coefficient	P-value	Probability	Mean	Observations
Firm-size specific spillovers					
Small firms	-0,3920	0,0007	0,3997	0,9400	350
medium-sized firms	-0,3868	0,0001	0,4003	0,9399	497
Large firms	0,4185	0,0000	0,4988	0,9402	705
Reference probability			0,4957		
Number of observations	1432				
-2Loglikelihood	1944,391	Llcorr:	0,6856		
Correct Classification (in per cent)	56,15				
Influencing variables	Coefficient	P-value	Probability	Mean	Observations
Industry-specific spillovers					
Mining	1,0963	0,0336	0,6288	0,8183	23
Construction	0,3365	0,4164	0,5375	0,7879	30
Chemicals	0,1214	0,4865	0,5109	0,8784	144
Services	0,2274	0,2448	0,5240	0,8398	123
Automobiles/aircraft	0,5877	0,0098	0,5683	0,8723	94
Precision/optical goods	0,1625	0,3935	0,5160	0,8790	120
Ceramics	-0,2136	0,4666	0,4694	0,8841	50
Machinery	-0,0364	0,7412	0,4914	0,8770	367
Metal products	0,619	0,619	0,5721	0,8559	45
Food/textile	-0,3844	0,0935	0,4484	0,8669	86
Steel processing	-0,1671	0,3619	0,4752	0,8421	136
Electronics	-0,0953	0,5639	0,4841	0,8745	161
Wood products	-0,8597	0,0007	0,3911	0,8245	86
Rubber products	-0,478	0,0365	0,4369	0,8989	87
Average			0,5039	0,8601	
Reference probability			0,4958		

[a] For a description of the indicators see table 1a.

Source: MIP 1993, own calculations.

Most of the industry-specific spillover effects show insignificant influences on general R&D-cooperations. One possible explanation for this can be drawn from König et al. (1994:230). There, the probability for R&D-cooperations in general increases when firms see universities and public research institutions as one major source for information. On the one hand, the insignificant coefficients in table 1b may reflect the fact that R&D cooperations in general constitute one possibility for firms to get access to high-quality knowledge from universities etc. On the other hand, firms may co-operate with consultants who can help to reduce market uncertainty. This may be relevant in the diffusion phase of the innovation process for example. The idea in both explanations is that lack of significance can be traced back to a lack of competition between firms and universities or other research institutions. Thus, the theoretical relationship between spillover effects, in the sense of an unintended knowledge transfer, and R&D-cooperations does not become evident in the same degree as in pure R&D-cooperations among firms.[23]

The fact that there are other motivations for R&D-cooperations may be one possible explanation for the result in the service sector, too. There, spillovers have no significant influence on R&D-cooperations, independent of the type of cooperation partners considered.[24] This is even more astonishing when two observations are taken into consideration. First, firms in this sector indeed behave co-operative. In diagram 2 (table 1b), the probability for R&D-cooperations lies above average. For an interpretation, it then has to be referred to the fact that the service sector includes production-related services in research and development and in data-processing. These firms may constitute the information producing cooperation partner, the consultants. Second, firms from the service sector indeed face the problem of spillover effects. The means in diagram 1(table 1a), are relatively high. Firms in the service sector thus presumably search for alternative means for solving the spillover problem.

For a preliminary conclusion, it is possible to say that firms have in general the incentive to form R&D-cooperations with other firms in order to internalise the spillover effects. However, looking at the effects that spillovers impose on R&D-cooperations in the various industries makes clear that distinct results can only be given on the basis of more detailed analysis. On the one hand, some industries show only slight, or even insignificant coefficients. On the other hand, different influences prevail, when cooperations with other firms are compared to cooperations in general. These results raise the question whether there is really a causal relationship between spillover effects and R&D-cooperations. On the one hand, cooperations may be induced by factors which are characteristic for some industries or firm-size. They are thus only indirectly influenced by spillovers. On the other hand, spillover effects may even prevent the formation of R&D-cooperations.

4.2 The Internalisation Effect Reconsidered

4.2.1 Industry-Specific Spillover Effects and Firm-Size

In order to work out the interaction between industry-specific spillover effects and firm-size the overall influence of industry-specific spillover effects is compared to the influence in the different groups of firm-size. For this, table 2 gives the respective results of the sensitivity-analysis. Starting point for the interpretation is the reference-probability which has been calculated on the basis of the significant parameters. There are also the values for the coefficients, which measure the impact of each spillover effect overall and within each group of firm-size. To allow a direct interpretation of the impact of each spillover, table 2 shows how the probability for R&D-cooperations changes in comparison to the reference probability when the specific spillover effect occurs.

The results for the chemical industry, for automobiles and aircraft and for precision and optical instruments suggests that the previously observed high coefficients cannot be traced back to firm-size differences. Spillovers in these industries have a positive influence on R&D-cooperations

---

[23] R&D-cooperations in general also include firms as cooperation partners.

