Technovation 30 (2010) 485–495

Contents lists available at ScienceDirect

Technovation

journal homepage: www.elsevier.com/locate/technovation

Cooperation patterns of incubator firms and the impact of incubator specialization: Empirical evidence from Germany

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ARTICLE INFO

Keywords:
Business incubators
Science parks
Specialization
Diversification
Networking
Academic–industry-linkages
Local technology policy

ABSTRACT

The article examines cooperation patterns of 150 firms located in German business incubators (BIs). More specifically, this study distinguishes between networking within the tenant portfolio and the academic–industry linkages of the tenant firms. We further contribute to the relevant literature by explicitly considering differences in cooperation patterns between firms located on diversified and specialized incubator facilities. Empirical results do not support the common assumption that specialized incubation strategies increase the effectiveness of incubator-internal networking compared to diversified BIs. Also, incubator specialization is not superior to diversified incubators with respect to the promotion of linkages of their tenants with academic institutions. For academic linkages, industry effects matter more than incubator characteristics.

1. Introduction

Research on the impact of being located in a Business Incubator (BI) or on a Science Park underscores the importance of the incubator as an intermediary – or mediating – organization, helping newly founded and young ventures to establish cooperative relationships with a broad range of economic actors (Löfsten and Lindelöf, 2005; Rothschild and Darr, 2005; Bergek and Norrman, 2008).

Generally, BI initiatives are policy instruments for the promotion of entrepreneurship, innovation and the development of new technology-based firms (OECD, 1997; European Commission, 2002; Hackett and Dilts, 2004). Two specific dimensions are of particular importance to client firms in forming essential network ties and thus supporting their access to various resources. First, efficient networking within the incubators fostering formal (R&D) agreements and informal interactions between the firms is understood as a critical factor for successful incubation processes (Hansen et al., 2000; McAdam and McAdam, 2006; Scillitoe and Chakrabarti, 2010). Second, through the promotion of linkages between client firms and academic institutions (universities in particular), incubators act as catalysts for the transfer of knowledge and technology, thereby facilitating and accelerating innovation processes (Mian, 1996; Vedovello, 1997; Bakouros et al., 2002).

Nevertheless, it is increasingly questioned if BIs are effective policy instruments to fulfil their essential role as intermediaries helping to develop such networking arrangements (e.g., van Dierdonck et al., 1991; Bakouros et al., 2002). In this respect, recent literature clearly emphasizes the potential for the increased effectiveness of specialized incubation strategies in encouraging communication and networking relationships, specifically with respect to incubator-internal cooperation patterns (Schwartz and Hornych, 2008). BIs are defined here as specialized if support elements and processes, as well as the selection criteria applied by the incubator management, focus on firms from solely one sector. Specialized business incubators (SBIs) are increasingly perceived by local decision-makers as equivalent alternatives to diversified business incubators (DBIs) (Cooke et al., 2006; Aerts et al., 2007; Schwartz and Hornych, 2008).

However, mostly specialization is simply assumed to be advantageous without any empirical proof of the actual impact of these strategies on the cooperation patterns of incubated firms. The present study contributes to the literature by filling this gap. More specifically, the paper tries to answer four questions: (1a) What cooperation patterns within BIs can be identified? (1b) Does incubator-internal networking differ between SBIs and DBIs? (2a) What cooperation patterns between incubator firms and academic institutions can be identified? (2b) Do linkages to academic institutions differ between SBIs and DBIs?

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doi:10.1016/j.technovation.2010.05.001

The empirical analyses are based on a recent survey of 150 firms located in 26 BIs in Germany—13 specialized and 13 diversified. Section 2 discusses theory on the importance of networks and how incubator support might contribute to the establishment of different relationships. Moreover, a brief review of the empirical evidence regarding cooperation patterns of incubator firms is provided. Hypotheses are derived and tested in the empirical part of the paper. Section 3 describes the data collection process. The empirical results are presented in Section 4. Section 5 discusses the results, and Section 6 shows some limitations.

2. Networking of incubator firms—Derivation of hypotheses

Most young innovative ventures are characterized by a considerable discrepancy between key resources that are crucial for long-term viability and the actual firm's resource base. These firms face a 'liability of newness', which relates to the high failure risk young firms face in the first years after market entry, because they do not possess the resources they need to survive (Stinchcombe, 1965; Hannan and Freeman, 1984). Therefore, access to various resources via differentiated networking activities is considered to be decisive for successful firm development. Resources might be physical (e.g., plants, equipment), financial (e.g., bank deposits), human (e.g., experiences, specialized knowledge), technological as well as a firm's reputation or intellectual property rights (Barney, 1991; Grant, 1991).

BI support mechanisms concentrate on the generation, complement, enhancement and exploitation of the resource base of new ventures (Aernoudt, 2004; Hytti and Mäki, 2007; McAdam and McAdam, 2008) and, therefore, focus on the compensation of early-stage resource deficits to ensure economic growth and to reduce the 'liability of newness'. The basic ingredients of incubation (infrastructure provision, shared services, management support, etc.), have been listed and discussed in numerous studies (e.g., Allen and McCluskey, 1990; Sternberg et al., 1996; Mian, 1996; Westhead and Batstone, 1998; European Commission, 2002; Hytti and Mäki, 2007). Because new firms lack necessary stable business relationships (Stinchcombe, 1965), the incubator takes the position of an intermediary organization, helping the firms to establish formal and informal contacts and to gain access to various resources. Incubators' networks may be comprised of, for instance, potential customers and suppliers, a wide network of specialized service providers (e.g., lawyers, tax accountants), different financial institutions (e.g., banks, venture capitalists), public and private research facilities and political institutions (e.g., local development agencies, funding agencies). Such cooperative relationships can themselves even be understood as critical intangible resources (DeBresson and Amesse, 1991; Uzzi, 1997).

Among these different access paths, the present study concentrates on inter-firm networking between incubated firms and their linkages to academic institutions. We focus on these two dimensions because they are of particular interest for incubator/incubation research as well as for policy makers that are concerned with the establishment and operation of incubator organizations. With respect to internal networking, prior research particularly questions the effectiveness of incubators in promoting inter-firm linkages within the tenant portfolio (Section 2.1). Regarding the linkages between incubated firms and academic institutions, there is also broad empirical evidence that incubators seem to fail as effective policy measures to promote technology transfer (Section 2.2). Therefore, on the basis of theoretical perspectives and prior research findings, the following two subsections discuss briefly how incubators are generally expected to contribute to these two modes of incubator-firm networking, and what might be the impact of an SBI concept on both types of networking. Each sub-section ends with a hypothesis that is tested in the empirical part of this paper.

