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–The Influence of Market Structure–

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Abstract

This paper examines empirically the role of market structure for the influence of spillover effects on R&D-cooperations. The results of a microeconometric analysis, based on firm data on innovation, let in general presume that with intensified competition also the influence of spillovers on R&D-cooperation increases. However, competition seems to induce firms to search for effective firm-specific appropriation facilities first. Spillovers that are sufficiently high such that the internalisation effect from R&D-cooperation more than outweighs the competitive effect from research, only arise whenever firms are not able to protect their research results through any appropriation facility. Additionally, there is some evidence that spillover effects may even hinder firms from cooperating in R&D when there is intensive competition on the research stage.

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

Keywords: spillover effects, R&D-cooperation, competition, market structure, microeconometric analysis

1. Introduction

This paper examines empirically the incentive of firms to cooperate in R&D whenever they are not able to fully appropriate their research results. In contrast to previous theoretical and empirical papers, it mainly analyses which role market structure, essentially the intensity of competition, plays for the influence of spillover effects on R&D-cooperations.

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. Having in mind these external economies due to research, several lines in economic theory see spillover effects as purely advantageous. However, when the researching firm has to fear that its internal research may indirectly spur competitors' profits, it will retain from investing into R&D. On the aggregate, investment into R&D may be suboptimal. Economists are proposing cooperations in R&D as one means for solving this market-failure due to spillover-effects. The idea is that by co-ordinating R&D, the external effect is exploited and by exchanging research results, know-how is disseminated. However, firms actually have to have an incentive to bind themselves in such contractual arrangements in order to internalise spillover effects. According to the basic line of theoretical results the incentive for cooperations in R&D exists whenever spillover-effects are sufficiently high such that the positive internalisation effect of cooperation more than outweighs the negative competitive effect from investment into research.

By and large, the incentive to cooperate depends on the structure of the market where the firms are operating. On the one hand, the type and the intensity of competition on the product market and during the innovation process determine the extent of the competitive effect from research. Additionally, spillover effects themselves may intensify (potential) competition. As a consequence, the threat of potential competition induces firms to invest heavily into R&D; there may be a high incentive to internalise spillover effects within R&D-cooperations. On the other hand, there are some doubts whether firms, especially those that have been successful in building up high market power, actually have an incentive to cooperate in R&D. One reason is that high market power reflects efficient research and production. Therefore, this firm is not easily affected. Or, it may even fear to increase the probability of their competitors winning the race by passing on its internal research results via co-ordination.

This paper analyses empirically the role of market structure for the incentive to cooperate in R&D in order to internalise spillover effects. This is done using a logistic regression model based on firm level data on innovation. The analysis starts with a short discussion of the main theoretical arguments in chapter 2. After elaborating on some crucial methodological points, the presentation of the empirical results will follow in chapter 3. The paper will close with a final assessment of the role of market structure for the internalisation aspect of R&D cooperations.

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[1] arise whenever firms use know-how of another firm without the researching firm being able to control or influence the degree of this unintended knowledge transfer. 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. According to Tirole (1993:403-4) there is only limited incentive for this firm to develop and launch a new product whenever one firm has to fear quick imitation. 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 suboptimal 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.[3] Standard means to correct for the market failure due to spillover effects include R&D-subsidies and a stronger patenting system. However, subsidies have to be financed by taxes and may - according to Katz and

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1 This notion is equivalent to the notion 'technological spillovers' that Katz and Ordover (1990) use in order to distinguish the external effects due to lack of appropriability from the pecuniary external effect from research itself, which they call the 'competitive spillovers'.

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

3 Concerning the relevance of spilloves for economic welfare and growth see for instance, Krugman (1992), Leahy and Neary (1997), Grossman and Helpman (1991), and Coe and Helpman (1995).

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 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 clear how spillover effects are actually internalised by R&D-cooperations.[4] 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 respect, Katz and Ordover (1990:150) speak of 'competitive spillovers'.[5] 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

4 This analysis will concentrate on the empirical test of the general theoretical relationship between spillover effects and R&D-cooperation. 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 change significantly by these extensions. R&D-cooperations and spillover effects in an open economy are analysed by Leahy and Neary (1997).

