Why do firms choose different modes of vertical cooperation for innovation? Evidence from German Innovation Survey Data

Werner Bönte* Max Keilbach†

Abstract

Although important in practice, informal cooperations for innovation have been largely overlooked in theoretical and empirical literature. This paper investigates empirically factors determining the firms' decision to cooperate informally and/or formally using German innovation survey data. We found that high innovation costs tend to work in favor of formal cooperation, whereas knowledge spillovers and an early stage of industry life cycle increase the propensity to cooperate informally. Costs of forming cooperations decrease the propensity to cooperate formally. However, an increase in effectiveness of knowledge protection increases the probability to cooperate formally as well as informally.

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*Correponding author. Universität Hamburg, Von-Melle-Park 5, D-20146 Hamburg. E-mail: boente@econ.uni-hamburg.de

†ZEW, Postfach 10.34.43, D-68034 Mannheim. E-mail: keilbach@zew.de

1 Introduction

A growing body of theoretical industrial organization (IO) literature deals with firms' cooperative arrangements for innovation.[1] From a theoretical point of view the appeal of such cooperations is their capacity to overcome market failures which are associated with the production of knowledge.[2] Reviewing the existing literature which deals with spillovers in innovative activities, DeBondt (1996) states that some general tendencies among the various models exist. The models "agree", for example, that (symmetric) spillovers have a positive effect on cooperative efforts.

However, there are still some white spots in this field of research. First, theoretical literature has dealt almost exclusively with formal cooperations between competitors.[3] Only recently, cooperations between vertically related firms have been investigated by Banerjee and Lin (2001) and Inkmann (2000).[4] Second, empirical literture on the determinants of vertical cooperations for innovation is scarce. Notable exceptions are the studies of Cassiman and Veugelers (1999), Fritsch and Lukas (2001), Kaiser (2001) and Tether (2000). Third, informal modes of cooperation, like the informal exchange of technical knowledge, have been largely overlooked so far.[5]

The lack of literature on informal vertical cooperations is somewhat surprising since empirical evidence suggests that such cooperations are very important in quantitative terms. Using German innovation survey data Harabi (1997) reports that 84% of all innovating firms are engaged in cooperations with either customers or suppliers or both. Among these cooperation, the informal exchange of technical knowledge is the most cited mode of cooperation (over 65% of all respondents). In contrast, only a minority of firms answers

[1] See for example, Katz (1986), D'Aspremont and Jacquemin (1988), Kamien and Zang (2000), Kamien et al. (1992), Suzumura (1992) and Ziss (1994)

[2] See Arrow (1962).

[3] Usually research joint ventures (RJVs) are examined in the literature.

[4] In an earlier study, Steurs (1995) has analyzed inter-industry R&D cooperations. However, he has assumed perfectly segmented industries.

[5] A related strand of literature investigates the effects of voluntary knowledge spillovers between verically related firms. See, for example, von Hippel (1986) and Harhoff (1996). However, cooperative arrangements for innovation are not explicitely taken into account in this literature.

to have formal cooperations.[6] The latter result is not specific for Germany but has also been reported for other countries.[7] Moreover, informal cooperation is important in qualitative terms too. Harabi (1997) finds that informal cooperation was perceived the most important mode of cooperation whereas research joint ventures are regarded as the least important one.[8]

The contribution of this paper to the existing literature is threefold. First, we derive from existing theoretical IO literature three testable hypothesis which concern the impact of knowledge spillovers, innovation costs and costs of forming formal cooperations on firms' decision to cooperate. Second, we derive from the literature on *technological regimes*[9] a hypothesis concerning the relationship between the technological regime in which firms act and the firms' decision to cooperate. Third, we investigate empirically the factors determining the decision to cooperate informally and/or formally using German innovation survey data. In doing so, we distinguish between cooperations with suppliers and those with customers.

The rest of the paper is arranged as follows. In the following section, we discuss four hypotheses concerning formal and informal cooperations. Section three describes the data source, the construction of the variables and it provides some descriptive statistics. Section four explains the econometric specification and presents the estimation results. The final section summarizes the findings.

2 Vertically Cooperation for Innovation

In this section we will derive from existing literature three empirically testable hypotheses concerning the firms' incentive to engage in *formal* cooperations for innovation and discuss whether these hypotheses can also be applied to *informal* cooperations. Then, we derive a fourth hypothesis concerning the

[6]However, formal cooperations between vertically related firms clearly outnumber those between competitors (horizontal cooperations). See Inkmann (2000).

[7]See Tether (2000)

[8]Besides reporting on occurence of cooperation, firms have rated the importance of different cooperative modes for innovative activities.

[9]See Audretsch (1995) and Nelson and Winter (1982).

impact of industries' state of life cycle on the firms' incentive to cooperate informally.