2.1. Networking within incubators

An important aspect of the value-added contributions of a BI location is seen in its potential to foster cooperative interactions and synergies between the firms 'in-house'. As social capital theory states, economic activities are embedded in social networks (Granovetter, 1985). Therefore, the existence of network relations and position in the social structure affect the scope for individual action, in particular by determining access to information (Coleman, 1990; Burt, 1992). Social networks among entrepreneurs are seen as a critical strategic resource (Lechner and Leyronas, 2007). Spatial proximity between BI firms facilitates the transfer of valuable information and knowledge and the exchange of experiences and provides opportunities to work on and acquire certain projects jointly. Incubator management tries to fulfil an essential bridging function, bringing together their tenant firms, for instance through the organization of periodic discussions, introductions of new tenants or the establishment of a cafeteria as meeting point.

However, it is increasingly argued that in traditional incubation models, that is diversified BIs, firms may lack the absorptive capacity to understand and acquire externally available knowledge provided by the other firms (Cohen and Levinthal, 1989, 1990). Does the clustering of firms in BIs help to develop networking arrangements and the exchange of resources within the tenant portfolio? There is some evidence confirming those agglomeration advantages, for instance, Phillimore (1999) finds for an Australian science park, there are valuable innovation-related networks within the park community. More recently, McAdam and McAdam (2008) support this view by studying young high tech firms in two university science park incubators. Inter alia, they find that close proximity is considered by the firms to be an important factor for the establishment of networking arrangements.

Nevertheless, there is a bulk of empirical work that seriously challenges this proximity effect on client networks within incubators. Bakouros et al. (2002) surveyed science parks in Greece and investigated different forms of interaction between park companies. While social interaction and commercial transactions can be identified as being at least important to some extent, incubator-internal networking activities in general and joint research in particular, seem to be rather limited. In this context, Chan and Lau (2005) find in their multiple case studies that incubator-initiated events cannot fulfil a bridging function resulting from barriers of communication and cooperation. More recent research highlights that certain tenant suitability seems to be necessary for communication processes and resource sharing within the incubator (Steinkühler, 1994; Mowery et al., 1998; Hansen et al., 2000; Kihlgren, 2003; Bøllingtoft and Ulhøi, 2005; Chan and Lau, 2005; Tötterman and Sten, 2005). To stimulate cooperation, some sufficiently overlapping core competencies, knowledge bases and market focus between the firms might be needed (Mowery et al., 1998; Hansen et al., 2000; Tötterman and Sten, 2005). These pre-conditions seem to be found in a BI that is specialized. Because of a more homogenous tenant portfolio, such SBIs might provide a stronger platform for cooperation processes. Hypothesis 1 is formulated accordingly:

H1. Firms located in specialized business incubators have a higher probability for incubator-internal cooperation compared to firms located in diversified business incubators.

2.2. Linkages with academic institutions

Linkages to academic institutions, including universities, technical colleges, extra-mural research facilities and private R&D laboratories/departments, are relevant in particular for technology-oriented firms and can be seen as a major source for innovation, firm growth and competitive advantage (for an overview of university-based technology transfer, see, for instance, Bozeman, 2000; Markman et al., 2005; Rothaermel et al., 2007). Through these linkages the most recent scientific knowledge and expertise in specific technological fields can be acquired or exchanged, joint R&D projects can be initialized and the firms might get access to specific tools and machinery not available in-house due to cost reasons. Furthermore, since the most important knowledge spillovers from universities seem to be geographically bounded (e.g., Jaffe, 1989; Acs et al., 1992), being in close vicinity to the sources of spillovers becomes crucial for their entrepreneurial exploitation (Audretsch and Feldman, 1996). Considering innovation efforts in particular, close linkages act as catalysts 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 between researchers, engineers and managers and is difficult to realize over great distances (Malmberg and Maskell, 1997).

In many cases incubator facilities provide this necessary proximity to academic institutions, thus supporting the development of their client firms. Sometimes, university faculties are even tenants in a BI. Besides formal agreements, such as joint patenting, informal relationships between incubated firms and academic institutions and personnel also matter for inter-organizational and inter-individual knowledge and resource transfer (Link et al., 2007). Bakouros et al. (2002: 126) define informal relationships between firms and academia as the personal relationships of the actors involved, access to technical literature and the latest research results, the attendance of seminars and conferences, access to equipment relevant for research and also the inclusion of students. As a study by Mian (1996) reveals, among university-related support components, specifically the reputation of being associated with a (well-known) university/research organization, enhanced opportunities for personnel recruitment, and access to highly specific and sophisticated equipment and laboratories are perceived by incubator firms to be very important for their own development (see also the study of McAdam and McAdam, 2008). Through linkages with universities, the incubated firms gain access to physical resources that might not otherwise have been available to them.

In general, studies investigating the level of interaction of incubated firms with academic institutions, particularly local universities, show that these linkages are mostly rather loose. Though, studies using the control-group concept find that on-park firms exhibit a higher degree of cooperation propensity in innovation processes with higher education institutions than comparable firms located outside those facilities (Colombo and Delmastro, 2002; Lindelöf and Löfsten, 2004; Fukugawa, 2006; Yang et al., 2009). There is broad evidence that informal relationships are more often a source of information and knowledge acquisition than more formalized connections (Monck et al., 1988; Massey et al., 1992; Westhead and Storey, 1994; Vedovello, 1997; Bakouros et al., 2002). For instance, van Dierdonck et al. (1991) analyzed science parks in Belgium and the Netherlands and their role in fostering R&D networks between incubated firms and the 'local science park environment'. Because the majority of firms have contacts with local universities, but only a small fraction of these contacts involves formal R&D cooperation's, the authors state that 'a science park is not necessarily the most effective way to become involved in industrial science and technology' (van Dierdonck et al., 1991, p. 122).

Considering the German incubator landscape in particular, on the level of the incubated firm, prior research has found a comparably high propensity to engage in cooperation with academic institutions. Studies report that approximately 75–80% of incubator firms have academic linkages (Sternberg, 1988; Tamásy, 1996; Seeger, 1997—for an overview see Sternberg et al., 1996). Nevertheless, in accordance with Massey et al. (1992) or van Dierdonck et al. (1991), most researchers question the effectiveness of German incubators to fulfil the underlying functions of technology transfer.

