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REGULAR ARTICLE

Technological proximity and the choice of cooperation partner

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Abstract This paper provides empirical tests of hypotheses of cooperative behavior provided by evolutionary approaches in the resource-based view of the firm. The influences of "technological proximity", individual incentives to cooperate and managerial tools to the choice of research partner are analyzed. Using German patent data we can show the positive influence of those three determinants. The results of this paper confirm theories dealing with the path-dependency of research activities.

Keywords Innovation · Resource-based view of the firm · Cooperation · Technological proximity · Organizational know-how

JEL Classification C30 · L14 · O32

1 Introduction

Since the early twentieth century, views concerning firm development have been enlarged in several dimensions. First, Schumpeter (1911) stressed innovation as a driver of change and economic growth, and established a third economic growth factor besides labor and capital. His entrepreneur introducing new products into the market ousts existing industrial structures in a manner called "creative destruction". Drawing on these Schumpeterian ideas, more recently the innovative process has attracted intense research interest. Here, innovative

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activities, understood as the trail-and-error based creation and marketing of new knowledge—then incorporated in new techniques, products and processes—are affected by strong uncertainty (Nelson and Winter 1982). Due to its inherent nature, this new knowledge is fundamentally different from traditional inputs (Dosi 1988). As a consequence, an actor developing new know-how is not able to internalize it completely. Its tacit part is sticky to the firm, whereas the rest may spill over to other actors in the economy. This latter effect relies on the partly public good nature of knowledge in the sense of Arrow (1962).

Nearly at the same time as Schumpeter Marshall (1920) established the notion of "industrial districts", a conception that a firm's development depends on the industrial environment. Further research on cluster development, regional innovation systems and collective innovation have been built on these two lines of research. A constituent mechanism within these conceptions is firm cooperation in research and development, on a formal as well as an informal basis. In the past two decades this latter informal cooperation has become a more and more observed phenomenon which has led to the notion of innovation networks. Between market and hierarchical structure, this institution is often a project-based collaboration of independent partners. Following the stream of evolutionary economists (e.g., Nelson and Winter 1982; Dosi 1988), we consider this cooperative behavior, especially the choice of the cooperation partner, as based on the participating firm assets of routines or resources developing over time.

Comparing recent literature, the motivations to cooperate are rather dispersed. Beside the existing well analyzed determinants of cooperative behavior in the sense of who is cooperative or not (e.g., Combs and Ketchen 1999; Miotti and Sachwald 2003), in this paper we are interested in a motive for the beginning of such an agreement or cooperation, the participation in the tacit knowledge base. We concentrate on the determinants crucial for two partners coming together in such a research effort. Here, technological overlap as a basis of a common technological understanding, reciprocity as a prerequisite for knowledge exchange, and the expected value of research cooperation are the major determinants considered.

We proceed as follows. After an overview of the theoretical basis of our paper we examine hypotheses concerning the determinants for cooperative research. Section 3 presents the method applied and the data base. Section 4 then presents the regression results and suggests appropriate interpretations. Finally, we conclude with a summary of the results and an outlook on future research to be pursued.

2 Literature survey

This paper analyzes determinants affecting the choice of a research cooperation partner. This section is devoted to a brief overview of recent literature in order to derive hypotheses relating to the factors influencing and directing the search for a research partner. Doing so the paper is based on the theoretical perceptions of the *resource-based view of the firm* (RBV). This original Strategic Management approach gives a number of useful insights into dynamic processes, like cooperation agreements in the field of research and development. After a brief introduction to the RBV approach, we discuss research cooperations and the three essential criteria they have to fulfil.

2.1 Resource-based view of the firm

During the last 20 years, mainly Strategic Management oriented scholars have developed a resource-based framework, where the competitive advantage of a firm is due to attributes that are "costly-to-copy" (Conner 1991).

In the beginning, papers on the resource-based approach mainly focused on variables exogenous to firms influencing their competitive advantages (Foss et al. 2001, p. 7). Based on the oligopoly theory of Porter (1980), they examined structural forces external to the firm. Going back to its origins, this paper draws on Penrose (1959) and Andrew (1980) and the *resource-based view of the firm* (RBV) in a close perspective.

2.1.1 Roots of the theory

Concentrating on the development of a single firm, the resource-based view is an ontogenetic approach (Witt 2003). Drawing heavily on Penrose (1959), a firm is treated as a collection of productive resources. Here, resources are defined as "those assets that are tied semi-permanently to the firm" (Wernerfelt 1984, p. 173). For the term "resources" within an enterprise, various definitions have been presented in terms of assets, knowledge, capabilities and organizational know-how. Grant (1991) provides a classification of resources, distinguishing between tangible, intangible and personnel-based resources. Resources of tangible nature are assets of the firm like equipment, machines or financial capital. The intangible resources generating a competitive advantage to the firm are brands, image and product quality (Huang et al. 2006, p. 985). Technical know-how and other knowledge assets are included in the personnel-based resources. More common in recent literature is a classification which only distinguishes between tangible and intangible resources (e.g., Silverman 1999; Barney 2001). Using this classification the knowledge related assets are a part of the intangible resources. An intangible asset also includes knowledge of specific markets or customer groups, decision-making techniques and management systems (Mowery et al. 1998, p. 508). An additional classification of productive resources refers to the distinction between static and dynamic resources (Lockett 2001). As to the static ones, they are considered a given stock of assets that can be utilized appropriately over a finite time. Dynamic resources, contrariwise, evolve over time and constitute, for example, the learning capacity of a firm (Lockett 2001, p. 725) and thus can be used even more intensely over time.

