Institut für Wirtschaftsforschung Halle
Halle Institute for Economic Research
IWH

What Determines the Innovative Success of Subsidized Collaborative R&D Projects? – Project-Level Evidence from Germany –

Michael Schwartz, Francois Peglow, Michael Fritsch, Jutta Günther

March 2010 No. 7

IWH-Diskussionspapiere
IWH-Discussion Papers

What Determines the Innovative Success of Subsidized Collaborative R&D Projects?
– Project-Level Evidence from Germany –

Michael Schwartz, Francois Peglow, Michael Fritsch, Jutta Günther

March 2010 No. 7

Author(s): *Michael Schwartz*
Department of Urban Economics
E- mail: Michael.Schwartz@iwh-halle.de
Phone: +49 (0) 345 7753-794

Francois Peglow
Max Planck Institute for Demographic Research, Rostock
E-mail: peglow@demogr.mpg.de
Phone: +49 (0) 381 2081-0

Michael Fritsch
Chair of Business Dynamics, Innovation, Friedrich-Schiller-University Jena,
E-mail: m.fritsch@uni-jena.de
Phone: +49 (0) 3641 9432-20

Jutta Günther
Department of Structural Economics
E-mail: Jutta.Guenther@iwh-halle.de
Phone: +49 (0) 345 7753-708

Editor:
HALLE INSTITUTE FOR ECONOMIC RESEARCH – IWH
Prof Dr Dr h. c. Ulrich Blum (President), Dr Hubert Gabrisch (Research Director)
The IWH is a member of the Leibniz Association.

Address:	Kleine Maerkerstrasse 8, D-06108 Halle (Saale), Germany
Postal Address:	P.O. Box 11 03 61, D-06017 Halle (Saale), Germany
Phone:	+49 (0) 345 7753-60
Fax:	+49 (0) 345 7753-820
Internet:	http://www.iwh-halle.de

Faktoren des Innovationserfolgs öffentlich geförderter FuE-Kooperationen - Empirische Ergebnisse auf Projektebene

Zusammenfassung

Die gegenwärtige europäische Innovationspolitik unterstreicht das systemische Verständnis von Innovationsprozessen, demzufolge Innovationen das Ergebnis interdependenter Austauschprozesse verschiedener Akteure sind. Dies spiegelt sich in einer verstärkten öffentlichen Förderung kooperativer FuE- und Innovationsvorhaben zwischen Wissenschafts- und Wirtschaftsakteuren wider. Der vorliegende Beitrag untersucht diesbezüglich den Einfluss wesentlicher Charakteristika solcher FuE-Verbundvorhaben auf deren innovativen Erfolg anhand eines Datensatzes von 406 geförderten FuE-Projekten. Zur Messung des Innovationsoutputs dieser Projekte werden Patentanmeldungen und Publikationen herangezogen. Ferner wird nach Verbundprojekten zwischen Wissenschaft und Industrie und Projekten mit ausschließlich industriellen Partnern differenziert. Die Ergebnisse zeigen, dass die Einbindung von Großunternehmen einen positiven Einfluss auf Patentanmeldungen hat, nicht aber auf die Zahl der Publikationen. Die Einbindung einer Universität in ein Verbundprojekt hat positive Effekte auf die Zahl der Publikationen, nicht aber auf die Anzahl der Patentanmeldungen. Ferner lassen sich signifikant positive Effekte für die Höhe der Förderung nachweisen. Räumliche Nähe der Kooperationspartner wie auch die Einbindung eines anwendungsorientierten Forschungsinstitutes haben keinen Einfluss auf den Innovationserfolg der FuE-Kooperationsprojekte. Der Beitrag schließt mit einer Diskussion der Ergebnisse hinsichtlich der Ausgestaltung von Förderprogrammen zugunsten von FuE-Kooperationen.

Schlagworte: FuE-Kooperationen; Innovationspolitik; Projekterfolg

JEL-Klassifikation: O31; O32; O38

What Determines the Innovative Success of Subsidized Collaborative R&D Projects? – Project-Level Evidence from Germany –

Abstract

Systemic innovation theory emphasizes that innovations are the result of an interdependent exchange process between different organizations. This is reflected in the current paradigm in European innovation policy, which aims at the support of collaborative R&D and innovation projects bringing together science and industry. Building on a large data set using project-level evidence on 406 subsidized R&D cooperation projects, the present paper provides detailed insights on the relationship between the innovative success of R&D cooperation projects and project characteristics. Patent applications and publications are used as measures for direct outcomes of R&D projects. We also differentiate between academic-industry projects and pure inter-firm projects. Main results of negative binomial regressions are that large-firm involvement is positively related to patent applications, but not to publications. Conversely, university involvement has positive effects on project outcomes in terms of publications but not in terms of patent applications. In general, projects' funding is an important predictor of innovative success of R&D cooperation projects. No significant results are found for spatial proximity among cooperation partners and for the engagement of an applied research institute. Results are discussed with respect to the design of R&D cooperation support schemes.

Keywords: R&D Cooperation; Innovation; Academic-Industry-Linkages; Innovation Policy

JEL classification: O31; O32; O38

1. Introduction

Collaborative research and development (R&D) and innovation projects bringing together science and industry to promote, facilitate and accelerate technological innovation efforts is at the heart of the current paradigm in European innovation policy (Muldur et al. 2006). Systemic innovation theory has given rise to the insight that technological innovation is the result of a division of innovative and creative labor (Freeman 1987; Nelson 1993; Lundvall 1992). From this perspective, the locus of technological innovation resides not only within the boundaries of the firm, but is the result of an interdependent exchange process between different organizations, such as private firms, universities, research laboratories, suppliers, and customers. Governmental agencies, therefore, allocate R&D subsidies to take an active role in designing and establishing collaborative R&D support programs.[1]

Given this major interest in these policy instruments in favor of R&D cooperation, surprisingly empirical evidence on how collaborative R&D consortia should be designed actually, in order to promote collective innovation efforts, is rather limited so far. The majority of research in this area is devoted to the impacts of R&D collaboration on the performance for one partner, either firms or academic institutions (e.g. Miotti and Sachwald 2003; Negassi 2004; Belderbos et al. 2006; Okamuro 2007; Kim and Park 2008). Within this strand of literature, there is also considerable empirical evidence with respect to the questions 'why to cooperate' and 'with whom' (e.g. Brockhoff et al. 1991; Miotti and Sachwald 2003). However, to date, only few studies analyze the relationship between the outcomes of R&D projects or partnerships and the individual attributes of these collaborative R&D projects. Exceptions for considerations of projects as the unit of analysis are recent contributions by Branstetter and Sakakibara (2002) and Bizan (2003).

Bizan (2003) investigates the success of 142 government supported research alliances between high technology firms from the US and Israel. Those collaborative R&D projects were funded by the Israeli-US Binational Industrial Research and Development Foundation (BIRD). Success of R&D projects is evaluated in terms of technical success and duration of commercialization (of technically successful projects). On the project-level, as most influential variables shaping R&D projects' success the project budget, the duration of collaboration, complementarities and kind of relatedness through ownership were identified. Employing panel data from 145 Japanese government-sponsored R&D consortia, Branstetter and Sakakibara (2002) relate consortium characteristics to its research productivity, measured through patent applications. Whereas technological proximity of participants affects outcomes positively, the degree of product market proximity of participants is negatively associated with consortia performance. Both ex-

[1] Associated with such policy initiatives are further objectives, that is to improve regional technology transfer and diffusion as well as industrial competitiveness, thus the stimulation of regional innovation systems.

isting studies provide detailed and systematic investigations using data sets including multiple R&D project attributes. However, they are restricted in their analysis to inter-firm R&D projects, while academic-industry R&D cooperations are not considered.

In the present paper, we employ a rich and large data set using project-level information on 406 subsidized R&D cooperation projects that were supported by the Free State of Saxony. Within its technology- and innovation policy framework, Saxony, as the most research intensive region of the former German Democratic Republic, established the '*Saxonian Support Scheme for R&D Cooperation*' in 1992. The present paper provides thorough insights on the relationship between the innovative success of R&D cooperation projects that have been funded through this support program between 2000 and 2006 and specific project characteristics. The data set allows us to account for several key variables that, as we argue, may shape the innovative success of R&D cooperation projects. More specifically, we include project duration, project scale (measured in terms of partners and funding received), differences in partner composition (universities, applied research institute, large firms), spatial proximity between project partners and the commercialization range of the project outcomes. Negative binomial regression models are estimated that identify the project-level determinants of the innovative success of R&D cooperation projects.

There is no single best indicator for the evaluation of collaborative R&D projects success. Defining as to whether R&D projects can be considered successful is a complicated task, since R&D projects might be idiosyncratic with respect to their primary objectives. These objectives might differ between the partners or type of partners within project consortia, such as private firms, academic institutions, or governmental organizations. While university researchers may consider R&D projects as successful that generate new knowledge that is published in peer-reviewed journals, private firms primarily may be interested in commercialization of R&D results, thus generating net profit. Therefore, the appropriateness of particular indicators to evaluate R&D projects success may vary with ones point of view. At best, multiple indicators are used to define projects' success, but in many cases available data do not allow for the consideration of multiple success variables. To account for those different objectives in R&D cooperation projects, innovative success of each R&D project is measured through patent applications and literature-based innovation output indicators.