A recent contribution (Schwartz, 2009) argues that firms in SBIs have a greater tendency to be associated with academic institutions. The basic argument is that most SBIs concentrate on R&D intensive firms. Such firms are dependent on highly specific and sophisticated equipment to perform continuous R&D. Not having access to facilities and equipment (e.g., mass spectrometers, laboratories with certain safety standards, etc.), can affect firms' development negatively. Pevious research shows that particularly firms with a high R&D intensity tend to engage in cooperations with academic institutions (Arundel and Geuna, 2004; Fontana et al., 2006). SBIs therefore have a considerable higher incentive to establish contacts between their tenants and academic institutions in order to facilitate access to these resources, i.e., to university-related inputs (Mian, 1996). This suggests a positive relationship between an SBI-location and linkages with academic institutions:

H2a. Firms located in specialized business incubators have a higher probability for linkages with academic institutions compared to firms located in diversified business incubators.

The argument related to R&D intensity, however, neglects that industry-specific resource needs might be also important for establishing linkages. As for instance, Cohen et al. (2002) show, the relevance of public research differs between industries. Academic research is especially important for industries with fast changing technologies (Veugelers and Cassiman, 2005). Most SBIs in Germany specialize in firms from sectors that are very likely to be associated with academic institutions because of their dependence on scientific know-how and technology, such as biotechnology, media-technology and medical-technology (Storper, 1989; Powell et al., 1996; Rosenfeld et al., 2008). Accordingly, we expect that introducing industry effects into the analysis will eliminate the above-formulated relationship between location in SBIs and firms' propensity to cooperate with academic institutions:

H2b. The probability for linkages with academic institutions is determined by firms' industry affiliations, not by the type of incubator the firm is located in.

3. Data collection

Incubation facilities in Germany are officially termed 'Innovation Centres' by the German Association of Technology Centres (ADT), whereas formerly the term 'Technologie- und Gründerzentrum' was used. Both terms must be understood as umbrella concepts, covering business incubators and technology centres. While business incubators focus mostly on newly founded ventures with little differentiation regarding technological sophistication, technology centres mainly focus on innovative small- and medium-sized firms (Sternberg et al., 1996; Tamásy, 2001; Baranowski et al., 2008). Neither type restricts itself to one target group or another though. Business incubators and technology centres both provide

comprehensive hands-on support, technical services and consultancy offers for young and newly founded firms in the first years after market entry (e.g., Schwartz and Hornych, 2008). To fulfil the underlying incubator function, after 3–5 years, the tenants are expected to leave the incubator. Thus, the German concept of incubation facilities corresponds to the definition of business incubation put forward by the United Kingdom Business Incubation (UKBI) (UKBI, 2009).

In practice, there exists a broad range of terminologies for business incubators and/or technology centres. This heterogeneity, which is a well-known problem in incubator-incubation research (Thierstein and Wilhelm, 2001; Hackett and Dilts, 2004), makes it difficult to distinguish between both types of German incubator facilities. Sometimes, a specific name for an incubator is chosen by its stakeholders primarily for marketing issues to attract attention in public. The name of an incubator organization does not necessarily reflect its 'content' (Tamásy, 2001). For instance, 16% of German incubator facilities call themselves 'Science/Technology Parks' (Baranowski et al., 2008: 34), but should actually be considered business incubators or technology centres. To avoid juggling with names, in the present paper the term BI will therefore refer to both constructs, that is business incubators and technology centres. On average, German BI organizations provide rental space of 5964 m^2 in addition to 900 m^2 of infrastructure space and have 33 tenant firms with seven employees each (Baranowski et al., 2005: 28).

In order to test the three hypotheses empirically, a cross-sectional analysis of firms located in German BIs was conducted in March/April 2008. First, all 415 German incubators operating at the end of 2006 (see Schwartz, 2007 for details about this survey) were classified as being specialized or diversified by the authors. There is neither a generally accepted definition nor a precise set of criteria that defines what constitutes an SBI. The decision as to whether an incubator is classified as specialized is made according to the specifications already put forward in the introductory section of this paper: 'BIs are defined here as specialized if support elements and processes, as well as the selection criteria applied by the incubator management, focus on firms from solely one sector.' The classification is based on several sources; primarily, the incubators' web presence (e.g., current tenant structure, equipment provided by the BI, scope and particularities of consulting offers, selection criteria) as well as brochures, and supplemented by official information from the ADT (Baranowski et al., 2005; 2008). Where difficulties emerged, the management of the respective incubator was contacted by telephone. In spite of this, classification decisions were not always straightforward. If no unambiguous final decision could be reached, the incubator was classified as diversified. This restrictive approach ensures that all SBIs in our sample clearly match the criteria noted above.

We initially chose to limit this study to a stratified random sample of thirteen SBIs and DBIs since the inclusion of all the operating incubators was not feasible, mainly because of the financial constraints of this research project. A brief comparison between the two incubator types using different criteria reveals slight differences. First, the average age of the specialized (diversified) incubators is 10.6 (12.5) years, the difference resulting from the relatively recent establishment of SBIs (Schwartz and Hornych, 2008). Concerning the rental space, SBIs (8533 m^2) are bigger than DBIs (5799 m^2) in this study, which can be traced back to one particular incubator with 41 000 m^2. Excluding this outlier, SBIs exhibit an average rental space of 5827 m^2. Furthermore, there are differences concerning the average number of firms incubated between SBIs (26.3) and DBIs (39.0). This can be explained by the fact that, in SBIs, there are considerably more faculties from universities and public research organizations than in DBIs. In most cases these organizations occupy much more rental space than small firms, and therefore limit the potential number of incubated firms in SBIs.

Based on information from the 26 incubators' websites, a dataset was created that included all organizations located in these BIs as at the end of February 2008. After some corrections (overall 21 non-private tenants such as universities and business development agencies were excluded), we obtained a dataset comprising 778 firms, 457 of them located in SBIs and 321 in DBIs. A standardized questionnaire was designed on the basis of prior BI-evaluations (e.g., Sternberg et al., 1996), pre-tested, with no modifications necessary, and mailed to all 778 firms at the beginning of April 2008. A second survey wave was done via e-mail at the end of April.