[24] In the first general stage of the analysis the overall effect has been estimated. Therefore, the coefficient may include additional effects, like pure industry factors.

independent of firm-size. There are continuously high significant influences in the chemical industry and in automobiles and aircraft. There, spillover effects in medium-sized firms increase the probability for R&D-cooperations by 25 per cent, in large firms the change is 25 per cent for chemicals and 26 per cent for automobiles and aircraft. There is one more argument against firm-size differences in the influence of industry-specific spillovers on cooperations between firms. In the chemical industry, in automobiles and aircraft and in precision and optical instruments spillover effects are continuously internalised within R&D-cooperations between firms, while this is not the case for R&D-cooperations in general. In contrast, R&D-cooperations in general are either not at all influenced by spillovers in the case of precision and optical instruments, or are only influenced in big-firms in the case of chemical industry, automobiles and aircraft, respectively.

In electronics, firm-size may influence the incentive to form R&D-cooperations in order to internalise spillover effects. Spillover effects in this industry only show a significant positive coefficient and are thus only cooperation-inducing when they occur in medium-sized firms. There, spillover effects raise the probability for R&D-cooperations by 20,07 per cent. In contrast, the overall effect of spillovers on R&D-cooperations between firms there is only about 8,87 per cent. What is astonishing is the fact that there is no significant influence of spillover effects when they occur in large firms, although electronics on the whole is - according to the industry-size-distribution in the appendix - represented to a high degree by large firms. This together with the points just mentioned raises a contradiction to the previous results where spillovers in large firms imposed a strong influence on R&D-cooperations. This can be explained on the ground of two observations: First, while the electronics-industry on the whole and general R&D-cooperations in this industry are to a high degree represented by large firms, this is not so much the case for R&D-cooperations between firms. Second, spillover-effects in the electronics industry as given by the respective spillover-means in diagram 1 are relatively low as compared to the average or the spillover effects in other R&D-intensive industries. By taking these two observations together, they indirectly support the presumption above that especially big firms have an incentive to co-ordinate R&D-activities when they fear spillover effects. In electronics it is rather the case that large firms are possibly able to protect their knowledge. In reference to existing studies of appropriability mentioned above this may be especially relevant for firm-specific appropriation methods.

For a preliminary conclusion with respect to the firm-size dependence of spillover effects, no unanimous relationship between spillover effects, R&D-cooperations and firm-size can be observed. While there is some evidence for the presumption that spillovers strongly influence R&D-cooperations when they occur in large firms, there is stronger evidence for the presumption from existing empirical studies that it is the interaction between industries and firm-size that matters.

4.2.2 Factors Preventing R&D-Cooperation?

Inter-industry differences in the influence of spillovers can arise from high pressure from existing or potential competition in both stages of the decision process. However, the results up to now have shown differences in the incentives due to spillovers even within the group of industries which can be characterised by similar degrees of competitive pressure. Therefore, the objective of this paragraph is to examine whether there are signs for potential factors that prevent the formation of R&D-cooperations. Table 3 gives the results of the regression where the influence of spillovers have been separated from factors which are characteristic for the specific industry or group of firm-size.

Table 3:
Spillover Effects and R&D-Cooperations -Industry and Firm-Size Effects

	R&D-cooperations between firms		R&D-cooperations in general	
Number of observations[a]	540		1438	
-2Loglikelihood	533,818	Llcorr:	1903,272	Llcorr:
Correct Classification (in per cent)	79,07	0,5143	60,08	0,6721
Influencing variables	Coefficient	p-value	Coefficient	p-value
Firm-size-specific spillovers				
Medium-sized firms	0,3455	0,8446	1,3588	0,2511
large firms	1,5635	0,3745	1,5836	0,0859
Industry-specific spillovers[b]				
Chemicals[c]	0,7224	0,2559	-0,7289	0,6327
Services[c]	-0,4175	0,6801	0,8875	0,0024
Electronics	-6,5598	0,6668	-1,1851	0,3402
Automobiles/aircraft	-5,3275	0,7319	-6,1967	0,5156
Precision/optical goods	1,0748	0,5992	-6,1124	0,3600
Rubber products	-5,7487	0,7968	-1,5269	0,3697
Machinery	-0,7568	0,6916	-1,6700	0,1020
Firm-size effects				
Medium-sized firms	-0,4860	0,7919	-1,3813	0,2424
large firms	-1,4590	0,4293	-0,7856	0,3933
Industry effects				
Chemicals[c]	-	-	1,2063	0,4298
Services[c]	-	-	-	-
Electronics	5,9688	0,6953	1,5545	0,2125
Automobiles/aircraft	6,1204	0,6940	7,1201	0,4551
Precision/optical goods	-0,7209	0,7285	6,8186	0,3072
Rubber products	6,5276	0,7699	1,5991	0,3459
Machinery	0,8843	0,6528	2,0312	0,0492
Constant[d]	1,1311	0,1516	-0,8136	0,0007

[a] With regard to the description of the goodness-of-fit statistics, compare table 1a. It has to be taken into account that coefficients may be insignificant due to multicollinearity problems. – [b] This table contains the results for the industries that are mentioned in the interpretation in the text. – [c] In chemicals and in services industry-effects have been highly correlated to industry-specific spillover effects (Spearman's correlation coefficient equal to one). Therefore, these effects cannot be statistically separated from each other. – [d] Here, all variables are taken into account. Therefore, it is more adequate to write it in accordance to the effect-specification.[See also the methodological appendix.] Estimations using the factor-specification showed no significant differences in the sign and impact of the various effects.