In theoretical IO literature cooperative arrangements are usually modelled as cooperating firms' joint decision upon R&D investments.[10] Although these cooperations are called research joint ventures (RJVs) in that literature, it is useful to think of RJV's as a synonym for all kinds of formal R&D cooperations, like joint development teams or contractual R&D cooperations. Therefore we use the phrase formal cooperation instead of RJV in the following.

A large number of theoretical studies has investigated whether knowledge spillovers can have a positive effect on cooperative efforts.[11] The main message is that firms tend to choose cooperative R&D when the level of knowledge spillovers is high enough.[12] However, these studies exclusively deal with cooperations between competitors (horizontal cooperation). Recently, Inkmann (2000) has extended previous models by introducing a second, vertically related industry into the "traditional" one industry oligopoly framework and has found that vertical formal cooperations are the only stable equilibrium.[13] Inkmann's model implies "that firms have no incentive to chose any other cooperation form than the vertical cooperation scenario."[14] Although this extreme prediction is in conflict with reality, it provides one explanation for the fact that in practice the number of vertical cooperations is much larger compared with the number of horizontal cooperations. Thus, theory suggests that a higher level of knowledge spillovers increases the incentive for vertically related firms to collaborate in R&D and the following hypothesis arises

> *Hypothesis 1*: Higher levels of knowledge spillovers foster formal cooperations for innovation between vertically related firms.

Vilasuso and Frascatore (2000) show that a central result of the previ-

[10] See, for example, D'Aspremont and Jacquemin (1989).

[11] See Kaiser (2001) for a brief review of that literature.

[12] See de Bondt (1996).

[13] A related strand of literature investigates the effects of voluntary knowledge spillovers between verically related firms. See, for example, von Hippel (1986) and Harhoff (1996).

[14] See Inkmann (2000; p. 20).

ous theoretical literature on formal cooperations - the consistence of R&D cooperation under profit maximizing behavior and social optimality - may not hold when costs of forming a formal cooperation are taken into account. Social beneficial cooperations might not be established because of high installation costs. Their results suggest that public policy could, in principle, increase social welfare by subsidizing formal cooperation if costs of formal cooperations are relatively low. If, however, formal cooperations are very costly, public policy should encourage R&D competition rather than joint ventures. However, for very high spillover rates and moderate costs of formal cooperation the decisions of profit-maximizing firms may be also socially optimal. In that case the private benefits from spillovers are high enough to cover the fixed cooperation costs. Although their model deals with horizontal cooperations, it is obvious that costs of establishing formal cooperations are relevant for the formation of vertical cooperations too. Thus the following hypothesis arises

> *Hypothesis 2*: With increasing installation and maintenance costs, the propensity engage into formal cooperation with suppliers and customers decreases.

Recently, Banerjee and Lin (2001) have examined innovation costs as incentive of firms to form vertical cooperation. In their model an input supplied by an upstream monopolist is used by a downstream oligopoly to produce a final good. The upstream monopolist can decide to undertake a research project in order to produce a process innovation which will in turn reduce the firm's marginal cost of production. The downstream firms will benefit from the process innovation since they purchase the input at a lower price. However, the key point in their model is the assumption that the research project costs a fixed amount of resources. If these costs are very high, the upstream monopolist may find it profitable not to run the research project even if the total benefit (supplier and customers) of this project exceeds its costs. Thus, the monopolist does not take the pecuniary spillover into account.[15] Firms form a vertical RJVs in order to share the

[15]The market failure arises because the indivisibility of research projects. However, if perfect price discrimination were possible this problem would not arise.

costs of R&D and to internalize these pecuniary spillovers. Thus the following hypothesis arises

> *Hypothesis 3*: Firms that are engaged mainly in large scale R&D projects, which are characterized by high innovation costs, have a preference for formal research cooperations with customers (suppliers).

Another strand of literature emphasizes the relevance of technlogical regimes for innovation and is therefore relevant in the context of this analysis. The hypothesis of technological regimes has been put forward by Nelson and Winter (1982)[16] who classify different innovation modes that have been suggested by Schumpeter (1911, 1942). While Schumpeter (1911) saw creative destruction, i.e. the replacement of incumbent firms by new firms with superior performance as a major source of innovation and economic development, the later Schumpeter rather saw the innovation advantage on the side of large incumbent firms that act in a stable environment. The view of Nelson and Winter (1982) was that both innovation modes exist but that different industries can be classified into either of both according to the technological regime of the industry. Or, as Winter (1984, p.297) put it: "*An entrepreneurial regime is one that is favourable to innovative entry and unfavourable to innovative activity by established firms; a routinized regime is one in which the conditions are the other way around.*"

Audretsch (1995) has hypothesized that industries in different technological regimes also follow different innovation modes. In an entrepreneurial regime, innovation can be seen as a process of search of new technologies or products while in a routinized regime, innovation is rather incremental improvments of technologies or products along established technological trajectories (see also Dosi, 1988). The latter are often large scale projects.