The following section 2 provides a characterization of the main features of the '*Saxonian Support Scheme for R&D Cooperation*'. Section 3 contains a discussion, based on theoretical arguments and prior empirical work, of the relationship between R&D cooperation projects attributes and project success. Eight hypotheses are formulated to be tested in the empirical part. Section four describes the data collection and explains the measurement of the dependent and explanatory variables. Regression results are presented in section 5. Discussion is held in the concluding section 6, which also points to implications and limitations of our findings.

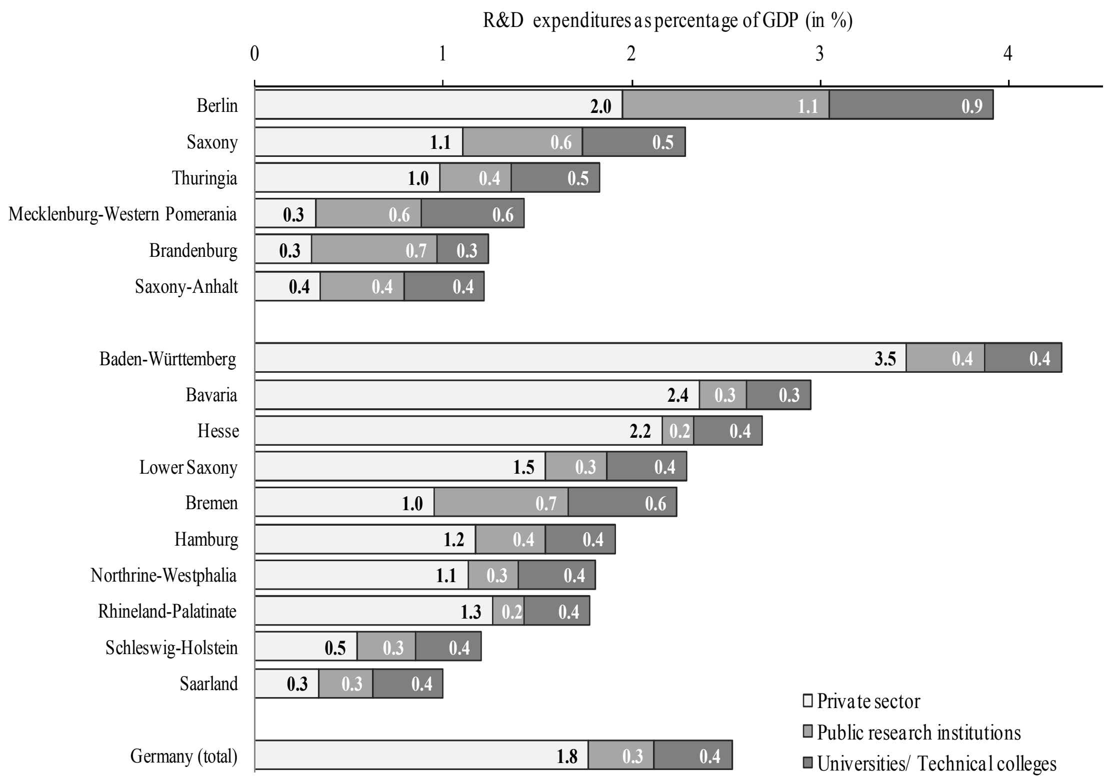
2. The Saxonian Support Scheme for R&D Cooperation

Initiated by the Saxon State Ministry for Economic Affairs and Labor ('SMWA'), the '*Saxonian Support Scheme for R&D Cooperation*' is an important element of the technology- and innovation policy in Saxony. With the financial means provided by the European Community, in 1992, The Free State of Saxony introduced this support program along with two further programs, 'Funding of Individual R&D Projects' and 'Funding of Innovation Assistants'. This comprehensive support and incentive system generally focuses on the support of small and medium-sized enterprises (SMEs) to reduce and to overcome considerable financial risks associated with innovation and R&D activities. During the period 2000 to 2006, the 'SMWA' granted financial support of 640 million Euros to more than 1.800 R&D projects, with financial means provided to 75% by the European Regional Development Fund (ERDF) and to 25% provided by the Saxonian State.

Despite the transformed economy of the former German Democratic Republic clearly lags behind the western part of the country in technological innovativeness and regarding the efficiency of regional innovation systems (Fritsch and Slavtchev 2009; Hornych and Schwartz, 2009), Saxony in particular has been a certain 'success story' in East Germany (Fritsch and Lukas 2001). For instance, since the German reunification, the research intensity in Saxony has increased continually and today is equal to that in some more established regional innovation systems in West Germany, e.g. North Rhine-Westphalia (Figure 1). In particular, the region surrounding the urban area of Dresden (the capital city of Saxony) is the most innovative region in Eastern Germany (*Hornych and Schwartz*, 2009).

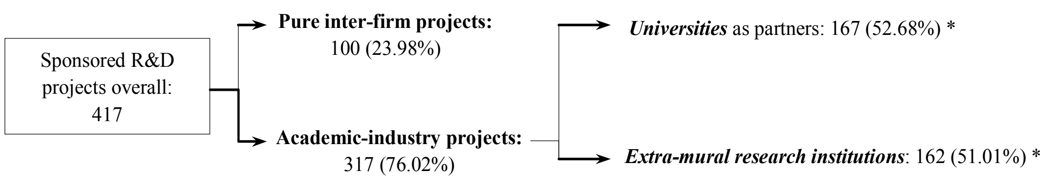
The '*Saxonian Support Scheme for R&D Cooperation*' is specifically designed to stimulate innovation and R&D cooperation between private firms (SMEs primarily, in few cases also large firms) and between private firms and academic institutions, thus bringing together science and industry in Saxony. Academic institutions include universities, technical colleges ('Universities of Applied Sciences') and applied (non-university) research institutes, such as institutes of the Leibniz Society or Fraunhofer Society. The '*Saxonian Support Scheme for R&D Cooperation*' aims at the reduction of financial risks of (complex, long-lasting, costly and fairly uncertain) R&D projects through the provision on non-repayable grants co-financed by the private firms. With the establishment of this support scheme, Saxony adopts an approach that Bozeman (2000, p.632) terms "the cooperative technology policy paradigm", where the government acts as an intermediary initiating policies that affect industrial technology development and innovation. This approach underscores '(…) an active role for government actors and universities in technology development and transfer'. Figure 2 provides an overview over the composition of partners in subsidized cooperation projects.

Figure 1
R&D expenditures as percentage of GDP in German states (Bundesländer), 2006



Source: Federal Statistical Office, Stifterverband.

Figure 2
Composition of cooperation projects subsidized by '*Saxonian Support Scheme for R&D Cooperation*'



Note: * R&D cooperation projects with *at least one* university/ extra-mural research institution as partner of the consortia.

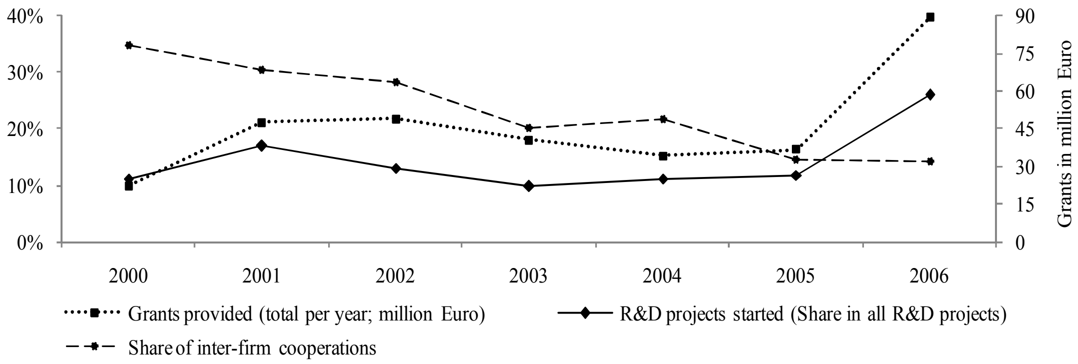
Source: Authors illustration.

417 R&D cooperation projects received funding within the framework of this support program between 2000 and 2006. More than three quarters of subsidized R&D projects involve at least one academic institution. Most of these academic-industry R&D cooper-

ation projects include either a university or an extra-mural research institution, while 31 R&D project consortia include both types of academic institutions.

Further information on this support program is given in Figure 3, which includes an overview over the distribution of R&D projects started per year, of the share of inter-firms R&D projects per year and of the total grants provided by the 'SMWA' per year during the support period 2000 until 2006. The number of subsidized R&D projects started as well as the grants provided by the 'SMWA' is relatively stable from 2000 to 2005. In 2006, which is the last year of the support period, a considerable increase can be recognized. The share of pure inter-firm R&D cooperation projects in all supported R&D projects continuously declines over the observation period. Whereas in the year 2000, approximately 65 percent of all projects include an academic institution, this number increased to 86 percent in 2006.

Figure 3
R&D projects started, share of inter-firms R&D projects, total grants provided during the support period 2000 until 2006



Source: Authors calculation.