According to the central research questions, BI firms were asked to assess their portfolio of network contacts with other tenants and academic institutions. The questionnaire differentiated between several types of cooperation: (i) 'supplier–customer', (ii) 'information exchange', (iii) 'technological cooperation' and (iv) 'labour mobility'. Firms were asked whether they maintain such contacts. These types of cooperation are frequently discussed in the literature on inter-firm networking (e.g., Freeman, 1991; Tödtling, 1994; Ozman, 2009) and have been found in prior studies to be important in the context of networking within incubators and between incubator firms and academic institutions (e.g., Sternberg et al., 1996; Westhead and Storey, 1994; Schwartz, 2009). In addition, the questionnaire included several questions with respect to firm-specific characteristics, such as start-up year or percentage of employees engaged in R&D.

Overall, 161 tenants participated in this study, yielding a total response rate of 20.7%; 67 respondents (41.6%) are located in SBIs and 94 (58.4%) in DBIs. While the aggregated response rates for both types of incubators are almost identical, with 20.9% for SBIs and 20.6% for DBIs, incubator-specific response rates vary between 7.7% and 44.4%. Further to this, 11 responses had to be excluded because the questionnaire was incomplete, reducing the final sample for this study to 150 firms, of which 84 are located in DBIs and 66 in SBIs. A complete list of all 26 BIs, their central characteristics and corresponding response rates is provided in Appendix A.

4. Empirical results

As elaborated in the previous section, tenants were asked to characterize their individual portfolio of networking activities with respect to other incubated firms as well as academic institutions. An overview of the 150 firms' cooperation patterns is presented in Table 1.

The following Section 4.1 investigates in more detail the incubator-internal relationships. Section 4.2 analyzes the linkages of surveyed firms to academic institutions. Both sub-sections differentiate between overall networking activities and the impact of incubator specialization on cooperation patterns. Finally, regression results considering the determinants of different types of cooperation activities are presented in Section 4.3.

4.1. Incubator-internal cooperation patterns

According to the survey results displayed in Table 1, 'information exchange' is the most common type of cooperation between the BI firms included in our study. It is mentioned by two-thirds of all respondents. In contrast, 'labour mobility' within the incubators seems to be rather unimportant for the incubated firms with a relative frequency of only 8.7% among our sample. With respect

to other formal types of cooperation activities, approximately every third tenant firm is engaged in 'supplier–customer' relationships (42 positive responses) and 33 out of 150 firms mention a 'technological cooperation'. Overall, a minority of respondents (18.7%) does not have any cooperative relationship within the BI, whereas about 81% of the BI firms have at least one contact at the firm level.

Table 2 provides a differentiated view of the surveyed firms' cooperative behaviour according to their specific incubator location, that is, DBI versus SBI. Differences in the relative frequencies of a particular type of cooperation of SBI firms compared to those of DBI firms were calculated. Values with a 'plus' indicate that firms in SBIs seem to have a (statistically significant) higher propensity to engage in a particular type of cooperation (based on a Chi-squared Test). 'Labour mobility' is omitted in this investigation because of its comparable low overall importance (see Table 1). With respect to H1, that is, as to whether tenant homogeneity in SBIs promotes intensified internal networking compared to DBI strategies, the corresponding findings are shown in the first line of Table 2. The results do not support the presumption that specialization strategies are conducive to incubator-internal networking. For instance, while 28.8% of SBI firms reported having a 'supplier–customer' relationship with other BI firms, 27.4% DBI firms are also engaged in this type of cooperation. The analysis reveals no statistically significant differences in all three types of incubator-internal cooperation patterns between SBI respondents and firms located in DBIs.

4.2. Linkages with academic institutions

Our survey results with respect to the networking of incubated firms with academic institutions show that informal relationships ('information exchange') are the most common channel of cooperation with academic institutions. 71 out of 150 respondents (47.3%) maintain such contacts. More formalized connections such as 'technological cooperation' and 'supplier–customer' relationships are mentioned less frequently by BI firms (see Table 1). Most interesting is that 57 tenants (38%) do not maintain any relationships with academic institutions, neither informal nor formalized. This value is *considerably higher* compared to findings from previous studies on German BIs. These studies report between 20% and 27% of incubator firms with no academic links (Sternberg, 1988; Tamásy, 1996; Seeger, 1997). Possible explanations are discussed in Section 5.

As for the investigation of incubator-internal linkages, the respondents were separated according to incubator type. Differences in the relative frequencies of a particular type of cooperation of SBI firms compared to those of DBI firms were calculated. The results are displayed in the second line of Table 2. There is considerable evidence to support H2a. SBI firms tend to have more academic–industry linkages compared to DBI firms. Considering 'supplier–customer' relationships as well as 'technological cooperations', the difference between the groups is statistically significant. Additionally, the findings reveal a distinct tendency that 'information exchange' occurs more frequently between SBI firms and academic institutions than between such institutions and DBI firms. Overall, 24.2% of all SBI firms do not sustain any relationships with academia while almost half of the DBI respondents (48.8%) have no academic linkages. The SBI value is widely comparable to previous findings on German BIs (Sternberg, 1988; Tamásy, 1996; Seeger, 1997).

Note, at this point we do not introduce industry effects. However, as formulated in H2b, our result might also be explained by industry differences (i.e., the sector/market focus of SBIs included in this study) and not so much by the support elements of the incubators themselves. All 13 SBIs concentrate on sectors that are known to have a high R&D intensity and that are essentially dependent on cooperative behaviour, that is biotechnology, media-technology and medical-technology (Storper, 1989; Powell et al., 1996; Rosenfeld et al., 2008). Additional survey data on respondents' R&D intensity, measured as the share of employees in R&D activities, reinforces this argument. SBI firms report an average R&D intensity of 49.6%, which is significantly higher than the average DBI firms' R&D intensity of 29.8%. It is therefore necessary to test for such industry effects. This will be part of the next section.

4.3. Regression analysis

To complement the descriptive analysis, binary regression models for the different types of firms' networking activities were estimated. This enables us to control for different firm-specific factors and to include industry effects that might determine the cooperative behaviour of the surveyed incubator firms. Four binary variables were specified as dependent variables that indicate (value one) whether an incubator firm: (i) maintains relationships with academic institutions, (ii) is engaged in customer–supplier relationships within the incubator, (iii) is engaged in information exchange within the incubator and (iv)

Table 1
Networking activities of incubator firms—number of surveyed firms being enagaged in cooperative relationships according to type of cooperation (relative frequencies in parentheses; multiple responses possible).
Source: Authors calculations.