We assume that the industries' innovation regimes have an influence on the mode of vertical R&D cooperation. We expect that firms belonging to an industry in an entrepreneurial regime, hence firms whose innovation process is mainly characterized by a search process, will rather engage into informal

[16] See also Winter (1984) and Audretsch (1991). Breschi, Malerba and Orsenigo (2000) and Audretsch and Fritsch (2001) give empirical evidence that supports this hypothesis.

but intense vertical cooperation. Firms who follow routinized patterns to improve existing technolgies will rather engage into formal cooperation. Thus the following hypothesis arises,

> *Hypothesis 4*: Firms in industries where the innovation regime is dominated by non-routine R&D (entrepreneurial regime) will have a higher propensity to engage in informal cooperations for innovation.

3 Data

3.1 Data Source

The data used in this paper are based on the first and the second wave of the Mannheim Innovation Panel (MIP) in 1993 and 1994.[17] These data were collected by the "Zentrum für Europäische Wirtschaftsforschung" (ZEW) and the "Institut für angewandte Sozialforschung" (infas).[18] We make use of both samples because the questionnaires contain different areas of information which are needed to test the hypotheses of the previous section. The questionnaire of the second wave contains questions related to different modes of cooperation for innovation between vertically related firms. The questionnaire of the first wave contains information on obstacles to innovation, like innovation costs, innovation risk and appropriability conditions. We have merged both samples at the cost of a reduction of observations. The original samples consist of 2860 (first wave) and 3065 (second wave) observations. After merging the number of observations is up to 4434 however with a large share of missing variables, depending on the question asked.

3.2 Construction of the Variables

Formal and Informal Cooperations: In contrast to other empirical studies we investigate the determinants of formal as well as informal modes

[17] The first part of the wave was part of the Community Innovation Survey (CIS) of the European Commission.

[18] Methods of this survey are described in detail by Felder et al. (1994).

of cooperation. The second wave of the MIP provides information about both modes of information. The surveyed firms were asked the following question:

> "*Cooperation with customers (suppliers) might have a special importance for your innovative activities. Which of the following modes of cooperation with customers (suppliers) have you had in your firm/line of business in the years 1991-1993.*"
>
> Possible answers were: *joint ventures, joint development teams, formal R&D cooperation, R&D orders and informal exchange of technical knowledge.*

We will differentiate between formal modes of cooperation, namely *joint ventures, joint development teams, formal R&D cooperation* and an informal mode of cooperation, namely *informal exchange of technical knowledge.* We exclude R&D orders because these are, in a strict sense, market transactions rather than cooperations. Moreover, in the following empirical analysis we do not distinguish between the remaining three modes of formal R&D but merge them into the variable "formal cooperation". This is procedure is supported by the results of Harabi (1997). Using multivariate statistical methods Harabi has found that the above mentioned modes of vertical cooperation can be reduced to these two subgroups.

Knowledge spillovers: In this paper we make use of a spillover measure that has been proposed by Cassiman and Veugelers (1999). This measure is based on the firms' perceived importance of publicly available information for the firms' innovative activities. In the first wave of the MIP firms rated the importance of a) patent information, b) specialist conferences and journals and c) trade fairs and expositions on a 5-point Lickert scale (from important (1) to unimportant (5)). Following Cassiman and Veugelers (1999), we have aggregated the answers and computed a firm-specific measure as well as an industry-specific measure.[19] The latter variable is measured as the average score at the NACE 2 digit sector level and provides information on the

[19] Aggregation has been done by summing the scores on each of the questions and rescaling the total score to a number between 0 and 1. The latter allows us to compare the coefficients.

importance of publicly available information within a certain industry. Of course, our indicator (publicly available information) represents only some of the many channels through which information spreads.[20] We think, however, that especially the industry-specific measure captures the idea of knowledge flows due to technology characteristics quite well.

Costs of forming formal cooperations: Theory predicts that costs of establishing formal cooperations play an important role for the firms' decision to cooperate. Installation and maintenance costs may include contracting, managing and monitoring costs. Since questionnaires do not contain direct information on these costs we make use of two indicators that are related to these costs, namely risk associated with innovations and appropriability conditions.

a) appropriability conditions: The costs of formal cooperations depend on appropriability conditions. The lower the level of appropriability conditions the higher the costs of cooperation which in turn reduces the incentive to cooperate. This may sound a little bit puzzling because we have argued above that a higher level of spillovers (lower level of appropriability) may increase the incentive to cooperate. However, it is less puzzling if one differentiates between incoming and outgoing spillovers. Cassiman and Veugelers (1999) postulate that firms do not only try to increase incoming spillovers but do also try to protect their own knowledge and restrict outgoing spillovers. One might argue that spillovers between customers and suppliers are not a great problem or may even be desirable.[21] However, firms may protect their knowledge for two reasons: First, the danger exists that their competitors get informed about relevant knowledge through the cooperation partner or as Cassiman and Veugelers (1999, p. 22) state it: "*competitors learn about their rivals through common suppliers and customers.*" Second, a low level of appropriability opens the opportunity for cooperation partners

