Concubinage or Marriage?
Informal and Formal Cooperations for Innovation

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Abstract

Based on a German panel dataset on firm innovation, we investigate importance of formal and informal modes of vertical R&D-cooperation and determinants of firms' decisions engage into such cooperations. We provide evidence that informal R&D-cooperation is the most relevant cooperation mode which contradicts theoretical suggestions. While there is only weak evidence for the relevance incoming spillovers, firms' ability to protect knowledge is a key determinant of formal and informal cooperations. Firms with R&D departments have a higher probability of cooperating formally while permanent R&D affects the decision to cooperate informally. Firms in industries with an intense development of new products have a higher propensity of cooperating informally.

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1 Introduction

Research partnerships between innovating firms have attracted great academic and political attention during the past decade. The organizational structure of such research partnerships is diverse. Innovation-based partnerships comprise formal as well as informal arrangements.[1] Formal cooperations, like Research Joint Ventures (RJVs), are typically characterized by an active participation of all cooperation partners in joint R&D. Since RJVs are often viewed as an efficient way of dealing with market failures in the innovation

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[1]See Hagedoorn et al. (2000) for a taxanomy of research partnerships.

process, they have been at the center of interest of theoretical and empirical literature.[2] In contrast, very little is known about informal partnerships. This may be due to the fact that it is difficult to quantify and to study them in detail because there are various forms of undefined arrangements which are informal in nature.[3]

This paper investigates empirically the driving forces of *formal* and *informal* cooperations between customers and suppliers for a sample of German firms. To do so, we pick up two ideas that have been presented recently by Cassiman and Veugelers (2002) (henceforth CV). First, CV distinguish between incoming and outgoing spillovers. Incoming spillovers increase the firms' stocks of knowledge which in turn may lead to product and process innovations. In contrast, outgoing spillovers may be a problem from the firms' point of view since low *appropriability* due to involuntary leakage of knowledge to competitors may reduce profits. Second, they postulate that cooperating firms try to "maximize the incoming spillovers *from* partners and nonpartners, while at the same time minimizing spillovers *to* nonpartners." (CV, p. 1169). Firms may use cooperations as a measure to maximize incoming spillovers. Cooperation partners, for example, may agree to share their knowledge.[4] However, even cooperating firms may have an interest to avoid involuntary leakage of knowledge because this would allow cooperation partners as well as nonpartners to free ride on each others R&D efforts.[5]

The bulk of theoretical literature on R&D cooperations has not taken these arguments into account. It is typically assumed that incoming and outgoing spillovers are symmetric and exogenous and firms may coordinate their R&D to internalize these spillovers (D'Aspremont and Jacquemin, 1988; DeBondt, 1996). Only a few studies incorporating knowledge sharing between competitors are based on models where firms can choose to fully share their knowledge.[6] Kamien et al. (1992) who first considered knowledge sharing between competitors as an explicit mode of cooperation have modeled different cooperation scenarios: firms can coordinate their R&D activities such as to maximize the sum of overall profits. The coordination of R&D efforts may be viewed as a metaphor for *formal* cooperations.[7] Sharing of technical knowledge without coordination of R&D

[2] A large body of theortical literature on Research Joint Ventures (RJVs) has focused on the impact of knoweldge spillovers on the performance of cooperating and non-cooperating firms (D'Aspremont and Jacquemin, 1988; DeBondt, 1996).

[3] See Hagedooorn et al. (2000, p. 569).

[4] Kesteloot and Veugelers (1995) show that knowledge sharing also reduces the incentives to defect from cooperation.

[5] However, outgoing spillovers to vertically related firms may be desirable. Harhoff (1996) shows that a monopolist supplier may have an incentive to contribute to downstream product improvements by creating knowledge spillovers since an expansion of downstream output will enhance the demand for the supplier's product.

[6] See, for example, Kamien at al. (1992), Kulti and Takalo (1998), Poyago-Theotoky (1999) and Kamien and Zang (2000).

[7] Kamien et al. call this "R&D cartelization" and "RJV cartelization". In the former scenario firm take

corresponds to *informal* cooperations.[8] From a social welfare point of view, the question whether firms cooperate informally and/or formally is highly relevant. For cooperations between competitors this has been pointed out by Kamien et al. (1992), Amir (2000) and Anbarci et al. (2002).

Recently, Atallah (2002) and Inkmann (2001) have extended the analysis to R&D cooperations between customers and suppliers.[9] Atallah reports that full knowledge sharing without coordination of R&D (informal cooperation) produces a lower welfare level as compared to knowledge sharing and coordination of R&D (formal cooperation).[10] Moreover, the results suggest that vertical coordination of R&D is more profitable than independent R&D if vertical spillovers exist. Thus, one would expect that vertically related firms would always choose to coordinate their R&D as long as formal cooperation is more profitable than non-coordination of R&D.