2.1.2 RBV in economics

The resource-based view has its roots in the field of strategic management. Nevertheless, it is useful to fill in the gaps in economic theory, especially in evolutionary theory. The Schumpeterian economic view regards economic development as a "process of creative destruction" (Schumpeter 1911, chapter 8), where development is driven by new concepts and products. The Schumpeterian entrepreneur recognizes and exploits market opportunities and replaces former market structures. The incentive to innovate is the possibility of a temporary monopoly power. Thus Schumpeter contradicts Bain's theory that monopolistical power necessarily has negative welfare implications (Conner 1991, p. 127). Drawing on Nelson and Winter (1982) the ability of a firm to innovate or of an entrepreneur to penetrate the market depend on internal routines. These routines are developed in a historical and path dependent process, as described in Penrose (1959) for resources. The heterogeneity of actors, depending on the path-dependent process, can be explained by the resource-based view (Lockett 2001).

2.1.3 Criteria for resources

For analyzing cooperative behavior, we mainly deal with more or less intangible and dynamic productive resources of firms. We follow Combs and Ketchen (1999) and Lockett (2001) that the RBV is based upon the assumption that the sticky and hard to imitate resources determine the performance of a firm (Barney 1991), that they are crucial for competitive advantage, and that firms are aware of this relationship. According to Combs and Ketchen (1999), productive resources able to generate a sustainable advantage of the firm have to satisfy three criteria. First, they have to be *valuable*, that is, there exists a demand side which appreciates the resources' output. If those resources enable a firm to produce a certain product with a higher quality, a group of customers is required that is willing to pay the appropriate higher price. Second, an asset must be *rare* to be considered a productive resource in the sense of the RBV. Third, the resource has to be *specific* to a firm. Without a certain degree of uniqueness, a firm will not be able gain a competitive advantage over competitors (Combs and Ketchen 1999, p. 869). This specificity of a productive resource to the firm prevents easy imitation (Barney 1991). As a consequence, productive resources fulfilling these three criteria provide for *distinctive competencies* (Andrew 1980, p. 18), which themselves are often based on tacit knowledge and capabilities difficult to transform into tangible assets (Barney 1991).

How do firms built up such distinctive competencies? First, they engage in own R&D activities and by this generate new knowledge which adds to their competitiveness. Second, the RBV considers cooperative agreements between firms as another option providing access to the specific productive resources of potential cooperation partners. Those cooperative agreements are of a specific kind, allowing the transfer and exchange of knowledge.

2.1.4 *Implications for cooperative behavior*

Teece et al. (1994) argue in this respect that market transactions of productive resources such as knowledge are the more difficult to organize the higher their degree of tacitness. Tacitness, of course, inhibits imitation—which preserves innovation incentives—but it also prevents a deliberate and intentional market based transferring of knowledge (Mowery et al. 1998, p. 508). This problem of the failure or the not-existence of such "markets for knowledge and capabilities" can be solved by the institution of (formal or informal) cooperative agreements, seen as devices between markets and hierarchies.

Framed by the RBV approach, the institution of research cooperations as voluntary agreements between independent actors can be analyzed in several dimensions. In the next step, we examine on the basis of the RBV three central features a research cooperation has to fulfil: (1) a common technological understanding of the research partners, (2) reciprocity as an incentive to exchange knowledge, and (3) experience in running cooperative research projects. We will address these issues in turn.

2.2 Technological overlap in cooperative agreements

Drawing on the RBV, a firm's motivation to engage in a (research) cooperation is to get access to the productive resources, here knowledge, of the partner, who has a knowledge base different from the own one. For those cooperations to work, two conditions have to be fulfilled: first, the knowledge bases of the potential partners have to be different—otherwise nothing can be learned (Mowery et al. 1998, p. 511); and second, the partners need to have the capability to understand each other. The heterogeneity of the knowledge bases among the (potential) cooperation partners accounts for both of these requirements.

With respect to the required differences in knowledge bases, the argument runs as follows. Innovation is considered as being often the result of recombining already existing knowledge. The opportunities for recombination depend on the heterogeneity of the given knowledge base in the sense that, the more different knowledge bases are, the more new recombinations can be tried. Diversity and different knowledge structures augment the capability for making novel linkages and emerging innovations (Cohen and Levinthal 1990, p. 133). With respect to research cooperations, the learning effect of a cooperation agreement is reduced when firms want to absorb rather similar knowledge (Wersching 2005, p. 3).

However, following Nooteboom (2000), this heterogeneity of the knowledge bases in a research cooperation has to be sufficiently small to allow an understanding of the partners. This implies that the access and the internalization of the partner's knowledge is rarely costless and usually requires resources already existing in the acquiring firm (Barney et al. 2001). Those costs, learning costs, are the higher the more the cooperation partners differ in their respective knowledge bases. Assuming the more different the knowledge bases of research partners the higher these costs, the relation between heterogeneity and cooperative agreements now is contrary to the one above.