[20] Another possible information channels is, for example, the movement of personnel. See Mansfield (1985, p. 221)

[21] See, for example, Harhoff (1996).

to extract the partners' knowledge and to benefit from free riding.[22]

In the first wave of the MIP firms rated the effectiveness of 5 protection mechanisms separately for product and process innovation on a 5-point Lickert scale (from 1 (very important) to 5 (unimportant)). Appropriability conditions are represented by two groups of mechanisms. The first group are *legal* protection mechanisms: patents, brand names and copyright. The second group are strategic protection mechanisms: secrecy, complexity and lead time in commercialization. Following Cassiman and Veugelers (1999), we have aggregated the answers and computed firm-specific measures as well as industry-specific measures.[23] Alternatively, Harabi (1999) makes use of factor analysis to construct firm specific measures of legal and strategic protection.

b) risk: It is likely that rist increases the cost of forming cooperations for innovation. The output of a cooperation and/or final costs of the cooperation are very uncertain.[24] A number of information asymmetries may then arise which create, for example, moral hazard problems. Under such circumstances it may be difficult or impossible to specify and enforce contracts.

In the first wave of the MIP one area of information concerned the factors hampering innovation. The following question asked:

> *"Please indicate the importance of the following factors hampering your innovative activity on a scale from 1 (very important) to 5 (unimportant)."*

Out of 13 possible answers we have choosen two for construction of an indicator variable of risk: a) innovation risk too high and b) difficulties in controlling innovation costs. Again, both measures have been aggregated to one variable as described above. However, innovation risk may not only increase costs but may also constitute an incentive for cooperation because

[22] Kesteloot and Veugelers (1994).

[23] Again, aggregation has been done by summing the scores on each of the questions and rescaling the total score to a number between 0 and 1.

[24] Chesnais (1988) emphasizes the importance of uncertainty due to unknown final cost of joint projects.

of risk sharing. If the cost effect is stronger than the risk-sharing effect we would expect to find a negative impact on the incentive to cooperate and vice versa.

Costs of innovation: Instead of a direct measure of innovation costs, which our data base does not contain, we use an indicator variable which represents the firms' perceived importance of innovation costs as an obstacle to innovation. The firms rated the importance of a) *low return to innovation expenditures because of high costs of the innovation* and b) *low return to innovation expenditures because of lasting amortization duration* on a 5 point Lickert scale (from important (1) to unimportant (5)). We have aggregated these answers and have rescaled the total score to a number between 0 and 1. We expect that this variable captures the impact of large scale R&D projects on the incentive to cooperate.

Non-routine R&D: In an entrepreneurial regime, innovation can be seen as a process of search of new technologies or new products where non-routine R&D dominates. One potential indicator for the non-routine R&D are innovation expenditures related to the invention and commercialization of new products. We proxy technological regimes by the firms' share of innovation expenditures that are spent on developing new products and markets. Two questions in the questionnaire of the second wave are related to this field. First, firms report on the share of innovation expenditures that is devoted to production tests, pilot projects and prototypes in their total innovation expenditures. Second, firms report on the share of innovation expenditures related to market tests and costs arising from introduction of new products into the market. We have computed the overall share of costs of developing new markets by the sum of these shares. We then have computed industry means of this measure in order to capture the industry-specific effect.

3.3 Descriptive Statistics

Tables 1 and 2 present the firms' judgements of the importance of different modes of vertical cooperation. Due to the occurence of missing variables, the

firms represented in these tables are only a subset of all firms in the sample. However we run different χ^2-tests on structural similarity of this subsample and the complete sample. In neither case, the Null of structural identity was rejected.

Table 1 shows firms that cooperate with suppliers. Several things are interesting to observe. First, the number of firms that engage in informal cooperation is very high compared to all other modes of cooperation, while RJVs are relatively unimportant (note that the questionnaire allowed for multiple entries). What is even more interesting, most of the firms that engage into RJVs do consider them as unimportant while approximately two third of the firms that engage in informal cooperations consider this form as important or very important. A similar pattern emerges for cooperation with customers (see table 2). This emphasises the quantitative and qualitative importance of informal research cooperations. Summary statistics of the variables used in the empirical analysis are given in table 3 (see appendix)

insert table [1] about here

insert table [2] about here

4 Econometric Specification and Estimation Results

To estimate the influence of the variables that have been discussed in section 2 we run two different types of regressions: *probit regressions* and *multinomial logit regressions.*[25] Both types of regressions are run for cooperation with customers and with suppliers respectively.

In line with previous empirical studies we make use of a binary probit regressions in order to test whether the variables of interest have an influence on the probability of engaging into formal or informal cooperation respectively.[26] This allows us to compare our results for formal cooperations with

[25]See Maddala (1983).