Source: MIP (1993), own calculations.

The results for automobiles and aircraft and for electronics speak in favour of the presumption that spillover effects may even prevent the establishment of R&D-cooperations. The coefficients of these industries are extremely negative. From the classification of industries in the appendix, it becomes clear that these industries include highly R&D-intensive branches. This is aircraft in automobiles and it is manufacturing data processing machines and television and communication equipment in electronics. In these branches, high pressure from competition in the research stage can be expected. Together with the theoretical considerations above it may therefore be presumed that firms from electronics and from automobiles and aircraft do not see R&D-cooperations as a method to internalise spillover effects. Rather they see R&D-cooperations as an additional channel through which internal knowledge can spill over to other firms.

In contrast, the results for chemicals and for precision and optical instruments discourage the presumption that spillover effects prevent the formation of R&D-cooperations. In table 3, the coefficient for precision and optical instruments is highly positive. For chemicals however, the pure sector effect can not be separated statistically from the spillover effect. Therefore, it is not possible to draw definite conclusions with respect to the sign and the extent of both effects there. The only basis for an interpretation can be seen in the positive internalisation effect within large-firms. From the first block in table 3, it becomes clear that spillovers are positively influencing R&D cooperations, when they arise in large firms. R&D-cooperations among firms in chemicals are established to a high degree by large firms. These two observations point to the presumption that also in the case of the chemical industry, there is no sign for a negative incentive from spillovers.

4.2.3 Different Motivations?

The results in table 3 demonstrate that in industries like electronics, automobiles and aircraft, rubber products and machinery the incentive for R&D-cooperations may depend on factors which are characteristic for the distinct industry, and may therefore be independent of spillover effects.[25] This can be seen from high positive coefficients of the industry effects in contrast to the coefficients of industry-specific spillover effects. One possible explanation for this result can be drawn from Hammes (1994).[26] According to him, industries like electronics, chemicals, automobiles, machinery and services show a high degree of cooperation anyway. He justifies this with three properties characterising these industries: They are all technology-intensive, they have a global orientation, and firms in these industries are producing complex products. One of the most convincing arguments in favour of cooperations then is their flexibility that allows firms to handle changing and country-specific needs. In the case of automobiles, Hammes (1994) and Graves (1996) point at the pressure from intense international competition that has to be seen as the definite driving force for a high extent of cooperation. According to them, this competitive pressure originates for the most part from the success of Japanese firms. They are gaining ground due to their capacity to keep on producing new goods while they are at the same time continuously lowering production costs. According to Hammes, the intensity of competition in automobiles is

---

[25] This presumption can be supported by a result in table 2. There, the coefficients of the chemical industry and of automobiles and aircraft are significantly positive, independent of the type of R&D-cooperation. Furthermore, - according to the firm-size distribution of each sector (in the appendix) - both sectors are to a high degree represented by big firms, regardless of the type of R&D-cooperation. From this it can be concluded that this impact is due to firm-size effects, and thus only indirectly related to spillover-effects.

[26] Hammes analyses strategic alliances in general. His study therefore, goes beyond the topic at hand. However, his results can be applied here, too, since R&D can be seen as one of the three basic motivations for building strategic alliances, next to production and marketing. [Hammes (1994:216-7)]

increased because of the fact that in this industry extremely high fixed costs for R&D have to be paid while product life cycles are shrinking. Thus, immense investment into R&D has to pay for itself within increasingly shorter periods.

With the result of Hammes (1994), the positive overall influence in chemicals may partly be caused by industry-factors, too. One argument supporting this presumption can be found in Gerybadze et al. (1997). They point at the increasing tendency of firms to specialise on specific technologies within R&D. Therefore, R&D-cooperations with firms that are competent in the specific field may provide access to up-to-date knowledge. Or, these cooperations enable firms to build up a common pool of qualified staff. Additionally, Gerybadze et al. (1997) point out that big firms have been intensively reducing centrally organised R&D during the last years. The result of the analysis at hand thus may reflect a tendency of large firms in the chemical industry to outsource R&D-units to producers that are specialised in the specific competencies.

In contrast, a comparison between the two types of R&D-cooperations underlines that firms co-operate with each other in R&D in order to internalise spillover effects, while alternative motivations may be more relevant whenever firms co-operate with different cooperation partners. This presumption is based on a comparison of the goodness of fit statistics for both regressions in table 3. By including spillover effects as exogenous variables, R&D-cooperations are correctly predicted with a probability of some 79 per cent, when only firms are considered as R&D-cooperation partners. In contrast, it is about 60 per cent, when also universities etc. are possible cooperation partners.

5. Is It Really the Internalisation? – Concluding Remarks

The empirical results in general support the theoretical relationship between spillover effects, in the sense of unintended knowledge transfer, and R&D-cooperations. Firms that fear spillover effects seem to have - in general - an incentive to co-ordinate their R&D-activities with other firms. Additionally, there is some empirical evidence for the theoretical presumption that spillovers significantly provide incentives to form R&D-cooperations when they occur in large firms, at least from the general perspective. However, also medium-sized firms show a highly significant incentive to internalise spillover effects through R&D-cooperations with other firms. This is the case from a general perspective as well as from a more desegregated one. These latter observations point at the interdependence between firm-size and industry effects when conclusions with regard to the internalisation effect of R&D-cooperations have to be drawn.