In general, to obtain financial support, applying project consortia must fulfill certain criteria. Project partners have to demonstrate in their proposals that i.) the R&D project under consideration is innovative or technology-oriented, or ii.) that it aims at the development/ improvement of products and services that are novel in a sense that they are not economically exploited in the European Union. The '*Saxonian Support Scheme for R&D Cooperation*' is explicitly directed towards nine industries or technology fields, defined by the Free State of Saxony as being highly relevant in the future (Free State of Saxony, 2000): Materials science, Physical and chemical technologies, Biological research and technology, Microsystems technology, Information technology, Production technology, Environmental technology and Medical technology. Most of these fields can be characterized as science-based technologies (Meyer-Krahmer and Schmoch 1998), which seem to have a relatively high propensity for university cooperation (e.g.

Belderbos et al. 2003). In fact, the list of industries or technology fields offers a wide spectrum so that nearly every research topic is covered.

Proposals could be submitted by private firms having at least one plant location in Saxony as well as by universities included in innovation and R&D cooperation projects. Further requirements refer to an appropriate financial contribution by the project partners (non subsidized, equity or credit capital) and to the assessment of commercial application chances of the project outcomes (commercialization strategy).[2] The maximum financial support granted by the 'SMWA' depends on the scale and the specific research content of one particular cooperation project and differs between private firms and academic institutions.

3. Hypotheses

3.1 Type and composition of partners in cooperation projects

The composition of partners in R&D and innovation cooperation, and subsequently the organization of the division of innovative labor are critical elements for the success of cooperative arrangements (Harrigan 1988; Fritsch and Lukas 2001). Technological performance of research consortia, for instance, is greatly dependent on the characteristics of these consortia, particularly with respect to the characteristics of co-operating partners (Branstetter and Sakakibara 2002). Basically, cooperation partners might be classified as customers, suppliers, competitors, firms from the same/ other industries and from other countries, specific service providers, universities, private or public research institutes, or governmental institution (e.g. Sakakibara 1997; Fritsch and Lukas 2001; Miotti and Sachwald 2003; Belderbos et al. 2006; Aschhoff and Schmidt 2006; Okamuro 2007). SMEs and young firms in particular are reliant on external relationships to a variety of partners to obtain resources such as skills, equipment, specialized knowledge, capital, business networks or intellectual property rights. Many studies on R&D partnerships concentrate on collaborative R&D with competitors (von Hippel 1987; Hamel, Doz and Prahalad 1989; Hamel 1991).

2 There exist no information with respect to the actual approval decisions by the 'SMWA'. This means that we do not have insights regarding the number and the attributes of project proposals that have been rejected by the 'SMWA'. Unfortunately, we must therefore ignore the possible selection bias caused by the approval decisions, meaning that applying project consortia with a considerable risk of being not successful in reaching their project objectives might be systematically excluded. This would suggest a tendency to over-estimate the effects of the program under consideration. See also *Bizan* (2003) with respect to such selection processes by governmental agencies. In this study, a strong selection by the BIRD foundation (Israeli-US Binational Industrial Research and Development foundation), leads to considerably high probabilities of the (technical and commercial) success of BIRD-funded projects. Since, the present study neither aims at a global evaluation of the '*Saxonian Support Scheme for R&D Cooperation*', nor it aims at direct comparisons with other government-sponsored R&D support programs, we consider this aspect as negligible in our setting.

In this analysis, we first of all distinguish between cooperation projects among private firms (industry only) and cooperation projects in which private firms and academic institutions participate (academic-industry).[3] With respect to academic-industry cooperations, we further differentiate between cooperations in which universities participate and those in which extra-mural research institutes with a strong focus on applied research participate. Furthermore, we consider R&D cooperations with the participation of one dominant (large) industry partner.

Cooperation with academic institutions, including universities, technical colleges and research institutions can be a major source for innovation, firm growth and competitive advantage. Particularly in novel or rising technological fields, accompanied by rapid technological change as well as high uncertainty, universities are essential research partners (Hall et al. 2003). There is clear empirical evidence on the positive effects of university R&D and academic knowledge on regional innovative output variables and on private sectors R&D (see e.g. Fritsch and Slavtchev 2007 for an overview). Through academic-industry linkages, the most recent scientific knowledge and expertise in specific technological fields can be acquired or exchanged, or firms might get access to specific tools and machinery, which are not available in-house due to cost reasons (for an overview of university-based technology transfer, see for instance Bozeman, 2000; Markman et al., 2005 and Rothaermel et al. 2007). As Miotti and Sachwald (2003) demonstrate using French CIS-data, firms co-operate with universities primarily to get access to complementary resources. A number of studies demonstrate positive effects of R&D collaboration with universities on different measures of innovation performance and technological success (e.g. Belderbos et al. 2003; Miotti and Sachwald 2003; Aschhoff and Schmidt 2006; Okamuro 2007; Lööf and Broström 2008).[4] We concretize the corresponding hypothesis as follows:

H1a: *There is a positive relationship between university involvement in R&D cooperation projects and the innovative output of R&D cooperation projects.*

There is considerable evidence that it is not only important for private firms to engage in cooperative R&D with applied research institutes, it is also more conducive to the output of cooperative R&D arrangements. Brockhoff et al. (1991), for instance, found for inter-firm cooperative R&D arrangements in the former West Germany that applied R&D is much more frequently an objective of cooperative R&D than purely basic research. In an analysis of a sample of 237 (inter-firm) research consortia in Japan, Sakakibara (1997) finds that particularly the commercialization of R&D projects' output (product or process) is significantly related to those projects that are designed as being more application-oriented; but aggregated patenting of all participating firms of one

3 Pure science cooperation's are not subject of this study.

4 It must be noted that there is empirical evidence that university involvement does not yield the expected positive returns (*Caloghirou et al.* 2003; *Miotti and Sachwald* 2003; *Lhuillery and Pfister* 2009).

consortia is higher for consortia that conduct more basic research (Branstetter and Sakakibara 2002). Kim and Park (2008) tested several cooperation partners with regard to their impact on Korean firms' innovative performance and found that co-operating with research institutes significantly increased the probability of process innovations. The hypothesis is formulated accordingly:

H1b: *There is a positive relationship between the involvement of applied research institute in R&D cooperation projects and the innovative output of R&D cooperation projects.*

We may further hypothesize that the involvement of large private firms as partners in R&D cooperation projects is more likely to increase R&D projects' innovative success. Collaborative R&D can benefit from the resources those large private firms allocate to the project. Large firms normally can rely on greater internal R&D capacities and equipment and a broader as well as deeper knowledge base, so they should contribute to the project output through resource sharing (Okamuro 2007). Considering knowledge-intensive small biotech-firms, for instance, adding large pharmaceutical firms as partners for facilitating and speeding up the commercialization, diffusion and acceptance of the innovation might contribute to the projects' success far beyond its time horizon (Belderbos et al. 2003). Large firms possess valuable resources, such as financial resources for patent applications, the availability of R&D laboratories, specific equipment, skills and technological knowledge of employees or budget for travelling and administration. Though, such constellations might be associated with some kind of dependency on large cooperation partners for small firms (Brockhoff et al. 1991)[5], small-sized partners in turn benefit from cooperative R&D with larger firms (Sakakibara 1997).

H1c: *There is a positive relationship between large-firm involvement in R&D cooperation projects and the innovative output of R&D cooperation projects.*

3.2 Proximity of partners

Considering innovation efforts, geographical proximity between actors involved in collective innovative endeavors acts as catalyst for the exchange of experiences, and the transfer of valuable information and knowledge, particularly non-codified tacit knowledge. The transfer of this kind of knowledge requires frequent personal interactions (face-to-face contacts) between actors and is mostly difficult to realize over great distances (Malmberg and Maskell 1997). The probability of repeated interactions increases, which in turn is assumed to enhance technological communication and mutual under-

5 Despite dependency, asymmetry between cooperating partners might also be problematic. Indeed, there is some evidence that stresses the importance of similarity (and complementarities) as important criteria for stable and successful R&D cooperation (*Veugelers* 1998; *Bizan* 2003; *Harrigan* 1988; *Häusler et al.* 1994; *Branstetter and Sakakibara* 2002). Asymmetry might also be a potential source of conflicts, if partners are less committed to the cooperation and collaborate less. However, we cannot control for such project-internal dynamics in our study.

standing (Cantner and Graf 2004). The general assumption behind this argumentation is that the most important knowledge spillovers occur between geographical proximate actors. Taking into account that knowledge spillovers seems to be geographically bounded (e.g. Jaffe, Trajtenberg and Henderson 1993; Anselin et al. 1997; Zucker et al. 1998), locating in close vicinity to the sources of spillovers becomes crucial for their exploitation (Audretsch and Feldman 1996).

Particularly research on the impact of agglomeration economies and clustering on firm growth and innovative performance underscores the importance of spatial proximity for intense communication and co-operation processes, and thus innovation-related knowledge spillovers (Feldman and Audretsch 1999; Breschi and Lissoni 2001). More recently, the social dimension of proximity is increasingly perceived as important determinant for innovation and learning (Boschma 2005). This view stresses that all economic actions are embedded in social networks, and therefore the existence of network relations and position in the social structure affect the scope for individual action, in particular by granting access to information (Granovetter 1985; Coleman 1990; Burt 1992; Koka and Prescott 2002). Although, spatial proximity is not necessarily directly associated with social proximity, spatial proximity is expected to facilitate the development of social connectedness between collaborating actors (Boschma 2005).