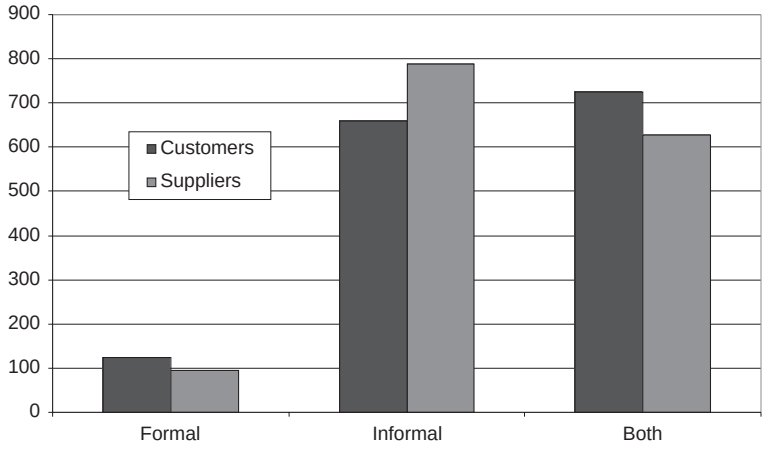

Figure 1: Firms' Choice of R&D-Cooperation with Customers and Suppliers

In practice, however, informal cooperations are a widely used mode of cooperation. Our data source, the Mannheim Innovation Panel (MIP), contains information about formal cooperation (RJVs, formal R&D cooperation and joint development teams) and informal cooperations (informal exchange of technical knowledge) with *customers* and *suppliers*.[11] As Figure 1 makes evident, the number of informal cooperations is much higher than the number of each of the formal modes of cooperation. Referring to the title of this study this suggests that most firms prefer concubinage while only a smaller fraction of firms prefers

spillovers as given while the latter scenario is characterized by full knowledge sharing.

[8] Kamien et al. call this form of cooperation "RJV competition".

[9] They introduce trade into the model of Steurs (1995) who has investigated cooperations between firms that belong to perfectly segmented industries.

[10] Atallah does not explicitely discuss informal cooperation but he analyzes a scenario with perfect vertical spillovers which is equivalent to full knowledge sharing.

[11] The Mannheim Innovation Panel from which our data are drawn does not contain information about informal cooperations with competitors or research institutes.

marriage and the latter typically engage into informal cooperations too. Moreover, the MIP data show that perceived importance to formal cooperation modes is low compared with the rating of informal cooperation.[12] Thus, it is worthwhile to investigate the factors that influence the firms' choice of cooperation mode.

Our paper contributes to the existing literature as follows: First, empirical studies on the relationship between appropriability conditions and informal cooperation do not exist so far. Previous empirical studies on cooperations for innovation have defined cooperative arrangements as "active participation of partners" in joint R&D (e.g. CV; Inkmann, 2001; Kaiser, 2002). Consequently, these studies focus on formal cooperations. Instead, our study aims at shedding empirical light on the determinants of both *informal* as well as *formal* cooperations. Second, we make use of alternative spillover measures. CV have used a measure of incoming spillovers that reflects publicly available information (e.g. patent information, specialized conferences, trade shows). The results of their empirical study suggest that incoming spillover do not affect vertical cooperations which is somewhat surprising since theory emphasizes the relevance of spillovers. We argue that their finding may be due to the measurement of spillovers. Their measure may not be appropriate to capture *specific* spillovers between vertically related firms which are important from the theoretical point of view. Customers and suppliers cooperate formally to internalize vertical spillovers (Atallah, 2002, Inkmann, 2001). Therefore, we make use of additional measures that capture vertical knowledge flows as measured by the importance of customers and suppliers as external information sources.

Our results suggest that firms' decision to cooperate is influenced by incoming spillovers, appropriability, organizational structure of R&D and industry characteristics. Incoming knowledge spillovers from customers have a positive effect on the decision to cooperate formally with customers. We find empirical evidence for a reverse effect of formal and informal cooperations on incoming spillovers. Appropriability is a relevant determinant of formal as well as informal cooperations. Firms will engage in vertical cooperations if they can protect their technological lead through strategic protection mechanisms, like complexity of product design. The organizational structure of R&D is relevant too. Firms that have R&D departments are more likely to be engaged in formal cooperation while the probability of cooperating informally is higher for firms that perform R&D on a permanent basis. We find that firms in industries which exhibit a high share of innovation expenditures related to the development of new products and new markets have a higher probability of cooperating informally with vertically related firms whereas formal cooperations are not affected by this variable.

The remainder of this paper is arranged as follows. Section 2 explains the empirical

[12]While roughly 30% of all firms consider informal modes of cooperation as being of high or very high importance, only 9% or less do so for formal modes of cooperation, research joint ventures being the least important mode of R&D-cooperation. See Harabi (2002) for similar obervations.

model. In section 3 we describe the data. Section 4 presents the estimation results. The final section summarizes the findings.