The reason is found in the relation between the existing knowledge inside the firm and the outside knowledge to be acquired and the notion of "absorptive capacities" introduced by Cohen and Levinthal (1990). Their approach deals with learning capacities on the organizational level of the firm that go *beyond what any one individual can achieve* (Cohen and Levinthal 1990, p. 133). Using cross-section data of the American manufacturing sector they find that the organizational absorptive capacity depends on former R&D expenditures inside the firm. Thus, the capacity to evaluate and use external know-how is largely a function of prior related knowledge (Cohen and Levinthal 1990, p. 128). The search for other knowledge which is in close relation to the own knowledge endowment reduces the uncertainty affecting the knowledge creating process (Dosi 1988). In a dynamic view, the close relationship between the accumulating absorptive capacity of a firm and the knowledge it is able to acquire leads to a (historically determined) path-dependency of productive resources, as emphasized by the RBV (Lockett 2001). Within this process, a higher internal knowledge base makes a firm more sensitive and more receptive for external technological opportunities.

Taking these two arguments together, we find that, while a sufficient degree of technological overlap ensures communication, diversity and different knowledge bases increase the opportunities for establishing new linkages and for the emergence of innovations (Cohen and Levinthal 1990, p. 133). Thus, there exists a trade-off between the better understanding of each other and the opportunity of creating something new (Wuyts et al. 2005). We assume that firms are aware of this problem when they are starting a research cooperation.

2.3 Incentive to cooperate

The impact of heterogeneity and technological overlap on cooperation probability and success stress the two-sided learning capability, on the one hand, and the potential of creating something new, on the other. However, these requirements for the structure of the knowledge bases are a necessary but not a sufficient condition for the potential partners to have an incentive to engage in a research cooperation.

When firms recognize cooperation potentials in the sense discussed above what is their incentive to engage in a research cooperation when they, due to the lack of an well established market for knowledge, cannot bill the partner for providing access to their knowledge? It is the exchange of know-how which is one key feature of a research cooperation agreement (Mowery et al. 1998). Seen in this way, a cooperation is a form of a voluntary knowledge transmitting process (Dosi 1988). Here, as both cooperation partners often (cooperation with public research institutes are unfortunately neglected here) act as market oriented firms, a cooperation needs to have a reciprocal incentive. Following Fehr and Gächter (2000), reciprocal organizational types often emerge in markets with incomplete contracts; the "market of knowledge abilities" with the intrinsic uncertainty is one example.

Thus, a cooperative agreement is no kind of an altruism oriented agreement. The latter is characterized by one unconditional kindness, while in the former, both cooperation partners engage in order to achieve access to some of the "sticky" knowledge (Fehr and Gächter 2000). Following the RBV approach, research cooperations are instruments achieving such accesses by reciprocity. Fehr and Gächter (2000) describe cooperation as reciprocal in a way that both partners are aware of the potential knowledge stock of the partner, but, in order to get access, they have to open their own stock. In addition, each cooperation partner will respond to friendly or hostile actions as long as the cooperation is a voluntary collaboration (Fehr and Gächter 2000, p. 160). Following this, in a research cooperation the involved actors have their specific incentives to engage in cooperation. The involved degree of reciprocity, however, depends not only on the amount of the individual incentives, but, following Sadrieh and Verbon (2002), also on the degree of inequality of these incentives. Actually, their paper deals with the impact of inequality on trust in a society. Bridging the gap to our research topic on cooperation phenomena, they conclude that trust includes reputation effects, that again enhance cooperation (Sadrieh and Verbon 2002, p. 2).

2.4 Organizational know-how

A cooperation is an organizational form between markets and hierarchy. Following Levitt and March (1988), organizational learning is target oriented and based on historical experience and stored in routines. Drawing on Nelson and Winter (1982), these routines are firm-specific resources. Concepts such as "learning by doing" and "learning by using" are based on experience from former actions (Prencipe and Tell 2001). Routines, as Nelson and Winter (1982) described, are dynamic capabilities within an organization (Zollo and Winter 2002) that need development over time. Realizing a research project cooperatively requires such organizational routines to handle the project. Dealing actually with project-based firms, Prencipe and Tell (2001) examined the importance of accumulated experience for imitation inside a project. We relate these findings to cooperative behavior as a project between two independent actors. The participation and transfer, according to the former statement, is described above as a core incentive for a firm to cooperate.

2.5 Hypotheses

The discussion above can be summarized in some testable hypotheses on the probability of actors/firms engaging in a research cooperation.

The first hypothesis dealing with the central question of this paper refers to the technological overlap and thus the technological proximity between cooperation partners. The two aspects of technological heterogeneity, cooperative potential and degree of common understanding, have to be taken into account. First, to absorb external technological know-how, both the sender and receiver of this know-how must have a certain common knowledge base. The larger this common base, the better the understanding, which in turn increases the probability of a common research project. This relationship is formulated in the following hypothesis, H1a:

H1a
With respect to a common understanding of potential research partners, the higher the technological overlap between them—compared to a sample of non-cooperating actors—the higher the probability that these partners will cooperate.

Second, however, firms looking for research partners face a trade-off. Being aware that novelty arises from the combination of different know-how a high degree of technological overlap between two firms reduces this potential and thus reduces their willingness to cooperate. Following this view, the technological knowledge used in cooperation has to have a certain degree of heterogeneity. Therefore, a firm's choice of cooperation partner includes the search of a knowledge base complementary but not identical to the own knowledge base. Hypothesis H1b refers just to this reasoning:

H1b
With respect to the innovative potential of a research cooperation, the incentive to choose a partner declines with the technological overlap between the partners becoming too large.