Type of relationship	Supplier–customer	Information exchange	Technological cooperation	Labour mobility	No contacts
Incubator-internal ($N=150$)	42 *(28.0%)*	100 *(66.6%)*	33 *(22.0%)*	13 *(8.7%)*	28 *(18.7%)*
Academic–industry ($N=150$)	22 *(14.7%)*	71 *(47.3%)*	52 *(34.7%)*	27 *(18.0%)*	57 *(38.0%)*

Table 2
Differences in relative frequencies of cooperative relationships of SBI firms compared to DBI firms (differences in percentage points; N(SBI)=66; N(DBI)=84).

	Supplier–customer	Information exchange	Technological cooperation
Incubator–internal	+1.4	−2.7	+6.7
Academic–industry	+9.0*	+10.2	+32.8***

* Indicates statistically significant differences between the two groups on 1% level (Pearson's χ^2-test).
*** Indicates statistically significant differences between the two groups on 10% (Pearson's χ^2-test).

is engaged in technological cooperation within the incubator. According to the binary nature of the dependent variable(s), separate probit models were estimated (Greene, 2000). The independent variables are described below.

In addition to the firms' *R&D intensity* as a measure for the technological sophistication of the surveyed firms, as already described in Section 4.2, we included several other firm-specific variables that potentially could influence the propensity to cooperate. Most of the variables are generated using our survey results. Regarding the *establishment type* of the incubator firms, a dummy variable is used that distinguishes between independent firms (value zero) and subsidiaries, for instance a local trade office or service centre (value one). In the context of business incubation, subsidiaries are frequently founded within a BI simply to benefit from the relatively low rents or the shared facilities offered by the BI. Therefore, subsidiaries might be less interested in engaging in networking activities. To control for age effects on networking propensity we included a metric variable that measures firms' *age* in years at the time this study was conducted. Finally, the dummy variable *spin-off* denotes whether the incubator firm has been started by at least one founder who, prior to the founding, was employed at a public research institution (value one). This includes universities as well as institutes of the Max-Planck Society, Helmholtz-Association, Leibniz Society and Fraunhofer Society—the four important research societies in Germany.

In a further step, all surveyed incubator firms were classified according to the two-digit level of the NACE Rev. 2 classification of economic activities. The classification decisions were primarily based on information from CREDITREFORM, the largest German credit rating agency, which collects detailed information on almost all firms in the German commercial register (see Almus and Nerlinger (1999) for a description of this database). Additionally, we searched the firms' web presences and collected information regarding their products and services. For the purpose of our study, we aggregated the industry classifications into six groups: 'Manufacturing' (NACE Rev. 2 codes 20–37), 'Wholesale and retail trade' (46 and 47), 'ICT and media' (58–62), 'Consulting and business-related services (BRS)' (including engineering consultants, 69–71), 'Research and development' (72), and 'Others' (including mostly non-knowledge based services like, for example, call-centre and facility management). Six dummy variables indicate whether a firm belongs to one of these groups. See Appendix B for the distribution of these groups. 'Others' serves as a reference category in the regression models.

Besides firm-specific determinants, BI-related variables were considered in our regression analysis. To analyze the impact of incubator specialization on incubated firms' networking (the main objective of the present paper), a dummy variable *specialization strategy* is used. This variable denotes if a firm is located in one of the specialized BIs (value one). *The number of tenants* at survey time is used as an indicator for the pool of potential cooperation partners within the incubators. Prior research on German BIs does not suggest a positive impact of increasing incubator size on cooperation intensity (Sternberg, 1988; Seeger, 1997). In order to measure the degree of firms' knowledge of the skills and competencies of other firms in their incubator, we include the variable *information*. This variable reflects firms' assessment of how informed they feel about other incubated firms on a five-point Likert scale (from '1'=very bad to '5'=very good). Descriptive statistics of all variables and the bivariate correlation matrix can be found in Appendix B. To check for potential multicollinearity in the regression models, variance inflation factors (VIFs) were calculated. Although there is no formal VIF threshold value that determines the presence of multicollinearity, VIFs exceeding the value of 10 are commonly regarded as indicating multicollinearity (Baum, 2006, p. 85). This test does not show evidence of multicollinearity as for any model specification the maximum VIF is less than 5.

Table 3 displays the regression results for all eight model specifications. The first four models are specified without the industry dummies (the upper half of Table 3). To test for possible industry effects, each model was re-estimated including industry variables (the lower half of Table 3). This allows us to estimate industry effects for each of the four cooperation types independently. The highest explanatory power is reached for the models using the 'academic–industry linkages' as dependent variable (models 1 and 5). Note that the explanatory power of the regressions, although increased by adding industry variables, is limited.

With respect to the three types of incubator-internal cooperation patterns (models 2–4), the regression results give no indication that specialization strategies and a greater homogeneity of the tenant structure would be conducive to their establishment. The market strategy applied by the incubator does not significantly influence networking activities within BIs. However, a statistically significant positive relationship within all three models can be found between the degree of information known about other tenants and the propensity to cooperate with other incubator firms. Additionally, there is some evidence for the positive influence of incubator size, measured as the number of incubated firms, on the propensity to engage in supplier–customer relationships and technological cooperations. Overall, firm-specific variables do not seem to have a huge impact on networking activities with other incubator firms. A significant positive effect is revealed for the type of establishment on supplier–customer relationships. For other incubator-internal cooperation types the effect of this variable is not statistically significant, but it tends to be negative. Not surprisingly, we find a positive relationship between a firms' R&D intensity and the existence of technological cooperations. The addition of industry variables (model 6–8) reveals that these findings are rather robust. Incubator-internal cooperation patterns are marginally influenced by industry effects. All significant variables from models 2–4 keep both their statistical significance and their direction after industry effects are introduced. Only the industry dummy for 'Research and Development' is significantly positive associated with the propensity to engage in information exchange within the BIs. Thus, contrary to our theoretical expectations, the regression results for incubator-internal cooperation patterns agree with our findings of Section 4.1.2 and support rejecting H1.