[26]See, for example, Cassiman and Veugelers (1999) and Tether (2000).

those of previous studies.[27] However, binary probit models may neglect relevant information.Firms cannot not only decide whether or not to cooperate but they can also decide to cooperate formally, informally or can cooperate in both modes. Therefore, we make use of multinomial logit regressions. We estimate the influence of the variables on the probabilites of choosing between alternatives 1: no cooperation, 2: informal cooperation 3. formal cooperation and 4: both (formal and informal cooperation).[28]

We have included three control variables: the logarithm of the firm size, measured as number of employees, a measure for the permanence of R&D and a dummy which takes the value one if a firm is located in Eastern Germany. The variable *Log of Firm Size* controls for effects of firm size which in previous studies have found to be relevant for cooperation. We would expect that larger firms are more likely to cooperate. Of course, we would also expect - and there is empirical evidence - that firms which are permanently engaged in R&D have a higher propensity to cooperate for innovation. East German firms may have a lower propensity to cooperate formally and maybe informally because of the transformation process. The first and the second wave of the MIP ask for cooperation in the years 1991-1993. At that time, research and cooperations networks in Eastern Germany changed drastically or vanished.

Results of probit regressions for cooperations with customers and suppliers are presented in tables 4 and 5. Here, we report estimates of changes in the probability for an infinitesimal change in each independent variable rather than regular coefficients.[29]

Knowledge spillovers do not have a statistically significant impact on *formal* cooperations between suppliers and customers. Thus, our results do not support *hypothesis 1* for formal cooperations. This confirms the results of Kaiser (2001) and Cassiman and Veugelers (1999) who have also found insignificant effects of knowledge spillover on formal cooperation between

[27] In these studies cooperation means that partners actively take part in joint R&D projects which is a definition that applies to formal cooperation but not informal exchange of technical knowledge.

[28] We assume that firms decide simultaneously upon cooperation for innovation and the mode of cooperation.

[29] Note, that for qualitative variables one should interpret this change with some caution.

vertically related firms.[30] However, our results suggest that spillovers positively affect *informal* cooperations with customers. The estimated coefficient of the industry-specific measure which captures knowledge flows due to technology characteristics is positive and statistically significant. Surprisingly, this coefficient is not significant for informal cooperation with suppliers.

Costs of forming cooperations seem to be relevant. Better appropriability conditions due to an increase in effectiveness of knowledge protection mechanisms increase the probability to cooperate formally and informally. This implies that the protection of knowledge is important for informal cooperations too. However, our results suggest that only strategic protection has a relevant impact. Firms that consider strategic protection of innovation as important engage more often in formal and informal cooperation with customers and suppliers. The significance level is somewhat higher for cooperations with suppliers. In contrast, firms' consideration of legal protection to be important does not increase their propensity to cooperate formally and informally. The sign of the estimated coefficient of the risk variable is negative throughout all regressions but is statistically significant only for formal cooperations with suppliers. This results provides weak empirical evidence of a negative effect of risk on cooperative arrangements. This clearly suggests that risk sharing is not a motive for cooperation with suppliers and customers. With respect to the effects of strategic protection and risk similar results have been found by Cassiman and Veugelers (1999). However, in contrast to our results they have found a positive impact of legal protection on formal cooperations. Results suggest that *hypothesis 2* cannot be rejected.

Innovation costs have a significant impact on the firms' propensity to engage in formal cooperation. Thus, *hypothesis 3* cannot be rejcted. The positive impact on formal cooperations confirms the results of obtained by Cassiman and Veugelers (1999) for Belgian firms. Cost sharing seems to be an important reason for formal cooperative arrangments between customers and suppliers. Regression results with respect to *informal cooperation* (last

[30]This is interesting because Kaiser (2001) has used a measure of vertical knowledge spillovers whereas the measure used in this paper and by Cassiman and Veugelers (1999) reflects public available knowledge in general.

2 columns of Table 4) differ in that the costs of the innovation projects do not have an influence anymore. One would expect an insignificant effect in the informal cooperation regression because such cooperations are simply not designed to share costs. Thus, we interpret this result as an additional piece of evidence that our specification is reasonable.

Our estimation results suggest that the *technological regime* in which a firm operates is relevant for its decision to cooperate informally. The share of innovation expenditures related to the commercialization of new products at the industry level increases the probability to make use of informal modes of cooperation. This is true for regressions for customers as well as suppliers which give support to *hypothesis 4*. Formal cooperations, however, are not affected by this variable.

The control variables have a significant impact. As expected, the probability of engaging into formal and informal cooperation depends positively on firm size. It is interesting to oberve that the influence of firm size is higher for the case of formal coopertions as compared to the case of informal cooperation. The probibility to cooperate informally and formally is positively affected by the permanence of R&D measures. This result may be viewed as support to the learning hypothesis of Cohen and Levinthal (1989) who have postulated that firms have to invest in their "absorptive capacity" in order to benefit from externally available knowledge. Moreover, firms in Eastern Germany engage significantly less into formal cooperation. As mentioned above, this may be due to process of transformation that has taken place in Eastern Germany during the observation period.