5 Sometimes, the terminus 'business-stealing effect' is used, for instance in Konrad (1997) and König et al. (1994).

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, internal R&D reduces marginal costs of the competitor, too. Thus it increases the competitors' 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 to invest into R&D diminishes due to the external effect of spillovers in favour of the competitor. In contrast, when the firms are co-ordinating their R&D activities, they can exploit this external effect. Morasch (1994:52) names it the positive 'indirect efficiency effects': Synergies between the research projects are exploited and double research is prevented. According to the theoretical model, there is an incentive to co-operate whenever high spillover effects prevail.[6] In this case, the positive internalisation effect from cooperation more than outweighs the negative competitive effect from research.[7]

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. Furthermore, according to Kamien et al. (1992:1302) the binding agreements on both stages reduce the incentive for free-ri-

6 In d'Aspremont and Jacquemin (1998) the critical value is around 0,5. This means that half of the research results of one firm can be used by the other firm. Simulations by Morasch (1994) support this result.

7 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) and Scherer (1997). Morasch (1994) shows that also in oligopoly models 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.

der-behaviour. 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.

2.3 The Influence of Market Structure

The incentive to cooperate depends on the structure of the market where the firms are operating. On the one hand, the type and the intensity of competition on the product market and during the innovation process determine the extent of the competitive effect from research. Additionally, spillover effects themselves may intensify (potential) competition: They reduce production costs of the competitors, which again may alleviate market entry. Or, immediate technological spillovers may increase the probability with which the competitor succeeds with his innovation. As a consequence, the efficiency effect of R&D-investment comes into place. According to Tirole (1993:393), 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.[8] 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.[9] There, the innovation success is a priori uncertain; the probability to succeed depends upon recent and past investment into R&D of all competitors. In the end, 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. As a consequence, in models of patent races, threat of potential competition induces also the market leader to invest heavily into R&D. As a consequence, there may be a high incentive to internalise spillover effects within R&D-cooperations. On the other hand, there are some doubts whether firms, especially those that have been successful in building up high market power, actually have an incentive to cooperate in R&D. One reason is that high market power reflects efficient research and production. Therefore, this firm is not easily affected. Or, it may even fear to increase the probability of their competitors winning the race by passing on its internal research results via co-ordination. In these cases, spillovers may even hinder firms from co-operating in R&D.

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8 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, especially if they are able to exploit economies of scale- and scope by networking and clustering. According to Mazzucato, spillover effects increase the probability for this leapfrogging.

9 See also Katz and Ordover (1990). For an overview of models of patent races see Reinganum (1989).

3. Empirical Analysis

3.1 Data Source and Definition of the Variables

We analyse the empirical relevance of spillover effects for R&D-cooperations with the help of a cross-sectional analysis, based on the Mannheim Innovation Panel (MIP), the German contribution to the Community Innovations Survey (CIS). In the set of 1993 all relevant data have been available simultaneously.[10] With respect to the choice of the variables, the analysis comes as close as possible to the theoretical considerations. First of all, the relevant data set comprises only firms for which there are data on R&D-cooperations with direct competitors.[11] Thereby, we estimated the internalisation aspect of R&D-cooperations by the help of a logistic regression model, i.e., the incentive for R&D-cooperations has been approximated by the probability with which firms cooperate in R&D. This is due to the fact that 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.

Secondly, in our analysis the capability to appropriate R&D-results is translated into the empirics by the help of firm data on the effectiveness of various appropriation facilities. By running a factor analysis the overall number of appropriation facilities could be reduced to three main groups: official measures like patents and registered designs, firm-specific measures like time lead, complex product design and secrecy, and finally, low fluctuation of qualified personnel[12]. In our view, the theoretical definition is best approximated when there is no means for knowledge protection that firms judge as really effective.[13] Within the MIP, the effectiveness of the various appropriation facilities has been measured on a scale ranging from 1 to 5 points. We then measured lack of appropriation of one group of appropriation facility as one minus the ratio between the total score actually achieved and the maximum score that is achievable within the respective group of appropriation facility. For instance, if firms judge patents

10 For a description of the MIP see ZEW (1998).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 cooperations.

11 In contrast, 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 does not reflect the competitive element of spillovers.