Combining these two aspect of technological overlap, the incentive to engage in a cooperation depends on the expected amount of knowledge transmitted within the cooperation. In addition, however, following the RBV approach, firms are willing to share their own knowledge in order to achieve that of the cooperation partner. Thus, it is also the reciprocal incentive which drives the incentive to cooperate and therefore the degree to which the exchange occurs on rather balanced terms. Hypothesis H2 combines this quantitative aspects of knowledge exchange:

H2
The higher and the more balanced the potential knowledge flows between two firms are expected to be, the higher the probability of a research cooperation between them.

Based on hypotheses H1a and H2, a cooperation between two independent partners is based on a technological overlap for a better understanding and a certain degree of reciprocal incentive. Reciprocal incentive here includes not only soft skills such as trust or fairness, but also some valuable knowledge that each partner has to offer. A combination of both, the technological overlap and the reciprocal incentive of knowledge transfer, can be interpreted as the value of cooperation. Cooperative agreements are more attractive if the value of the planned cooperation is relatively high. Hypothesis H3 refers to this relationship:

H3
The probability of firms to cooperate increases with the value of the prospective cooperation.

The organizational knowledge of how to manage a research cooperation is built up from experience gathered in former cooperations. This may help cooperative firms manage the problematic coordination of competencies and the assignment of duties. Therefore, firms are more likely to cooperate with each other if a certain degree of experience in cooperating has been accumulated. Hypothesis 4 represents this.

H4
Cooperation experience with a certain partner increases the probability to start a new cooperation with the same partner.

3 Methodology

3.1 Conception

In order to test the hypotheses above, we use patent data information on firms that applied to the German patent office between 1998 and 2003. Those applicants, who applied for a patent together with a cooperation partner in 2003, provide the basis of the paper. Using patent information for the years before 2003 allows us to characterize various technological relationships between firms. This information is then used to analyze bilateral cooperations starting in 2003.

We are aware of the problems using patent data. These data are suited to characterize the technological knowledge base inside a firm which might attract other firms for cooperation. Two qualifications, however, are obvious here. First, patent data do not represent the whole knowledge base of a firm, but rather are a reasonably good indicator. In this sense, patents satisfy the criteria Combs and Ketchen (1999) have claimed for competitive relevant resources. They are supposed to be rare, as well as valuable and specific in their nature. Therefore patent data at least indicate the technological competitive advantages a firm has. Second, other determinants influencing the choice of the cooperation partner likewise exist. Because of our broad German-wide analysis, we cannot include firm structure variables such as size, age or industry. Beside this theoretical justification of using patent data, Griliches (1990) showed that patents are a sufficient indicator for the innovative output of firms.[1] As an innovation is a knowledge driven phenomena, we conclude that without the necessary knowledge base a firm cannot file for a patent.

For taking account of the technological differences among firms we construct a measure of their technological proximity. To obtain this measure, we refer to the technological fields listed in each patent. These fields are categorized in

[1] For a deeper analysis of patents as innovative output, you can read, for example, Trajtenberg (1990), who has introduced a weighted scheme to overcome shortcomings of counting measures.

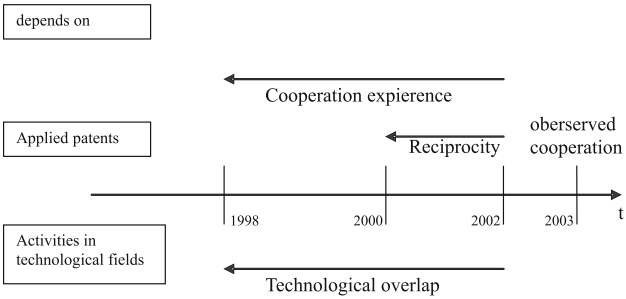

Fig. 1 Research concept

accordance in the International Patent Classification (IPC). IPC is a hierarchical system classifying technology by sections, classes, subclasses and groups. In order to reduce the widespread IPC classification with 7-digit classes, we use a concordance list developed by Schmoch et al. (2003) to convey the IPC classification into a NACE-code-oriented classification, containing 43 technological fields.

Using these 43 classes we construct indexes related to the technological proximity between any two firms or actors in the sample, the technological overlap (TO) and the reciprocal incentive (REC). In addition, we set up dummy variables on several dimension of the experience potential cooperation partners show. Figure 1 shows the time dimension of these variables.

The technological endowment of firm A in the database consists of her activities in the $n = 43$ technological fields (T_i^A) $i, i = 1, \ldots, n$ between 1998 and 2002 (see Fig. 1). As a measure the capability to learn from each other, the TO in a research cooperation between firm A and firm B is calculated from the activities over all technological fields:

$$TO_{A,B} = \frac{2 \times \sum_{i=1}^{n} \min(T_i^A; T_i^B)}{\sum_{i=1}^{n} T_i^A + \sum_{i=1}^{n} T_i^B}. \tag{1}$$

TO is twice the sum of all minimum activities of both partners divided by the sum of all activities of both partners. This value increases with an enlarging technological overlap and has a maximum value of 1, which means that both partners have the same knowledge endowment, and so the two-sided absorptive capacities are maximal.

Reciprocal incentive in a specific cooperation is given, if each partner's own knowledge is valuable for the other cooperation partner(s). Since a cooperation is a project the partners join voluntarily, a two-sided incentive in the cooperation has to exist before starting this project.