Following the seminal contribution by Allen (1970), who studied inter-personal communication networks within R&D laboratories, few attempts have been undertaken to assess the impact of partner distance within cooperative R&D and innovation projects on project performance (Keller 1986; Hoegl and Proserpio 2004; Mora-Valentin et al. 2004). As the most detailed study, Hoegl and Proserpio (2004) provide empirical evidence with regard to the positive impact of proximity between innovation team members and the quality of their joint output. Based on data of 145 German collaborative software development teams (within organizational boundaries), amongst others, they find that team member proximity is positively related to communication, coordination processes and mutual support within the team structure. According to the authors (p. 1160), communication between partners is eased "(…) as the high number of spontaneous and/ or informal moments of contacts ensure a higher level of richness of the information transferred." In general, close proximity reduces time and money spent for traveling and communication and cooperation costs in general. We hypothesize that proximity contributes to the innovative output of the project, because of a more efficient and effective project execution.

H2: *There is a positive relationship between the geographical proximity of the partners of R&D cooperation projects and the innovative output of R&D cooperation projects.*

3.3 Duration of cooperation project

Duration time of cooperative R&D projects might influence its success in several ways. First, internalizing pieces of knowledge provided by cooperation partners is not straightforward. In this respect, time can be a critical factor to provide fertile grounds for acquiring and understanding knowledge that circulates within the project network. For the disclosure of particularly tacit knowledge, frequent personal interaction is a necessary precondition (see section 3.2). Those interactions essentially are based on trust and reciprocity. In a long-term relationship with dense social interactions, there is the implicit assumption that every partner contributes roughly equal to the project objectives.[6] Shorter project duration might prevent reciprocal exchange from certain partners, and thus weakens the whole relationship. This could reduce the probability of success of the whole innovation project. Social connectedness accompanied by reciprocity can be a driving force for trust-based relationships (including loyalty, reliability and honesty), which in turn bear the potential to neutralize opportunistic behavior and free-riding (Häusler et al. 1994; Uzzi 1997; Kale et al. 2000). Indeed, free-riding by project partners cannot be neglected, as Veugelers (1998, p. 427) states:

> "(…) once the agreement [to cooperate] has been reached, each participant has an incentive to cheat on the agreement and conceal its own technological expertise. What is learned from the expertise of the loyal partner can be used in own R&D projects."

The development of trust is, however, a process which takes time and involves continuous efforts by all cooperation partners. Cooperations need a long-term horizon to become stable (Veugelers 1998). Trust-based relationships between collaborating partners develop and are strengthened as the duration of the cooperation advances (Cooke and Morgan 1998; Lorenzen 1998). Based on an initial degree of trust because of contract agreements, the partners get to know each other better, they pursue common objectives and trust develops further as by-product of the project. Mora-Valentin et al. (2004) establish a link between trust and academic-industry cooperation. The found empirically that global satisfaction as well as the evolution of the cooperative relationship is significantly associated with trust among participants. Because project duration is associated with the establishment of reciprocal trust-based relationships within the project consortia, we assume a positive impact on innovative project success.

H3: *There is a positive relationship between the duration of the R&D cooperation projects and the innovative output of R&D cooperation projects.*

---

6 The importance of reciprocity, that is the process of mutual valuable exchange of information, knowledge or technology, is particularly emphasized in research on knowledge sharing through informal networks. It is shown that reciprocity is required to make networking a mutually fruitful and sustainable channel of the transfer of information and knowledge (*von Hippel* 1987; *Carter* 1991; *Dahl and Pedersen* 2004).

3.4 Scale of cooperation project

The size of cooperation teams, as one measure of the scale of cooperation projects, has been found to be an important structural factor shaping the success of team processes considerably (Hoegl and Prosperio 2004). One of the most important driving forces to engage in collaborative R&D and innovation endeavors is to benefit from knowledge and resources that are complementary to ones' own resource base (Hagedoorn 1993; Brockhoff et al.1991; Sakakibara 1997). The chance for every project partner to receive complementary know-how naturally increases with a broader project knowledge base; that is with increasing size of the project team. Larger-scaled R&D projects enable the project partners to extend their technological know-how beyond their own organizational boundaries. If unforeseen problems occur that might require novel solutions, large-scaled projects including a high number of cooperation partners, increase the probability that one team member has encountered comparable or even identical problems in the past and probably has developed problem-solving strategies already. Such specialized know-how bears immense potential to save time and costs, and thus contributes to the overall projects success.

Conversely, a larger project normally increases the costs of coordination and administration. Team size has been found as negatively impacting team cooperation and communication (Hoegl and Prosperio 2004). Larger project teams further bear greater potential for free-riding (Kandel and Lazear 1992). Assuming that project partners are located in close physical proximity (see section 3.2), these costs (particularly transportation costs) might be of minor significance. Given a spatially dispersed network of a larger number of project partners, however, the complexity of and expenses for coordination processes easily become a problem. However, in sum, larger projects are assumed to be more successful than projects of smaller scale. As Bizan (2003:1627) states:

> "…as the size of the project increases, firms tend to allocate better their resources to the project; the best research facilities are used, the best workers are assigned to the project, etc. This concentration of better resources is the source of economies of scale at the project level."

Accordingly, we propose the following hypotheses:

H4a: *There is a positive relationship between the extent of funding and the innovative output of R&D cooperation projects*.

H4b: *There is a positive relationship between the number of partners and the innovative output of R&D cooperation projects*.

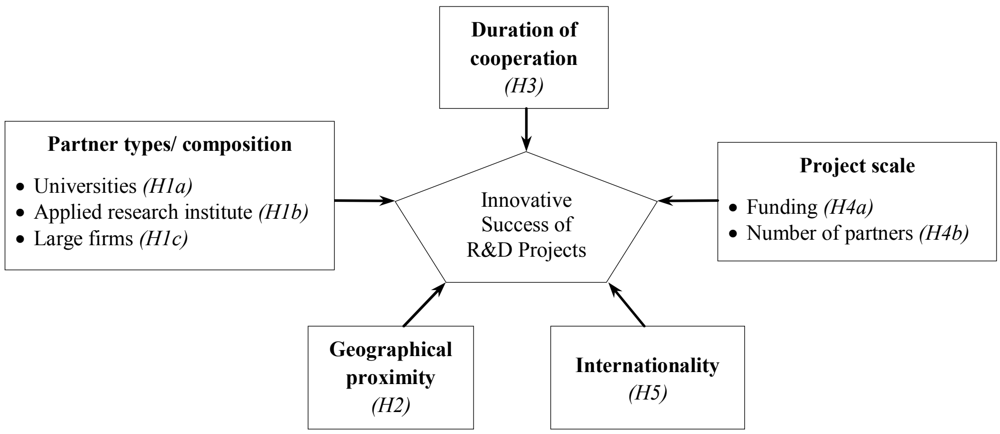
3.5 Internationality

The competitive pressure those R&D project might encounter, which results focus on international rather than domestic markets, might further influence its outcomes. Research provides some evidence on this issue with results that the success of inter-firm collaborative R&D is positively affected if participating firms are affiliates of foreign multinational groups; firm productivity increases (Belderbos et al. 2003) and the whole R&D cooperation is less likely to fail (Lhuillery and Pfister 2009). Project partners in general and participating R&D personnel in particular, may be forced to enhance effectiveness and efficiency of the project due to the more intense competition in international market environments. It is therefore reasonable to assume that the intended commercialization (or exploitation) range of R&D cooperation affects innovation incentives (Negassi 2004) and therefore the innovative output of R&D cooperation projects.

H5: *There is a positive relationship between an intended international commercialization range of the R&D projects results and the innovative output of R&D cooperation projects*.

Figure 4 below summarizes the framework our analysis:

Figure 4
Framework for analyzing the innovative success of cooperation R&D projects



Source: Authors illustration.

4. Data and measurement

4.1 Data collection

Data on R&D cooperation projects were provided by the Development Bank of Saxony (‘SAB’). The ‘SAB’ is the central development agency of Saxony and, acting on behalf of the state, the ‘SAB’ is responsible for the implementation and administration of support schemes (including EU) at the regional level. Furthermore, the ‘SAB’ offers guidance for the several support schemes and related issues. Within the ‘*Saxonian Support Scheme for R&D Cooperation*’, the ‘SAB’ serves as intermediary, allocating and distributing the funds available as well as documenting the information needed to fulfill these responsibilities. Thus, it collects comprehensive data on all cooperative R&D projects that have been supported within the above described program (see 4.2.).

Project leaders of subsidized cooperative R&D projects (consortia) provide detailed information to the ‘SAB’ regarding project progress. For each of the subsidized cooperative R&D projects within the funding period 2000 to 2006, complete datasets were provided by the ‘SAB’. Overall, 417 sponsored cooperative R&D projects were identified and made available for the analytic purposes of this paper. Besides basic information, such as the project title, the starting date of the R&D project and the amount of funding, the data sets for these 417 projects include specific information on the partners that are involved in the R&D project, such as geographical location. With respect to the individual outcomes of each subsidized R&D cooperation project, project leaders must inform the ‘SAB’ as to whether the cooperation resulted in the application of a patent or in a publication; and if so, how many (see section 4.2.1).