The empirical results support the presumption from several theoretical considerations that different influences of spillovers may result from different degrees of existing or potential competition on both stages of the decision process. Highly significant influences of spillovers on R&D-cooperations between firms can be observed in automobiles and aircraft, chemicals and in precision and optical instruments. Unambiguous support for the theoretical hypothesis may only be seen in precision and optical instruments. There, spillovers exert a highly significant influence on R&D-cooperations between firms. This is the case regardless of firm-size. Moreover, spillovers in precision and optical instruments significantly influence R&D-cooperations between firms but not those with universities or reserach institutes. Finally, cooperation-inducing spillover effects more than outweigh cooperation-hindering effects that are characteristic for this industry.

According to theoretical considerations spillover effects may even hinder firms from co-operating with other firms in R&D. This can be shown for automobiles and aircraft and for electronics. There, industry-specific spillover effects negatively influence R&D-cooperations, in electronics especially R&D-cooperations with other firms. What precisely supports the theoretical presumption above is the fact that in both industries there are branches where high pressure from potential competition on the research stage may be expected. In the case of electronics this is manufacturing data processing machines and equipment. In the case of automobiles etc. this is aircraft and spacecraft. Taking this together with the positive overall influence of spillovers in these branches one conclusion may be drawn which is different from the theoretical hypothesis: If there is the threat of existing or potential competition on both stages of the decision process the relationship between spillover effects and R&D-cooperations can no longer be expected to be linear. Rather, in this case it should be understood in the sense of an ‘inverted u-curve’, backward sloping when there is high pressure from competition on the research stage.

The empirical results underline the importance of different motivations for the formation of R&D-cooperations. On the one hand, comparing the influences of the various industry-specific spillovers on R&D-cooperations between firms and those with universities and research institutes graphically speaks in favour of the internalisation motivation in R&D-cooperations between firms. This is also supported by the overall goodness-of-fit statistics. However, several positive influences from factors that are characteristic for the industry speak against. Therefore, firms presumably co-ordinate R&D-activities for several reasons besides the internalisation of spillover effects. Possible reasons for R&D-cooperations with universities etc. may be the access to up-to-date knowledge and information. Possible reasons for R&D-cooperations with other firms may be to reduce or eliminate market uncertainty and financing restrictions. Or firms may co-operate in order to directly manipulate competition.

With regard to the lessons to be drawn, three caveats have to be mentioned: Firstly, this analysis focussed on the spillover effects as sole direct determinant of R&D-cooperations. From the empirical results however, it becomes evident that additional motivations have to be taken into account. Secondly, this analysis was based on the most general theoretical relationship between spillover effects and the formation of R&D-cooperations. The empirical results however, make clear that various aspects reflecting competitive pressure may influence the incentive aspect of spillovers. There are for example the degree of concentration, the number of existing cooperations, and a differentiation between product and process innovations to be mentioned. By incorporating such aspects in the theoretical as well as the empirical analysis sound conclusions with regard to the influence of competitive pressure on the relationship between spillover effects and R&D-cooperations can be drawn. Finally, for the time being, the empirics have been restricted to a cross-sectional analysis. However, a real panel analysis can give more interesting insights. First of all, it can examine changing cooperational behaviour. Secondly, a panel-analysis may help to elaborate on the interactions between spillover effects, R&D-cooperations and market structure just mentioned.

Reference List

Bihn, M. (1997) Forschungs- und Entwicklungskooperationen - eine Wettbewerbstheoretische und Wettbewerbspolitische Untersuchung; Frankfurt am Main: Europäische Hochschulschriften, Reihe V, Bd. 2078.

Coe, D. T., Helpman, E (1995) 'International R&D Spillovers', European Economic Review 39: 859-87.

D'Aspremont, C., Jacquemin, A. (1988) 'Cooperative and Noncooperative R&D in Duopoly with Spillovers', American Economic Review 78(5):1133-7.

Fahrmeir, L., Hamerle, A., Tutz, G. (eds) (1996) Multivariate Statistische Verfahren, Berlin: de Gruyter.

Geroski, P. (1995) 'Markets for Technology: Knowledge, Innovation and Appropriability', in: Stoneman, P. (ed.) Handbook of the Economics of Innovation and Technological Change, Oxford, UK: Blackwell.

Gerybadze, A., Mayer-Krahmer, F., Reger, G. (1997) Globales Management von Forschung und Innovation, Stuttgart: Schäffer-Poeschel.

Graves, A. (1996) 'Innovation in a Globalizing Industry: The Case of Automobiles', in: Dodgson, M. and Rothwell, R. (eds): The Handbook of Industrial Innovation, Cheltenham: Edward Elgar.

Greene, W.H. (1997) Econometric Analysis, London: Prentice-Hall International.

Grossman, G., M., Helpman, E. (1991) Innovation and Growth in the Global Economy, Cambridge, Massachusetts: MIT Press.

Grupp, H., Gehrke, B. (1994) Innovationspotential und Hochtechnologie: Technologische Position Deutschlands im Internationalen Wettbewerb; Heidelberg: Physika Verlag.