2 Empirical Model

We analyze the effects of incoming spillovers and appropriability on the firms' decision to cooperate with their customers and suppliers by estimating probit models. To do so, we specify the following two estimation equations for formal and informal cooperations:

$$\begin{aligned} Formal_i^* &= \alpha_1 + \beta_1 Spillover_i + \gamma_1 Appropriability_i \\ &\quad + \delta_1 Firm_i + \eta_1 Industry + u_{1i} \\ Formal_i &= \begin{cases} 1 & \text{if } Formal_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \end{aligned} \tag{1}$$

$$\begin{aligned} Informal_i^* &= \alpha_2 + \beta_2 Spillover_i + \gamma_2 Appropriability_i \\ &\quad + \delta_2 Firm_i + \eta_2 Industry + u_{2i} \\ Informal_i &= \begin{cases} 1 & \text{if } Informal_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \end{aligned} \tag{2}$$

where the variable *Spillover* represents incoming spillovers, the variable *Appropriability* reflects the firms ability to appropriate the benefits from its product and process innovations. Better appropriability means that firms can limit involuntary outgoing spillovers. In addition, we include other firm- and industry specific variables which may have an effect on cooperations. Table 4 on page 19 gives a concise description oth the data used. The index i denotes the i'th firm and u_{1i} and u_{1i} are error terms of the estimation equations. These equations can be estimated separately using a single equation probit model if the error terms are uncorrelated: $cov(u_{1i}, u_{2i}) = 0$. If they are, however, correlated this has to be taken into account. We assume that u_{1i} and u_{2i} follow the standard bivariate normal distribution and estimate a seemingly unrelated bivariate probit model.

The measure of incoming spillovers, which has been used by CV, reflects the importance of publicly available information (patents, trade shows, specialist conferences) for the firms' innovation process.[13] We argue that this measure captures more generic spillovers since it may comprise spillovers from competitors, other firms, research institutes or customers and suppliers.[14] Thus, we call it the generic spillover measure. Theory, however,

[13] See next section and table 4 in the appendix for a detailed description of the variables.

[14] Moreover, the generic measure takes into account only a few channels (patents, conferences) through which information spreads. It is likely, however, that other channels, e.g. movement of personnel from one firm to another, are important, too. See Schmutzler and Gersbach (2003).

suggests that formal cooperations between vertically related firms are fostered by *vertical* spillovers (see Atallah 2002, Inkmann 2001). Therefore, we introduce additional spillover measures that capture the vertical knowledge flows between customers and suppliers. We call these measures specific spillover measures. They are based on the beliefs of the firm's management about the importance of customers and suppliers as information sources for the firm's innovation process. We include both measures into the estimation equations.

Appropriability conditions are captured by two variables, one is industry-specific and the other is firm-specific. The industry-specific variable is legal protection of innovations as measured by the effectiveness of patents, brand names and copyrights in protecting process and product innovations. The firm-specific indicator of appropriability is the effectiveness of strategic protection mechanisms, like secrecy, complexity of product design and lead time in commercialization.

Like CV, we include three additional variables that may explain why firms enter into formal cooperations: innovations costs, innovation risk and complementarities. Vertically related firms may cooperate in order to share innovation costs of large scale R&D projects (Banerjee and Lin, 2001) or to share the risks of innovation. Another motive is the access to complementary knowledge. The availability of technical know-how within a firm may increase its attractiveness as a cooperation partner.

A firm's decision to cooperate is influenced by its R&D activities. We make use of two indicators which reflect the organizational structure of firms' R&D. We expect that a higher degree of organizational structure of R&D increases the probability of cooperating. The first indicator is dummy variable which takes the value 1 if a firm performs R&D permanently and 0 otherwise. Firms which perform R&D on a permanent basis produce permanently new knowledge which can be exchanged with vertically related firms. This facilitates a long lasting exchange of knowledge. The second one is a dummy variable that takes the value 1 if a firm has a R&D department and 0 otherwise. We suspect that firms with R&D departments have a higher probability of cooperating formally because the management of formal cooperations, like RJV's, joint development teams or formal R&D cooperation, requires a lot of organizational efforts. Legally binding contracts have to be written and enforced or some researchers have to be assigned to long term joint R&D projects. [15]

Industry characteristics may also be relevant for vertical cooperations. We make use of two industry-specific measures. To capture all unobserved industry-specific characteristics that influence the firms' decision to cooperate we include industry levels of informal and formal cooperation. Moreover, we try to investigate in further detail the industry charac-

[15] Alternatively, one could use R&D intensity as an indicator for firms' R&D efforts. However, for this variable endogeneity is very likely since theoretical models predict that cooperation leads to an increase in R&D efforts and empirical studies provide evidence for this hypothesis (Kaiser, 2002; Colombo and Garrone, 1996).

teristics that foster cooperative behavior. We expect that firms in industries with intense development of new products and markets have a higher probability of cooperating formally and informally since the development of new products may require cooperation with customers and suppliers. Therefore, we include the industry-specific measure of the share of innovation expenditures related to development of products and markets.

Other control variables which enter the estimation equations are firem size, measured ad the logarithm of the number of employees and a dummy that takes the value one if a firm is located in Eastern Germany and 0 otherwise. The first one controls for effects of firm size which in previous studies have found to be relevant for cooperation (CV, Kaiser 2002). The second accounts for idiosyncratic shocks that occured through the transition process in Eastern Germany at the time of observation.[16]

So far, we have argued that the level of incoming spillovers and appropriability may influence the firms' decision to cooperate. However, a reverse effect of formal and informal cooperations on incoming spillovers and appropriability may also exist since firms may "use cooperative agreement as a vehicle to manage knowledge flows" (CV p. 1173). Then, firms may form informal and formal cooperations in order to manage knowledge flows. Our data do not contain information about the *degree* of voluntary knowledge sharing. The only information we have is that there is voluntary knowledge sharing in informal cooperations but we can not say whether it occurs in formal cooperations.