Using patent data to capture incentives to cooperate, we refer to literature arguing that cooperations are combinations of complementary assets. In order to account for this, we need to know more about the complementarity of the technology classes, which requires a more detailed analysis of the technology classes involved. However, we leave this consideration for further research and claim here that all patents and thus every knowledge new to the market is (equally) valuable to a potential partner.

In constructing a measure of reciprocal incentive, we thus assume that the knowledge a firm can offer to a partner consists of the number of patents (P), independently from technological fields, applied three years before the cooperation (in the years 2000–2002). Firm A's incentive Rec_A^B to cooperate with firm B is the new knowledge inside the cooperation divided by the new knowledge of firm A.

$$Rec_A^B = \frac{\sum_{i=1}^{n} P_A + \sum_{i=1}^{n} P_B + 1}{\sum_{i=1}^{n} P_A + 1}. \tag{2}$$

The potential knowledge that may be acquired is thus set in relation to the given new knowledge inside the firm. The lowest value the index can take is 1, which is the case for both potential partners offering no knowledge, that is $P_A = P_B = 0$. The larger Rec_A^B the higher the incentive for A to cooperate with B. An equivalent index can be computed for B. As reciprocal incentive is a two-sided variable, the individual incentives to cooperate have to be combined. Doing this by computing the natural logarithm of the multiplied individual values, we achieve an index for the reciprocal incentive REC.

$$REC_{A,B} = \ln\left(Rec_A^B \times Rec_B^A\right). \tag{3}$$

In order to test hypothesis 3, a kind of "cooperation value" (CV) is needed. Therefore, we design a variable consisting of the multiplied values of TO and REC.

$$CV_{A,B} = TO_{A,B} \times REC_{A,B}. \tag{4}$$

This cooperation value includes the aforementioned trade-off between the two-sided capabilities to internalize spillovers and tacit knowledge from the cooperation partner, on the one hand and the potential knowledge stock valuable for the cooperation partner, on the other hand.

Cooperation experience indicates a kind of organizational knowledge that may positively influence the probability to cooperate. Different cases of cooperation experience can be distinguished, which will be represented by the use of the three dummy variables, $SCOEX$, $BCOEX$ and $OCOEX$. In the first case, the partners may have previously worked together. In this case, the dummy variable $SCOEX$ takes a value of 1, otherwise zero. Second, experience in cooperation can be of a rather general type. Here two scenarios are possible. If both partners have such experience, the dummy variable $BCOEX$ takes the value 1; if only one partner has gathered cooperation experience, $OCOEX$ will take a value of 1. Third is the case in which, the cooperation considered is just the first for both partners. In this case all three dummy variables take the value of 0.

3.2 Data base

According to Fig. 1, we are interested in the formation of research cooperations in the year 2003. In that year, 765 German patent applicants assigned 1,156 patents in cooperation with at least one other firm or institute. We dropped foreign partners because the independent variables are based on German patent applications. Therefore, a foreign firm will probably be accounted against the reality as non-innovative before this cooperation. We exclude agreements with foreign cooperation partner also because of systematic problems arising with including this kind of actor. As our data base contains only German patent applications, we cannot capture the whole knowledge base even in our sense for this actor; we would have agreements with nearly no prior knowledge. To avoid such a systematic mistakes we exclude actors located abroad.

The aim of the paper is to control whether and in what way the independent variables determine the choice of cooperation partner. As the independent variables are values concerning a cooperative relation, we design dyads of all possible cooperation constellations. Here we take all firms willing to cooperate and to share their knowledge with a partner.

The key point of this paper is not to detect the determinants enhancing cooperation activities, but to explore the choice of partner. By analyzing only cooperating firms, the former research topic is excluded. Based on 765 firms or institutes, 292,230 dyads are possible, including 472 cooperations which finally got realized. In this respect, our dependent variable, *COOP*, has a binary nature which takes the value 1 if the dyad is a real cooperation and 0 otherwise. We are aware of the fact that realized cooperation is a rare event and the overwhelming majority of the used variable *COOP* are fictive combinations of actors.

The independent variable *TO*, representing the technological overlap of the knowledge base between two potential partners, takes a value between 0 and 1. In most of the designed dyads it takes a value of zero (see the left chart in Fig. 2), that is, there is no technological overlap between the two potential partners considered. Even in the case of finally realized cooperations in the right chart in Fig. 2, a couple of these cooperations have a non-overlapping knowledge base. This will be discussed below.

Comparing the two charts in Fig. 2, it is obvious and also expressed by the higher mean value that in real cooperations, the degree of the technological overlap is higher than in the designed fictive dyads. This is to be considered a first and only a descriptive confirmation of hypothesis H1a we will analyze in more detail below.

The variable *REC* indicates the two-sided incentive for a certain cooperation. As natural logarithm of the multiplied individual value of the variable has a domain of zero to infinite. Comparing the overall mean value in the left chart in Table 1 (1.79) with the one for real cooperations in the right chart of Fig. 3 (1.96), there is no obvious difference. On this descriptive and preliminary basis, hypothesis H2 finds no support.