Gujarati, D. (1995) Basic Econometrics (3rd edition), New York: McGraw-Hill, International.

Hagedoorn, J. (1997) 'The Economics of Cooperation among High-Tech Firms - Trends and Patterns in Strategic Technology-Partnering since the Early Seventies', in: Koopmann, G., Scharrer, H.-E. (eds) The Economics of High-Technology Competition and Cooperation in Global Markets, Baden-Baden: Nomos Verlag.

Hammes, W. (1994) Strategische Allianzen als Instrument der strategischen Unternehmensführung, Wiesbaden: Deutscher Universitätsverlag.

Harhoff, D. (1997) 'Innovationsverhalten in einem strukturellen Oligopolmodell', Zeitschrift für Wirtschafts- und Sozialwissenschaften 117:333-64.

Kamien, M.I., Muller, E., Zang, I. (1992) 'Research Joint Ventures and R&D Cartels', American Economic Review 82:1293-306.

Katz, M. Ordover, J. (1990) 'R&D Cooperation and Competition', Brookings Papers of Economic Activity: Microeconomics, 137-203.

Klodt, H. (1995) Grundlagen der Forschungs- und Technologiepolitik, München: Vahlen.

König, H., Licht, G., Staat, M. (1994) 'F&E-Kooperationen und Innovationstätigkeit', in: Gahlen, B., Hesse, H., Ramser, H-J. (eds): Europäische Integrationsprobleme aus wirtschaftswissenschaftlicher Sicht, Tübingen: Mohr.

Konrad, E. (1997) FuE-Kooperationen und Internationale Wettbewerbsfähigkeit, Wiesbaden: Gabler.

Krafft, M. (1997) 'Der Ansatz der Logistischen Regression und seine Interpretation', Zeitschrift für Betriebswirtschaft, 67, 5/6: 625-42.

Krugman, P.R. (1992) 'New Thinking about Trade Policy', in: Krugman (ed.): Strategic Trade Policy and the New International Economics, Cambridge, Massachusetts: MIT Press.

Leahy, D., Neary, J.P. (1997) R&D Spillovers and the Case for Industrial Policy in an Open Economy, Centre for Economic Performance Discussion Paper, London.

Mazzucato, M. (1998) 'A Computational Model of Economies of Scale and Market Share Instability', Structural Change and Economic Dynamics 9:55-83.

Morasch, K (1994) Strategische Allianzen, Anreize-Gestaltung-Wirkungen, Heidelberg: Physica-Verlag.

Scherer, N. (1997) Kooperationsentscheidungen in Forschung und Entwicklung, Frankfurt am Main: Europäische Hochschulschriften, Reihe 5, No. 1798.

Suzumura, K. (1992) 'Cooperative and Noncooperative R&D in an Oligopoly with Spillovers', American Economic Review, 82(5):1307-20.

Symeonides, G. (1996) 'Innovation, Firm Size and Market Structure: Schumpeterian Hpotheses and Some New Themes', OECD Economic Studies, No.27, 1996/II.

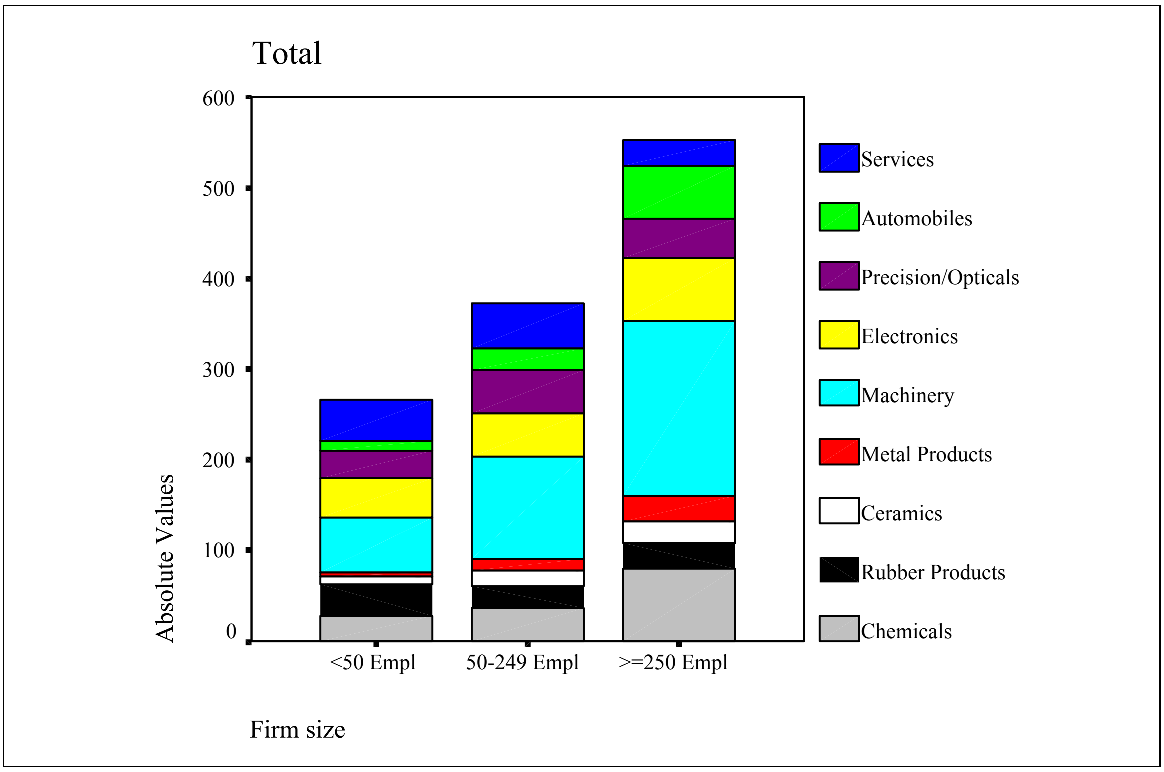
Tirole, J. (1993) The Theory of Industrial Organisation, Cambridge, Massachusetts: MIT Press.