Regarding the probability of establishing linkages to academic institutions (H2a and H2b), the results are not so straightforward. The results from model 1 seem to confirm our descriptive results from Section 4.2. According to this finding, firms located in SBIs seem to be more likely to cooperate with academic institutions when compared to firms located in DBIs. As expected, firms' R&D intensity as well as the spin-off variable are positively associated with interactions with academic institutions. Statistically significant negative relationships are identified for firms' age and establishment type. However, introducing industry effects in this regression (model 5) changes the results considerably. Whereas firms that are active in 'Manufacturing' and in 'Research and development' have a significantly positive probability of being academically linked, the variable denoting SBIs ('Specialization strategy') loses its significance. The same effect is observed for firms' R&D intensity, which is no significant predictor of academic–industry linkages in model 5. Taking these findings together, there is not enough empirical evidence to support H2a from our findings. In contrast, the regression results disclose that the propensity for incubated firms to cooperate with academic institutions is less dependent on the type of incubator than on industry differences. This leads us to support H2b.

Table 3
Results of bivariate probit regressions (N(obs)=150; standard errors in parentheses).

	Academic–industry linkages (*Model 1*)	Supplier–customer (*Model 2*)	Technological cooperation (*Model 3*)	Information exchange (*Model 4*)
Firm variables				
R&D intensity	0.008 (0.003)**	−0.004 (0.004)	0.006 (0.003)*	0.003 (0.003)
Spin-off	0.624 (0.238)***	−0.119 (0.250)	0.306 (0.280)	0.117 (0.242)
Establishment type	−0.622 (0.342)*	0.598 (0.332)*	−0.186 (0.386)	−0.269 (0.315)
Age	−0.053 (0.028)*	−0.000 (0.019)	−0.008 (0.021)	0.016 (0.019)
Incubator variables				
Specialization strategy	0.403 (0.242)*	0.293 (0.272)	0.415 (0.295)	−0.121 (0.255)
Number of tenants	–	0.012 (0.006)*	0.019 (0.006)***	0.004 (0.006)
Information	–	0.311 (0.121)***	0.227 (0.133)*	0.226 (0.110)**
Constant	106.407 (56.337)*	−1.428 (39.677)	13.577 (43.223)	−32.501 (38.306)
McFadden R^2	0.162	0.095	0.104	0.039
Log likelihood	−83.065***	−80.457**	−70.799**	−91.744
	Academic–industry linkages *(Model 5)*	Supplier–customer *(Model 6)*	Technological cooperation *(Model 7)*	Information exchange *(Model 8)*
Firm variables				
R&D intensity	0.006 (0.004)	−0.005 (0.004)	0.007 (0.004)*	−0.000 (0.004)
Spin-off	0.567 (0.249)**	−0.099 (0.258)	0.339 (0.289)	0.100 (0.254)
Establishment type	−0.713 (0.357)**	0.587 (0.339)*	−0.183 (0.396)	−0.252 (0.327)
Age	−0.045 (0.029)	0.002 (0.020)	−0.006 (0.022)	0.024 (0.020)
Incubator variables				
Specialization strategy	0.157 (0.274)	0.203 (0.300)	0.386 (0.318)	−0.377 (0.282)
Number of tenants	–	0.010 (0.006)*	0.019 (0.007)***	0.003 (0.606)
Information	–	0.300 (0.122)**	0.233 (0.134)*	0.222 (0.113)**
Industry effects				
Manufacturing	0.927 (0.539)*	0.177 (0.532)	0.014 (0.535)	0.372 (0.462)
Wholesale/retail Trade	0.347 (0.552)	0.818 (0.584)	0.140 (0.608)	0.244 (0.552)
ICT/media	−0.164 (0.386)	0.280 (0.426)	−0.220 (0.493)	−0.008 (0.379)
Consulting/'BRS'	0.366 (0.327)	0.345 (0.368)	0.258 (0.393)	0.453 (0.328)
Research/development	0.893 (0.497)*	0.429 (0.488)	0.134 (0.465)	1.055 (0.558)**
Constant	89.542 (58.125)	−6.016 (40.679)	9.627 (44.132)	−48.534 (40.348)
McFadden R^2	0.201	0.108	0.114	0.082
Log likelihood	−79.230**	−79.293*	−70.046	−87.695

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

5. Discussion and implications

5.1. Incubator-internal cooperation

The empirical results do not support the theory-based assumption that specialized incubation strategies increase the effectiveness of incubator-internal networking compared to diversified BIs. In fact, it is the similarities between the SBIs and DBIs, rather than the differences between them, that are striking, leading to questions about the presumed superiority of SBIs regarding networking within the tenant portfolio (e.g., Kihlgren, 2003; Chan and Lau, 2005; Tötterman and Sten, 2005). Based on our analysis we arrive at the conclusion that specialization strategies fail to satisfy their high expectations in this respect.

The more general results of this study show that incubator-internal inter-firm networks are dominated by informal relationships between the tenant companies. This confirms previous research on networking activities within German incubators (Behrendt, 1996; Tamásy, 1996; Seeger, 1997). Informal networks provide manifold opportunities to organize valuable flows of information and knowledge between the incubated firms (e.g., regarding funding, support programmes and market structures) or to combine complementary resources (Von Hippel, 1987; Pyka, 1997; Dahl and Pedersen, 2004). And, as Freeman (1991, p. 503) highlights 'behind every formal network, giving it the breath of life, are usually various informal networks.' It is important for the overall BIs' networking effectiveness that these informal ties are strong enough to evolve into more formalized connections, such as supplier–customer relationships, joint R&D agreements, technology exchange agreements or joint exploitation of distribution channels. However, more formal types of cooperation are found to be of minor relevance for incubator firms in our sample.

Overall, our results strengthen the existing knowledge of the dominance of informal contacts as well as the limited ability of BIs to foster formal relationships between their tenants. But more importantly, we provide novel insights with respect to the differences in cooperation patterns according to the market strategy applied by the incubators. This broad-based empirical study reinforces recent case-study research (Schwartz and Hornych, 2008) that the homogenization of tenant structures through specialization strategies is no guarantee of intensive inter-firm network relationships. In particular, problems resulting from too-closely related market segments may impede interaction and have a negative effect on the working climate within the incubator (see also Tötterman and Sten, 2005). Indeed, problems caused by reluctance to share information within the BI community because ideas, business secrets (e.g., with respect to funding agents or government grants) and intellectual property rights might be stolen by other firms are also prevalent in diversified BIs, as McAdam and Marlow (2007) have recently shown. These problems might even be intensified within the context of specialization. This might explain why we do not find a positive effect of incubator specialization on incubator-internal cooperation.