Therefore, we follow CV and make use of a two step estimation procedure. The first step is the regression of the endogenous variables on instrument variables. The latter are those variables which are exogenous by assumption. The second step is the estimation of equations (1) and (2) using the predicted values of the potentially endogenous variables as explanatory variables. It is very likely that our measures of specific spillovers are endogenous with respect to cooperation. Firms may rate customers or suppliers as important external sources of information because formal and/or informal cooperations are important channels for the transfer of knowledge between vertically related firms. In contrast to CV we do *not* treat generic spillovers, appropriability and permanent R&D as endogenous variables.[17] Nevertheless, we have performed second stage regressions for these variables but we have not found any evidence for endogeneity.[18]

[16] In the second wave of the MIP firms reported on their vertical cooperations during the years from 1991 to 1993. At that time, a transformation process took place in Eastern Europe and research and cooperations networks in Eastern Germany changed drastically or vanished. Therefore, firms located in Eastern Germany can be expected to have a lower propensity to cooperate formally and informally.

[17] It is unlikely, for example, that the effect of cooperation is strong enough to let firms switch from non-permanent to permanent R&D.

[18] To save space we will not report the results. They are available from the authors upon request.

3 Data

The data used in this paper is based on the first and the second wave of the Mannheim Innovation Panel (MIP) in 1993 and 1994.[19] This data was collected by the "Zentrum für Europäische Wirtschaftsforschung" (ZEW) and the "Institut für angewandte Sozialforschung" (infas). 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. The original samples consist of 2860 (first wave) and 3065 (second wave) firms. We have merged both samples at the cost of a reduction of the number of observations. Due to missings the number is further reduced to 730 firms.

Cooperation for innovation: The second wave of the MIP provides information about different modes of cooperation. 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 differentiate between *formal* and *informal* modes of cooperation and we distinguish between cooperations with customers and suppliers. The variable reflecting *informal cooperation* with customers (suppliers) takes a value of 1 when firms reported that they had informal exchange of technical knowledge with their customers (suppliers) and 0 otherwise. The variable reflecting *formal cooperations* with customers (suppliers) takes a value of 1 when firms reported that they had joint ventures and/or joint development teams and/or formal R&D cooperation with their customers (suppliers) and 0 otherwise. We exclude R&D orders because these are, in a strict sense, market transactions rather than cooperations. The construction of the variable "*formal cooperation*" is supported by the results of Harabi (2002).[20]

Table 1 shows the firms in our dataset classified according to different modes of vertical R&D-cooperation. Wee see from columns 1 and 2 that only 3 to 4% of all firms engage into formal R&D- cooperation alone, while roughly 25% engage in *informal* cooperation alone. Another quarter of all firms engage in both, formal and informal cooperation. Some 40% of all firms in the dataset do not engage in any cooperation.

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

[20] Harabi (2002) reports that the above mentioned modes of vertical cooperation can be reduced to these two subgroups.

Table 1: Number of firms and their choice of modes of R&D-cooperation with Customers and Suppliers by firms in the sample

	Customers	Suppliers
No Cooperation	192	187
(share)	(0.263)	(0.256)
Only Formal Cooperation	26	23
(share)	(0.036)	(0.032)
Only Informal Cooperation	229	274
(share)	(0.314)	(0.375)
Formal and Informal Coop.	283	246
(share)	(0.388)	(0.337)
Sum	730	730

Incoming spillovers: The *firm-specific* measure of generic incoming spillovers is based on the beliefs of the firm's management about the importance of publicly available information (patent information, specialist conferences and journals and trade fairs and expositions) for the firm's innovation process. This measure avoids the difficulties of constructing spillover measures by "jointly measuring the extent of the pool of relevant knowledge and its productivity for the firm's innovation process" (CV, p.1171).[21] In the first wave of the MIP firms rated the importance of (1) patent information, (2) specialized conferences, meetings and publications, and (3) trade shows and seminars on a 5-point scale. Following Cassiman and Veugelers we aggregate the answers by summing the scores on each of these questions and the total score is re-scaled to a number between 0 and 1. We apply this form of re-scaling to all variables which are based on qualitative answers.

The measure for the spillovers from customers is based on the firms' rating of the importance of customers as information sources. In the questionnaire firms rated the importance of (1) suppliers of intermediate inputs and (2) suppliers of equipment on a 5-point scale. We have aggregated both answers by summing the scores of these questions. We acknowledge that these measures may not only capture voluntary and involuntary spillovers from customers (suppliers) but may also reflect knowledge flows that arise from market transactions, like R&D orders or licensing.

Appropriability: In the first wave of the MIP firms rated the effectiveness of protection mechanisms separately for product and process innovations on a 5-point scale. Appropriability conditions are represented by two groups of mechanisms. The first group are *legal* protection mechanisms: (1) patents, brand names and copyright. The second group are

[21] Kaiser (2002) and Inkmann (2000) have used external R&D capital stocks as spillover measures. However, this requires the estimation of firm (industry-)- specific R&D capital stocks and the computation of weights to aggregate them (see Griliches, 1992).

strategic protection mechanisms: secrecy, complexity and lead time in commercialization. The answers have been aggregated to variables appropriability and legal protection.