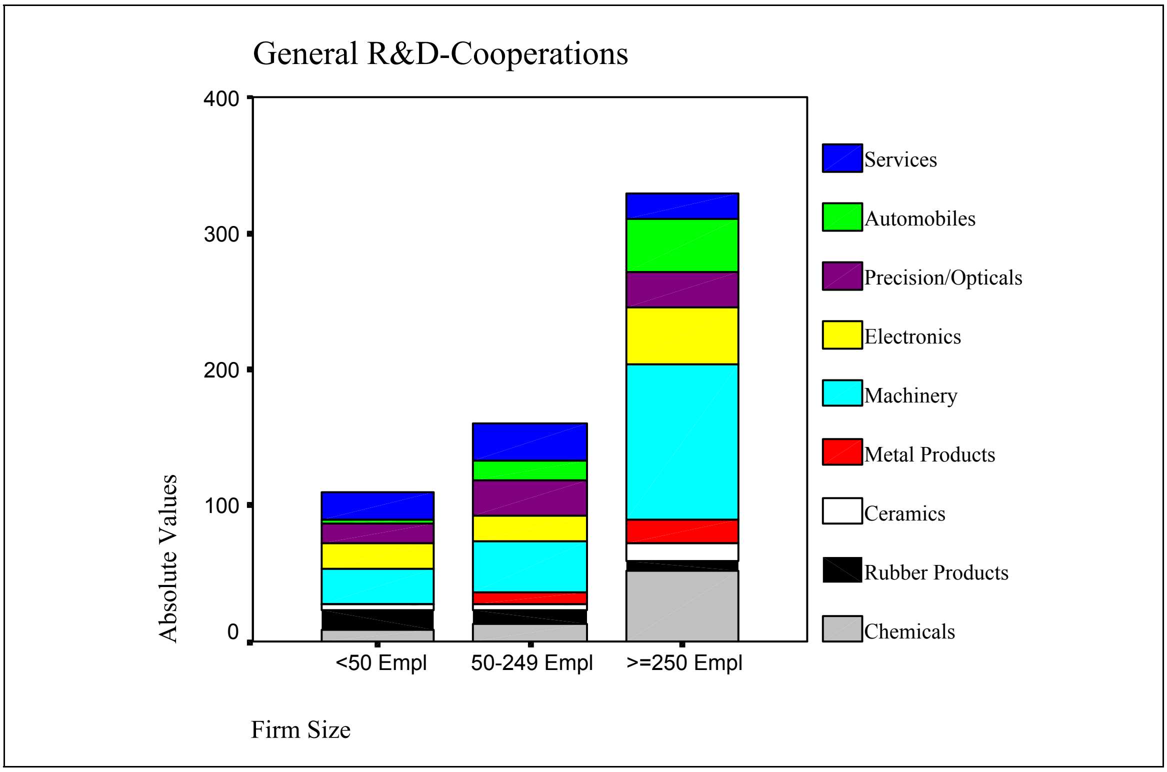
United Nations Industrial Development Organization (UNIDO) (1997) International Yearbook of Industrial Statistics, Vienna: Edward Elgar.