Former cooperation experience is, as introduced above, represented by three dummy variables. In more than half of all dyads both partners have such

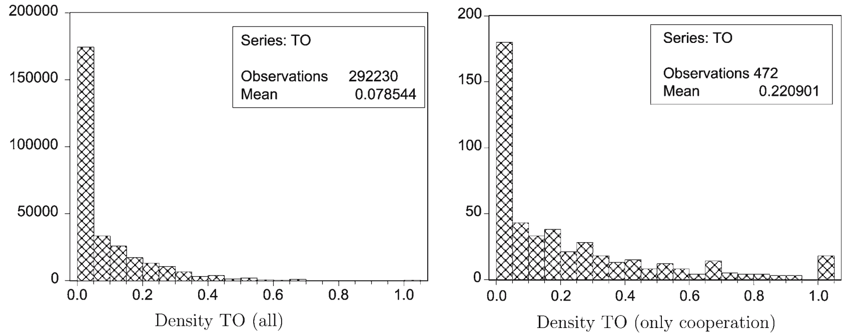

Fig. 2 Histogram of *TO*

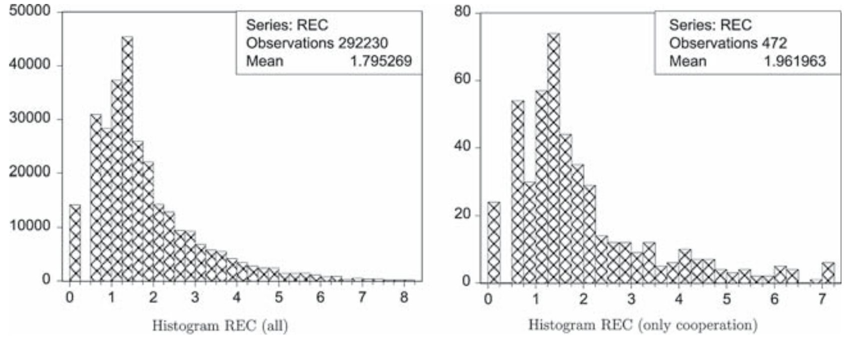

Fig. 3 Histogram of *REC*

Table 1 Descriptive statistics

	COOP	*TO*	*REC*	*CV*	*BCOEX*	*OCOEX*	*SCOEX*
Mean	0.002	0.079	1.795	0.136	0.524	0.400	0.002
Median	0.000	0.018	1.407	0.018	1.000	0.000	0.000
Maximum	1.000	1.000	8.011	8.011	1.000	1.000	1.000
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Std. dev.	0.040	0.120	1.256	0.270	0.499	0.490	0.039
Observations	292,230	292,230	292,230	292,230	292,230	292,230	292,230

experiences (see mean value of $BCOEX$ in Table 1). 211 of the 765 firms in the data base have no cooperation experience, $OCOEX = 0$. The share of dyads with no cooperation experience here amounts to 7.6%. The remaining cases in which only one cooperation partner has cooperation experience applies to 40% of all dyads. These variables indicate a sort of organizational knowledge concerning cooperation experience. The highest level of experience in a dyad is given, if these partners already had a cooperation before the year 2003 (variable $SCOEX$). There have been 441 of such cooperations between firms of the database or 0.2% of all dyads.

Table 2 Correlation relation statistics

	COOP	*TO*	*REC*	*CV*	*BCOEX*	*OCOEX*	*SCOEX*
COOP	1.000						
TO	0.048	1.000					
REC	0.005	−0.030	1.000				
CV	0.036	0.769	0.303	1.000			
BCOEX	0.000	0.001	0.122	0.044	1.000		
OCOEX	0.000	−0.002	−0.056	−0.021	−0.857	1.000	
SCOEX	0.405	0.068	0.007	0.053	−0.001	0.001	1.000

To show the relationship between all the variables to be used later, their correlations are computed. As a couple of variables in our analysis are Dummies, we are aware of the problems using a correlation analysis. Nevertheless, because of the used metrical variables (*REC* and *CV*) we analyze the degree of synchronism between the variables using such a correlation matrix, without any further consideration of their magnitude.

Table 2 contains the correlation among all variables, the dependent and independent ones. Not surprisingly, the highest amount of synchronism is between *TO–CV* and between *REC–CV*. This obviously is a result of the design of the cooperation value index. The most asynchronism is found between the former cooperation dummy variables *BCOEX* and *OCOEX*. Even this is due to the design of the variables. Former cooperation activities of firms in a dyad seems to have a high influence on a further cooperation agreement in 2003.

3.3 Operationalization of the concepts

The aim of this paper is to analyze the determinants for the choice of the cooperation partner. We therefore design dyads of firms as mentioned above. The hypotheses are tested on the dummy variable *COOP*, which states whether a firm was engaged in a respective cooperation in 2003. All analyses apply a Logit-analysis to identify the impact of the independent variables.

Hypotheses H1a and H1b on the impact of the technological overlap on the probability of cooperating are tested by Eqs. 5 and 6. Equation 5 estimates the linear influence of the technological overlap, *TO*.

$$P_{Coop} = \beta_0 + \beta_1 \times TO. \tag{5}$$

To sustain hypothesis H1a, the estimated coefficient has to be positive. Hypothesis H1b claims an inverted-U relation between *COOP* and *TO*. Therefore, in Eq. 6, the squared overlap index *squTO* is included:

$$P_{Coop} = \beta_0 + \beta_1 \times TO + \beta_2 \times squTO. \tag{6}$$

For the claimed inverted-U relationship, the coefficient of the linear term β_1 has to be positive, whereas the coefficient of the squared term β_2 has to take a negative value.