12 The terminology is similar to Harhoff (1997:348). The results of the fatcor analysis are given in the appendix.

13 In contrast, König et al. (1994) see spillovers arising whenever firms judge ‘firm-specific appropriation facilities’ as effective in protecting internal research results, since – in their view - the latter directly reflects the reaction of the firms to an ineffective patenting system. Despite of the appeal of this view, no high and significant negative correlation could be found between high effectiveness of firm specific appropriation facilities on the one hand and ineffective patenting system on the other hand.

as very effective (score =5) and registered design as medium effective (score=3) the spillovers due to the patenting system takes the value 1-((5+3)/10). Finally, the indicator for overall spillovers is a weighted average of the spillovers due to the three main groups of protective facilities.

Table 1 gives an overview of spillover effects in various industries.[14] For instance, in the data processing and electronics industry some 30 per cent of research results cannot be appropriated on average, whereas about 51 per cent can not be appropriated through the patenting system. According to these descriptive results in table 1, the critical value of spillovers that resulted from the theoretical model of d'Aspremont and Jacquemin fits to the assessment of firms as long as it concerns the patent system. In contrast, it looks like as if firm-specific appropriation facilities are much more capable to protect knowledge as compared to the patenting system. Therefore, firms presumably use firm-specific appropriation facilities as a reaction on insufficient patent protection – similar to the basic assumption in König et al. However, the role as well as the effectiveness of the various appropriation facilities differ between industries. For instance, the result of Mansfield prevails again, where patenting was found to be relevant for pharmaceuticals, chemicals and mineral-oil processing, while they had only limited relevance in industries like office machinery.[15]

Table 1: Knowledge spillovers in manufacturing industries

	General	Type of appropriation facility		
		Patents	Firm-specific	Personnel
Mining	0,49	0,68	0,51	0,28
Wood products	0,37	0,59	0,33	0,19
Food and Textiles	0,35	0,57	0,30	0,18
Ceramics	0,36	0,55	0,31	0,21
Steel and Metal products	0,36	0,53	0,35	0,20
Precision /optical instruments	0,32	0,52	0,27	0,15
Rubber products	0,30	0,52	0,25	0,16
Electronics	0,33	0,51	0,30	0,16
Automobiles and aircraft	0,31	0,49	0,29	0,15
Chemicals	0,29	0,46	0,25	0,16
Machinery	0,30	0,46	0,28	0,17

Source: Mannheim Innovation Panel 1993.

With respect to market structure, we have chosen indicators following the concept of the 'optimal intensity of competition'. According to Kantzenbach[16] this is given within a wide oligopoly, i.e., a market that is characterised by a relatively small number of firms, thus with relatively high concentration, but that is open for potential competition.

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14 The classification of the industries is given in the appendix.

15 Cited from Geroski (1995). With regard to appropriation conditions, and thus with respect to the relevance of spillover effects see also Symeonides (1996).

16 Cited from Berg (1993: 245).

As indicators we use therefore firstly, the level of the Herfindahl-Index of 1993 measuring the absolute level of concentration, and secondly, the average rate and the range with which concentration as well as the number of firms within an industry have been changing since the end of the seventies, indicating intensified and potential competition. These are given in Monopolkommission (1996). Due to differences in the industrial classification, the Herfindahl-index that fits to the classification in the MIP is a weighted average of the Herfindahl-indices of the industries at three-digit-level. The weights are the number of firms of the respective industry on the three-digit-level relative to the total number of firms of the aggregated industry on the MIP-level. An additional indicator for potential competition is directly given within the MIP. There, firms have been asked to assess the previous and the expected intensity of competition within the output market where they are operating.

According to table 2, the criteria for the optimal intensity of competition are mostly fulfilled by precision and optical instruments and data processing and electronics. Very competitive industries are further on steel and metal products, wood and paper products, and rubber products. With respect to rubber products and data processing and electronics, the enormous change and variation in the number of firms indicate a market that is open for potential competition. In contrast, chemical industry, and automobiles and aircraft are industries characterised by stable concentration, i.e., that are not very affected from (potential) competition.