Overall, the regression gives strong evidence that it is large firms which engage into large innovation projects with long term horizons and which act in established markets that engage in formal cooperations with customers. In contrast, firms in industries where knowledge spillovers are important and firms in industries where a large share of innovation expenditures is spent for the developement of new markets have a higher propensity to cooperate informally with their customers. We interprete this as evidence that it is rather firms that act in entrepreneurial regime where innovation is partly a process of searching new products engage into informal research cooperations.

insert table [4] about here

insert table [5] about here

We now turn to the estimation results for the multinomial logit regressions. Note, that the absolute value of the estimated coefficients of the different modes of cooperation cannot be compared. They have to be interpreted relative to the coefficients of a comparison group.[31] Here, the comparison group are the firms that choosed informal cooperation exclusively.

As can be seen from tables 6 and 7 , the findings presented above are in general confirmed by the results of multinomial logit regressions. The estimated coefficients of group of firms that have *no cooperation* with customers and suppliers are significantly lower for the effectiveness of strategic protection and the share of innovation expenditures related to the commercialization of new products. The coefficient of knowledge spillovers is negative only in the regression for cooperation with customers. These diffences are statistically significant at usual significance levels. This implies that for high values of these measures the proability to be in the non-cooperation group is (much) lower compared to the probability to be in the group of firms that cooperate informally. All control variables - firms size, permanence of R&D and Eastern Germany dummy - are significantly lower.

For the group of firm that have *formal cooperations* exclusively only two coefficients in the regression for cooperations with suppliers are statistically significant at 5% and 10% significance level. These are the coefficients of the strategic protection and the innovation share variable. A higher level of the former has a positive effect on formal cooperation whereas the effect of the latter is negative. However, only a few firms have formal cooperatons exclusively. The bulk of firms use both modes of cooperation. The low number of observtions in this group may explain that estimated coefficients are statistically insignificant in general.

For the group of firms that make use of *both modes of cooperation* more significant results can be obtained. The estimated coefficient of the cost of innovation projects variable is higher compared to the group of informal cooperation. Again, the coefficient of the risk variable is only significant

[31] See Maddala (1983), pp. 41.

for the regression for coopertions with suppliers. This confirms the results presented above. The estimated coefficients of firm size and the permanence of R&D variable are also positive and statistically significant which implies that firms that make use of both modes are larger and are more R&D oriented compared with firms using informal cooperations solely.

insert table [6] about here

insert table [7] about here

5 Conclusion

This paper investigates the influence on firms' decision to cooperate formally and informally with their customers and suppliers. We first provide evidence that firms consider informal cooperation as highly important. We then have tested four hypotheses on the impact of knowledge spillovers, innovation costs, costs of forming cooperations and technological regime on firms' decision to cooperate informally and/or formally with their customers (suppliers). Our results suggest that in general, these hypotheses cannot be rejected. Hence there is empirical evidence that these factors determine indeed the decision to cooperate. However, their impact differers between informal and formal modes of cooperation. Thus, our results point out that it is relevant to distinguish between formal and informal modes of cooperation. In particular, our findings can be summarized as follows:

First, results suggest that knowledge spillovers tend to increase the probability to cooperate informally but do not affect formal cooperations. Second, costs of forming cooperations, which depend positively on appropriability conditions but negatively on risk, have an impact on the firms' decision. An increase in the effectiveness of knowledge protection mechanisms increases the probability to cooperate formally and informally. Surprisingly, the impact of legal protection mechanisms, like patents and copyrights, is statistically insignificant while strategic protection mechanisms, like secrecy, complexity and lead time, have a statistically significant positive effect. The sign of the risk variable is negative throughout all regression but statistically insignificant only for formal cooperations with suppliers. Thus, results provide only

weak support for the hypothesis that risk increases the costs of cooperations and reduces in turn the probability to cooperate. Third, high innovation costs are relevant for the formation of formal cooperation but not for the formation of informal cooperations. This result suggests that cost sharing is indeed an important reason for firms to cooperate formally. Fourth, results suggest that the propensity to cooperate informally with customers and suppliers is clearly increased by the share of innovation expenditures spend for the development of new markets measured at the industry level. In contrast, this variable does not have an significant impact on formal cooperations.

Viewed through the lens of the theory of technological regimes, our results would point out that firms may operate in industries with different technological regimes which follow different innovation modes. Our results suggest that firms that are engaged in a large scale R&D projects will choose formal cooperation with vertically related firms in order to share innovation costs. This can be interpreted as a routinized regime, where innovation rather consists of incremental improvments of technologies or products along established technological trajectories. In contrast, firms operating within an industries with spillovers and where the share of innovation expenditures devoted to market development are high operate in an entrepreneurial regime. These firms are more likely to engage into informal cooperations.