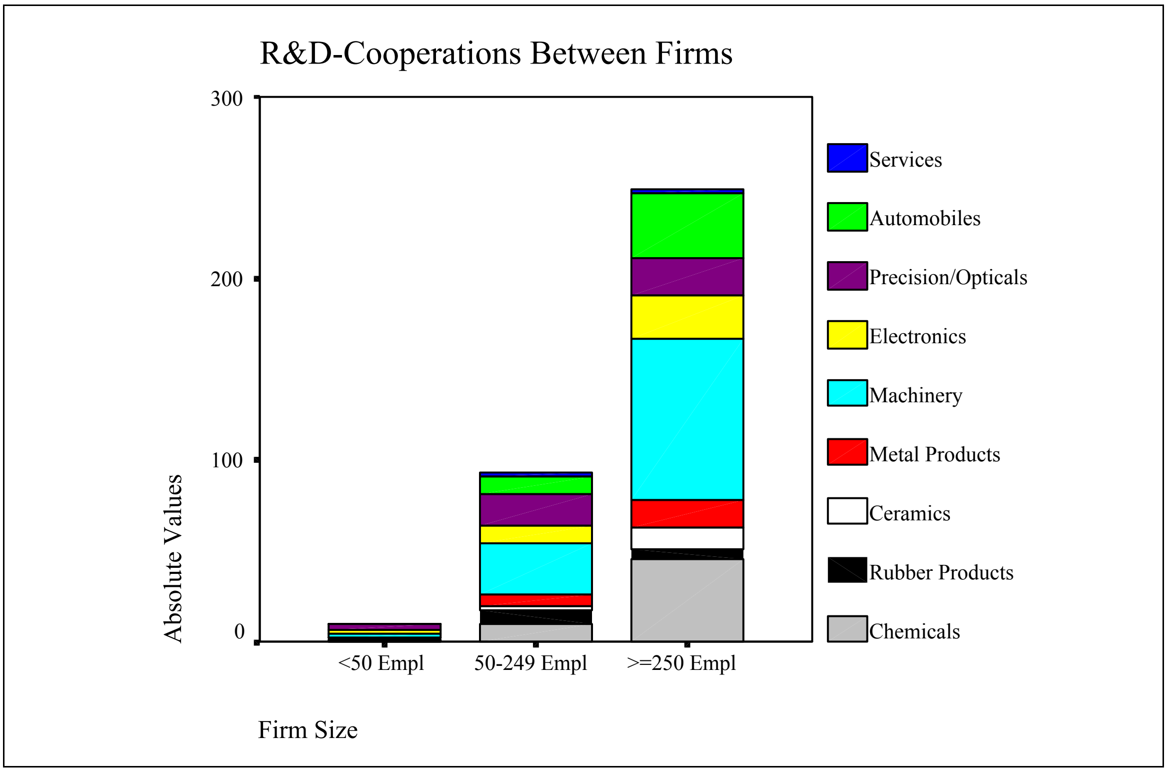
Zentrum für Europäische Wirtschaftsforschung (ZEW) (1998): Das Mannheimer Innovationspanel (MIP) 1993 - data and description, corrected 1998.

Appendix

Diagram A1:
Firm-Size and Industry Distribution







Source: MIP (1993), own calculations.

Table A1:
Classification of Industries:

Terminology in the text	Industry according to WZ 93 and NACE-Rev.1	2 digits accord. to WZ 93	ISIC-Classif[a]
Mining	Mining, minerals, energy and water supply	10-14, 40, 41	0
Food Products/ Textiles	Food manufacturing, Tobacco manufactures, textiles and wearing apparel	15, 16, 17, 18, 19	0
Wood Products	Manufacture of wood and paper products, printing and publishing; manufacture of furniture, jewellery, music instruments, sporting goods and manufacturing industries not classified elsewhere (n.e.c.)	20, 21, 22.2, 22.3, 36	0
Chemicals	Chemical industry;	24,	1
	mineral oil processing, manufacture of coal	23	0
Rubber Products	Manufacture of rubber and plastics	25	0
Ceramics	Manufacture of glass, pottery and earthenware	26	0
Metal Products	Manufacture of fabricated metal products	27	0
Steel Processing	Iron and steel basic industries	28	0
Machinery	Manufacture of machinery, weapons; electrical appliances and houseware n.e.c.	29	1
Electronics	Manufacture of office, computing and accounting machinery, radio, television and communication equipment	30, 32	2
	Manufacture of electricity distribution and control apparatus etc.	31	1
Precision/ Optical Instruments	Manufacture of medical appliances, appliances for measuring, checking etc.,	33	2
	Optical instruments, photographic equipment		1
Automobiles/ Aircraft	Manufacture of aircraft and spacecraft,	35.3	2
	Manufacture of motor vehicles, parts and accessoires,	34, 35.2	1
	Manufacture of transport equipment, n.e.c.,		0
Construction	Construction	45.2	0
Services b)	Data processing a. database, research and development, technical, physical a. chemical services,	72, 73; 74.3,	2
	Architecture- a. engineering,	74.2	1
	Recycling, metal waste and scrap	90	0

[a] ISIC-Classification, '0' represents non R&D-intensive industries, '1': high-level technologie, '2': R&D-intensive industries. – [b] Classification following the ISIC/SITC-Classification [Grupp and Gehrke (1994)].

Source: ZEW (1998), ISIC-Classification, UNIDO (1997).

Methodology:[27]

This analysis applied the Logit-model in order to examine the relationship between spillover effects and R&D-cooperations. It estimates the probability π_i that R&D-cooperations are formed ($y_i = 1$) when spillover effects arise. This general relationship can be written as follows:

$\pi_i = P\left(y_i = 1 | \underline{x_i}\right) = F(Z_i)$. Hereby, Z_i represents the sum of influences of the specific spillovers: $Z_i = \sum_{k=1}^{K} \beta_k x_{ik}$.

There, the x_{ik} stand for the spillover effects of the specific industry or group of firm-size respectively. In the analysis they are operationalised by multiplying the spillover variable with the respective industry- or firm-size-dummy. The β_k represent the coefficients that measure the impact of each spillover.[28]

Within this model the influence of the spillover effects is linked to the logit of the probabilities. This is given as the quotient of the probability that R&D-cooperations are formed and the probability that this is not the case. Thus, the general formulation of the regression model is as follows: $\ln\left[\pi_i / \left(1 - \pi_i\right)\right] = Z_i$.