Table 2: Concentration and Competition in Manufacturing

	Herfindahl-Index				Change in firm number			Concentration	Competition
	Level	Std.Dev	Change	Std.Dev	Std.Dev	Change	Std.Dev		
Machinery	2,2	46,5	-1,4	42,8	7,3	1,9	4,3	-	+
Food/textiles	4,8	9,6	-1,9	11,9	4,2	-0,5	4,2	-	-
Steel/metal	6,2	41,3	-11,1	14,8	6,0	1,0	5,1	-	+
Rubber products	6,9	16,1	-6,5	7,5	10,7	4,1	4,9	-	+
Wood/paper	8,0	12,3	4,5	12,2	6,0	-1,0	5,0	-	+
Ceramics	12,10	4,6	-1,5	5,0	9,7	-2,0	4,0	-	-
Precision/ optical	15,0	15,8	4,0	18,1	5,5	-1,3	3,4	+	+
Chemicals	33,9	6,4	-1,7	5,7	2,5	0,2	2,1	+	-
DP/electronics	60,6	7,9	1,7	12,4	12,0	4,1	5,1	+	+
Auto/aircraft	99,8	5,1	0,2	5,2	6,0	-1,3	4,6	+	-
Median	12,1	12,3	3,5[a]	11,9	6,0	1,7[a]	4,6		

[a] Median of the absolute values; light shading stands for values below, dark shading for those above the mean value.

Source: Monopolkommission (1996).

Table 2 only describes the market structure on the German product markets. However, additionally intensive international competition may be expected in some industries, especially in electronics and data processing, and automobiles and aircraft. With respect to the latter, Hammes (1994) and Graves (1996) explain the competitive pressure with 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, intensive competition in automobiles additionally results from the extremely high fixed costs for R&D in times of shrinking product life cycles. Thus, immense investment into R&D has to pay for itself within increasingly shorter time periods. Table 2 can also only indirectly account for competition on the research stage of the innovation process. Competitive scenarios that are similar to models of patent races however, may prevail in R&D-intensive industries like machinery, chemicals and especially automobiles and aircraft, data processing and electronics, and the precision and optical instruments industry.

The role of market structure for the internalisation effect of R&D-cooperations then has been analysed by looking at the effect that spillovers have - given they are interacted with market structure. The idea behind is that high incentives to cooperate in R&D may be expected whenever firms are faced with spillover effects as well as intensive competition. In detail, the role of market structure is first of all, indirectly analysed by testing for differences in the probability for R&D-cooperations due to spillovers arising in industries that are charcterized by intensive competition. Alternatively, we directly interacted the spillover variable with dummies for market structure. Here, due to correlations among the individual indicators for market structure which are sufficiently high such that they bias parameter estimation, but too low to allow an interpretable factor analysis, we have selected the Herfindahl-Index, the change in the number of firms and the intensity of expected competition, since they can be seen as best indicators for the above mentioned characteristics of the optimal intensity of competition.

However, table 1 together with table 2 let presume that spillovers may be interrelated with market structure. This raises the question of exogeneity of the explanatory variables. On the one hand, spillovers may intensify (potential) competition. Thus, the variables for market structure may not be seen as exogenous anymore, but are rather determined by spillovers. However, one can presume that spillover effects do not dramatically influence market structure within one single period. On the other hand, just the other way round, spillover effects themselves may be determined by market structure and may not be exogenous anymore, since firms that are faced with intensive competition may try to prevent spillovers from arising. This problem has been solved by explicitly taking into account that these firms may first choose among the different appropriation facility, especially those that are different from the patenting system, before they decide about participating in R&D-cooperations. Thus, we asked whether the fact that the level of spillovers depends on the type of appropriation facility accounts for different influences of spillovers on R&D-cooperations.[17] As a consequence, in the

[17] With this, we implicitly ask for the ‘true’ spillovers for which the theoretical relationship between spillovers and R&D-cooperations is valid.

case where firms are able to protect knowledge through some mechanism spillovers have no or only low effects on R&D-cooperations, despite intensive competition; except, these alternative appropriation facilities are as ineffective as the patenting system.

Finally, we included several controlling variables that may determine the innovation process and thus, the propensity to cooperate in R&D. These are industry and firm-size dummies as well as impediments for innovations. With respect to the latter, by running a factor analysis we were able to reduce the various impediments for innovations into four main groups: first, factors like costs and risks related with innovation projects, second, government regulation or slow administration, third, lack of internal capital or insufficient access to external financing, and finally, what we called ‘linkages’; these comprise problems that arise due to lack of willingness to innovate within the individual firm or at the side of suppliers and customers, or that arise due to insufficient access to relevant information.