4.2 Measurement of key variables

4.2.1 Innovative success of subsidized R&D cooperation projects

The innovative output[7] of subsidized R&D cooperation projects is measured as patent applications and publications as *direct outcomes of R&D projects*.[8] Patent applications

[7] Another approach to determine success in case of R&D projects is to compare the actual outcomes of the R&D cooperation with the expected, or even explicitly defined, outcomes at the beginning of the partnership. However, those benchmarking criteria are mostly absent and remain rather vague formulated by the participants. Bizan (2003) notes further concerns with respect to R&D projects that consist of several successive phases. There might be phases of R&D projects that can be considered successful, while other parts can be considered a failure.

[8] There are different well-known methodological problems associated with patent applications as indicator for innovative performance (*Grilliches* 1990; *Schmoch* 1999). For instance, patent intensity differs across industries and not all inventions are patented. With respect to the latter, there are several reasons why inventors may prefer other mechanisms to appropriate rents from R&D activities, most frequently secrecy (*Mansfield et al*. 1991; *Cohen et al.* 2000). Reasons for not patenting might include application costs, the high efforts to demonstrate the novelty of the invention or the ease of inventing around (see *Cohen, Nelson and Walsh* 2000). Notwithstanding

include all applications at the German Patent and Trade Mark Office ('DPMA') as well as applications at the European Patent Organisation ('EPO').[9] Using patent applications instead of patent grants further ensures that there is no underestimation of the project output, since the actual time span between application and grant may be considerably long (Okamuro 2007). The second element of our measure of the innovative output of subsidized R&D cooperation projects are literature-based innovation output indicators (Coombs et al. 2006), that is scientific publications and publication in technical papers of project members. Besides publication of articles in international refereed academic journals, we also include publications in more professional technical journals that are specialized in publishing information on new products and processes in particular industries. The term publication will be used in the remainder of the paper to refer to both types.

Data on patent applications and publications as innovative output of particular cooperation projects were extracted from the project database of the 'SAB' (see 4.1 for more details). This approach enables us to establish direct linkages between projects' organization and characteristics and its innovative performance. Therefore, the issue that partners can be involved in multiple R&D cooperation projects (simultaneously or consecutively) (see Sakakibara 1997; Okamuro 2007 for a similar structure) does no bias our results.

While the initial data collection took place in 2008, at the beginning of 2010 the 'SAB' provided an update with respect to data on patent applications and publications. We therefore allow for a maximum four-year time lag between project ending and the application of patents and publications respectively. Neglecting this time lag in the analysis would introduce a severe bias in the analysis, since approximately one third of R&D cooperation projects started close to the end of the observation period (Figure 3). Without time lag consideration we would systematically under-estimate the innovative output of these R&D projects. Overall, in 2010, the 'SAB' records 539 patent applications and 1 219 publications for these 417 R&D projects. Few R&D projects record more than two patent applications (13.7%); the average number of patent applications per project is 1.29. 7% of R&D projects record at least ten publications; while for 60% of R&D projects, there is a maximum of one publication. 31.2% of subsidized R&D cooperation projects neither had a patent application nor a publication.

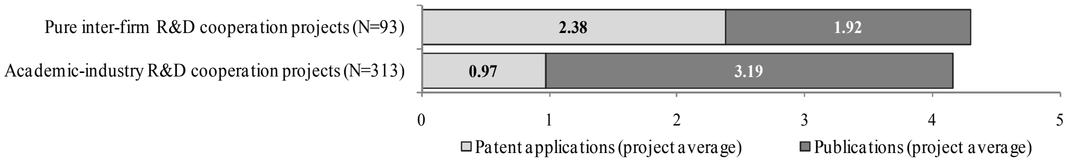
---

these concerns, patents show a strong relationship to R&D expenditure and therefore are a suitable indicator of both inventive input and output (*Grilliches* 1990).

9 There is no possibility to identify as to whether the reported patent applications refer to the German Patent and Trade Mark Office or to the European Patent Organisation. Applying for a patent at the 'EPO' involves more costs and is more complicated than applying for a patent at the 'DMPA'. Therefore, it is usually assumed that 'EPO'-applications are economically or commercially more important than 'DPMA'-applications (*Frietsch et al.* 2008; *Fornahl and Brenner* 2009). Contrary, using solely 'EPO'-applications would underestimate the patent activity by small firms that mostly apply for a patent at the 'DPMA'. Since 92.6 percent of all private firms in our sample being involved in R&D cooperation projects are SMEs (see section 4.2.2), it is important consider those 'DMPA'-applications.

To take account of differences regarding the importance of project characteristics between the two measures of innovative output of R&D cooperation projects, two dependent variables were specified. While PATENTS reflect the total number of patent application per R&D project, PUBLICATIONS measures the total number of publication recorded for R&D projects as innovative output.

Figure 5
Average number of patent applications and publications per R&D cooperation project; differentiated by cooperation type



Source: Authors calculation.

We are particularly interested in comparing differences between academic-industry R&D projects and pure inter-firm R&D projects. Figure 5 shows that the total innovative project output is comparable between these two types of R&D projects. Academic-industry projects record 4.15 patent applications/ publications on average, pure inter-firm projects record 4.30 patent applications/ publications on average. However, differences are observable regarding the proportions between patent applications and publications. While the innovative output of academic-industry projects is characterized by a high share of publications, for pure inter-firm projects the two innovation measures contribute almost in equal parts to the project output. This finding underscores the importance to distinguish between these two types of R&D projects in the regression analyses.

4.2.2 Explanatory variables and descriptive statistics

Three hypotheses were developed with respect to impact of partner composition in R&D cooperation projects on innovative performance. In sum, 564 different partners (firms, universities, research institutes, etc.) were involved. Whereas the majority of actors participated in one (N=353) or two (N=110) cooperation projects, there are nine actors that were involved in at least ten projects during the time period 2000 to 2006. The maximum number of participations is 29. Similar patterns are reported for government-sponsored research consortia in Japan (Branstetter and Sakakibara 2002) and for cooperative R&D agreements between firms and research organizations in Spain (Mora-Valentin et al. 2004).

We introduce a dummy variable UNIVERSITY taking the value of one, if a R&D project involves a (department of a) university or technical college.[10] A further dummy variable APPLICATION indicates an applied research institute (such as an institute of the 'Fraunhofer Society') as part of the project consortium. Note that both constructs are neither mutually exclusive nor they specify how many universities (or academic institutions respectively) are involved. LARGE indicates if there is at least one large private firm within the project consortia. With respect to employment figures, private firms are considered to be large by the European Commission, if they have at least 250 employees.[11] We adopt this threshold value for our analysis. It is not differentiated between project consortia including multiple large firms.

For our empirical analysis, we apply a measurement of proximity as static physical distance, thereby assuming that close physical proximity interacts with and simultaneously favors social proximity of the partners involved in the cooperation project. The dataset allows us to construct a variable, where proximity is measured as the mean distance between the locations (based on postal codes) of all project partners (DISTANCE) at the time the project proposal was accepted by the 'SMWA'. Related studies measure proximity using arbitrary constructs (less/ more than a particular threshold value, e.g. Mora-Valentin et al. 2004) or via specific constructs including several items (Keller 1986; Hoegl and Proserpio 2004). Duration of the particular R&D project - as given in the 'SAB'-database - is measured as metric variable (DURATION). Other studies use project duration as proxy for the size of R&D projects (Bizan 2003), however, most studies do not include the cooperation duration in their analysis at all (e.g. Aschhoff and Schmidt 2006). To control for non-linear effects of project duration, we additionally specify a variable containing the squared duration time (DURATION^2).

Project scale can be proxied through different measures. We use two criteria. Following Hoegl and Prosperio (2004), the size of the cooperation team, that is the absolute number of partners according to the project proposal, will be included in the regression (PARTNERS). Within the '*Saxonian Support Scheme for R&D Cooperation*' there were no restrictions with respect to the maximum number of project partners. Most projects consist of two or three partners, whereas only few projects have more than five cooperation partners. This pattern again corresponds to other studies (Mora-Valentin et al. 2004). As the second measure of project scale, the amount in funding (in million Euros) enters the regression analysis (FUNDING). We expect both variables to have positive impacts on project innovative outcomes.

---

10 Technical colleges, or 'Universities of Applied Science' (Fachhochschulen), are a specific type of higher education institutions in Germany. These technical colleges have a particular focus on teaching (predominantly in engineering) and application-oriented research. Different from universities, they are usually not allowed to devote a doctor (PhD) degree. In our analysis, we follow *Fritsch and Slavtchev* (2007) and do not differentiate between universities and these technical colleges.

11 Overall, 450 actors participating in R&D projects are private firms (79.8 percent). Thereof, 69.3 percent are classified as small-sized firms (less than 50 employees); further 23.3 percent can be classified as mid-sized firms (at least 50, but not more than 249 employees).