Cost and risk: In the first wave of the MIP one area of information concerned the factors hampering innovation. Firms rated the relevance of various factors hampering their innovative activities on a 5-point scale. Out of 13 possible answers we have chosen two for the construction of an indicator variable of risk: a) innovation risk too high and b) difficulties in controlling innovation costs. To construct an indicator for innovation costs we used the following answers: c) low return to innovation expenditures because of high costs of the innovation and d) low return to innovation expenditures because of lasting amortization duration.

4 Results

We will now present the results for the second stage regressions of equations (1) and (2), where the predicted values of the specific spillover variables are used to correct for endogeneity.[22] We treat cooperations with customers and suppliers separately since theory suggests that the incentives to cooperate with customer may differ from the incentive to cooperate with suppliers. In particular, the distribution of profits may be asymmetric between customers and suppliers. While vertical cooperation leads to an increase in joint profits, customers may benefit less from vertical cooperation than suppliers (see Atallah, 2002).[23] Tables 2 and 3 report on the estimated coefficients for formal and informal cooperations with *customers* and *suppliers*. The first and the second column of the tables contain the regressions which include the industry levels of formal and informal cooperations respectively while columns three and four contain regressions with the industry level of the share of innovation expenditures related to the development of new products and new markets. The positive and statistically significant correlations between the errors of both equations indicate that the bivariate probit model is appropriate in both cases.

First, we discuss the relevance of incoming spillovers for the firms' decision to cooperate formally and/or informally with their customers and suppliers. The estimated coefficient of the *generic* spillover measure is statistically insignificant for formal cooperations which confirms the findings of CV. In contrast, the estimated coefficient of the *specific* spillover measure is positive and statistically significant at the 10% level for formal cooperations with customers. This result is in line with the theoretical models, which predict that higher *vertical* spillovers provoke an increase in profitability of formal cooperations (coordination of R&D efforts) and in turn a higher probability of (formal) cooperation.

[22] We have also performed second stage regressions for the specific spillover measures. See appendix for a discussion of estimation results.

[23] The model predicts a relatively larger increase in R&D costs of customers. However, profits of suppliers and customers could be identical if firms decided to share joint profits.

Table 2: Results of two Bivariate Probit Regressions for Cooperation with Suppliers

	Cooperation		Cooperation	
	formal	informal	formal	informal
Incoming Spillovers (generic)	0.1434	0.2422	0.1253	0.2149
	(0.607)	(0.399)	(0.653)	(0.458)
Incoming Spillovers* (specific)	-0.7392	1.4223	-1.1168	1.8444
	(0.684)	(0.403)	(0.519)	(0.283)
Appropriability	0.7874	0.6606	0.7868	0.6834
	(0.002)	(0.006)	(0.002)	(0.005)
Industry Level Legal Protection	0.2350	-0.1893	0.0815	-0.5162
	(0.830)	(0.886)	(0.946)	(0.700)
Existence of R&D-Lab (0/1)	0.4773	0.0590	0.4994	0.0972
	(0.000)	(0.698)	(0.000)	(0.519)
Permamence of R&D (0/1)	0.0614	0.4968	0.0369	0.5081
	(0.724)	(0.003)	(0.829)	(0.002)
Cost of R&D	0.6183	-0.0234	0.6622	-0.0291
	(0.023)	(0.929)	(0.012)	(0.911)
Risk of R&D	-0.2540	-0.3739	-0.1787	-0.4301
	(0.480)	(0.285)	(0.605)	(0.222)
Complementarities	-0.0596	-0.1957	-0.0551	-0.2002
	(0.780)	(0.368)	(0.796)	(0.359)
Industry Level of Formal Cooperation	1.0334			
	(0.196)			
Industry Level of Informal Cooperation		2.0807		
		(0.002)		
Share of New Products on Industry Level			2.5042	8.6830
			(0.235)	(0.000)
Firm Size	0.1018	0.1150	0.1034	0.1197
	(0.002)	(0.001)	(0.002)	(0.001)
Firm is located in Eastern Germany (0/1)	-0.4254	0.0266	-0.4065	-0.0205
	(0.018)	(0.876)	(0.022)	(0.905)
Constant	-1.6949	-2.5121	-1.5420	-2.7564
	(0.072)	(0.004)	(0.091)	(0.002)
Wald $\chi^2(22)$		203.86		204.76
		(0.000)		(0.000)
$\hat{\rho}$		0.4926		0.4949
		(0.000)		(0.000)
Number of Observations		730		730

p-values in brackets denote probability of H_0 : parameter estimate equals zero.

** specific incoming spillovers are results from an instrument variable regression*

The difference between the results of CV and our results may be explained by the fact that the specific knowledge flows from customers comprise information about the customers' products (e.g. design) or production processes. However, the positive effect of vertical spillovers is restricted to formal cooperations with customers. Thus, our results provide merely weak evidence for the relevance of incoming spillovers. The probability of cooperating *in*formally is not influenced by incoming spillovers. Neither is the estimated coefficient of the generic spillover measure statistically significant nor is the estimated coefficient of specified spillover measure.

Next, we turn to the relevance of appropriability conditions. The coefficient of the appropriability measure is positive and statistically significant for informal as well as formal cooperations with suppliers. The same is true for informal and formal cooperations with customers (Table 3). Thus, a high effectiveness of strategic protection increases the probability of cooperating formally and informally with customers and suppliers. If a firm is better in protecting the rents from its product and process innovations through secrecy, complexity and lead time, it is significantly more likely that this firm cooperates with its customers and suppliers.