Based on these results, we strongly recommend that stakeholders engaged with the establishment and operation of BIs (such as local authorities and incubator management) realistically assess the potential of SBI strategies with respect to the promotion of inter-firm networking. Simply concentrating support infrastructure in BIs on firms from solely one sector, or few but complementary sectors, and generating some homo-

geneity does not seem to intensify inter-firm networking between the tenants per se. Our (regression) results specifically imply that an increasing degree of firms' knowledge of mutually valuable skills and competencies is strongly and positively associated with engagements in cooperation activities with other incubator firms. This holds for all three types of incubator-internal cooperations. It is debatable, however, whether the degree of information causes cooperation, as suggested by our results, or whether cooperating tenants are more informed about other incubator firms simply because they cooperate with them. We suggest that management teams, of both SBIs and DBIs, have a particular responsibility to pay particular attention to the creation of a communication-friendly atmosphere in their incubators.

The results underscore the importance of incubator management, within SBIs in particular, to provide the basis for trust-based relationships between incubatees. Trust-based relationships are crucial for the establishment and strength of mutual valuable network relationships, and have the potential to neutralize opportunistic behaviour (see, e.g., Tötterman and Sten, 2005; Uzzi, 1997). In order to create an atmosphere of trust, including elements such as reliability, honesty and loyalty, we suggest that client selection could be a valuable starting point. As suggested elsewhere (Schwartz and Hornych, 2008), potential tenants could be screened according to complementarities regarding the existing competencies in the incubator. Future selections could be based on managements' own experience and knowledge, or the incubator management could systematically collect information about the needs and ideas of the existing tenant portfolio and use this to select new tenants.

5.2. Linkages with academic institutions

Basically, our findings reinforce the prevalent picture depicted in empirical studies on the cooperation patterns of BI firms (Monck et al., 1988; Massey et al., 1992; Westhead and Storey, 1994; Vedovello, 1997; Bakouros et al., 2002). The respondents do not possess strong connections with academic institutions, and formal relationships are less frequent than informal connections.

The descriptive results suggest that SBI firms are significantly more engaged in cooperations with academic institutions than their DBI counterparts, particularly with respect to formal relationships. However, a more differentiated regression analysis demonstrates that incubator specialization is not superior to the diversified incubator model with respect to the promotion of linkages between their client firms and academic institutions. We conclude that industry matters more than the support (elements) of the incubators themselves. When considering differences between SBI and DBI firms, the findings *do* suggest an increasing heterogeneity between incubators, or types of incubators, with respect to the degree of academic–industry linkages of their tenant firms. These results might lead to the conclusion of an increasing 'two-tier society' when looking at the underlying technology-transfer function of BIs in Germany. For diversified incubators in particular, this also suggests that local policy makers (in Germany) should be more realistic in their expectations regarding possible relationships with academic institutions and the subsequent transfer of knowledge and technology between academia and incubator firms. Their current expectations in this regard lead to a huge amount of public spending that is devoted to the establishment of DBIs, the rationale for this allocation of funds would seem to be questionable based on this papers findings. Whereas DBIs seem to attract more non-academic firms from less knowledge-based or technology-oriented industries, firms showing a high R&D intensity tend to locate in SBIs. Consequently, firms seeking to locate in close proximity to science-based ventures with good academic relationships (e.g., to conduct R&D projects jointly) have a higher probability of finding appropriate partners in SBIs compared to DBIs.

As a final point, incubated firms included in the present study have considerably weaker linkages with academia than firms included in prior evaluations of German BIs during the late 1980s and 1990s (Sternberg, 1988; Tamásy, 1996; Seeger, 1997). This might be the result of a decreasing share of knowledge-based or technology-oriented innovative firms in the German BIs over the last decade(s)—empirical evidence for this presumption is given by Sternberg et al. (1996) and, more recently, by Schwartz (2007). This process is the consequence of a greatly limited or even decreasing availability of BI target firms on the one hand, and the area-wide distribution of BIs in Germany on the other hand, which in the long run forces the BIs to downgrade their admission criteria with respect to technology orientation (Sternberg, 1988; Sternberg et al., 1996). Our results seem to confirm such a decrease of academic-oriented networking of BI firms.

6. Limitations

The present paper provides evidence concerning the effects of incubator specialization on inter-firm cooperation patterns of incubated ventures within incubator facilities and on their linkages with academic institutions. Though some important findings for incubator-incubation research could be derived, there are some open questions remaining and limitations. First, given our definition of the central networking variables from the questionnaire as a binary construct (yes/no), there is no evidence in the data considering the frequency of utilization of a particular contact and with regard to the total number of partners with a particular cooperation type. For instance, a surveyed firm might be engaged in a durable cooperation with one university or it might have several short-lived cooperation agreements with multiple academic institutions. With our dataset, it is not possible to distinguish between such cases. In this context, one may also raise the issue as to whether particular networking relationships between tenant companies existed prior to the incubation process, or were established primarily during incubation (through the support of the incubator management). The study also does not address whether BI-formed relationships persist beyond graduation from the BI.

We also have no indication of the actual value of a particular type of networking relationship for the participating incubator firms. This limitation is particularly relevant for informal relationships, since it is the dominant type of contact within incubators as well as between incubator firms and academic institutions and personnel. There is an ongoing debate as to whether agents in informal networks in fact diffuse information and knowledge with considerable proprietary value or only knowledge generally of a low value (see Von Hippel, 1987; Fauchart, 2003; Dahl and Pedersen, 2004). This study does not address this difference, but doing so is essential to disentangling the basic mechanism of such informal cooperation. The focus should be on how these relationships emerge initially, what conditions are required to make them a mutually fruitful and sustainable channel for the transfer of information and knowledge, and how incubator management might effectively support such transfers.

Since the particularities of incubator support mechanisms may differ between nations or regions (e.g., hierarchy of selection criteria or degree of profit orientation), this study focused exclusively on one underlying incubation model, in this case, the German one. Although this approach ensures homogeneity among the incubators included, one might argue that the validity of our analysis is restricted. Regarding BIs in Germany in particular, linkages to academic institutions are less pronounced than is the case for science parks, such as in the United Kingdom (e.g., Westhead and Storey, 1994), the United States (e.g., Link and Scott, 2003, 2006) or in Sweden (e.g.,

Löfsten and Lindelöf, 2002; Lindelöf and Löfsten, 2004). Only a few German facilities maintain formal linkages with higher education institutions (Tamásy, 2001; Sternberg, 2004). We therefore do not know whether our results are applicable to different incubation models that focus more intently on close proximity to universities and research organizations. However, with respect to the inter-firm relationships within BIs' tenant portfolios, we are confident that our results are valid for incubators in other countries. Therefore, we strongly encourage other researchers to investigate whether or not our findings can be confirmed for varying incubation models.