Based on the proposals submitted to the 'SMWA', we measure the intended commercialization range of the results of R&D cooperation projects through a dummy variable INTERNATIONALITY. This variable takes the value one, if R&D projects' outcomes focus on international markets, rather than domestic markets (variable takes the value zero). Other studies on the determinants of innovative performance and the performance of R&D cooperation use, for instance, export ratios or the degree of foreign ownership (e.g. Belderbos et al. 2003; Günther and Gebhardt 2005; Schneider et al. 2010).

We have full information on 406 R&D cooperation projects. Eleven R&D projects must be omitted from the regression analyses due to missing data for one or several variables. Table 1 gives a summary and descriptive statistics of all variables and Table 2 additionally gives the correlation matrix. Assuming multicollinearity problems when correlations exceeding an absolute value of 0.8 (Hair et al. 1998), we only expect, and indeed find, those values for the correlation between DURATION and DURATION². The correlation matrix, therefore, does not raise concerns for multicollinearity.

Table 1
Description and descriptive statistics of dependent and explanatory variables that are included in the regression analysis (*N* (obs) = 406)

Variable	Description	Mean	St. D.	Min	Max
Dependent variables of innovative output					
PATENTS	Total number of patent applications	1.29	2.60	0	19
PUBLICATIONS	Total number of publications	2.90	6.09	0	74
Scale of cooperation project					
FUNDING	Project funding (in million Euros)	0.781	1.190	0.013	14.778
PARTNERS	Total number of partners	2.67	1.01	2	7
Project characteristics					
DURATION	Duration of the R&D project (in days)	825	274	244	1956
DURATION²	Squared value of duration of the R&D project (in days)	757021	497546	59536	3825936
DISTANCE	Mean distance of all partners in R&D projects (in km)	31.31	31.45	0	147
INTERNATIONALITY	International commercialization range of results (1/0)	0.34	0.47	0	1
Cooperation partners					
UNIVERSITY	Involvement of university/ technical college (1/0)	0.41	0.49	0	1
APPLICATION	Involvement of applied research institute (1/0)	0.06	0.24	0	1
LARGE	Involvement of at least one large firm (1/0)	0.19	0.39	0	1

Table 2
Bivariate correlations of dependent and explanatory variables that are included in the regression analysis (*N* (obs) = 406)

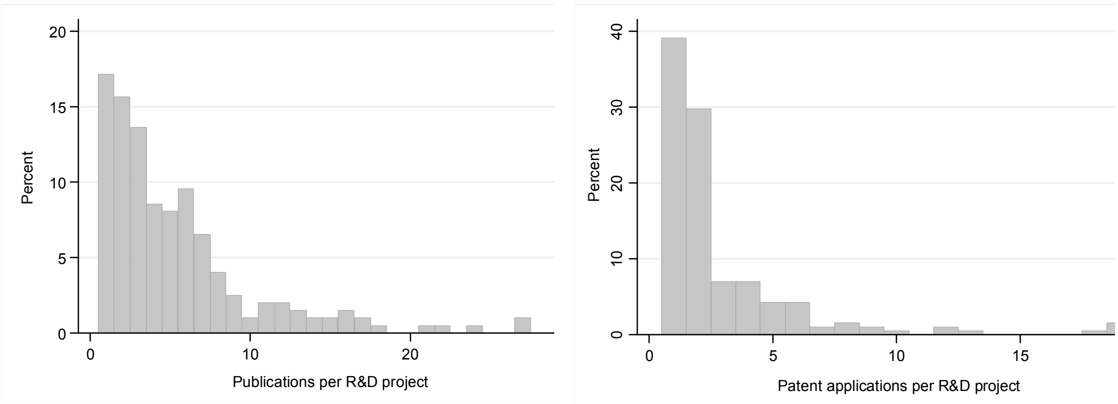
Variable		1	2	3	4	5	6	7	8	9	10	11
Dependent variables of innovative output												
(1)	PATENTS	1										
(2)	PUBLICATIONS	**0.21**	1									
Scale of cooperation project												
(3)	FUNDING	**0.57**	**0.26**	1								
(4)	PARTNERS	**0.22**	**0.10**	**0.22**	1							
Project characteristics												
(5)	DURATION	0.06	**0.31**	**0.15**	**0.17**	1						
(6)	DURATION²	0.08	**0.32**	**0.18**	**0.19**	**0.98**	1					
(7)	DISTANCE	**-0.11**	**-0.11**	**-0.15**	**0.12**	-0.01	-0.15	1				
(8)	INTERNAT.	-0.03	**0.26**	0.02	-0.02	**0.31**	**0.28**	-0.05	1			
Cooperation partners												
(9)	UNIVERSITY	**-0.11**	**0.19**	**-0.10**	0.07	0.09	0.08	-0.02	-0.01	1		
(10)	APPLICATION	-0.36	-0.01	**-0.09**	0.05	-0.05	-0.05	**0.11**	-0.07	**-0.17**	1	
(11)	LARGE	**0.34**	0.09	0.34	**0.28**	**0.13**	**0.14**	-0.01	0.01	-0.09	-0.07	1

Bold numbers indicate significant correlations on the 5%-level.

4.3 Estimation technique

Patent applications and publications as our dependent variables are count response data. Variables can take any non-negative integer value. Standard estimation technique for count data is Poisson regression. Figure 5 gives an impression of the distribution of patent applications and publications. It shows clearly that the data is skewed to the right. What follows from Figure 6 is that the general condition of Poisson distribution (that is equality of mean and variance; generally known as equidispersion) is not given by our data. In contrast, both dependent variables seem overdispersed.

Figure 6
Distribution (histograms) of publications and patent applications



Notes: Histogram of publications is restricted to R&D projects with non-negative publication output and to projects with a maximum of 30 publications (N (*Obs*) = 192). Histogram of patent applications is restricted to R&D projects with non-negative patent output (N (*Obs*) = 184).

Source: Authors calculation.

In fact, the sample mean of PATENTS is 1.29, and the variance is 6.76, which supports the assumption of overdispersion (for PUBLICATIONS - mean: 2.9, variance: 37.1). This is further confirmed by the calculation of Pearson dispersion statistics, as given in Hilbe (2007). Neglecting overdispersion with a Poisson regression model would under-predict the probability zero patent applications/ publications and would lead us to assess coefficients as misleadingly significant (Hilbe 2007, Cameron and Trivedi 2005). The most common way to account for overdispersed count data is a negative binomial model. This family of count models ‘relaxes the very restrictive equality condition between conditional mean and conditional variance’ (Plasmans 2006:265). Negative binomial models are estimated using maximum likelihood. We apply this technique to analyze the effects of project characteristics on projects’ innovative output.

5. Regression results

Below we present the results from negative binomial regression for the project characteristics that are expected to shape the innovative success of R&D cooperation projects. Descriptive results emphasize the requirement to distinguish between patent applications and publications in the analysis. The first three models use PATENTS as dependent variable. We first estimate a model using all 406 observations. To control for possible differences in the effects of explanatory variables between academic-industry projects and pure inter-firm projects, independent models are estimated for these two cooperation types. Models 1-3 are re-estimated for PUBLICATIONS as dependent variable (model 4-6). Discussion of the results is held in the following section 6. Table 3 displays the regression results for all six model specifications.

Starting with H1a, our regression results give support for the assumption that university involvement (UNIVERSITY) is an important predictor for PUBLICATIONS as innovative output of R&D cooperation projects (models 4 and 5). With respect to PATENTS, we do not find a statistically significant positive impact for university involvement. Regarding the integration of an applied research institute, the results do not support H1b with respect of a positive impact on patent applications and/or publications as innovative output of R&D cooperation projects. APPLICATION is insignificant for all specifications.[12] Large-firm involvement in R&D cooperation projects (LARGE) is generally positively associated with PATENTS (model 1), particularly in pure inter-firm projects (model 3), but not if the project consortium involves an academic institution. No significant relationships are found for PUBLICATIONS as output variable.

In hypothesis 2, we proposed a positive relationship between spatial proximity of partners in R&D cooperation projects and innovative project performance. Though, there is a slight tendency that decreasing distance (i.e. increasing proximity) might be conducive for innovative success, the respective coefficients of DISTANCE are no significant predictors of innovative project output; neither for PATENTS nor for PUBLICATIONS. Regression results therefore do not confirm H2.[13]

According to hypothesis 3, we expect that duration of cooperative R&D projects is positively associated with its innovative output. There is no clear evidence in the regression results. With respect to PATENTS, we find a significant U-shaped relationship between project duration and patent applications for pure inter-firm R&D projects. For PUBLICATIONS, there is a tendency for an inverse U-shaped relationship (model 4 and 5), but the effect is only positive significant for DURATION, but not for the squared value $DURATION^2$. Pure inter-firm projects seem not to be affected by duration.

We assume a positive impact of international commercialization strategies of R&D cooperation projects on innovative output of R&D projects. Regression results let us confirm this hypothesis (H5) only for the PUBLICATION specifications (model 3, 4 and 5). In contrast, for patent applications the intended commercialization range is insignificant and, furthermore, INTERNATIONALITY has the tendency to exert negative effects on PATENTS. However, the effect is not significant.

---

12 We also controlled for possible joint effects of a combination of universities and an applied research institute by including an interaction term (UNIVERSITY x APPLICATION) indicating this constellation. No significant results were obtained.