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Table 1: Number and Perceive Importance of Formal and Informal Modes of Cooperations with Suppliers

	RJV	FRDC	JDT	RDCT	InfCo	Other	Sum
very low	45	32	35	32	15	0	209
share	0.446	0.177	0.169	0.155	0.027	0.000	0.127
low	14	23	22	32	30	1	130
share	0.139	0.127	0.106	0.155	0.055	0.125	0.097
average	14	33	49	51	126	0	241
share	0.139	0.182	0.237	0.248	0.230	0.000	0.218
high	14	57	53	63	203	2	334
share	0.139	0.315	0.256	0.306	0.370	0.250	0.313
very high	14	36	48	28	175	5	322
share	0.139	0.199	0.232	0.136	0.319	0.625	0.244
sum	101	181	207	206	549	8	1236

RJV: Reempharch Joint ventures, FRDC: Formal Reempharch Cooperation,
JDT: Joint Development Teams, RDCT: R&D Contracts,
InfCo: Informal Cooperation

Table 2: Number and Perceived Importance of Formal and Informal Modes of Cooperation with Customers

	RJV	FRDC	JDT	RDCT	InfCo	Other	Sum
very low	60	41	36	52	17	3	209
share	0.465	0.189	0.162	0.423	0.033	0.100	0.169
low	22	30	23	20	34	1	130
share	0.171	0.138	0.104	0.163	0.066	0.033	0.105
average	20	45	46	18	110	2	241
share	0.155	0.207	0.207	0.146	0.214	0.067	0.195
high	17	58	59	19	173	8	334
share	0.132	0.267	0.266	0.154	0.336	0.267	0.270
very high	10	43	58	14	181	16	322
share	0.078	0.198	0.261	0.114	0.351	0.533	0.261
sum	129	217	222	123	515	30	1236

RJV: Reempharch Joint ventures, FRDC: Formal Reempharch Cooperation,
JDT: Joint Development Teams, RDCT: R&D Contracts,
InfCo: Informal Cooperation

Table 3: Summary statistics for data used in regression

Variable x_i	Mean	Std. Dev.	Min	Median	Max
Costs of Innovation Projects	0.533	0.285	0	0.500	1
Risk of Innovation Projects	0.484	0.253	0	0.500	1
Importance of Knowledge Spillovers	0.595	0.203	0	0.583	1
Imp. of Knowl. Spill. by Industry	0.589	0.049	0.426	0.592	0.670
Effectiveness of Strategic Protection	0.668	0.203	0	0.688	1
Eff. of Strat. Prot. by Industry	0.665	0.048	0.435	0.678	0.721
Effectiveness of Legal Protection	0.345	0.271	0	0.313	1
Eff. of Leg. Prot. by Industry	0.352	0.068	0.154	0.352	0.448
Log of Firm Size	5.092	1.808	1.099	5.056	12.085
Cost shares for Developing New Markets*	0.157	0.033	0.069	0.153	0.270
Permanence of R&D measures	0.628	0.491	0	1	3
Regional Dummy East Germany	0.313	0.464	0	0	1

Note: Number of observations: 788. * Share of innovation expenditures for developing new markets in total innovation expenditures

Table 4: Results of two Probit Regressions for Cooperation with Customers

	Formal Cooperation		Informal Cooperation	
Variable x_i	$\mathrm{d}P/\mathrm{d}x_i$	P-value	$\mathrm{d}P/\mathrm{d}x_i$	P-value
Costs of Innovation Projects	0.21068	0.005	0.06515	0.325
Risk of Innovation Projects	-0.04275	0.620	-0.02423	0.752
Importance of Knowledge Spillovers	0.19353	0.060	0.06133	0.507
Imp. of Knowl. Spill. by Industry	1.38272	0.094	1.91883	0.007
Effectiveness of Strategic Protection	0.23709	0.022	0.20570	0.020
Eff. of Strat. Prot. by Industry	-0.14733	0.826	-0.21448	0.708
Effectiveness of Legal Protection	0.02869	0.716	0.09035	0.193
Eff. of Leg. Prot. by Industry	-0.43830	0.469	-0.98774	0.085
Cost Shares for Developing New Markets	1.40323	0.095	2.85422	0.001
Log of Firm Size	0.03794	0.001	0.03230	0.004
Permanence of R&D	0.16023	0.000	0.16005	0.000
Firm is in Eastern Germany (0/1)	-0.08567	0.044	0.04442	0.231
Number of Observations	793		779	
LR $\chi^2(12)$	142.99		137.65	
P-value for LR-test	0.0000		0.0000	
Pseudo R^2	0.1338		0.1473	