3.2 Empirical Results

Whether there is empirical evidence for the hypotheses above can be seen from the following results. Thereby, the first part focuses on possibly different influences of spillovers on R&D-cooperations, depending on the specific industries or on the degree of concentration and competition. The second part then asks for different influences of spillovers on R&D-cooperations taking into account that the level of spillover depends on the type of appropriation facility. Here again, we analyse both, spillovers in various industries as well as interacted with the indicators for market structure.

Spillovers, Market Structure and R&D-Cooperations at First Glance

In general, one can presume from the results in table 3 that the incentive to cooperate in R&D increases with the degree of competition when spillover effects arise. R&D-cooperations are strongly encouraged by spillover effects in machinery, in automobiles and aircraft, data processing and electronics, and in precision and optical instruments. Furthermore, highly positive and significant coefficients of spillovers prevail in the competitive industries machinery and especially in the precision and optical instruments industry, as well as when spillover effects are interacted with the intensity of competition. However, noticeably significant coefficients prevail also in industries that are – according to table 2 - not at all characterised by intensive competition, i.e., in the food and textiles industry, and in the chemical industry. Instead, spillovers in very competitive industries like rubber products, data processing and electronics, and automobiles and aircraft do not show significant influences.

There are mainly two reasons that may account for these results: Firstly, intensified competition may lead to a scenario where the competitive effect is too high to be counterweighted by the reduction of the research cost within R&D-cooperations. In that case, the individual firm facing intensive competition may be induced to search for effective means other than the patenting system to protect knowledge. As a consequence, spillovers are low, and when firms do not cooperate each firm has – like Shy (1996: 233) describes it – ‘a lot to gain from R&D since under small spillover effects, the R&D intensifies the cost advantage of the firm that undertakes a higher level of R&D’. From table 1 we have seen that firms that are not able to protect their research effectively through patents and registered designs may search for more effective appropriation facilities. Accordingly, insignificant coefficients let presume that spillovers do not arise because of effective firm specific appropriation facilities. Therefore, although spillovers may have a strong influence on R&D-cooperations whenever they arise in competitive industries, the coefficients are not significant due to the low number of firms that are not able to appropriate at all.

Second, insignificant but highly positive coefficients in the case of automobiles and aircraft, and data processing and electronics may be due to the fact that firms operating in these industries have generally a high incentive to cooperate in R&D. According to Hammes (1994), industries like electronics, chemicals, automobiles, and machinery show a high degree of cooperation anyway[18]. He justifies this with three properties characterising these industries: They use technology intensively, they have a global orientation, and firms in these industries are producing complex and differentiated products. One of the most convincing arguments in favour of cooperations is the flexibility that allows firms to handle changing and country-specific needs. The significant coefficient when costs or risks are hampering innovation may additionally speak in favour of this presumption.

The drastic influence of spillovers in the chemical industry together with the significant coefficient of the Herfindahl-Index for R&D-cooperation – without spillovers - reflect a result in Gerybadze et al. (1997) that is similar to the one just mentioned: They point at the increasing tendency of firms within the chemical industry to specialise on specific technologies within R&D. Especially dominant firms within the chemical industry have been intensively outsourcing R&D-units to producers that are specialised in the specific competencies. 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.

[18] Hammes (1994:216-7) 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. See here also Hagedoorn (1997).

Table 3: Spillovers, Market Structure and R&D-Cooperations

Number of observations	616	616
Deviation [a)]	40,39	251,13
Correct Classification (in per cent)	60,71	79,22
Influencing variables [b) c)]	Exp(ß) [d)]	Exp(ß) [d)]
Industry-specific spillovers		
Food/textile	3,77	
Machinery	1,61	
Chemicals	2,59	
Automobiles/aircraft	1,17	
Data Processing/Electronics	1,42	
Rubber products	0,84	
Ceramics	0,82	
Steel/Metal products	0,46	
Precision/optical instruments	1,56	
Wood products	1,11	
Interaction spillovers – market structure		
Herfindahl		0,77
Change in firm number		0,73
Expected intensity of competition		1,43
Indicators for market structure		
Herfindahl	1,21	
Change in firm number	0,95	
Expected intensity of competition	1,03	
Firm Size		
Medium		0,42
Large		0,84
Impediments for innovation		
Linkages	0,85	0,91
Costs and risks	0,92	1,27
Government	1,04	1,13
Finance	0,89	0,82

[a] Difference between the Loglikelihood measure of the estimation without the exogenous variables and the estimations where the exogenous variables are included. The larger the value the better the fit of the model. - [b] To include firm-size or industry dummies in the first regression was not possible due to high correlations with some firm-specific spillovers. Instead market structure indicators are included. - [c] In the second regression, additionally industry dummies have been included. They showed significant influences except for steel and metal products. - [d] Dark shading is equivalent with a significance level of 95%, light shading with 90% significance.