13 Alternative specifications as categorical variables comparable to *Mora-Valentin et al.* (2004) were tested. For instance, based on postal codes, we specified a binary variable indicating that all project partners are located in the same city (mainly Dresden, Leipzig and Chemnitz – the three big cities in Saxony). All alternatives produced similar results and are therefore not reported here.

We proposed two hypotheses, relating to a positive impact of the scale of cooperation projects on innovative output. Whereas significant results for the number of partners in R&D cooperation projects (H4b; PARTNERS) are found for PATENTS (model 1 and model 3), project funding exerts statistically significant positive effects on innovative output of R&D projects across all but one models (H4a; FUNDING). This leads us to confirm both hypotheses.

Table 3
Results of negative binomial regression for the determinants of innovative output of R&D cooperation projects (standard errors in parentheses).

	Dependent variable: (number of) *PATENTS*			Dependent variable: (number of) *PUBLICATIONS*		
	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6
	Full sample	Academic-industry	Inter-firm	Full sample	Academic-industry	Inter-firm
Project scale						
FUNDING	**0.386 (0.088)** [a]	**0.544 (0.145)** [a]	**0.159 (0.081)** [b]	**0.240 (0.756)** [a]	0.209 (0.156)	**0.436 (0.134)** [a]
PARTNERS	**0.145 (0.082)** [c]	0.091 (0.095)	**0.351 (0.142)** [b]	0.326 (0.098)	0.032 (0.110)	0.032 (0.226)
Project characteristics						
DURATION	-0.002 (0.001)	0.001 (0.002)	**-0.008 (0.002)** [a]	**0.003 (0.002)** [c]	**0.004 (0.002)** [b]	0.001 (0.003)
DURATION²	0.000 (0.000)	-0.000 (0.000)	**0.000 (0.000)** [a]	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
DISTANCE	-0.001 (0.003)	-0.000 (0.003)	-0.006 (0.005)	-0.000 (0.003)	-0.001 (0.003)	0.005 (0.005)
INTERNATIONALITY	-0.011 (0.177)	-0.073 (0.212)	-0.215 (0.315)	**0.884 (0.180)** [a]	**0.893 (0.206)** [a]	**0.659 (0.373)** [c]
Cooperation partners						
UNIVERSITY	-0.152 (0.175)	-0.072 (0.199)	- -	**0.696 (0.185)** [a]	**0.533 (0.210)** [b]	- -
APPLICATION	0.077 (0.362)	0.193 (0.372)	- -	0.372 (0.378)	0.303 (0.395)	- -
LARGE	**0.637 (0.204)** [a]	0.328 (0.253)	**1.066 (0.322)** [a]	0.056 (0.250)	0.298 (0.292)	-0.683 (0.543)
Constant	-0.024 (0.618)	**-1.404 (0.786)** [c]	**2.347 (1.054)** [b]	**-2.062 (0.726)** [a]	**-2.665 (0.858)** [a]	-0.952 (1.461)
Number of Observations	406	313	93	406	313	93
Pseudo R² (Prob>Chi²)	**0.0673 (0.000)** [a]	**0.0365 (0.000)** [a]	**0.1384 (0.000)** [a]	**0.0575 (0.000)** [a]	**0.0587 (0.000)** [a]	**0.0734 (0.001)** [a]
Log Likelihood	-568.21108	-404.3089	-153.43476	-763.00154	-609.09754	-148.5535

Bold coefficients/ standard errors indicate statistical significance. – [a] Significant at the 1 percent-level. – [b] Significant at the 5 percent-level. – [c] Significant at the 10 percent-level.

6. Discussion

The present paper provides insights on the relationship between the innovative success of R&D cooperation projects and project characteristics and organization. For our analysis, we build on project-level data on 406 R&D cooperation projects. The innovative output of R&D cooperation projects is measured as patent applications and publications of project members as outcomes of R&D projects. Besides the small amount of research carried out on the project-level in general, there is – to the best of our knowledge – no previous empirical evidence for Germany.

In accordance with existing results on the success of cooperative agreements (Harrigan 1988; Branstetter and Sakakibara 2002; Okamuro 2007), our findings particularly emphasize the importance of systematic considerations 'with whom to co-operate with' when setting up an innovation cooperation.[14] Our findings are coherent with this literature since they suggest that the design of the R&D consortium can be an important predictor of consortiums' innovative success. First, whereas the diffusion and commercialization of R&D outcomes via patent applications is the predominant objective of R&D cooperation, the involvement of large private firms is more likely to increase R&D projects' success.[15] This relationship seems particularly relevant for pure inter-firm cooperations, which implies that this type of collaborative R&D particularly benefits from the resources large firms allocate to the project. For R&D cooperation projects involving academic partners, we could not find such relationships. Second, including large industry partners seems less important for R&D consortia that primarily focus on the exploitation and dissemination of their outcomes from collective R&D efforts through publications. For those R&D consortia, the integration of universities, which naturally aim at more radical types of innovation and generic knowledge creation, seems to be more effective than including application-oriented academic organizations or large private firms.

We provide further evidence on the importance of the financial level of resources that are devoted to the cooperative R&D project. We find a positive relationship between the extent of funding of R&D projects and both indicators of innovative success patents and publications. In such, we contrast results of Bizan (2003) who reports insignificant re-

[14] Branstetter and Sakakibara (2002, p. 156) even conclude from their research: "(…) the *design* of a consortium matters much more then the *level of resources* expended on it. Putting more money into a consortium in which the members have little prospects for technological spillover, little incentive to cooperate (…) will not help matters much. Likewise, a well-designed consortium may have beneficial effects even if the direct subsidies expended are modest." [italics in original].

[15] Nevertheless, in the present study, we could not control as to whether the inventions developed during R&D cooperation projects are commercially successful. As noted previously, we use the patent applications as proxy for project innovation output and not the actual grant, because the time span between application and grant may be considerably long. Studying the post-project performance of participants, thereby linking projects output to performance measures, seems therefore to be an important research objective in the future.

sults for technical success (but significantly negative results for duration to commercialization) using project funding as indicator for project scale.

Contrasting the common assumption, spatial proximity between partners in collaborative R&D could not be confirmed as a factor for the success of R&D cooperation projects. We may hypothesize that, although partner are located proximate to each other, they mostly tend to fail to establish other dimensions of proximity (social, cultural) (*Katz* 1994; *Boschma* 2005). In the present study we could not account for social dynamics within R&D projects, such as decision-making processes. Those interactions naturally take place on an inter-individual level rather than between organizations. For reasons of simplicity, in research settings sometimes such personal networks are subsumed under inter-organizational relationships (between firms). But such an approach fairly ignores complex interactions on the (inter-) personal level, possibly shaping R&D project outcomes. This issue is addressed and criticized recently (Grabher and Ibert 2006).

Our investigation has some further limitations. Additional characteristics (of the project partners) that potentially might contribute to the success of the project could not be included. It seems reasonable to assume that most partners within a project consortium were previously related and have, for instance, co-operated on other R&D projects before. There was no information in our database as to whether the partners in one project knew each other before co-operating. We further raise the question under which particular constellations R&D and innovation projects tend to fail to reach their objectives. We are aware that not all projects that do not end up applying for a patent or publish an article in an academic journal can be deemed failures. However, the explicit investigation of cooperation failures, opposed to the investigation of the determinants and outcomes of R&D cooperation, has yet attracted sparse attention by researchers (e.g. Caloghirou et al. 2003; Lhuillery and Pfister 2009).

References

Allen, T.J. (1970): Communication networks in R&D laboratories, *R&D Management* 1, 14-21.

Anselin, L.; Varga, A.; Acs, Z. (1997): Local geographic spillovers between university research and high technology innovations, *Journal of Urban Economics* 42, 422-448.

Aschhoff, B.; Schmidt, T. (2006): Empirical evidence on the success of R&D cooperation: happy together? *ZEW Discussion Papers* 06-59, Centre for European Economic Research.

Audretsch, D.B.; Feldman, M.P. (1996): R&D spillovers and the geography of innovation and production, *American Economic Review* 86, 630-640.

Belderbos, R.; Carree, M.; Lokshin, B. (2006): Complementarity in R&D Cooperation Strategies, *Review of Industrial Organization* 28, S. 401-426.

Bizan, O. (2003): The determinants of success of R&D projects: evidence form American-Israeli research alliances, *Research Policy* 32 (9), S. 1619-1640.

Boschma, R. (2005): Proximity and Innovation: A Critical Assessment. *Regional Studies* 39, 61-74.

Bozeman, B. (2000), Technology transfer and public policy: a review of research and theory, *Research Policy* 29, 627-655.

Branstetter, L.; Sakakibara, M. (2002): When do research consortia work well and why? Evidence from Japanese panel data. *American Economic Review* 92, 143-159.

Breschi, S.; Lissoni, F. (2001): Knowlegde Spillovers and Local Innovation Systems: A Critical Survey. *Industrial and Corporate Change* 10, 975 - 1005.

Brockhoff, K.; Gupta, A.K.; Rotering, C. (1991): Inter-firm R&D co-operations in Germany, *Technovation* 11 (4), S. 219-229.