Hypothesis H2 is on the cooperation incentive as given by the reciprocity *REC* influencing the cooperation probability. The coefficient value β_1 in Eq. 7 has to take a positive value to confirm the second hypothesis:

$$P_{Coop} = \beta_0 + \beta_1 \times REC. \tag{7}$$

The influence of technological overlap and reciprocity for the partner choice (*TO* and *REC*) is estimated in Eq. 8 in order to explore the additional explanatory power reciprocity has on the cooperation probability:

$$P_{Coop} = \beta_0 + \beta_1 \times TO + \beta_2 \times squTO + \beta_3 \times REC. \tag{8}$$

To test hypothesis H3 on the influence of the cooperation value we use Eq. 9. If the variable *CV* enhances the probability of a research cooperation, the coefficient has to be significantly positive:

$$P_{Coop} = \beta_0 + \beta_1 \times CV. \tag{9}$$

The last hypothesis to be tested is on former cooperation experiences. Besides the variables used in the regressions above, the three dummy variables concerning cooperation experience are included:

$$\begin{aligned} P_{Coop} = {} & \beta_0 + \beta_1 \times TO + \beta_2 \times squTO + \beta_3 \times REC \\ & + \beta_4 \times BCOEX + \beta_5 \times OCOEX + \beta_6 \times SCOEX. \end{aligned} \tag{10}$$

As mentioned above, four levels of prior experience are possible. If the coefficients of all three dummy variables are insignificant, cooperation between inexperienced partners are as probable as cooperation between experienced partners.

4 Empirical results

4.1 Technological overlap

This subsection shows the results of the coefficient estimation on the technological overlap in the cooperation dyads. Table 3 presents coefficients and their *p*-values concerning hypothesis H1a (R1a) and hypothesis H1b (R1b), respectively.

Testing the influence of technological overlap on the probability to cooperate (R1a), the coefficient of *TO* (4.444) is significantly positive. Therefore, hypothesis H1a can be confirmed. The explanatory power of this regression with only one independent variable is acceptable with a McFadden-R^2 value

Table 3 Regression results hypothesis 1

Dependent variable	R1a coop.	R1b coop.
Intercept	−7.013***	−6.941***
	(<0.001)	(<0.001)
TO	4.444***	3.541***
	(<0.001)	(<0.001)
squTO		1.100**
		(0.049)
McFadden-R^2	0.053	0.0534

p-value in parenthesis

of 0.053. The closer the knowledge bases between two firms, the higher the probability that they establish a research cooperation. This result corresponds with recent findings (Mowery et al. 1998; Sorenson et al. 2005; Woolthuis et al. 2005). A small technological distance, that is, a high technological overlap, enhances the cooperation probability. Thus, firms chose their cooperation partner in their technological environment. This fortifies the statements about the absorptive capacity theory as well as the resource-based view of the firm. As stated in hypothesis H1b, a too close technological proximity leads to an involuntary knowledge flow. Contrary to theoretical results and empirical findings, the coefficient of the squared technological overlap degree *squTO* has a significant positive value ($\beta_2 = 1.1$). Probably this is due to the distribution of *TO* in our data base. Although the whole range between 0 and 1 is covered by our data, the magnitude of the overwhelming majority, even of real cooperations, is below 0.5. Additionally, the McFadden-R^2 of 0.0534 remains at the same level as in regression R1a (0.053). If there exists a critical distance in the sense that the firms are too close in their knowledge base, this cannot be found in our data. Our results, therefore, do not confirm hypothesis H1b.

4.2 Reciprocal incentive

In the former set of regressions, the impact of the two-sided understanding between firms for cooperative activities are analyzed. This ability to learn from each other says nothing about the potential knowledge that can be transferred. Hypothesis H2 claims that the higher the potential bilateral knowledge flow, the higher the probability of cooperating. Regression R2a in Table 4 tests for this. Following the estimated coefficient (0.096), a higher reciprocal incentive value enhances the probability of a cooperation substantially.

The estimation R2b includes all variables used so far. Again, hypotheses H1a and H2 can be confirmed. Both the technological proximity between cooperation partners and an increasing degree of reciprocal incentive enhance the likelihood of a research cooperation. So, besides a common understanding a potential knowledge base offered by both cooperation partners is a necessary precondition for a common research project. An actor willing to cooperate in a research project has to offer own valuable knowledge to become an attractive

Table 4 Reciprocal incentive impact on cooperation probability

Dependent variable	R2a coop.	R2b coop.
Intercept	−6.606***	−7.151***
	(<0.001)	(<0.001)
TO		3.606***
		(<0.001)
squTO		1.030
		(0.065)
REC	0.096***	0.109***
	(0.004)	(0.001)
McFadden-R^2	0.054	0.055

p-value in parenthesis

partner. This valuable knowledge embodied in former patent applications is an intangible resource in the sense of the RBV.

4.3 Cooperation value

In hypothesis 3, we argue that the combination of both independent variables also enhance the cooperation probability. In Table 5, we test whether there exists a general linear impact of the cooperation value on the choice of a cooperation partner.

Not surprisingly, in accordance with the regression results above, the cooperation value (coefficient = 0.998) enhances the likelihood of cooperation. The trade-off often mentioned between the ability to learn from each other and the potential pool of knowledge that can be transferred inside the cooperation can be solved by using this simple variable. Of course, there are real cooperations with a lower technological overlap, but a higher degree of reciprocal incentive. Because of the significant coefficient estimated in regression R3, hypothesis H3 is confirmed for our data.