Source: MIP 1993, Monopolkommission (1996), own calculations.

The Internalisation Effect Reconsidered

According to the results in table 4, the incentive to cooperate in R&D depends crucially on the type of appropriation facility that firms use to protect knowledge. These results make clear that the true spillovers, i.e., spillovers that are sufficiently high such that R&D-cooperation is profitable, only arise whenever also firm-specific appropriation facilities are not effective. This can most of all be seen from the strong and significant coefficients when spillovers arise due to lack of appropriation from firm-specific means as compared to coefficients of spillovers due to an ineffective patenting system. It looks like as if firms trade-off between the returns from 'internalising' research by keeping it secret etc., and the return from internalising it by coordinating R&D with competitors.

Table 4: Industry-specific spillovers and R&D-cooperations – various appropriation facilities

Number of observations	620	622	639
Deviation	26,79	53,66	20,54
Correct Classification (in per cent)	59,35	62,54	60,72
Influencing variables [a)]	Exp(ß)	Exp(ß)	Exp(ß)
Industry-specific spillovers	Patents	Firm-Specific	Personnel
Food/textile	1,18	4,70	1,67
Machinery	1,64	1,76	0,99
Chemicals	1,67	3,03	1,23
Automobiles/aircraft	1,02	1,10	1,23
Data Processing/Electronics	1,20	1,25	1,69
Rubber products	0,67	2,53	0,67
Ceramics	0,92	1,22	0,62
Steel/Metal products	0,59	1,00	0,57
Precision/optical instruments	1,22	2,11	1,37
Wood products	1,12	1,64	0,79
Indicators for market structure			
Herfindahl	1,24	1,13	1,20
Change in firm number	0,98	0,93	0,96
Expected intensity of competition	1,03	1,03	1,02
Number of observations	620	622	639
Deviation	251,08	258,29	259,61
Correct Classification (in per cent)	79,03	78,46	79,19
Interaction spillovers - market structure			
Herfindahl-index	0,81	0,80	0,94
Change in firm number	0,92	0,87	0,72
Expected intensity of competition	1,08	1,65	1,27
Firm-Size			
Medium	0,42	0,41	0,44
Large	0,84	0,87	0,86
Impediments for innovation			
Linkages	0,92	0,93	0,93
Costs and risks	1,26	1,26	1,28
Government	1,13	1,15	1,17
Finance	0,85	0,83	0,85

[a] In the first three regressions impediments for innovation had the same values, but have not been significant. In the second three regressions additionally industry dummies have been included. Coefficients were similar to the ones from the regressions in table 3.

Source: MIP 1993, own calculations.

This latter presumption seems to be even more relevant when the intensity of competition is taken into account. R&D-cooperations are significantly influenced when spillovers arise in machinery, rubber products, precision and optical instruments and – to some degree – also in data processing and electronics, thus, in industries that are characterised by intensive competition. Additionally, it is the interaction between spillovers on the one hand and the expected intensity of competition or the change in firm number on the other hand, that influences significantly the incentive for R&D-cooperations. Finally, especially the result in data processing and electronics, precision and optical instruments, and in rubber products point out that the trade off between R&D-cooperations and alternative appropriation facilities becomes more relevant with increasing competition. Only when firms are not able to protect their research through appropriation facilities other than the patenting system spillover effects are sufficiently high such that the internalisation in cooperations outweigh the competitive effect from research which has been increased due to intensified competition. Therefore, until now, the results speak in favour of the presumption from the theoretical considerations: the threat of potential competition may induce also the market leader to invest heavily into R&D. As a consequence, there may be a high incentive to internalise spillover effects within R&D-cooperations.

However, there is also some evidence for the hypothesis that in industries that 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. Most of all this can be seen from the relatively weak and insignificant coefficients for automobiles and aircraft, and for data processing and electronics as compared to the strong and significant coefficients of the other industries – as long as firm-specific appropriation facilities are considered. 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 may judge R&D-cooperations as an additional channel through which internal knowledge can spill over to other firms.