Burt, R.S. (1992): *Structural Holes – The Social Structure of Competition*, Cambridge.

Caloghirou, Y.; Hondroyiannis, G.; Vonortas, N.S. (2003): The performance of research partnerships, *Managerial and Decision Economics* 24 (2-3), S. 85-99.

Cameron, A.C.; Trivedi, P.K. (2005): *Microeconometrics: methods and applications*. Cambridge University Press.

Cantner, U.; Graf, H. (2004): Cooperation and specialization in German technology regions. *Journal of Evolutionary Economics* 14, 543-562.

Carter, A.P. (1989): Knowhow trading as economic exchange, *Research Policy* 18, 155 – 163.

Cohen, W.M.; Nelson, R.R.; Walsh, J.P. (2000): Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not). *National Bureau of Economic Research (NBER) Working Paper* No. W7552.

Coleman, J.S. (1990): *Foundations of Social Theory*, Cambridge.

Cooke, P.; Morgan, K. (1998): *The Associational Economy: Firms, Regions and Innovation*. University Press, Oxford.

Dahl, M.S.; Pedersen, C.Ø.R. (2004): Knowledge Flows through Informal Contacts in Industrial Clusters: Myth or Reality?, *Research Policy* 33, 1673 – 1686.

Feldman, M.P.; Audretsch, D.B. (1999): Innovation in cities: Science-based diversity, specialization and localized competition, *European Economic Review* 43, 409-429.

Fornahl, D.; Brenner, T. (2009): Geographic Concentration of Innovative Activities in Germany. *Structural Change and Economic Dynamics* doi:10.1016/j.strueco.2009.05.001

Freeman, C. (1987): *Technology policy and economic performance: lessons from Japan*. London: Pinter.

Free State of Saxony (2000), *Operationelles Programm zur Strukturfondsförderung des Freistaates Sachsen: 2000 – 2006* (CCI-Nr.: 1999 DE 16 1 PO 006). Geänderte Fassung vom 09.05.2006, Dresden.

Frietsch, R.; Köhler, F.; Blind, K. (2008): Weltmarktpatente - Strukturen und deren Veränderungen. Studien zum deutschen Innovationssystem Nr. 7-2008.

Fritsch, M.; Lukas, R. (2001): Who cooperates on R&D? *Research Policy* 30, 297—312.

Fritsch, M.; Slavtchev, V. (2007): Universities and Innovation in Space, *Industry and Innovation* 14, 201-218.

Fritsch, M.; Slavtchev, V. (2009): How does industry specialization affect the efficiency of regional innovation systems?, *Annals of regional science*, DOI10.1007/s00168-009-0292-9.

Grabher, G.; Ibert, O. (2006): Bad company? The ambiguity of personal knowledge networks. *Journal of Economic Geography* 6, 251 – 271.

Granovetter, M.S. (1985): Economic action and social structure: A theory of embeddedness, *American Journal of Sociology* 91, 481-510.

Griliches, Z. (1990): Patent Statistics as Economic Indicators: A survey. *Journal of Economic Literature* 28, 1661-1707.

Günther, J.; Gebhardt, O. (2005): Eastern Germany in the process of catching-up. The role of foreign and Western German investors in technological renewal, *Eastern European Economics* 43, 78-102.

Hagedoorn, J. (1993): Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences, *Strategic Management Journal* 14, 371-385.

Hall, B.; Link, A.; Scott, J. (2003): Universities as Research Partners. *Review of Economics and Statistics* 85, 485-491.

Hamel, G. (1991): Competition for competence and inter-partner learning within international strategic alliances. *Strategic Management Journal* 12, 83-103.

Hamel, G.; Doz, Y.; Prahalad, C. (1989): Collaborate with your Competitors - and win. *Harvard Business Review* 67, 133–139.

Häusler, J.; Hohn, H.-W.; Lütz, S. (1994): Contingencies of innovative networks: A case study of successful R&D interfirm collaboration, *Research Policy* 23, S. 47-66.

Harrigan, K. (1988): Strategic alliances and partner asymmetries. in: Contractor, F., Lorange, P. (eds.), *Cooperative Strategies in International Business*. Lexington Books.

Hilbe, J.M. (2007): *Negative Binomial Regression*. Cambridge University Press.

Hoegl, M.; Proserpio, L. (2004): Team member proximity and teamwork in innovative projects, *Research Policy* 33 (8), S. 1153-1165.

Hornych, C.; Schwartz, M. (2009): Industry concentration and regional innovative performance: Empirical evidence for Eastern Germany, *Post-Communist Economies* 21, 513-530.

Jaffe, A.B.; Trajtenberg, M.; Henderson, R. (1993): Geographic localization of knowledge spillovers as evidenced by patent citations, *Quarterly Journal of Economics* 63, 577 – 598.

Kale, P.; Singh, H.; Permutter, H. (2000): Learning and protection of proprietary assets in strategic alliances: building relational capital. *Strategic Management Journal* 21, 217-237.

Kandel, E.; Lazear, E.P. (1992): Peer pressure and partnerships. *Journal of Political Economy* 100, 801-817.

Katz, J.S. (1994): Geographical proximity and scientific collaboration. *Scientometrics* 31, 31-43.

Keller, R.T. (1986): Predictors of the performance of project groups in R&D organizations, *Academy of Management Journal* 29, 715-726.

Kim, H.; Park, Y. (2008): The impact of R&D collaboration on innovative performance in Korea: A Bayesian network approach, *Scientometrics* 75, S. 535-554.

Koka, B.R.; Prescott, J.E. (2002): Strategic Alliances as Social Capital: A Multidimensional View. *Strategic Management Journal* 23, 795-816.

Lhuillery, S.; Pfister, E. (2009): R&D cooperation and failures in innovation projects: Empirical evidence from French CIS data, *Research Policy* 38, S. 45-57.

Lööf, H.; Broström, A. (2008): Does knowledge diffusion between university and industry increase innovativeness? *Journal of Technology Transfer* 33, 73-90.

Lorenzen, M. (1998): Information cost, learning, and trust, DRUID Summer Conference 1998, http://www.business.auc.dk/druid/conferences/summer1998/conf-papers/lorenzen.pdf.

Lundvall, B.-A. (1992): *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

Malmberg, A.; Maskell, P. (1997): Towards an Explanation of Regional Specialization and Industry Agglomeration, *European Planning Studies* 5, 25 – 42.

Mansfield, E.; Schwartz, M.; Wagner, S. (1981): Imitation costs and patents: an empirical study. *The Economic Journal* 9, 907 -918.

Markman, G.D.; Phan, P.H.; Balkin, D.B.; Gianiodis, P.T. (2005): Entrepreneurship and university-based technology transfer. *Journal of Business Venturing* 20, 241-263.

Meyer-Krahmer, F.; Schmoch, U. (1998): Science-based technologies: university-industry interactions in four fields. *Research Policy* 27, 835-851.

Mora-Valentin, E.M.; Montoro-Sanchez, A.; Guerras-Martin, L.A. (2004): Determining factors in the success of R&D cooperative agreements between firms and research organizations, *Research Policy* 33 (1), S. 17-40.

Motti, L.; Sachwald, F. (2003): Co-operative R&D: why and with whom?, *Research Policy* 32 (8), S. 1481-1499.

Muldur, U.; Corvers, F.; Delanghe, H.; Dratwa, J.; Heimberger, D.; Sloan, B.; Vanslembrouck, S. (2006): *A New Deal for an Effective European Research Policy : The Design and Impacts of the 7th Framework Programme*. Springer.

Negassi, S. (2004): R&D co-operation and innovation a microeconometric study on French firms, *Research Policy* 33 (3), S. 365-384.

Nelson, R.R. (1993): *National Innovation Systems: A comparative Analysis*. Oxford University Press.

Okamuro, H. (2007): Determinants of successful R&D cooperation in Japanese small businesses: The impact of organizations and contractual characteristics, *Research Policy* 36 (10), S. 1529-1544.

Plasmans, J. (2006): *Modern Linear and Nonlinear Econometrics*. Springer.

Rothaermel, F.T.; Agung, S.D.; Jiang, L. (2007): University Entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change* 16, 691-791.

Sakakibara, M. (1997): Evaluation government-sponsored R&D consortia in Japan: who benefits and how?, *Research Policy* 26, S. 447-473.

Schmoch, U. (1999): Impact of International Patent Applications on Patent Indicators. *Research Evaluation* 8, 119-131.

Schneider, L.; Günther, J.; Brandenburg, B. (2010): Innovation and skills from a sectoral perspective - A linked employer-employee analysis, *Economics of Innovation and New Technology* 19, 185-202.

Uzzi, B. (1997): Social Structure and Competition in Interfirm Networks: The Paradox of Embeddedness, *Adminstrative Science Quarterly* 42, 35-67.

Veugelers, R. (1998): Collaboration in R&D: An Assessment of Theoretical and Empirical Findings, *DeEconomist* 146, S. 419–443.

Von Hippel, E. (1987): Cooperation Between Rivals: Informal Know-How Trading, *Research Policy* 16, 291 –302.

Zucker, L.G.; Darby, M.R.; Brewer, M.B. (1998): Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises, *American Economic Review* 88, 290 – 306.