4.4 Former cooperation experience

The organizational capabilities within a cooperation facilitate the knowledge exchange between the cooperation partner and enhance the probability of a

Table 5 Cooperation value impact on cooperation probability

Dependent variable	R3 coop.
Intercept	−6.636***
	(<0.001)
CV	0.998***
	(<0.001)
McFadden-R^2	0.022

p-value in parenthesis

successful cooperation. The corresponding regression results are presented in Table 6.

Neither the cooperation experience of one or of both cooperation partners in general (regression R4a and R4b) enhances the probability of a cooperation between those two partners. If both cooperation partners have a former common research project, this increases the probability of further cooperation (regression R4c).

There seem to be specific routines or resources in the sense of the RBV required in every cooperative relation. General knowledge of "how to manage" a cooperation project does not exist or does not influence the choice of research partner. Probably because of the knowledge base developed collectively dyads with a former cooperation relation choose their partners because of the technological overlap. This latter variable becomes a insignificant coefficient with of the inclusion of *SCOEX* as an independent variable. In other words, the technological overlap between these cooperation partners is due to the common research of the past (regression R4d). Moreover, including former research relations to explain the choice of cooperation partner increases the explanatory power. While the regression without former cooperation relations explains around 5% of all cooperations, this value increases with the inclusion of this Dummy variable to a value of 27.6%.

Recapitulating, with regard to the regression results, we can confirm hypothesis 1a, that an increasing technological overlap enhances the probability of a research cooperation. Also hypothesis 2 is confirmed for the given data base, the higher the two-sided incentive to cooperate the higher the likelihood of cooperation. The acceptance of the two former hypotheses leads to confirmation

Table 6 Former cooperation impact on cooperation probability

Dependant variable	Coop. R4a	Coop. R4b	Coop. R4c	Coop. R4d
Intercept	−7.137***	−7.155***	−7.216***	−7.169***
	(<0.001)	(<0.001)	(<0.001)	(<0.001)
TO	3.6069***	3.6063***	0.9766	0.9813
	(<0.001)	(<0.001)	(0.1262)	(0.1243)
squTO	1.0271*	1.0287*	1.7858**	1.7815**
	(0.0657)	(0.0653)	(0.0288)	(0.0291)
REC	0.1102***	0.1092***	0.0788**	0.0812**
	(0.0011)	(0.0011)	(0.0304)	(0.0274)
BCOEX	−0.029			−0.071
	(0.7548)			(0.7209)
OCOEX		0.0114		−0.035
		(0.9033)		(0.8602)
SCOEX			6.1800***	6.1792***
			(<0.001)	(<0.001)
McFadden R^2	0.055	0.055	0.276	0.276

p-value in parenthesis

of the third hypothesis concerning the cooperation value solving the trade-off between overlap and reciprocal incentive. Former cooperation experience as a firm specific routine does not enhance the likelihood of cooperation. Two firms where at least one partner has such experience are not more likely to cooperate, with exception of a former cooperation between the two. The special case, where both have cooperation experience with each other, increases the probability of cooperation in a research project.

5 Conclusion

The phenomena of research cooperation inspired different fields of research. This paper analyzes the determinants influencing the choice of cooperation partner. In doing so, we presume that to start a research cooperation, three criteria have to be fulfilled. First, the knowledge bases of the two firms has to have a certain degree of overlap. This common knowledge base enhances better understanding and eases the aspired knowledge transfer. Second, the knowledge transfer logically requires a certain stock of knowledge that is valuable for the other partner. A two-sided incentive has to exist for both partners to start such a voluntary agreement, knowing that partly their own sticky knowledge will be transferred. As a third criteria, we conjecture a certain degree of organizational knowledge on how to manage such a research cooperation.

Using German patent data, we have analyzed determinants influencing the choice of cooperation partner. We show that, for German cooperative relations, the technological overlap of the potential partners enhanced the probability that they cooperate in the year 2003. This finding is in line with the results of recent literature (e.g., Mowery et al. 1998; Sorenson et al. 2005). While Mowery et al. (1998) hypothesize an inverted-U relationship between the likelihood to cooperate and technological overlap, we cannot confirm this result on our data. Beside other factors not observed in this work, such as firm size, kind of actor, etc., we demonstrate that valuable knowledge as an incentive to cooperate has to be given for all partners. High-value knowledge as an indicator enhances the attractiveness of a firm to become a cooperation partner. Both partners have to offer such values.

Recent literature stresses a trade-off relation between the two criteria. By using the cooperation value as a combination of both criteria, we find this trade-off to be resolved. Organizational learning literature stresses the importance of cumulative experiences increasing the recent activity. Concerning the routine "cooperation", we cannot confirm that experience in how to manage such a project in a dyad enhances the probability of being cooperative. However, this kind of knowledge enhances the likelihood to start a further cooperation with the same partner. Routines developed with a certain partner seem to be as specific that they cannot be transferred to other agreements.

Being aware of the disadvantages using patent data, in our opinion we find meaningful results underlining the necessity of a certain degree of technological homogeneity among partners. Beside deepening the existing recent literature, the findings can explain phenomena in other fields of cooperation research. For example, an extreme degree of heterogeneity in a regional network can explain very scarce connectivity between actors, although spatial proximity as another proximity dimension (Boschma 2005) is given. This is one possible dimension we can enlarge the analysis. But first, we want to combine these findings with micro-data of firms in order to explain the influence of being cooperative on economic success more deeply than recent literature has done.

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