4. Conclusion

The empirical results support in general the presumption that with intensified competition also the influence of spillovers on R&D-cooperation increases. Strong and significant influences of spillovers show up in competitive industries – most of all in precision and optical instruments, as well as when spillovers are interacted with indicators for the intensity of competition. However, competition seems to induce firms to trade off between alternative appropriation facilities and R&D-cooperations. True spillovers, i.e., spillovers that are sufficiently high such that the internalisation effect from cooperation more than outweighs the competitive effect from research, only arise whenever firms are not able to protect their research results through any appropriation facility. This can be seen from strong and significant coefficients whenever firms are not able to protect their knowledge through firm-specific appropriation facilities as compared to relatively weak and insignificant coefficients in the case of an ineffective patenting system.

There is also some evidence that spillover effects may even hinder firms from co-operating with other firms in R&D. Most of all this can be seen from the relatively weak and insignificant coefficients for automobiles and aircraft, and for data processing and electronics, as compared to the strong and significant coefficients of the other industries – as long as firm-specific appropriation facilities are considered. What precisely supports this presumption 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 industries one conclusion may be drawn which is different from the general 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, it may be backward sloping when there is already high pressure from competition on the research stage.

These empirical results let presume that one crucial assumption within the basic theoretical models of the relationship between spillovers and R&D-cooperations may not be fulfilled: In contrast to these modells, spillovers may not simply arise proportionally to the level of R&D produced within the economy; rather, they are endgenous; they are influenced by each firm's ability and decision to protect own and to use external knowledge; and the degree of (potential) competition seems to play a crucial role in this decision. Up to now, this results from a very simple empirical analysis. In future work, the relationship between spillovers and R&D-cooperations will have to take into account more explicitly – theoretically as well as empirically - the interdependencies between the level and the effects of spillovers and the intensity of competition or market structure in general.

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Appendix:

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, mineral oil processing manufacture of coal	24, 23	1 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 Manufacture of electricity distribution and control apparatus etc.	30, 31, 32	2 1
Precision/Optical Instruments	Manufacture of medical appliances, appliances for measuring, checking etc., Optical instruments, photographic equipment	33	2 1
Automobiles/Aircraft	Manufacture of aircraft and spacecraft, Manufacture of motor vehicles, parts and accessoires, Manufacture of transport equipment, n.e.c.,	34, 35	2 1 0
Construction	Construction	45.2	0
Services[b]	Data processing a. database, research and development, technical, physical a. chemical services, Architecture- a. engineering, Recycling, metal waste and scrap	72, 73, 74.2, 74.3, 90	2 1 0

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

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

Table A2: Results of the Factor Analysis 'Appropriation Facilities'

	Main factors		
Facilities	Patents	Firm-Specific	Personnel
Registered product design	0,754		
Secrecy product innovation		0,735	
Complex product design		0,667	
Patents product innovation	0,819		
Qualified personnel product innovation			0,800
Time lead product innovation		0,598	
Other rights	0,801		
Secrecy process innovation		0,725	
Complex process design		0,699	
Patents process innovation	0,831		
Qualified personnel process innovation			0,886
Time lead process innovation		0,574	

[a] Extraction Method: Maximum Likelihood. Rotation Method: Varimax with Kaiser Normalisation.
Source: Mannheim Innovation Panel (1993), own calculations.

Table A3: Results of the Factor Analysis 'Impediments for Information'

	Main Factors[a]			
Impediments	Costs/Risks	Regulation	Finance	Linkages
High risks of innovation	0,538			
Impediments within the firm				0,446
Lack of info about technology level				0,696
Lack of info marketing				0,703
Lack of info external know-how				0,787
Lack of cooperation with firms				0,566
Lack of cooperation with universities				0,519
Restrictive regulations		0,820		
Bureaucracy		0,858		
Lack of tax incentives		0,485		
Lack of innovation at customers				0,330
Control of innovation costs	0,506			
Lack of innovation at suppliers				0,372
Market not yet capable				0,332
Lack of internal capital			0,972	
Lack of outside capital			0,721	
High costs of innovation	0,796			
Amortisation of costs	0,787			
Imitation	0,479			
Lack of qualified personnel				0,384

[a] Extraction Method: Maximum Likelihood. Rotation Method: Varimax with Kaiser Normalisation.
Source: Mannheim Innovation Panel (1993), own calculations.