From this, the probability for R&D cooperation given the specific spillover effects arise, is derived as:

$$\pi_i = F\left(Z_i\right) = \frac{e^{Z_i}}{1 + e^{Z_i}} = \frac{1}{1 + e^{-Z_i}}. \qquad (1)$$

By applying these general considerations to the analysis at hand the specification on the three steps of the procedure can be formulated as follows:

The regression models on the first step are:

for the industry-specific spillover effects: $\ln \frac{\pi_i}{1 - \pi_i} = \sum_{k=1}^{K} \beta_k x_{ik}$, k = 1,..,14, (2)

for the firm-size specific spillover effects: $\ln \frac{\pi_i}{1 - \pi_i} = \sum_{j=1}^{J} \beta_j x_{ij}$, j = 1,..,3. (3)

With respect to the precise specification on this first step, it is useful to enter the exogenous variables in the form of the factor-specification[29]. Thereby, all categories of the variables are included in the estimation model, instead of including a constant.

---

[27] This methodological appendix serves for an illustration of the description of the procedure in the text.

[28] In the Logit-model these parameters are estimated by the Maximum-Likelihood method. [Fahrmeir et al. 1996)]

[29] This term is chosen in analogy to the variance analysis [for a description see Fahrmeir et al. (1996).] A direct application of the variance analysis for the problem at hand however, is impossible due to the qualitative endogenous variable. See here also the argumentation in the text.

An OLS estimation of a linear combination of variables gives an unbiased estimator that is equivalent to the linear combination of the individual estimators. In the Logit-model the coefficients are estimated by the Maximum-Likelihood (ML) estimation method. The resulting estimators are biased, but consistent. When the number of observations is very large the estimators are approximately equal to the true value Therefore, the ML-estimator of a linear combination of variables can be expected to be optimal, at least approximately.

On the second step of the procedure the overall sample has been split into subsamples according to the groups of firm-size. Then, R&D-cooperations have been regressed on the industry-specific spillover effects by using equation (2) within each of the subsamples.[30] Within the sensitivity analysis the impact of each specific spillover effect is assessed by comparing the probability of R&D-cooperations when this specific spillover effect occurs with some reference probability. Both probabilities are calculated by applying equation (1) on the basis of the significant variables. Therefore, only the significantly estimated β_k and the x_{ik} for these significant variables enter Z_i in equation (1). For the calculation of the reference probability the unweighted means of all significant industry-specific spillovers are set as x_{ik}. Therefore, Z_i represents the average of the spillover effects. For the assessment of the influence of one specific spillover on the R&D-cooperations, the mean of R&D-cooperations is set as this specific x_{ik}. Thus, both the spillover effect as well as the R&D-cooperations are captured. Additionally, the other variables are still taken into account within the equation. However, by leaving their x_{ik} unchanged as the spillover means, their influence stays constant. The difference between the resulting probability with the reference probability finally measures the impact of this specific spillover on the formation of R&D-cooperations.[31]

On the third step finally, the influence of spillover effects has been separated from potential influences from firm-size or industry in general. Methodologically, this means that additionally to the specific spillover effects the industry- and firm-size dummies are included in the estimation model. Here it is more adequate to include a constant and to choose one of the categories of each variable as the reference category.[32] With respect to firm-size specific spillovers ‘small firms’ has been chosen for reference because of the low number of observations there. With respect to the industry-specific spillover effects it has been ‘mining’. The estimation equation can thus be written as follows:

$$\ln\frac{\pi_i}{1-\pi_i} = \alpha + \sum_{k=1}^{K-1}\beta_k x_{ik} + \sum_{j=1}^{J-1}\beta_j x_{ij} + \sum_{k=1}^{K-1}\gamma_k d_k + \sum_{j=1}^{J-1}\gamma_j d_j , \qquad (4)$$

There, x_{ik}, x_{ij} represent the industry- or firm-size specific spillover effects, and d_k, d_j the industry- or firm-size dummies respectively. k stands for the specific industry (K=14), j stands for the specific group of firm-size (J=3); α represents the constant and β_k, β_j and γ_k, γ_j represent the respective coefficients.

---

[30] According to Fahrmeir et al. (1996:258) the ML-estimator is consistent as long as the overall sample is converging towards infinity. See here also footnote in the Table 3.

[31] The reference probability is supposed to serve as a neutral scenario representing the case where no spillover effects arise. One more appropriate way to calculate this reference scenario would be to set the industry-means as the x_{ik} instead of the spillover-means. However, this was not possible in the analysis at hand. Some industry-means were bigger than the mean of R&D-cooperations. In these cases, there would have resulted a negative change in probability, compared to the reference probability, although the respective coefficient was highly positive. Another alternative reference probability is the relative frequency of R&D-cooperations as it is given in the data set. However, there is one argument in favour of the calculation method that has actually been used in the analysis at hand: By setting the spillover means as the x_{ik} all variables enter the calculation of both probabilities, the reference, as well as the spillover-probability. This makes a direct comparison of the two probabilities possible. [For an extensive description of the general procedure within the sensitivity analysis in a Logit model see Krafft (1997).]

[32] Therefore, the formulation is in accordance to the effect-specification of the multivariate variance analysis. [see Fahrmeir et al. (1996).]