There may be two explanations for this result: First, effectiveness of strategic protections lowers the risk of free riding. Cooperating firms may fear that their technical knowledge leaks out to competitors via common suppliers or customers. Moreover, a low level of appropriability opens the opportunity for cooperation partners to extract the partners' knowledge and to benefit from free riding.[24] Firms will cooperate if they can avoid involuntary leakage of knowledge to partners or non-partners. Second, cooperating firms are technology leaders in their market and produce complex products. Cassiman et al. (2002) show that a leading technological firm has an incentive to make strategic investments to increase the complexity of the product or process design since this reduces the danger of imitation. Then, these firms may not have to fear that leakage of knowledge leads to an immediate imitation of their innovations by their competitors and in turn to an erosion of their profits. In both cases, a high degree of effectiveness of strategic protection is something like a prerequisite for vertical cooperations. Concerning legal protection mechanisms, like patents, copy-rights and brand names, our results suggest that these are not relevant for the cooperation decision. The estimated coefficient of industry-level legal protection is negative but statistically insignificant indicating that better appropriability conditions due to more effective legal protection of product and process innovations does not influence the firms' decision to cooperate formally or informally.

The evidence for other cooperation motives is mixed. Costs of innovation have a positive and statistically significant impact on the firms' decision to cooperate formally with customers and suppliers but do not influence the decision to cooperate informally. On

[24] Kesteloot and Veugelers (1994).

Table 3: Results of two Bivariate Probit Regressions for Cooperation with Customers

	Cooperation		Cooperation	
	formal	informal	formal	informal
Incoming Spillovers (generic)	0.3677	0.2856	0.3506	0.2877
	(0.180)	(0.312)	(0.199)	(0.310)
Incoming Spillovers* (specific)	1.9161	1.1908	1.9048	0.3084
	(0.068)	(0.171)	(0.079)	(0.736)
Appropriability	0.5395	0.5066	0.5219	0.5117
	(0.028)	(0.033)	(0.033)	(0.031)
Industry Level Legal Protection	-1.1864	-1.5901	-0.5622	-0.4827
	(0.278)	(0.235)	(0.621)	(0.705)
Existence of R&D-Lab (0/1)	0.4735	0.1398	0.5226	0.1925
	(0.000)	(0.351)	(0.000)	(0.195)
Permamence of R&D (0/1)	0.1655	0.3596	0.1649	0.3622
	(0.237)	(0.009)	(0.238)	(0.008)
Cost of R&D	0.4420	0.0520	0.4784	0.2300
	(0.079)	(0.831)	(0.057)	(0.342)
Risk of R&D	-0.2462	-0.1096	-0.2076	-0.0283
	(0.323)	(0.667)	(0.406)	(0.912)
Complementarities	0.2051	-0.2925	0.2233	-0.2937
	(0.331)	(0.181)	(0.288)	(0.179)
Industry Level of Formal Cooperation	1.6335			
	(0.006)			
Industry Level of Informal Cooperation		2.3280		
		(0.000)		
Share of New Products on Industry Level			2.5094	8.4749
			(0.229)	(0.001)
Firm Size	0.0795	0.0957	0.0780	0.0983
	(0.018)	(0.008)	(0.020)	(0.006)
Firm is located in Eastern Germany (0/1)	-0.2281	0.1489	-0.2495	0.1472
	(0.066)	(0.229)	(0.044)	(0.232)
Constant	-3.3817	-2.1515	-3.4474	-1.9796
	(0.000)	(0.000)	(0.000)	(0.000)
Wald $\chi^2(22)$		209.29		201.21
		(0.000)		(0.000)
$\hat{\rho}$		0.5596		0.5644
		(0.000)		(0.000)
Number of Observations		730		730

p-values in brackets denote probability of H_0 : parameter estimate equals zero.

** specific incoming spillovers are results from an instrument variable regression*

might expect this since the informal exchange of technical knowledge is not designed to share costs. The estimated coefficients of the measure of innovation risk and the measure of complementarities are statistically insignificant indicating that risk sharing and the search for external know-how are not relevant drivers of formal and informal cooperations with vertically related firms.

Firm characteristics play an important role for a firm's cooperation decision. Especially, the organization of R&D activities has an important impact on cooperative behavior. Firms that perform R&D on a permanent basis have a higher probability of cooperating informally whereas the existence of a R&D department has no influence. The results for formal cooperation are just the opposite. Here, the estimated coefficient of the dummy variable for the existence of a R&D department is positive and highly significant whereas the estimated coefficient of permanent R&D is statistically insignificant, once controlled for the existence of a R&D department. Firms with own R&D departments have the organization structure which allows them to manage formal cooperation while others may not. Although informal cooperations are less resource demanding, permanent R&D seems to promote them. Another important determinant for both modes of cooperation is the firm size.[25] Moreover, firms located in Eastern Germany have a lower probability of cooperating formally whereas informal cooperations are not affected by a firm's location.