Table 5: Results of two Probit Regressions for Cooperation with Suppliers

	Formal Cooperation		Informal Cooperation	
Variable x_i	$\mathrm{d}P/\mathrm{d}x_i$	P-value	$\mathrm{d}P/\mathrm{d}x_i$	P-value
Costs of Innovation Projects	0.17673	0.018	0.04236	0.522
Risk of Innovation Projects	-0.19312	0.022	-0.08945	0.240
Importance of Knowledge Spillovers	0.06459	0.518	0.01421	0.877
Imp. of Knowl. Spill. by Industry	0.80654	0.317	0.67743	0.321
Effectiveness of Strategic Protection	0.29137	0.005	0.24719	0.005
Eff. of Strat. Prot. by Industry	-0.23952	0.706	0.61989	0.257
Effectiveness of Legal Protection	0.10673	0.163	0.09827	0.159
Eff. of Leg. Prot. by Industry	-0.26432	0.656	-0.89205	0.118
Cost Shares for Developing New Markets	0.62534	0.441	3.08360	0.000
Log of Firm Size	0.04445	0.000	0.03228	0.003
Permanence of R&D	0.10908	0.011	0.15174	0.000
Firm is in Eastern Germany (0/1)	-0.18934	0.000	0.04209	0.250
Number of Observations	787		788	
LR $\chi^2(12)$	140.11		127.2	
P-value for LR-test	0.0000		0.0000	
Pseudo R^2	0.1353		0.1355	

Table 6: Results of Multinomial Logit Regression for Informal Cooperation with Customers vs. No Cooperation, Formal Cooperation or Both Cooperation Modes

	No Cooperation		Formal Cooperation		Formal and Informal Cooperation	
Variable x_i	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Costs of Innovation Projects	0.04220	0.918	0.49323	0.531	0.84469	0.020
Risk of Innovation Projects	0.05551	0.907	0.10568	0.907	-0.22925	0.587
Importance of Knowledge Spillovers	0.55419	0.340	-1.03260	0.331	1.10500	0.030
Imp. of Knowl. Spill. by Industry	-10.07823	0.021	1.38209	0.875	3.18355	0.443
Effectiveness of Strategic Protection	-1.22578	0.026	0.71507	0.522	0.33750	0.517
Eff. of Strat. Prot. by Industry	1.35300	0.704	-3.33736	0.644	-0.69173	0.847
Effectiveness of Legal Protection	-0.38002	0.387	-0.19792	0.809	0.18607	0.625
Eff. of Leg. Prot. by Industry	4.63204	0.189	4.81848	0.501	-1.05902	0.719
Cost Shares for Dev.New Markets	-15.23305	0.005	-10.51285	0.310	1.84113	0.652
Log of Firm Size	-0.13241	0.061	0.10281	0.414	0.15572	0.007
Permanence of R&D	-0.82687	0.000	0.55565	0.230	0.37513	0.078
Firm is in Eastern Germany (0/1)	-0.55746	0.015	0.08317	0.849	-0.56969	0.007
Constant	7.23471	0.001	-1.81283	0.667	-3.36800	0.110
Number of Observations					781	
LR $\chi^2(36)$					228.36	
P-value for LR-test					0.0000	
Pseudo R^2					0.1213	

Table 7: Results of Multinomial Logit Regressions for Informal Cooperation with Suppliers vs. No Cooperations, Formal Cooperation or Both Cooperation Modes

	No Cooperation		Formal Cooperation		Formal and Informal Cooperation	
Variable x_i	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Costs of Innovation Projects	-0.08161	0.835	0.35498	0.619	0.91659	0.018
Risk of Innovation Projects	-0.26017	0.567	-0.65883	0.411	-1.10640	0.013
Importance of Knowledge Spillovers	0.14387	0.791	-0.17826	0.845	0.54772	0.288
Imp. of Knowl. Spill. by Industry	-5.75785	0.150	-6.39213	0.388	4.45185	0.293
Effectiveness of Strategic Protection	-0.93807	0.070	1.80931	0.079	0.72206	0.188
Eff. of Strat. Prot. by Industry	-3.63574	0.285	-4.75817	0.404	-3.02404	0.400
Effectiveness of Legal Protection	-0.16823	0.691	-0.65798	0.378	0.63209	0.110
Eff. of Leg. Prot. by Industry	5.36563	0.108	8.64798	0.186	-1.10781	0.712
Cost Shares for Dev. New Markets	-15.71196	0.003	-19.61832	0.039	-0.56804	0.889
Log of Firm Size	-0.15764	0.020	0.10567	0.346	0.17090	0.004
Permanence of R&D	-0.71109	0.001	0.26348	0.518	0.20296	0.364
Firm is in Eastern Germany (0/1)	-0.67631	0.002	-0.92021	0.035	-1.18528	0.000
Constant	8.06697	0.000	3.71440	0.269	-2.06539	0.337
Number of Observations					787	
LR $\chi^2(36)$					242.83	
P-value for LR-test					0.0000	
Pseudo R^2					0.1247	