Acknowledgements

The authors are particularly grateful to the Editor and the two anonymous reviewers for valuable comments and suggestions. We also want to thank K. Zick for providing research assistance.

Appendix A

See Table A1

Appendix B

See Table A2

Table A1
Business incubators included in the investigation (total number of surveyed firms per BI/responses per BI) (*main field of specialization*, *year of establishment*, *rental space*).

Specialized business incubators (SBIs)	Diversified business incubators (DBIs)
• Medical Technology Centre, Aachen—(18/8) *(Medical Technology, 1994, 4300 m²)*	• MikroForum Technology Park, Wendelsheim—(18/2) *(2000, 8200 m²)*
• Biotechnology Center, Dresden—(16/2) *(Biotechnology, 2003, 5982 m²)*	• Industrial- and Technology Center, Raisdorf—(42/12) *(1987, 2946 m²)*
• BioTech Park, Freiburg—(15/2) *(Biotechnology, 1998, 5500 m²)*	• Technology- and Business Park, Bad Mergentheim—(16/3) *(1992, 4800 m²)*
• BioTechnikum, Greifswald—(18/5) *(Biotechnology, 1993, 4195 m²)*	• Center for Technology, Potsdam—(26/7) *(2000, 4500 m²)*
• BioCentiv, Jena—(24/6) *(Biotechnology, 2000, 3200 m²)*	• Start-Up Center, Marburg—(20/4) *(1997, 2723 m²)*
• Multimedia-Internet Park, Zweibrücken—(26/2) *(Media Technology, 1998, 10 000 m²)*	• Innovation- and Technology Center, Bremen—(42/9) *(1986, 11 572 m²)*
• b-9 Media and Technology Center, Munich—(22/2) *(Media Technology, 1999, 2500 m²)*	• Technology- and Founder Center, Kassel—(63/14) *(1996, 9300 m²)*
• Central German Multimedia Centre, Halle—(18/5) *(Media Technology, 2002, 5400 m²)*	• Innovations Campus, Lübeck—(19/4) *(2003, 5000 m²)*
• BioPark, Regensburg—(19/5) *(Biotechnology, 1999, 6000 m²)*	• Innovation- and Founder Center, Wernigerode—(22/8) *(1992, 2760 m²)*
• Technology Park, Heidelberg—(60/7) *(Biotechnology, 1985, 41 000 m²)*	• hit-Technopark, Hamburg—(42/4) *(1985, 10 000 m²)*
• BioTechnology Park, Luckenwalde—(32/6) *(Biotechnology, 1996, 3350 m²)*	• Technology- and Innovation Center, Gießen—(47/5) *(1996, 5000 m²)*
• Innovation Center for Biotechnology, Martinsried—(41/12) *(Biotechnology, 1995, 11 500 m²)*	• Technology- and Founder Center, Bautzen—(19/4) *(1995, 4990 m²)*
• Bio-Centre, Halle—(12/5) *(Biotechnology, 1998, 8000 m²)*	• Technology Center, Hannover—(81/18) *(1985, 3600 m²)*

Table A2
Descriptive statistics and bivariate correlations (N(obs)=150).

		Mean	SD	Min	Max	Median	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cooperation variables																							
(1)	Academic–industry linkages	0.62	0.485	0	1	1	1																
(2)	Supplier–customer	0.28	0.451	0	1	0	0.08	1															
(3)	Technological cooperation	0.22	0.416	0	1	0	**0.31**	0.06	1														
(4)	Information exchange	0.67	0.473	0	1	1	**0.19**	0.00	0.10	1													
Firm variables																							
(5)	R&D intensity	35.10	35.258	0	100	25	**0.28**	−0.11	**0.17**	0.08	1												
(6)	Spin-off	0.65	0.478	0	1	1	**0.28**	−0.11	0.08	0.02	**0.21**	1											
(7)	Establishment type	0.13	0.334	0	1	0	**−0.16**	**0.16**	−0.06	−0.07	−0.10	0.00	1										
(8)	Age	5.55	5.834	0	57	4	0.15	0.01	−0.00	−0.08	−0.10	−0.06	−0.05	1									
Incubator variables																							
(9)	Specialization strategy	0.44	0.498	0	1	0	**0.24**	0.02	0.08	−0.03	**0.30**	**0.20**	0.03	0.06	1								
(10)	Number of tenants	39.18	21.649	12	81	41	−0.11	0.13	0.15	0.07	−0.15	**-0.18**	−0.02	−0.06	**−0.41**	1							
(11)	Information	2.96	0.996	1	5	3	**0.18**	**0.22**	0.12	0.16	0.10	−0.10	0.05	0.04	0.15	−0.04	1						
Industry variables																							
(12)	Manufacturing	0.10	0.301	0	1	0	**0.17**	−0.06	−0.02	−0.05	0.11	**0.18**	0.05	0.09	0.10	−0.15	0.01	1					
(13)	Wholesale/retail trade	0.05	0.225	0	1	0	−0.00	0.12	0.02	−0.02	0.08	−0.01	0.09	−0.03	0.04	−0.01	0.11	−0.08	1				
(14)	ICT/media	0.15	0.355	0	1	0	**−0.19**	−0.01	−0.08	−0.11	−0.12	−0.03	0.01	−0.04	−0.13	0.11	−0.02	−0.15	−0.09	1			
(15)	Consulting/'BRS'	0.34	0.475	0	1	0	−0.06	0.05	0.03	0.06	**−0.23**	**−0.22**	−0.07	0.01	**−0.20**	**0.18**	−0.06	**−0.25**	**−0.16**	**−0.29**	1		
(16)	Research/development	0.19	0.396	0	1	0	**0.27**	−0.01	0.11	**0.17**	**0.38**	**0.20**	−0.04	0.07	**0.42**	**−0.18**	0.08	**−0.17**	0.11	**−0.20**	**−0.35**	1	
(17)	Others	0.17	0.318	0	1	0	−0.12	−0.04	−0.04	−0.02	−0.11	−0.07	−0.07	−0.05	−0.10	0.03	−0.03	−0.13	−0.08	−0.15	**−0.25**	**−0.17**	1

Bold numbers indicate significant correlations on the 5%-level (two-sided test).

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