Industry characteristics are important, too. The estimated coefficients of industry levels of formal and informal cooperation are positive and highly significant. Since these variables capture all unobserved industry-specific characteristics that affect the firms' decision to cooperate with vertically related firms, we do not know what these characteristics are. We have included an alternative industry-specific measure in order to shed some light on relevant industry characteristics. This is the industry level share of innovation expenditures related to the development of new product and new markets. Our estimations provide an interesting finding. Firms in industries where firms are engaged in the development of new products and new markets have a higher probability of cooperation informally with their customers and their suppliers. In contrast, formal cooperations are not affected by this industry-specific variable.

5 Conclusion

We have investigated the relationship between spillovers and vertical cooperation for innovation. In contrast to the existing literature we have investigated informal as well as formal cooperations. Moreover, we distinguish between the effects of incoming spillovers and appropriability. Our results suggest that incoming spillovers, appropriability, organi-

[25] Note, that the logaritm of employees is used as an indicator for firm size. A positive coefficient implies a nonlinear, concave, relationship. However, we have also included the squared term of the size measure but the estimated coefficient is statistically insignificant.

zational structure of R&D and industry characteristics are relevant determinants of firms' decision to cooperate. In particular, our study provides the following findings:

Incoming spillovers have a positive impact on formal cooperations with customers. This seems to contradict the results of CV, who report an insignificant effect of incoming spillovers on vertical cooperations. The difference between our finding and that of CV can be explained by the fact that we make use of alternative spillover measures and that we treat cooperations between customers and suppliers separately. Using the generic spillover measure, which they have used, we also find no evidence for a positive impact of incoming spillovers. However, our specific spillover measure that reflects spillovers from customers has a significant impact. This suggests that estimation results depend on the measurement of spillovers. Moreover, there seems to be a difference between cooperations with customers and suppliers, since specific spillovers from suppliers do not have any effect on formal cooperation with suppliers. Suppliers may have a higher incentive to cooperate formally with customers than the other way around if the profits from cooperation favor suppliers. Furthermore, our results provide some evidence for a reverse effect since cooperation with customers increases the relevance of customers as external information sources. This may indicate that formal cooperation comprises coordination of R&D as well as knowledge sharing. Our results suggest that informal cooperation are a relevant channel of knowledge transfer. The significant relationship between cooperation and specific spillovers as opposed to the irrelevance of generic spillovers may indicate that vertical cooperations are characterized by the transfer of very specific knowledge.

Appropriability is an important determinant of cooperations between vertically related firms. Firms with a highly effective protection of their technological lead have a higher probability of cooperating formally. This confirms the results presented by CV. Furthermore, we find that the effectiveness of protection mechanisms, like secrecy, complexity and lead time, is also a key determinant of informal cooperations. Our results suggest that a firm's ability to protect it's competitiveness seems to be something like a prerequisite for vertical cooperations. Especially technologically advanced firms, which produce complex products, do not have to fear the leakage of knowledge to competitors through common suppliers (customers), since their innovations can not be imitated immediately. This means that 'strong' partners cooperate formally and informally while 'weak' ones do not.

Firm and industry characteristics have an impact on the choice of mode of cooperation. Large firms engaged in a large scale R&D projects which have own R&D departments are more likely to choose a mode of formal cooperation with vertically related firms. Informal cooperation is also positively affected by firm size but a high degree of organizational structure of R&D is less important. However, firms that perform R&D on a permanent basis have a higher probability of cooperating informally. Furthermore, we find that firms in industries with an intense development of new products and new markets have a higher

probability of cooperating informally. In contrast, formal cooperations are not influenced by this.

As mentioned in the introductory section, theoretical models show that under welfare considerations formal cooperation between vertically related firms is more desirable than informal cooperation. Moreover, theory predicts that formal cooperations are more profitable than informal cooperations. Nevertheless, many firms choose to cooperate informally. Why this? Our results suggest that costs of cooperation may be relevant. Highly formalized cooperations are much more resource demanding than informal cooperations. Moreover, informal cooperation is a much more flexible mode of cooperation compared with formal cooperations. It allows a flexible transfer of specific and commercially sensitive information, e.g. information about new product design, new production processes or market development, without writing and enforcing contracts. Fix costs of formal cooperation may work as a threshold for firms which are willing to engage in formal cooperations. This may explain why the number of formal cooperations is considerably lower than the number of informal cooperations.

Future theoretical research dealing with knowledge sharing and R&D coordination should take into account the costs of switching from informal mode of cooperation to a formal mode of cooperation. This may also alter the welfare position of informal relative to formal cooperation. First steps in this direction have been made by Vilasuso and Frascatore (2000). However, their model is based on the assumption that knowledge sharing is costly but not R&D coordination. Our results do not support this assumption. From the theoretical point of view the issue of knowledge protection has only recently been developed by Cassiman et al. (2002). However, they investigate whether the inflow of knowledge (due to cooperation) increases strategic investments in protection but do not consider the influence of knowledge protection on the firms' decision to cooperate. Another interesting point is the stability of informal exchange of knowledge. Which factors reduce or increase the incentives to defect from informal cooperation? Future empirical studies could investigate informal cooperations between horizontally related firms, since the bulk of theoretical models is dealing with kind of cooperation. To our best knowledge no wave of the Community Innovation Survey (CIS) contains a question concerning the informal exchange of technical knowledge between competitors. However, such a question could easily be included in questionnaire. This would allow researchers to investigate whether R&D efforts of firms which cooperate informally are lower than those of firms with formal cooperations. Given the lack of industrial organization literature on informal cooperations and the practical relevance of this mode of cooperation fruitful research can be expect in the future.

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A Description of Variables

The following Table 4 gives a concise description of the variables.

Table 4: Description of Variables

Formal cooperation with customers	value=1, if firms have (1) joint ventures, or, (2) joint development teams, or, (3) formal R&D cooperation with customers.
Industry level of formal cooperation with cust.	Mean of formal cooperation with customers at industry level. Industry level is defined at 2-digit NACE.
Formal cooperation with suppliers	value=1, if firms have (1) joint ventures, or, (2) joint development teams, or, (3) formal R&D cooperation with suppliers.
Industry level of formal cooperation with supp.	Mean of formal cooperation with suppliers at industry level. Industry level is defined at 2-digit NACE.
Informal cooperation with customers	value=1, if firms have informal exchange of technical knowledge with customers.
Industry level of informal cooperation with cust.	Mean of informal cooperation with customers at industry level. Industry level is defined at 2-digit NACE.
Informal cooperation with suppliers	value=1, if firms have informal exchange of technical knowledge with suppliers.
Industry level of informal cooperation with supp.	Mean of informal cooperation with suppliers at industry level. Industry level is defined at 2-digit NACE.
Incoming Spillovers (generic measure)	Sum of scores of importance of following information sources for innovation process (number between 1 and 5): (1) Patent information, (2) specialized conferences, meetings and publications, (3) trade shows and seminars. (rescaled between 0 and 1)
Industry level of incoming spillovers (generic measure)	Mean of incoming spillovers (generic measure) at industry level. Industry level is defined at 2-digit NACE.
Incoming Spillovers from customers (specific measure)	score of importance of customers as information source for innovation process: number between 1 and 5, rescaled between 0 (unimportant) and 1(crucial).
Industry level of incoming spillovers (cust.)	Mean of incoming spillovers from customers at industry level. Industry level is defined at 2-digit NACE.
Incoming Spillovers from suppliers	sum of scores of importance the following information sources for innovation process (number between 1 and 5): (1) suppliers of material, and components, (2) suppliers of equipment. (rescaled between 0 (unimportant) and 1 (crucial))
Industry level of incoming spillovers (supp.)	Mean of incoming spillovers from customers at industry level. Industry level is defined at 2-digit NACE.
Appropriability	Sum of scores of effectiveness of following methods for protecting new products/processes (number between 1 and 5): (1) Secrecy for protecting products, (2) complexity of product design, (3) lead time in comercialization, (5) secrecy for protecting processes, (6) complexity

Continued on next page

Table 4: (continued)

	of process design, (7) lead time in adoption of processes. (rescaled between 0 (unimportant) and 1(crucial))
Industry level of Appropriability	Mean of appropriability at industry level. Industry level is defined at 2-digit NACE.
Size	log of employees in 1992
Permanent R&D	value=1 if a firm conducts R&D permanently
R&D department	value=1 if a firm has a R&D department
EAST	value=1 if a firm is located in Eastern Germany
Cost	Sum of scores of importance of following obstacles to innovation process (number between 1 and 5): (1) High costs of innovation, (2) pay back period too long. (rescaled between 0(unimportant) and 1(crucial))
Risk	Sum of scores of importance of following obstacles to innovation process (number between 1 (unimportant and 5 (crucial)): (1) High risk of innovation, (2) innovation costs hard to control. (rescaled between 0 and 1)
Complementarities	value = 1 - (importance of lack of technological information as obstacle to innovation

Note: Firms report about their formal and informal cooperations in the years from 1991 to 1993.

B Endogeneity of Incoming Spillovers and Appropriability

The results of second stage regressions of specific spillovers are reported in Table 5. As can be seen from this table, formal cooperations have a positive and statistically significant impact on spillovers from customers while informal cooperations have a positive and statistically significant influence on specific spillovers from suppliers. These results suggest, that spillovers from customers and suppliers are at least partly the result of voluntary knowledge sharing. Moreover, industry characteristics seem to be relevant. In both regressions specific spillovers measured at the industry level have a positive and statistically significant impact on firm-specific spillovers.

Table 5: Results of Regressions of Spillover Measures on a Set of Variables

	Incoming Spillovers from	
	Suppliers	Customers
Formal Cooperations with Suppliers*	-0.0235	
	(0.406)	
Informal Cooperations with Suppliers*	0.1586	
	(0.003)	
Formal Cooperations with Customers*		0.1032
		(0.002)
Formal Cooperations with Customers*		0.0212
		(0.450)
Existence of R&D-Lab (0/1)	-0.0044	-0.0481
	(0.878)	(0.101)
Permamence of R&D (0/1)	-0.1160	-0.0112
	(0.001)	(0.666)
Firm Size	-0.0172	-0.0081
	(0.037)	(0.218)
Specific Spillovers on Industry Level	0.4607	1.0792
	(0.027)	(0.000)
Share of New Products on Industry Level	-1.1507	-0.8287
	(0.025)	(0.070)
Constant	0.5517	0.1299
	(0.001)	(0.508)
R_c^2	0.0251	0.108
Number of Observations	730	730

p-values in brackets denote probability of H_0 : parameter estimate equals zero.

** Asterisks dentote that values are results from an instrument variable regression*